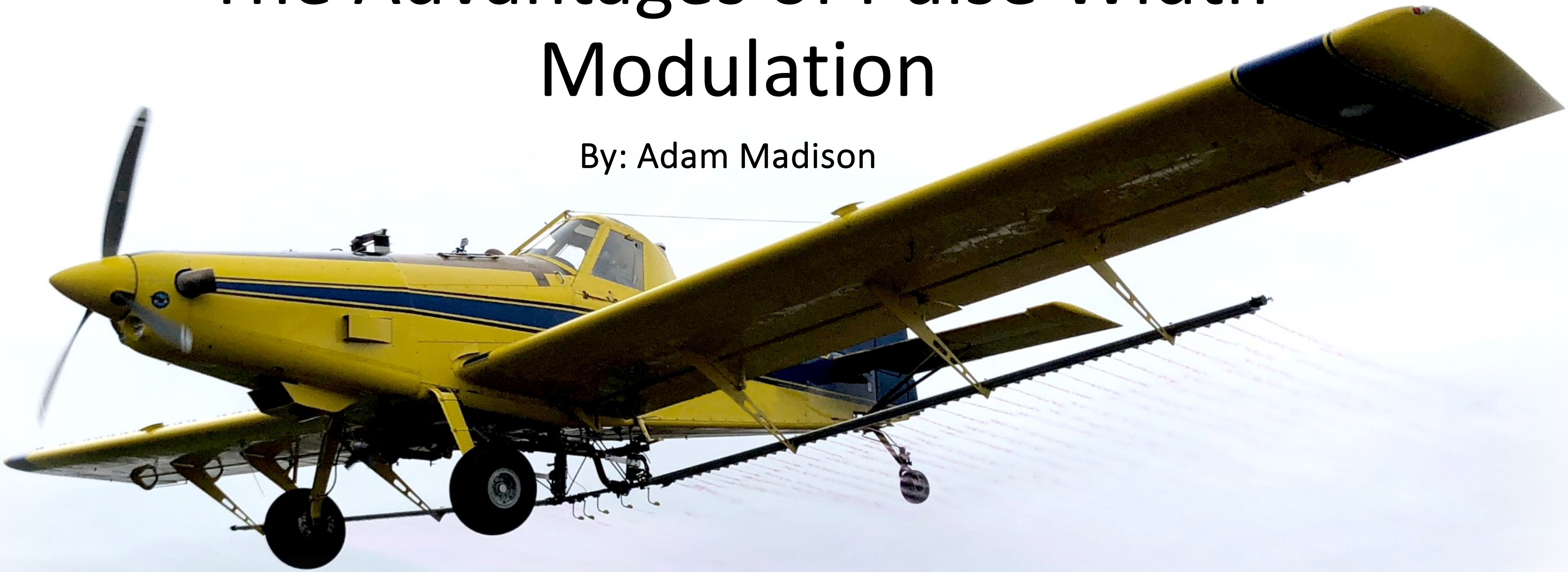
Enhancing Aerial Application Efficiency: The Advantages of Pulse Width Modulation

By: Adam Madison



CapstanAG™

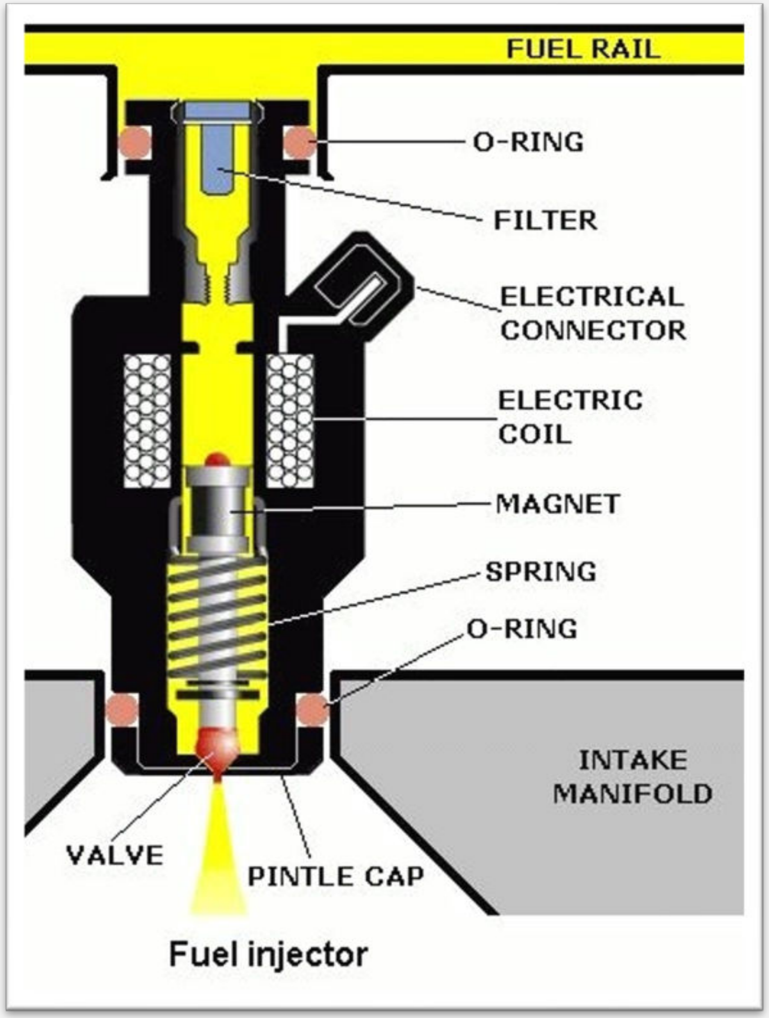
APPLICATION SYSTEMS FOR PROFESSIONALS™

Who is CapstanAG™ and Adam Madison

- Small manufacturing company based in Topeka, KS.
- In 1996, we introduced the first PWM (Pulse Width Modulation) system for ground spraying.
- Late 1990’s installed PWM spray system on a plane in Northeast, KS.
- In 2016, started installing and testing on planes.
- I have been with Capstan since 2013 as a Field Technical Specialist.
- I have been working with PWM on planes since 2019.
  - Before that I was lead on Capstan’s PWM planter product.

Pulse Width Modulation (PWM)

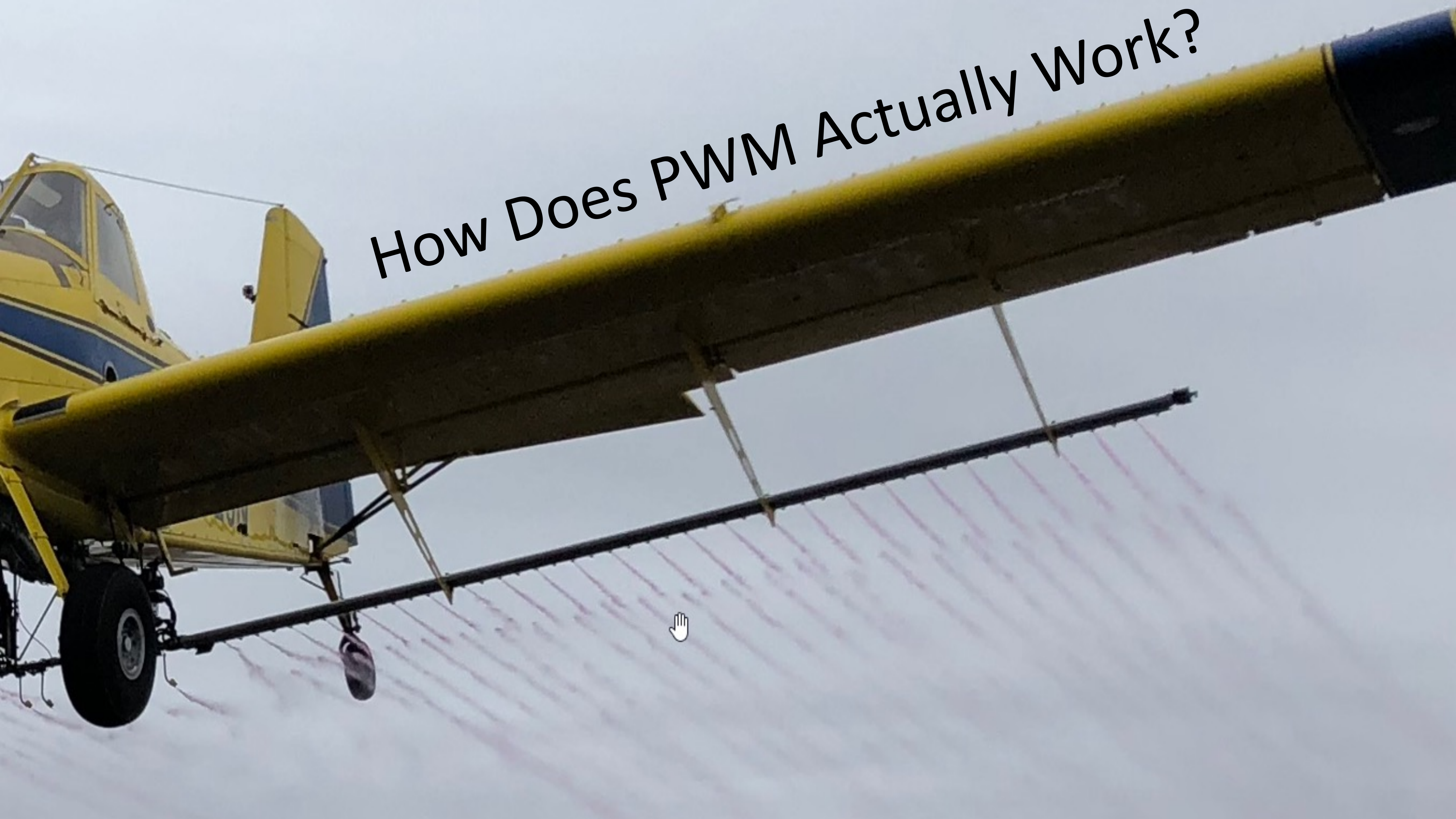
- What is one widely used PWM application in vehicles today?
  - Electronic Fuel Injection (EFI)
  - At 1800 RPM's, EFI pulse at about 15Hz.
- Would you go back to a Carburetor? (Unless you are an old school car lover).
- So why not use PWM on your plane's spray system?



Revolutionizing Agricultural Spraying with Pulse Width Modulation (PWM):

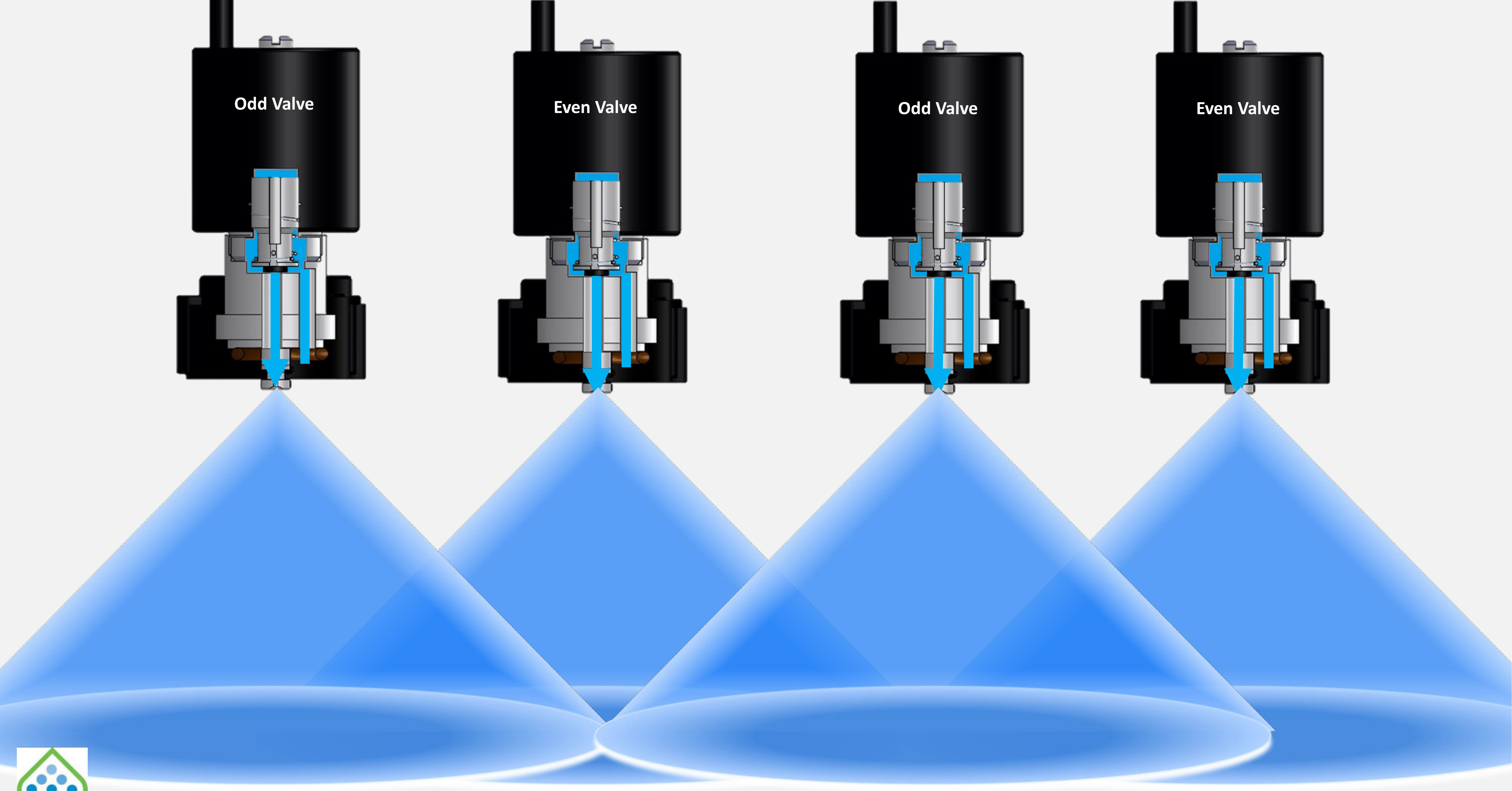
- **Defining PWM:**
  - PWM is a technology that controls flow rate and pressure in sprayed liquids.
  - Involves electronically modulating spray nozzle output by toggling them on and off in cycles. The key is adjusting the Duty Cycle, the “**ON**" time within each cycle.
    - Lower Duty Cycle reduces liquid sprayed, while a higher Duty Cycle increase output.
  - By manipulating the Duty Cycle, PWM enables precise control of application rates and spray patterns.
- **Consistent Pressure with Precise Nozzle Control:**
  - Traditional sprayers regulate flow rates by altering system pressure.
  - PWM systems hold a steady pressure in the boom, irrespective of speed, while individual or grouped solenoids are electronically managed, enabling precise adjustments to each nozzle's flow rate.
- **Flexible Flow Control:**
  - Pulse width modulation allows for control through manual or automated adjustments.
  - This automated control factors in ground speed, target application rate, and variables, optimizing the spraying process.

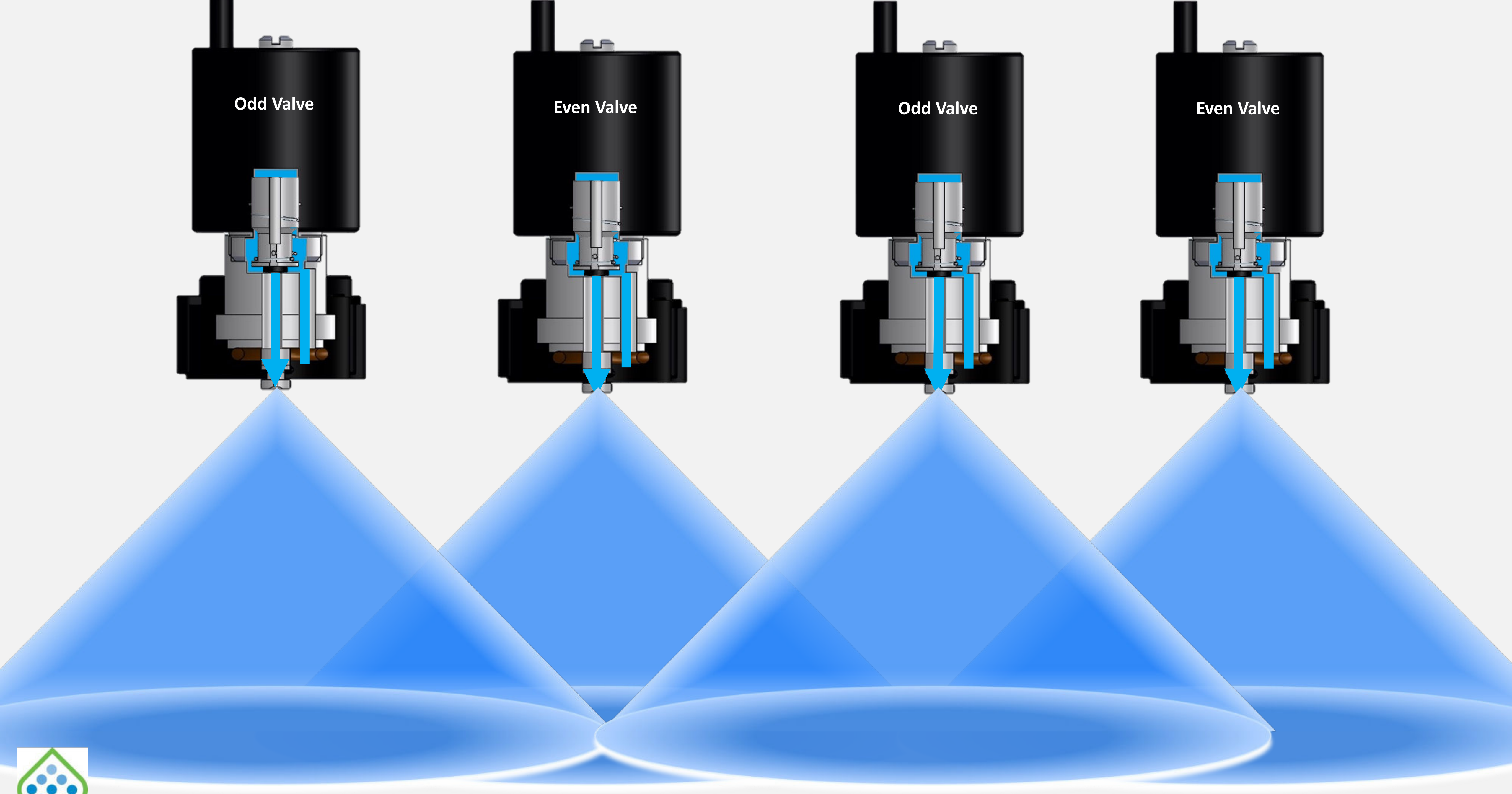
How Does PWM Actually Work?



PWM Valve assembly pulsing at 20Hz

- Instant on, on in 7 milliseconds (ms)
- Instant off, off in 7 milliseconds (ms)
  - Off in 1.5 feet.
- At 150 mph, that is 11 feet per pulse.


Odd Valve
Even Valve
Odd Valve
Even Valve


Odd Valve
Even Valve
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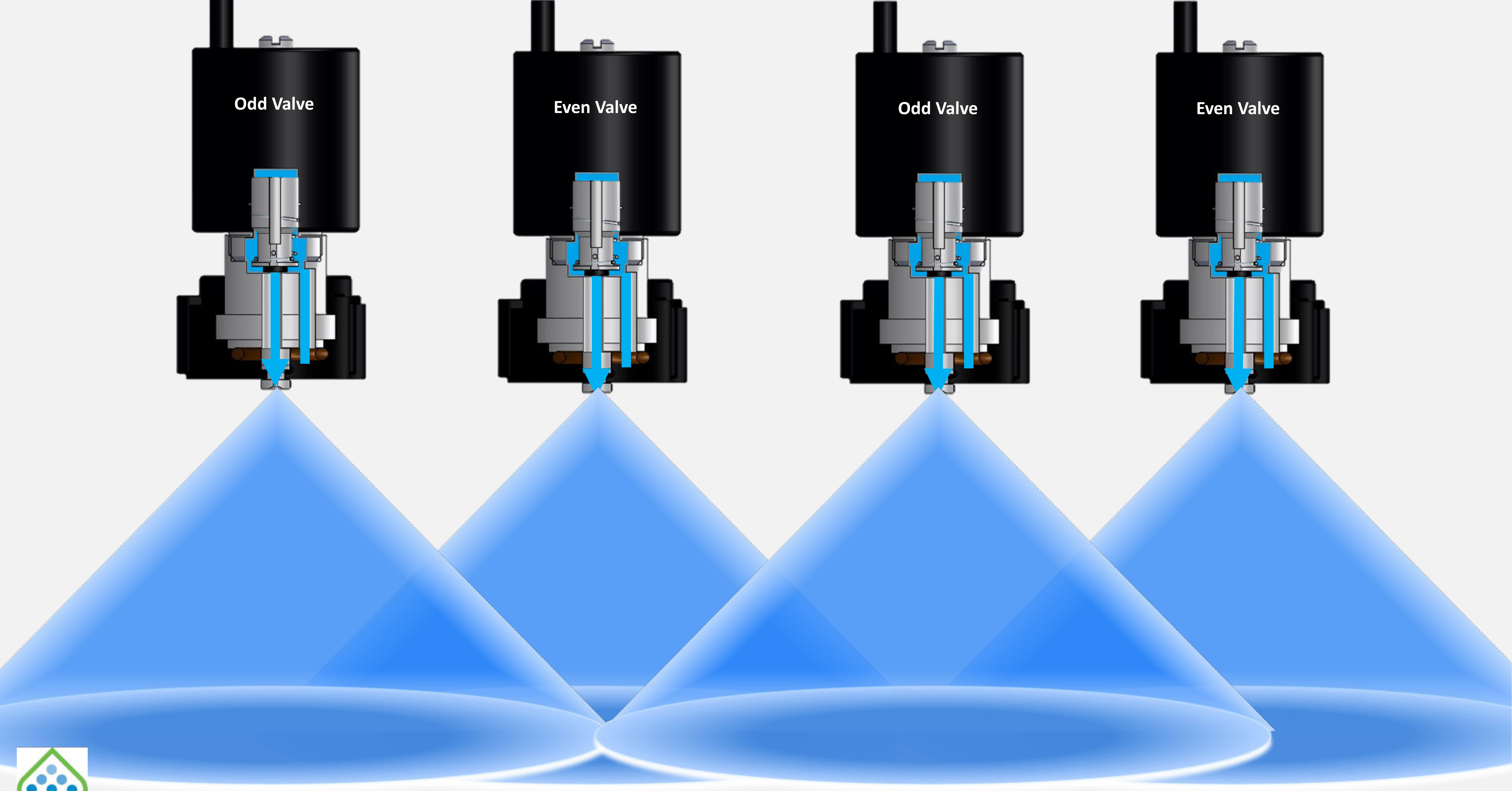

Odd Valve
Even Valve
Odd Valve
Even Valve

PWM Creates a Variable Tip

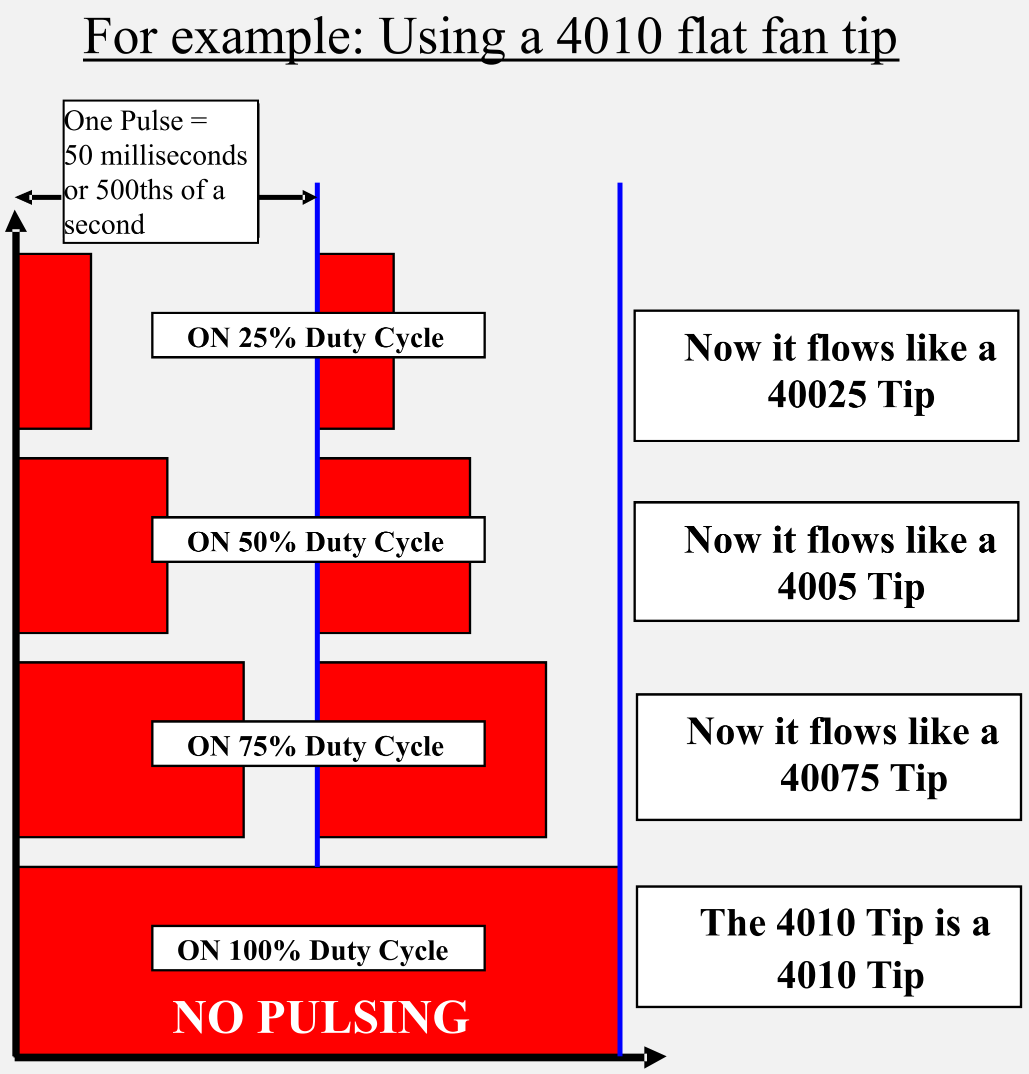
1. Uses a larger tip

   (Top Rate and Maximum Speed)

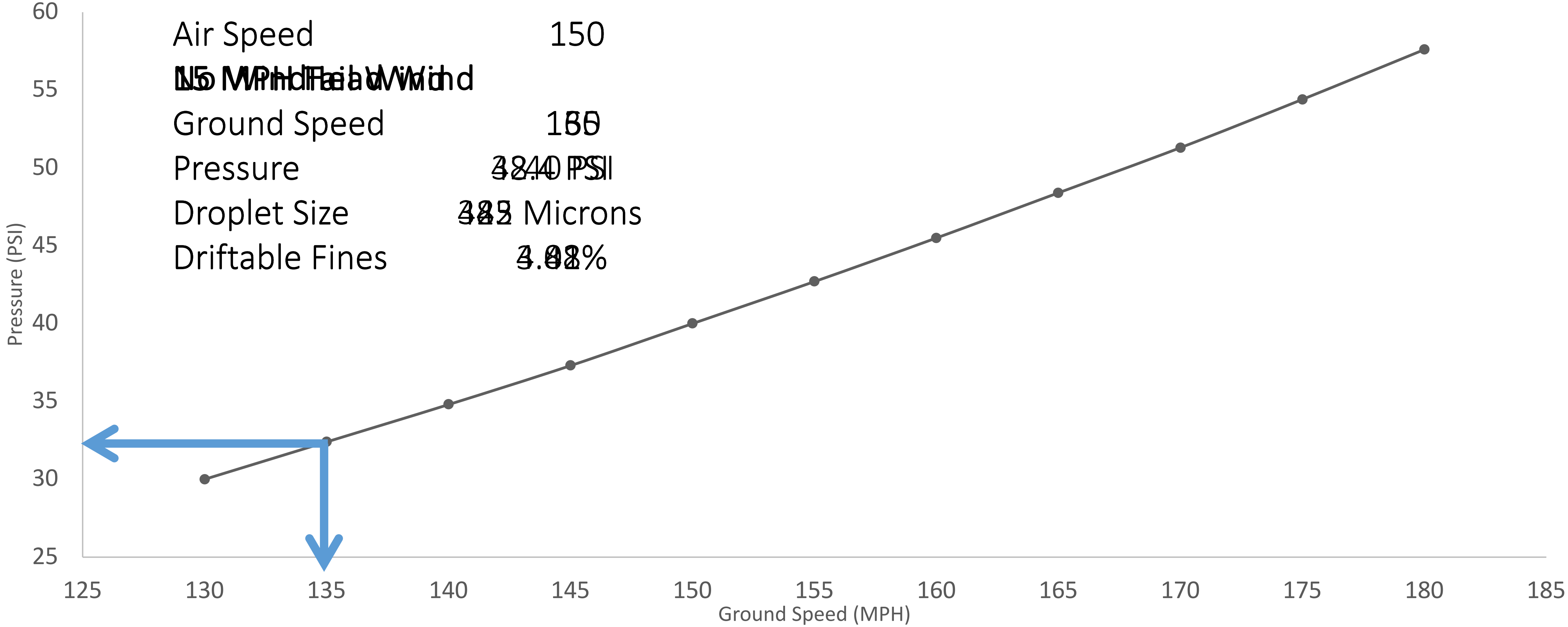
2. Use PWM to Simulate a Smaller Tip

   a. Achieve Variable Rates

   b. Manage Pressure



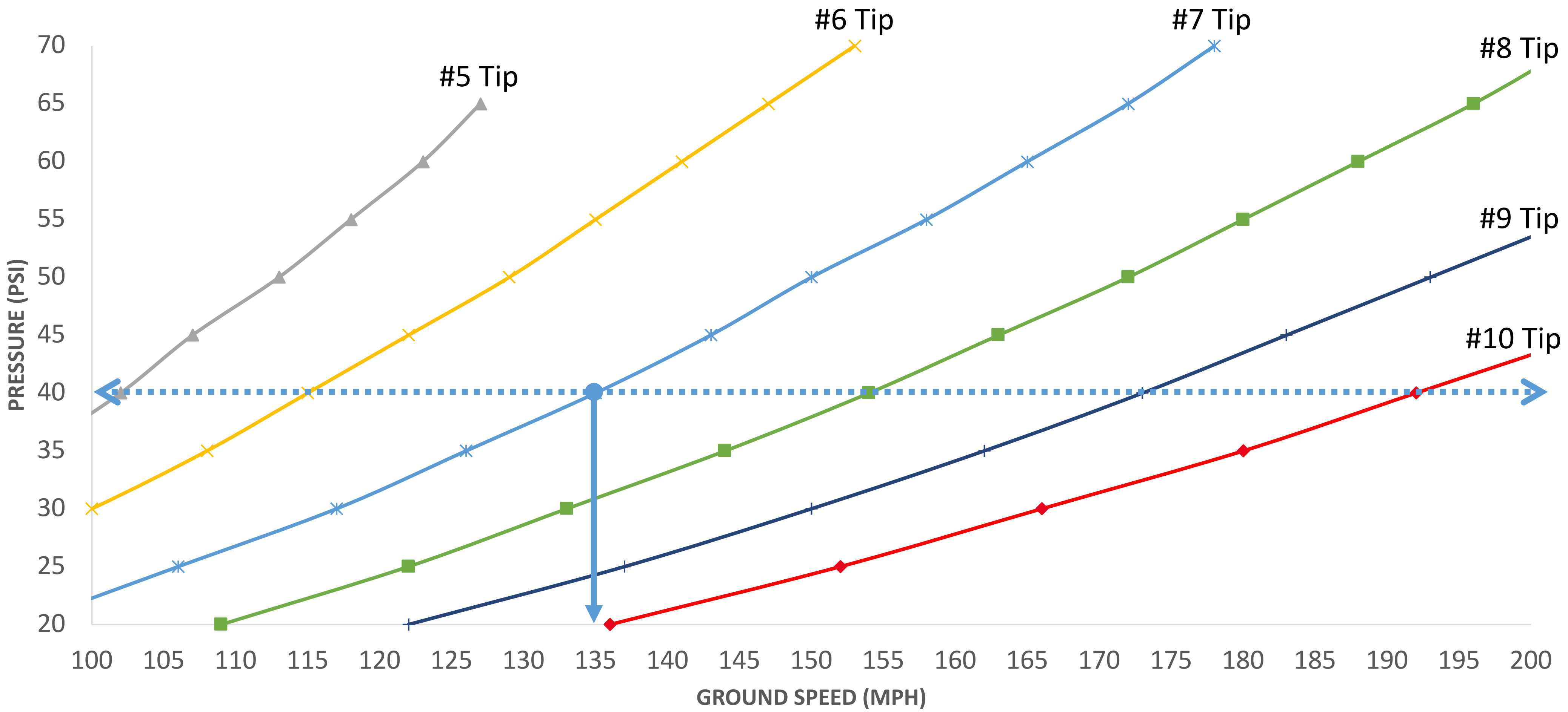
Conventional Tip Curve



Tip: CP11TT-0010 Straight Stream
(Ref: USDA ARS Nozzle charts)

Tip: CP11TT-0010 Straight Stream
(Ref: USDA ARS Nozzle charts)

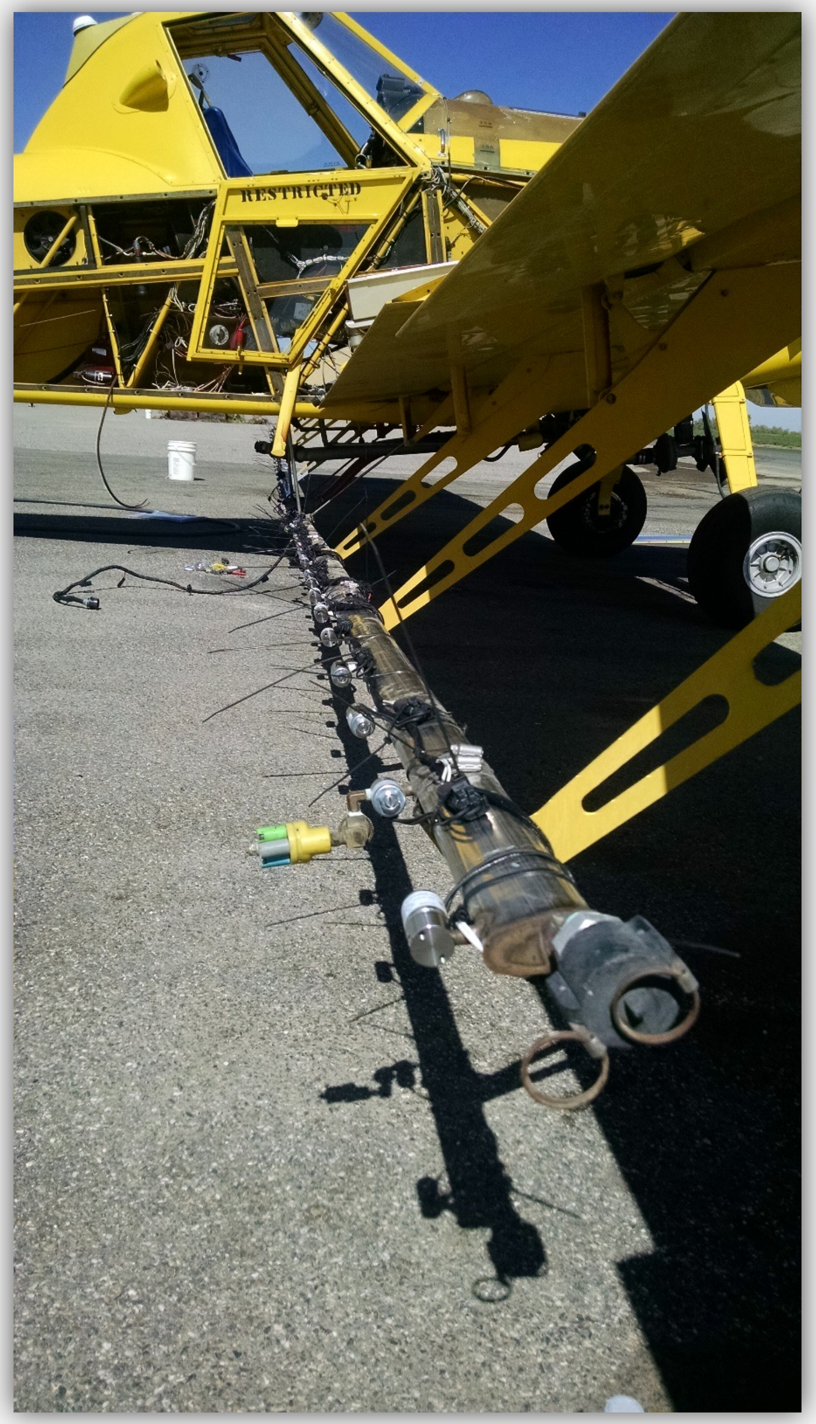
PWM TIP CURVE



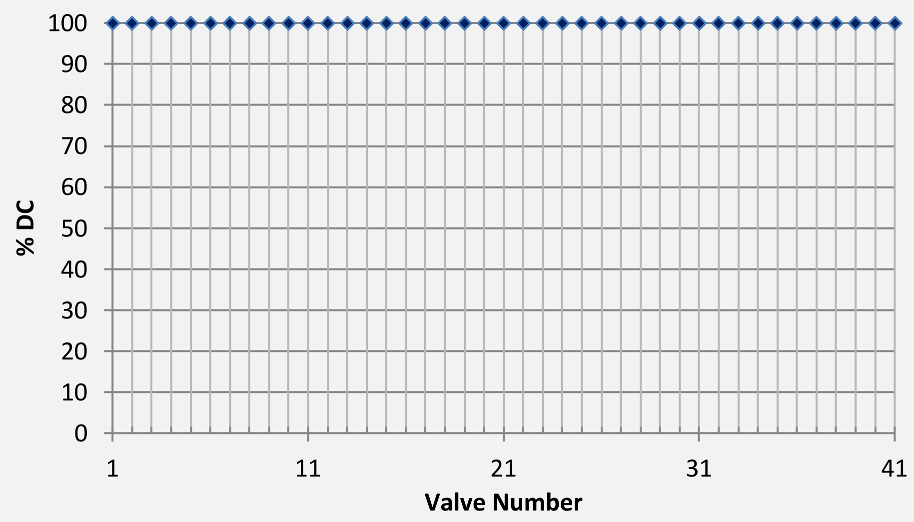
Air Speed	150
15 MPH Head Wind	
Ground Speed	135
Pressure	40 PSI
Droplet Size	383 Microns
Driftable Fines	4.08%

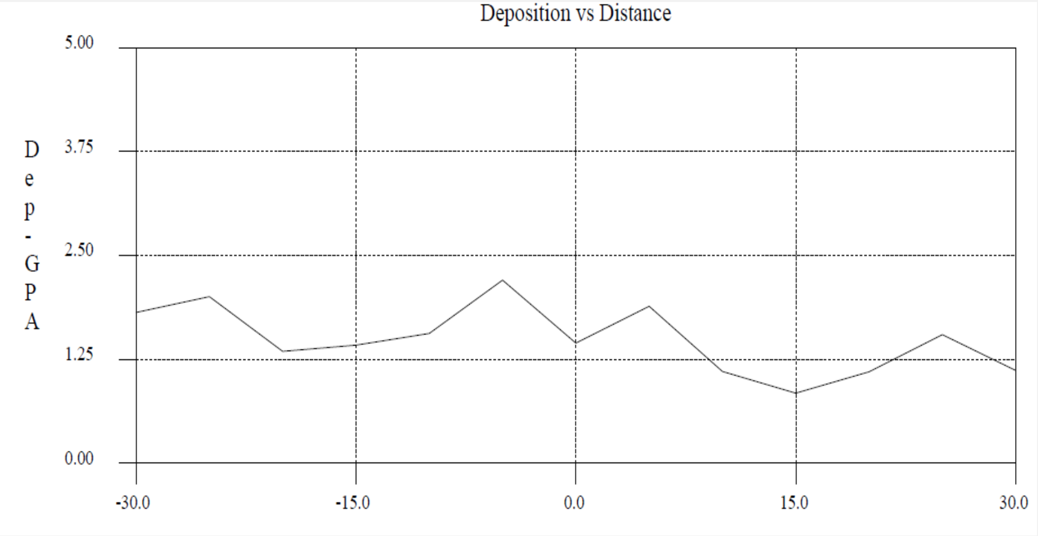
Early Verification
9-22-2016

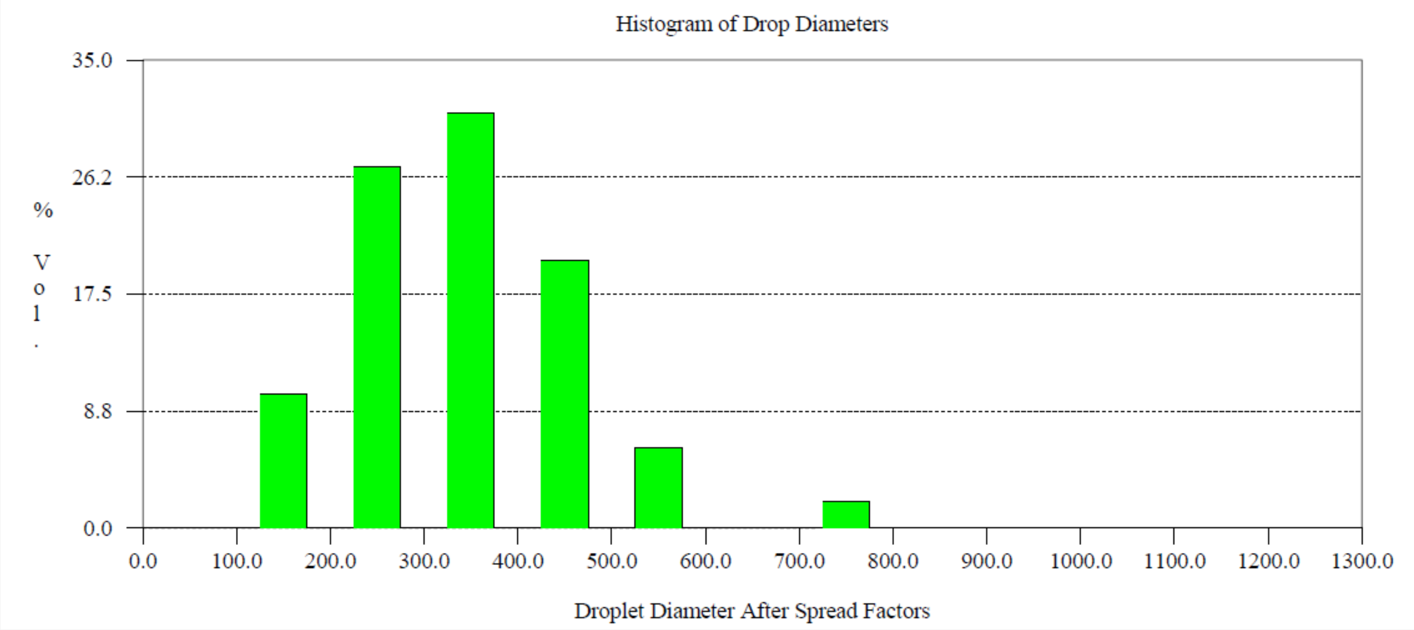
- Off the shelf components
- Droplet cards to measure pattern
- 41 Nozzles - CP11TT 4025 tips
- 50 PSI



(Base Line 100% DC)

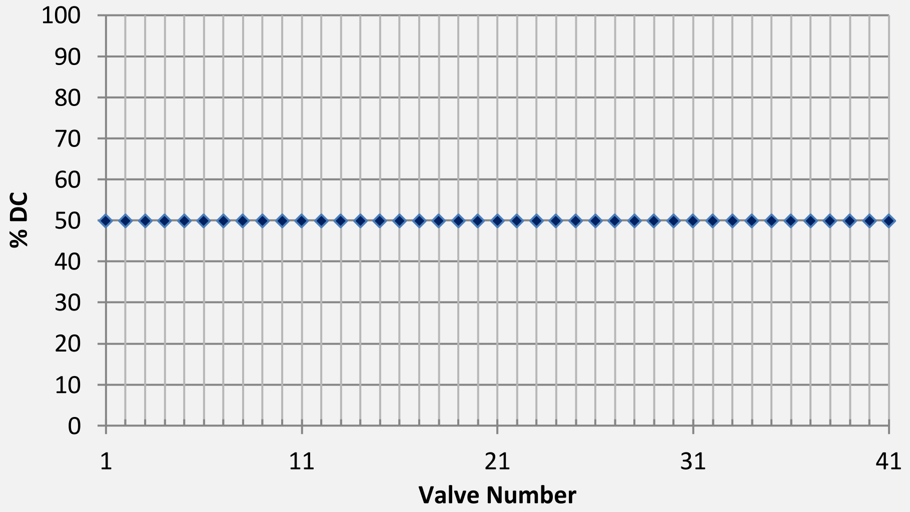


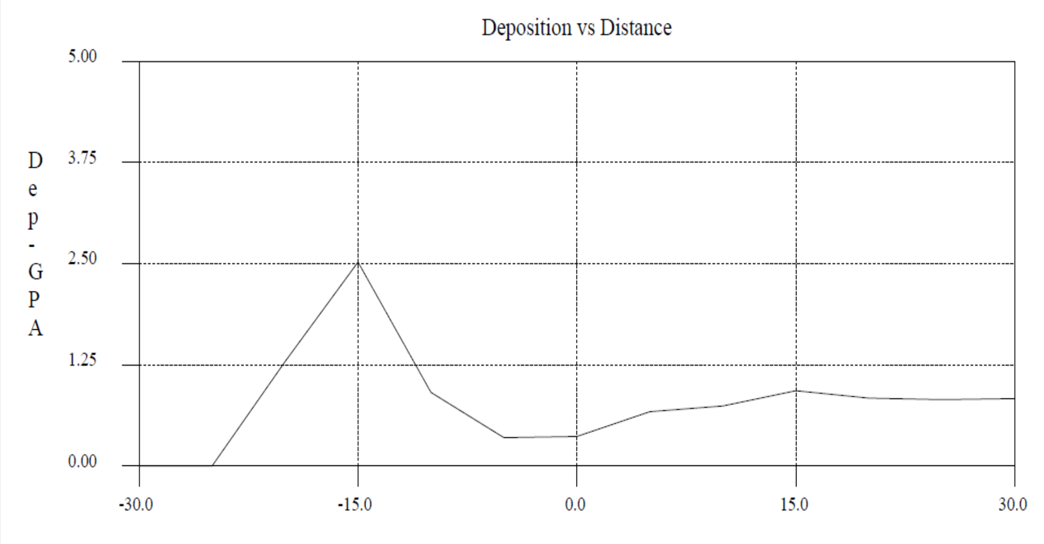


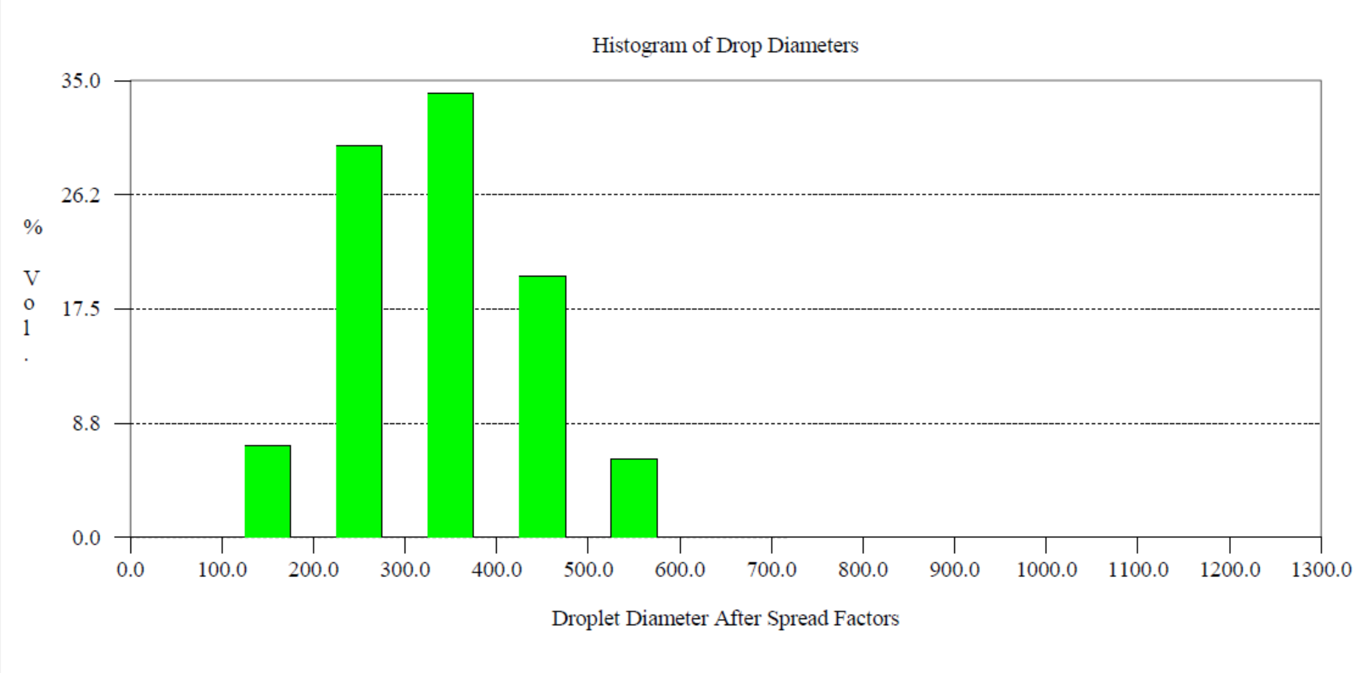


Composite results
VMD = 335
VD(0.1) = 197
VD(0.9) = 497

(Half Rate 50% DC)

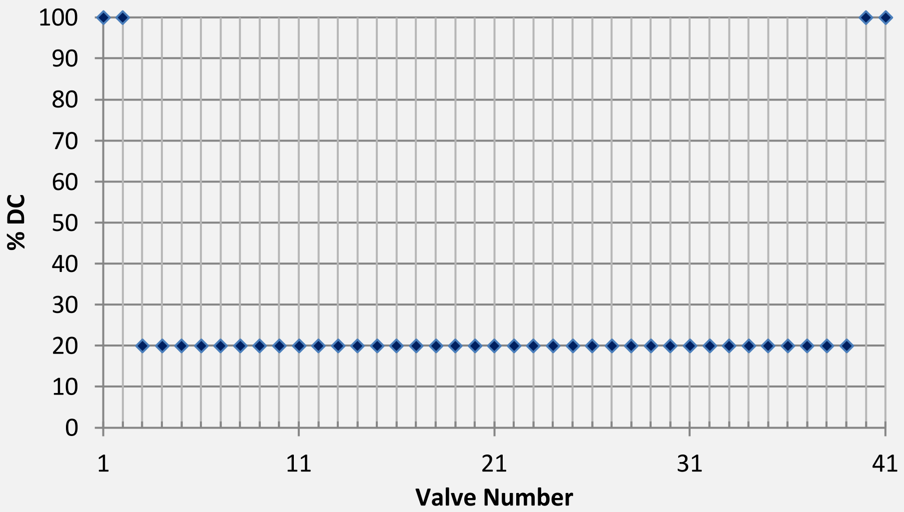


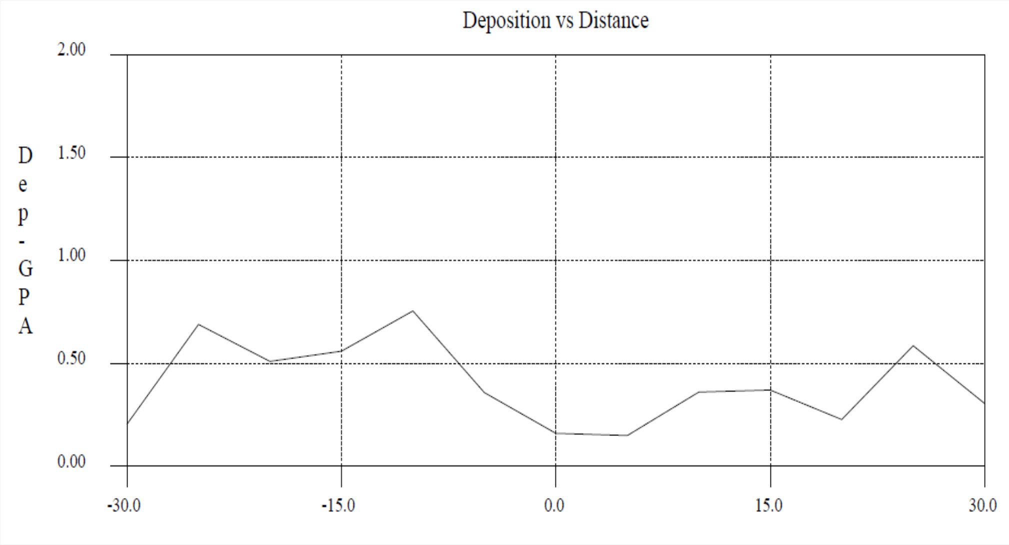


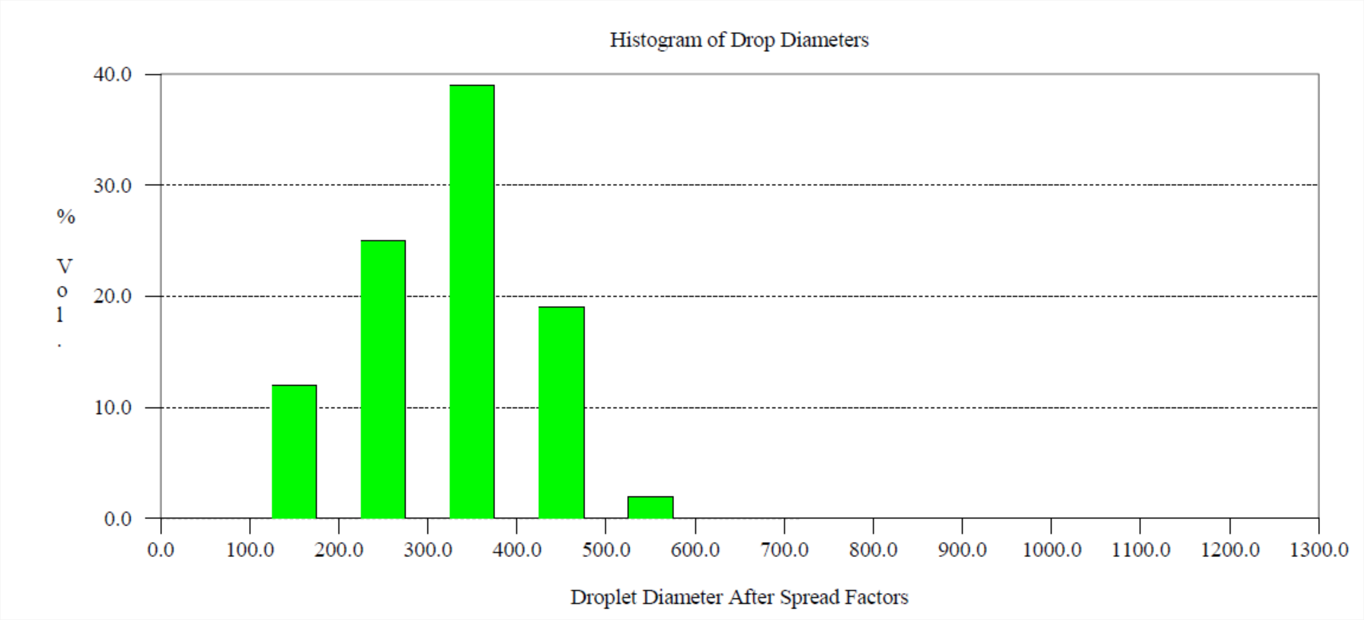


Composite results
VMD = 324
VD(0.1) = 210
VD(0.9) = 467

(Low 20% DC)







Composite results
VMD = 325
VD(0.1) = 184
VD(0.9) = 451

Wind Tunnel Testing

Measured droplet size resulting from:

25, 50, 75 and 100% Duty Cycle

TeeJet Stainless Steel 4010
40 PSI @ 140 mph

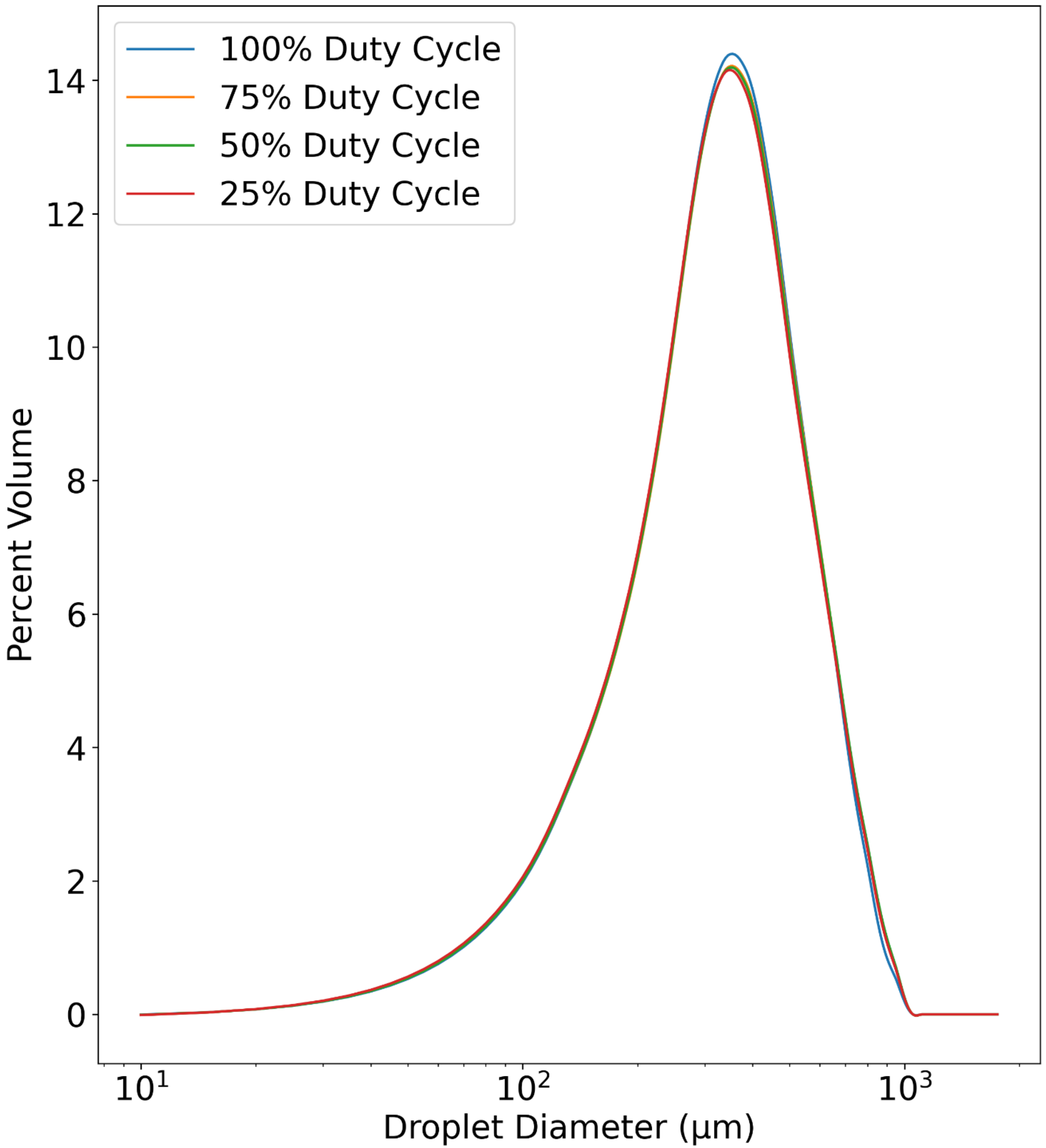
Duty Cycle:
100% → 75% → 50% → 25%

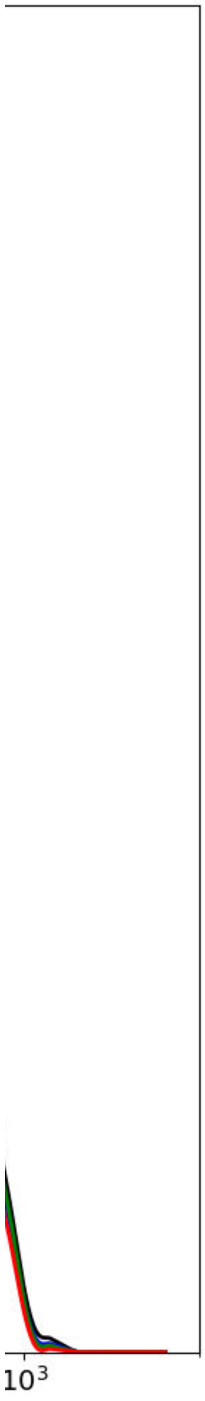
Dv0.1:
123 → 122 → 122 → 120 µm

Dv0.5:
294 → 295 → 295 → 292 µm

Dv0.9:
527 → 535 → 536 → 532 µm

Percent Fines:
6.7 → 6.8 → 6.7 → 7.0





CP11TT 4010
40 psi @ 140 mph

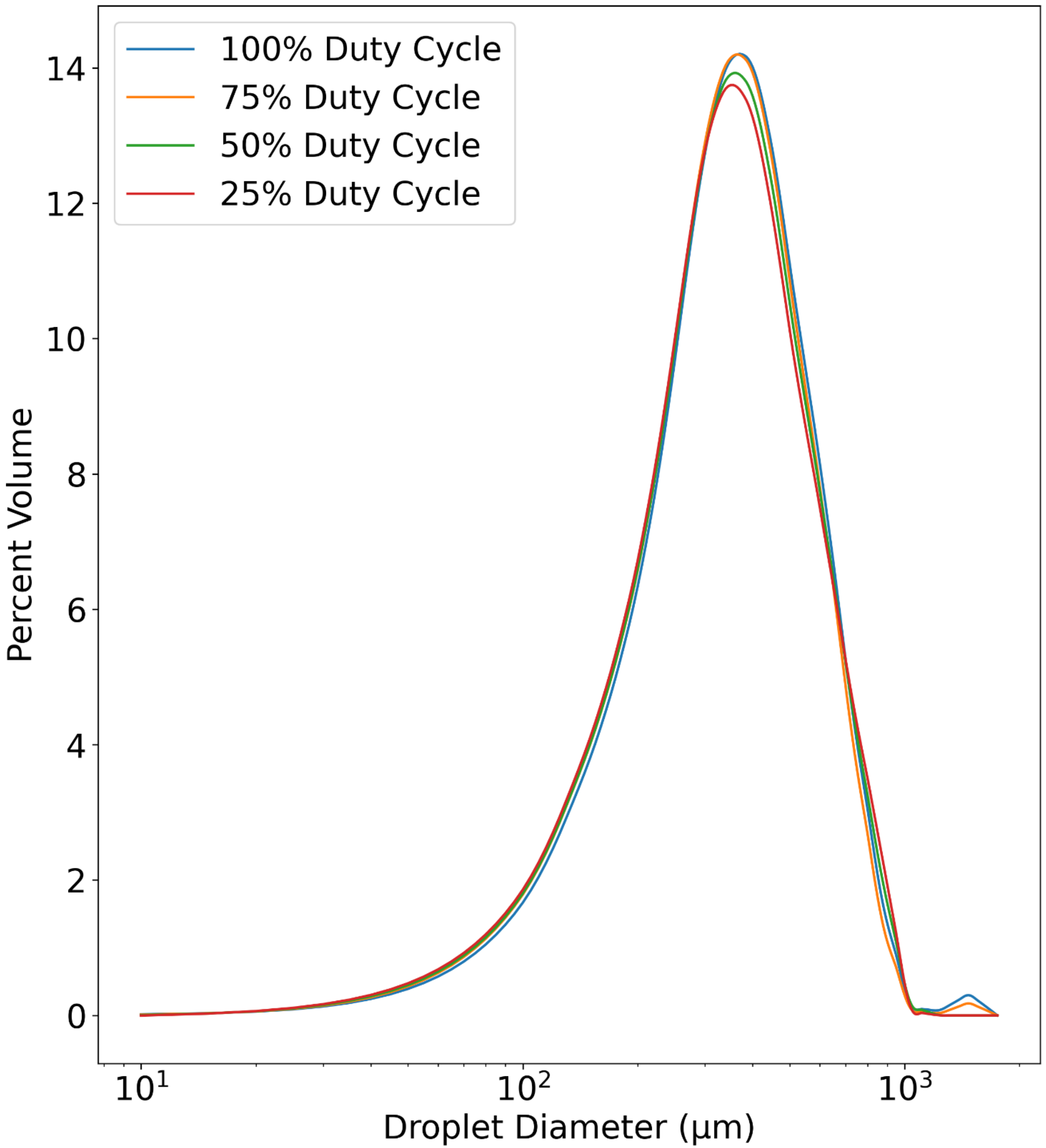
Duty Cycle:
100% → 75% → 50% → 25%

Dv0.1:
136 → 131 → 130 → 128 µm

Dv0.5:
312 → 305 → 305 → 302 µm

Dv0.9:
566 → 552 → 565 → 569 µm

Percent Fines:
5.3 → 5.7 → 5.8 → 6.1



TeeJet Stainless Steel 0010
40 PSI @ 140 mph

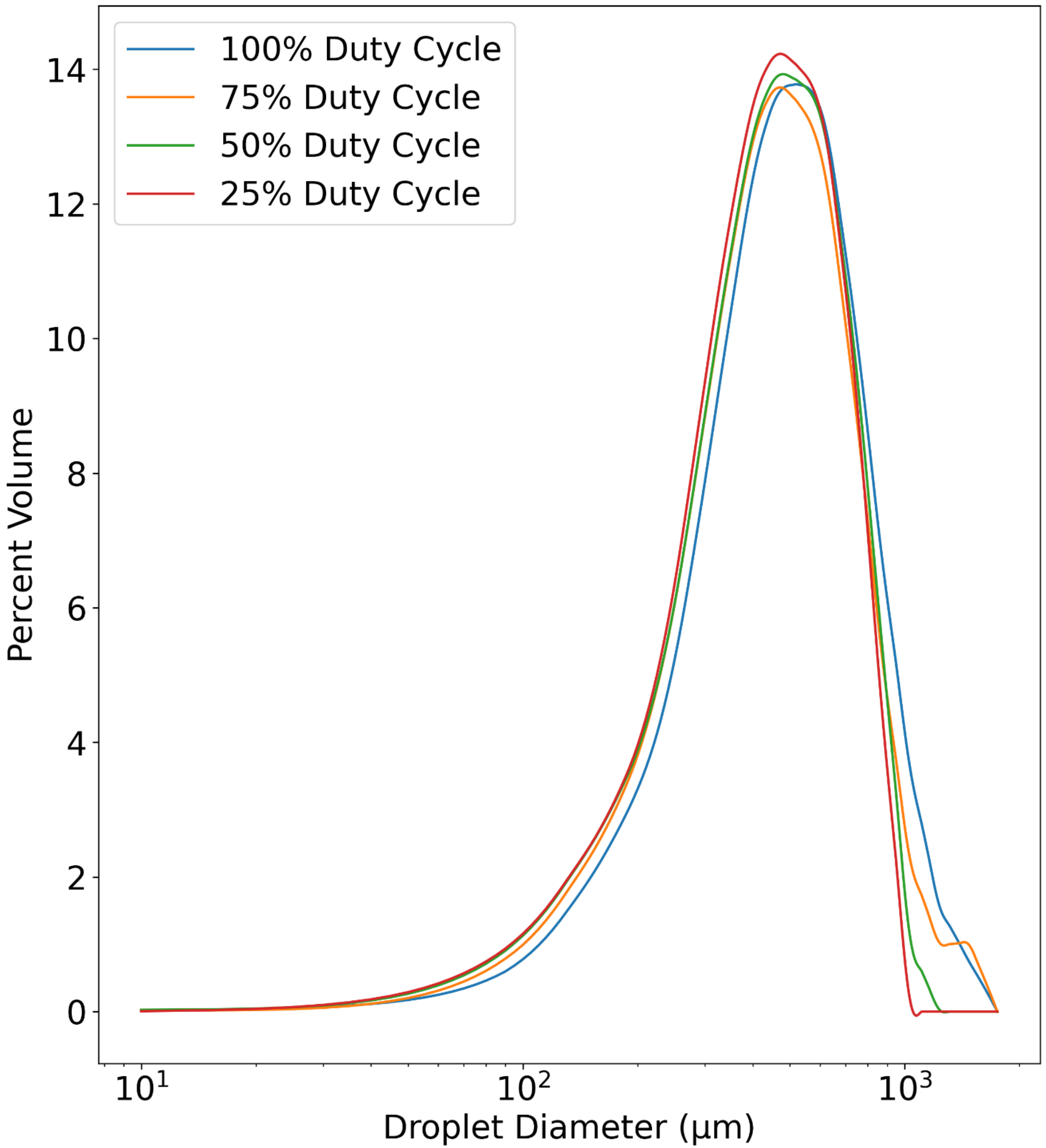
Duty Cycle:
100% → 75% → 50% → 25%

Dv0.1:
191 → 176 → 166 → 164 μm

Dv0.5:
432 → 405 → 398 → 389 μm

Dv0.9:
784 → 730 → 688 → 662 μm

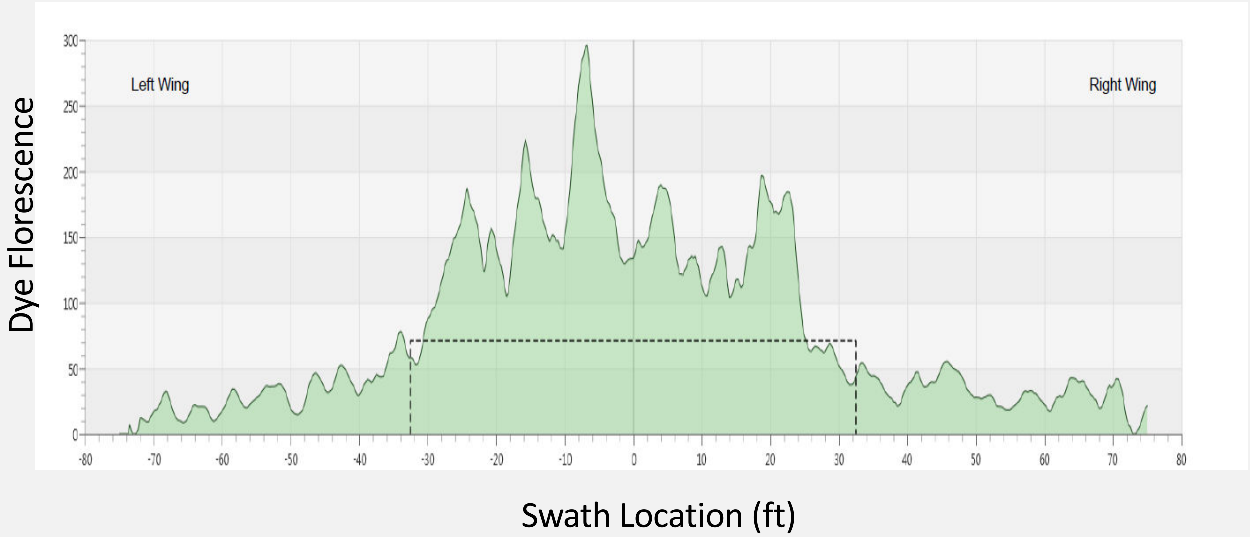
Percent Fines:
2.4 → 2.9 → 3.6 → 3.7



ReCurve™ Nozzle Configuration Software

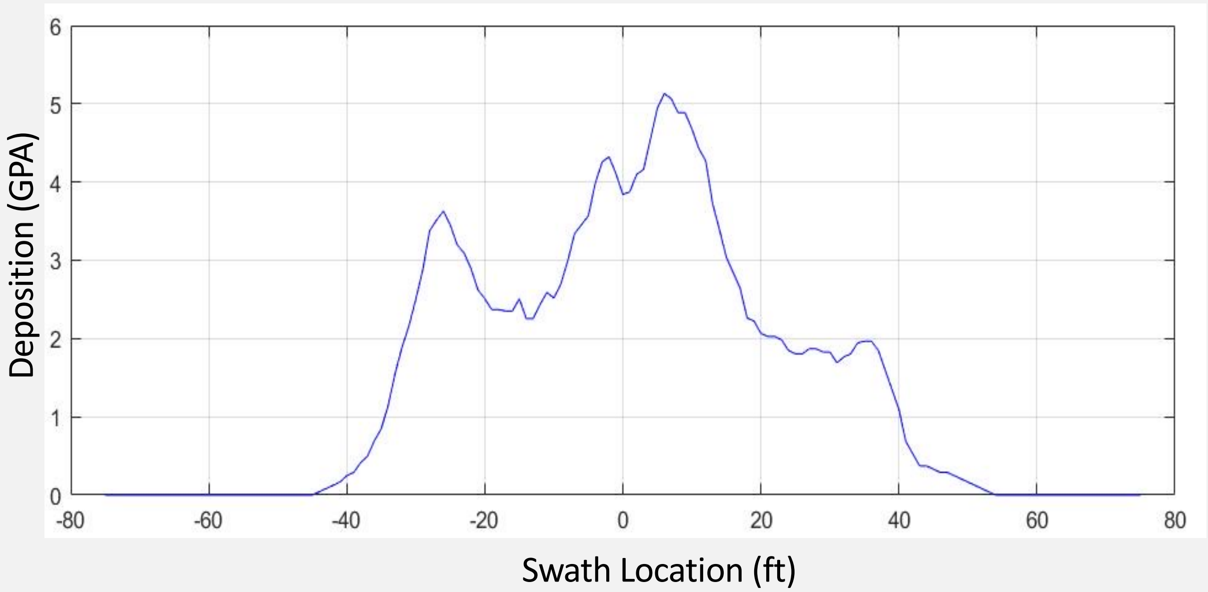
Graphical Representations Identifying Pattern Shaping Recommendations

WRK String Results of Conventional Pattern



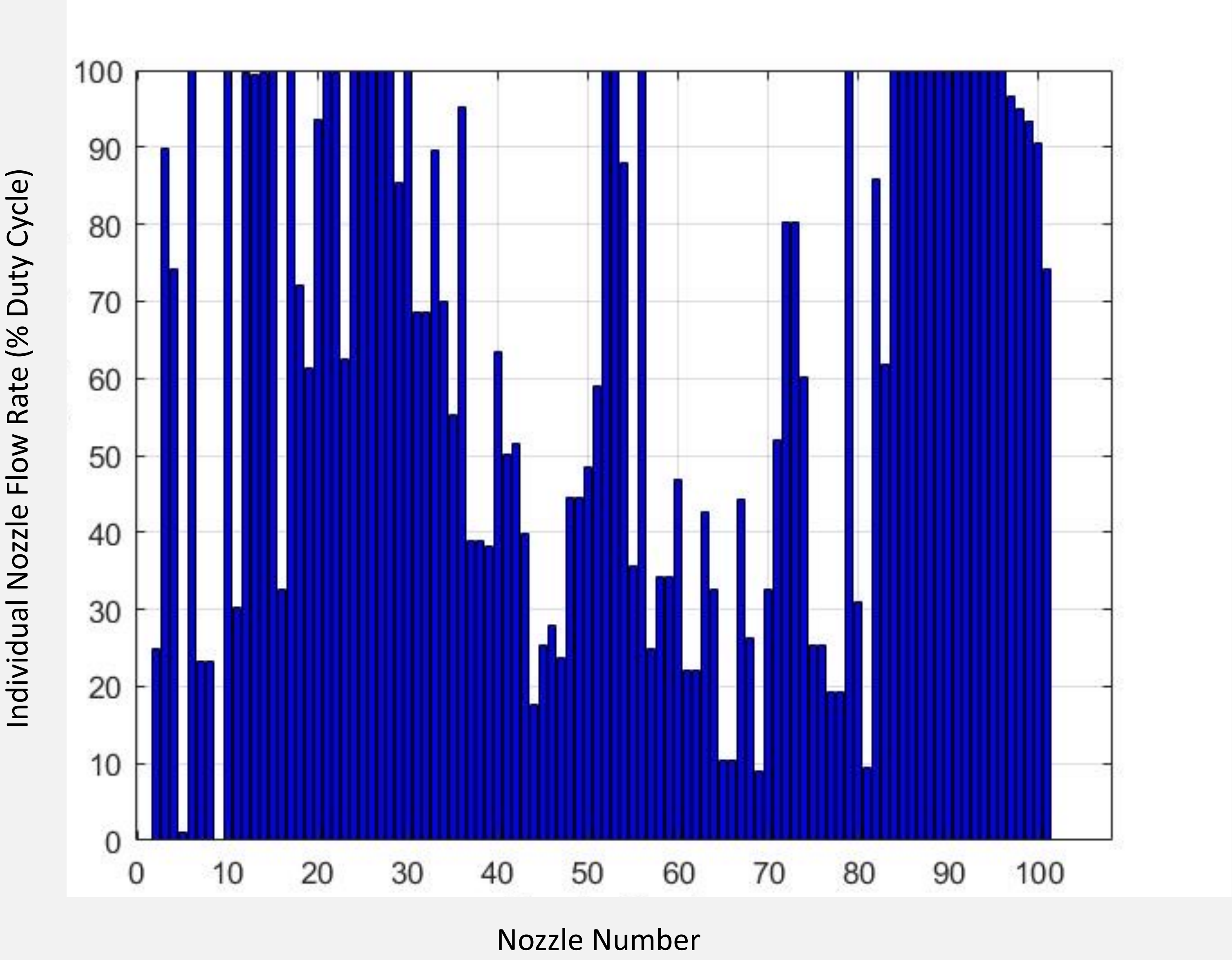
Swath (ft)	CV (RT)	CV (BF)
56	20%	21%
57	20%	22%
58	20%	24%
59	21%	25%
60	22%	25%
61	24%	26%
62	25%	27%
63	26%	28%
64	27%	29%
65	27%	29%
66	28%	29%
67	28%	30%
68	29%	30%
69	30%	30%
70	31%	30%
71	32%	30%
72	33%	30%
73	34%	31%
74	34%	32%

ReCurve™ Prediction of Conventional Pattern



Swath (ft)	CV (RT)	CV (BF)
55	17.1%	19.1%
56	17.1%	19.1%
57	18.8%	20.9%
58	18.8%	20.9%
59	20.8%	23.2%
60	20.8%	23.2%
61	22.6%	25.3%
62	22.6%	25.3%
63	24.3%	27%
64	24.3%	27%
65	25.5%	28.2%
66	25.5%	28.2%
67	26.4%	29.3%
68	26.4%	29.3%
69	27.1%	30.3%
70	27.1%	30.3%
71	27.7%	31.4%
72	27.7%	31.4%
73	28.4%	32.4%
74	28.4%	32.4%
75	29.2%	33.5%

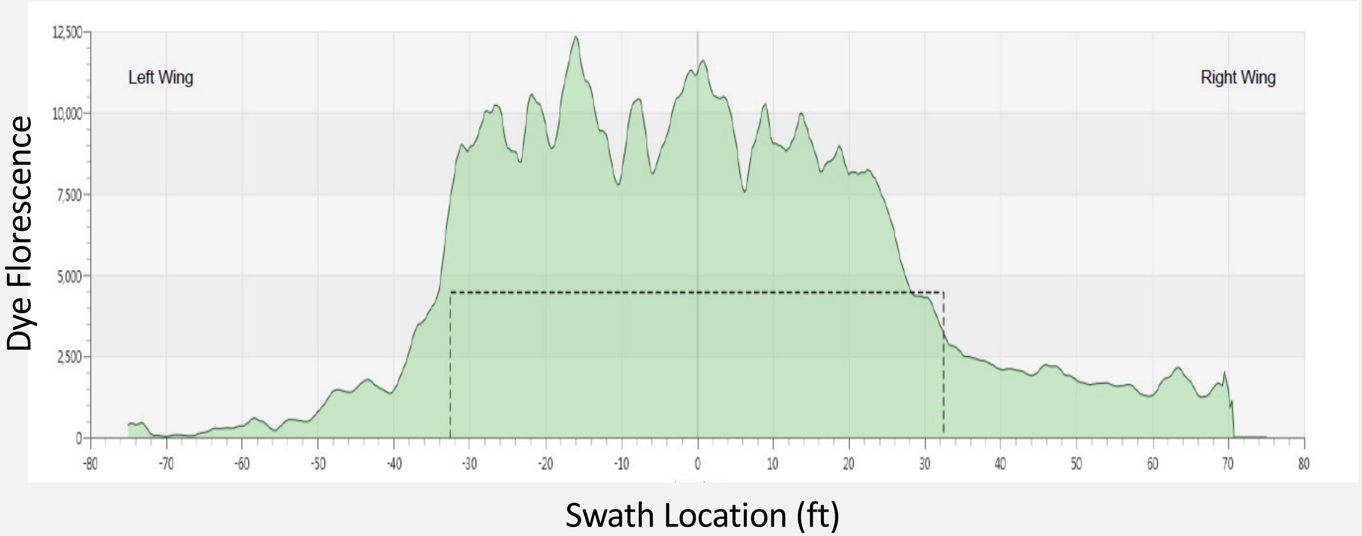
ReCurve™ Recommended Individual Nozzle Flow Configuration



ReCurve™ Prediction of Recommended Pattern

Swath (ft)	CV (RT)	CV (BF)
55	13.4%	14.9%
56	13.4%	14.9%
57	13.6%	15.2%
58	13.6%	15.2%
59	13.8%	15.6%
60	13.8%	15.6%
61	14.1%	15.9%
62	14.1%	15.9%
63	14.5%	16.3%
64	14.5%	16.3%
➡ 65	14.9%	16.8% ⬅
66	14.9%	16.8%
67	15.4%	17.2%
68	15.4%	17.2%
69	16%	17.6%
70	16%	17.6%
71	16.7%	18.1%
72	16.7%	18.1%
73	17.5%	18.5%
74	17.5%	18.5%
75	18.3%	19.1%

WRK String Results of ReCurve™ Configuration



Swath (ft)	CV (RT)	CV (BF)
56	11%	18%
57	11%	18%
58	10%	18%
59	10%	18%
60	10%	18%
61	11%	18%
62	12%	18%
63	12%	17%
64	13%	17%
➡ 65	14%	17% ⬅
66	16%	17%
67	17%	17%
68	18%	17%
69	19%	18%
70	20%	18%
71	21%	19%
72	22%	20%
73	23%	20%
74	24%	21%

Summary Pulse Width Modulation (PWM)

- PWM technology provides several benefits and advantages in agricultural spraying, including:

1. **Improved accuracy and precision:**
    - Enables precise control over the flow rate of liquid through nozzles, resulting in more accurate and consistent application of chemicals.
2. **Reduced environmental impact:**
    - By controlling droplet size and mitigating drift, it reduces the amount of chemicals that drift away from the intended target area, reducing the impact on the environment and neighboring crops.
3. **Increased efficiency:**
    - The ability to adjust the duty cycle allows for precise application control, minimizing waste and ensuring that the right amount of spray is applied to the target area. This leads to increased efficiency and reduced input costs.
4. **Ease of use:**
    - Can be integrated into existing rate control systems, making it easy for operators to adopt and use the technology without significant changes to their equipment or processes.
5. **Autonomous Boom:**
    - Being able to change flow rates at each valve based off weather inputs.

Overall, PWM technology provides significant benefits in agricultural spraying, improving accuracy, reducing environmental impact, increasing efficiency, and saving costs for operators and farmers.

Thank You!!

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OR
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