The Ins and Outs of Pulse-Width Modulation Sprayers

Wisconsin Agribusiness Classic

Madison, WI

Thomas R. Butts, Extension Weed Scientist

17 Jan 2019

Spray Application History

Figure 8. Row-crop compressed-air sprayer

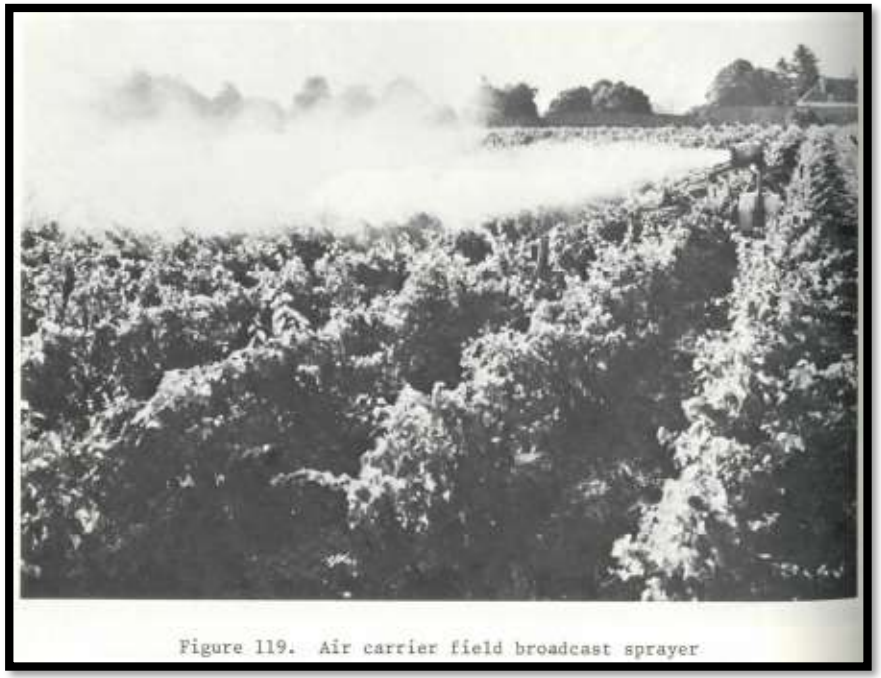
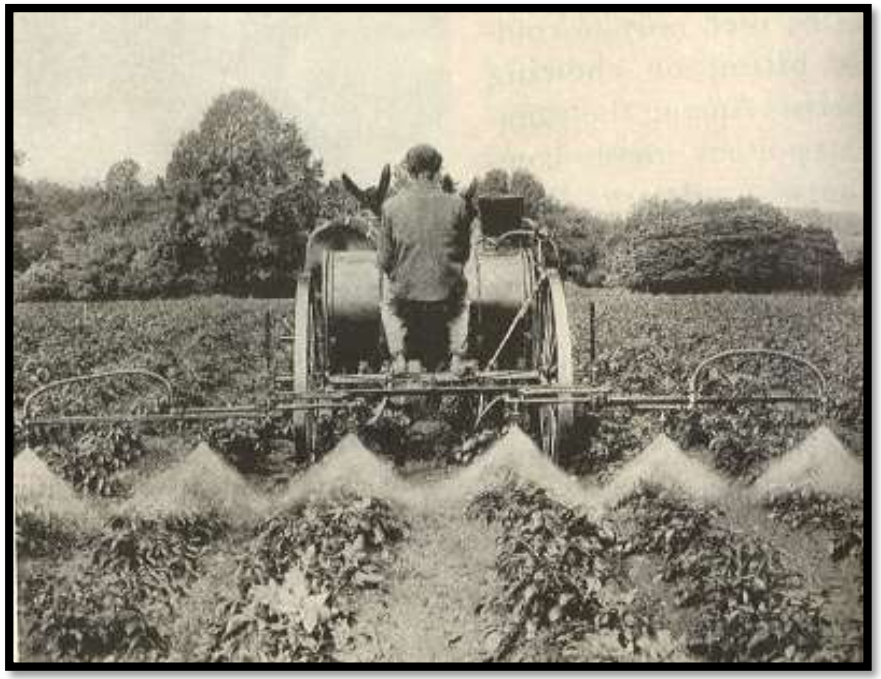


Figure 119. Air carrier field broadcast sprayer



Hammonds and Woods 1938. *Today's Agriculture*. 498p.
Akesson and Yates 1979. *FAO Agricultural Services Bulletin* 38:220p

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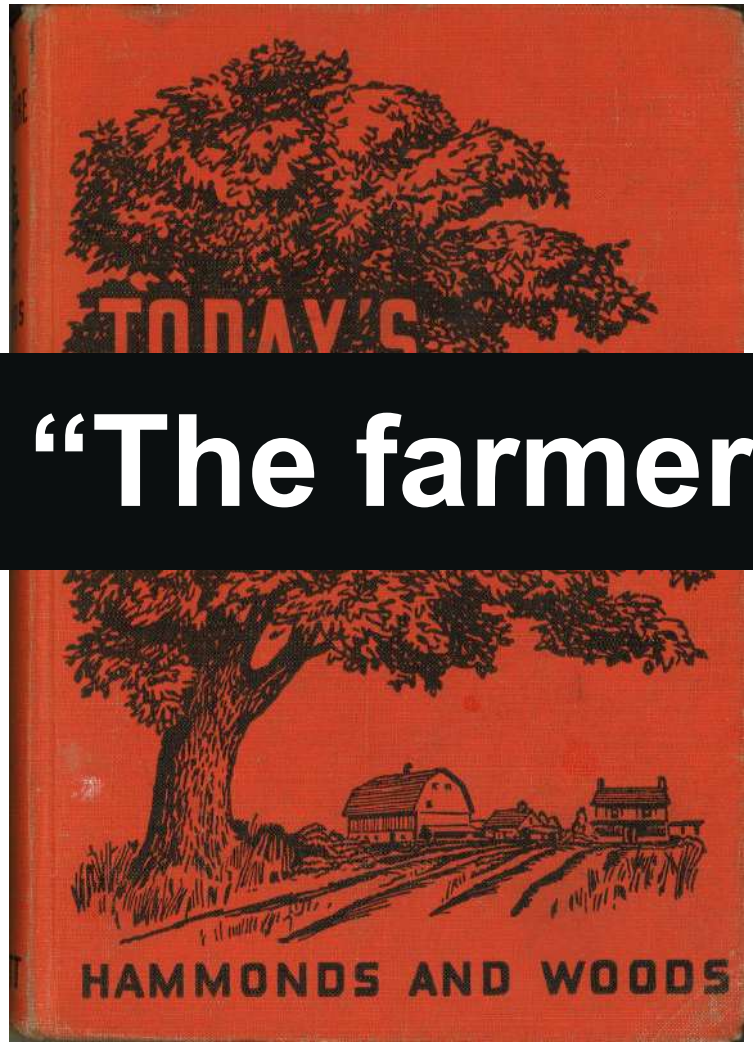
Spray Application History

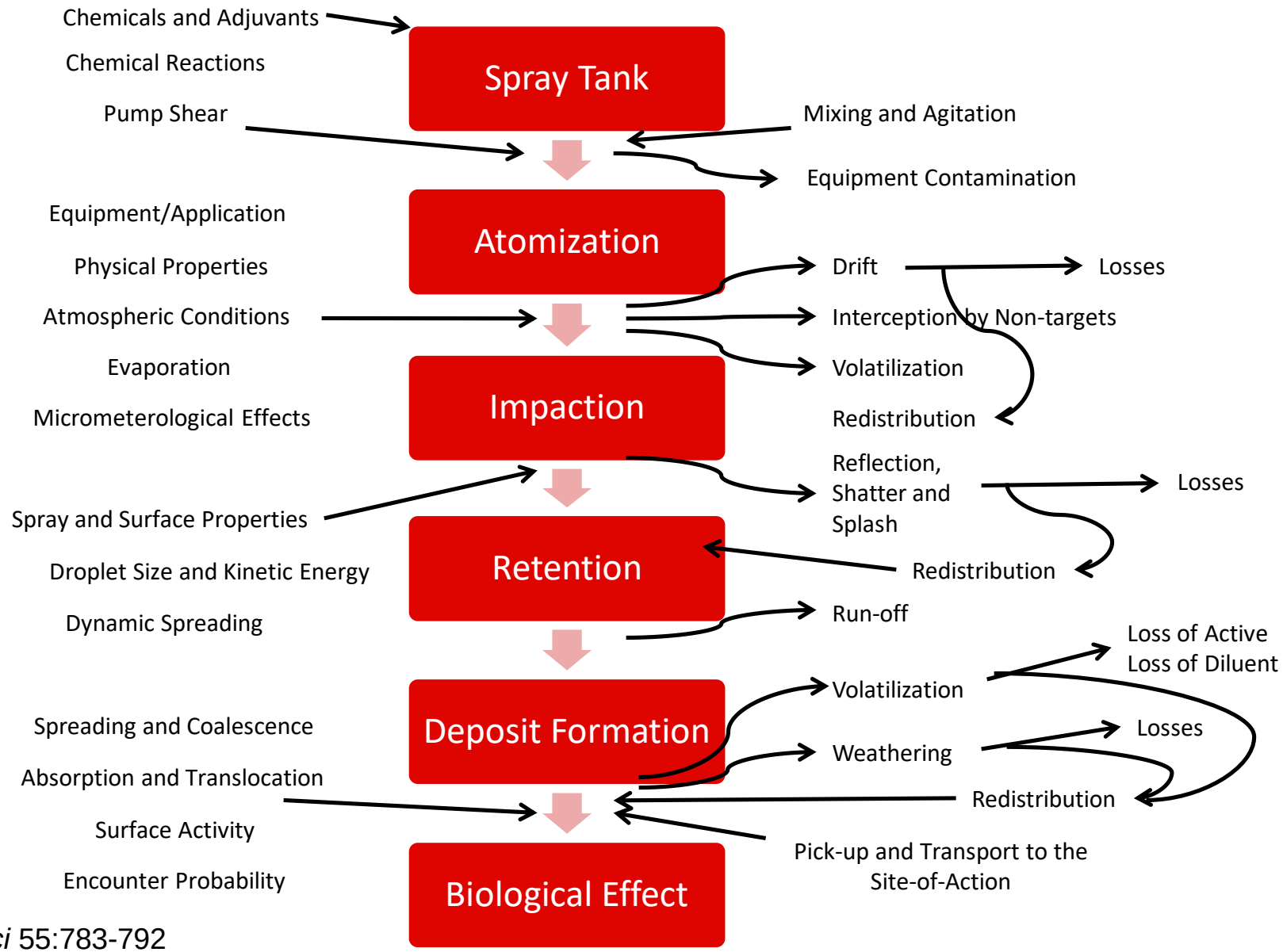


The farmer has many problems. He confers with specialists on plant disease (*top left*); hog management (*bottom left*); soils (*top right*); and dairy management (*bottom right*).

"The farmer has many problems."

Hammonds and Woods 1938. *Today's Agriculture*. 498p.

Pesticide Spray Applications



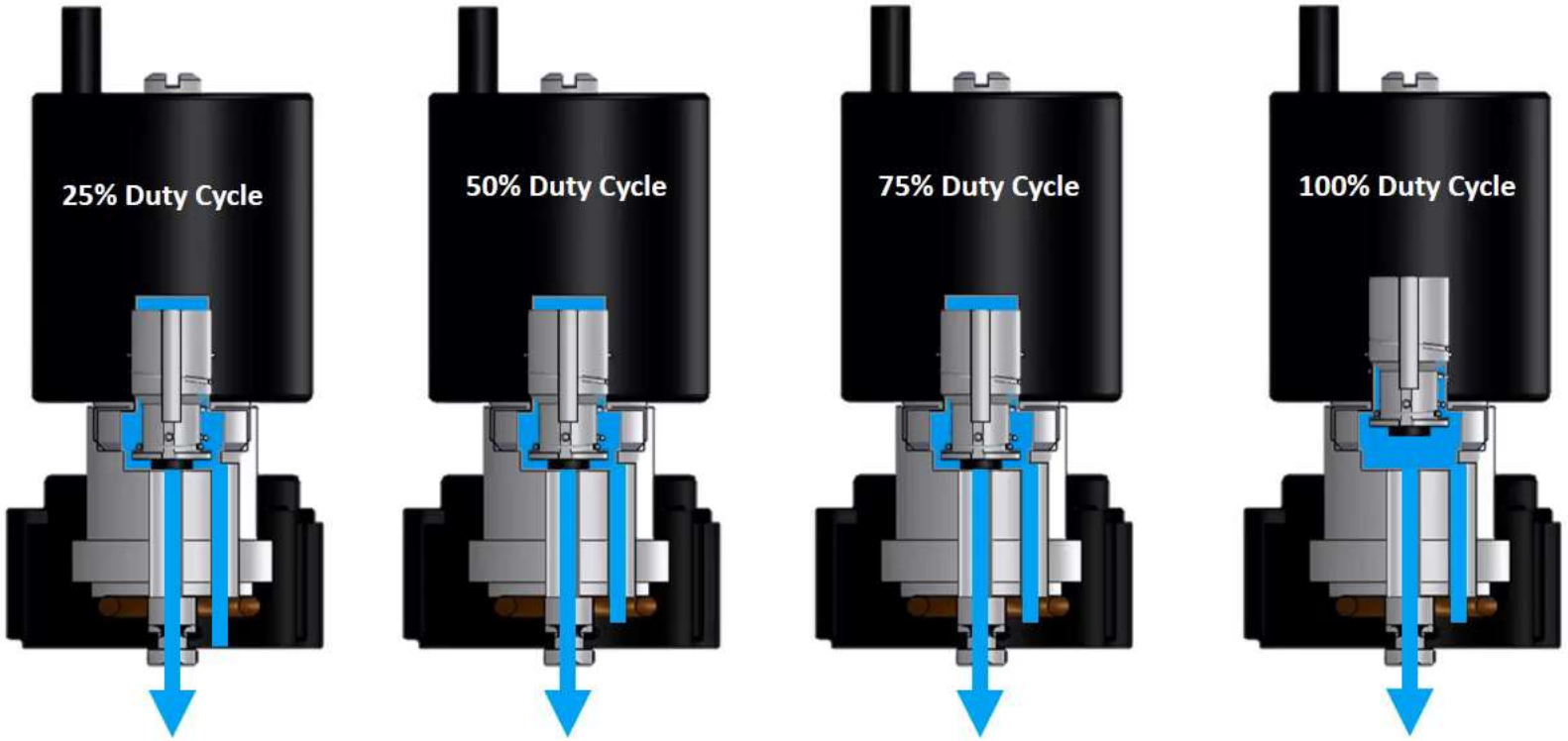
Ebert et al. 1999. *Pestic Sci* 55:783-792

Optimizing Applications

- Pulse-width modulation (PWM) allows for flow to be controlled by the relative proportion of time each electronically actuated solenoid valve is open (duty cycle)[1]
- Duty cycle has minimal impact on droplet size[2]
- PWM system advantages for site-specific management:
  - Individual nozzle control
  - Turn compensation
  - Quick, real-time flow rate changes
  - No pressure-based changes needed

- [1]Giles and Comino, 1989. J. of Commercial Vehicles. SAE Trans. 98:237-249. DOI: 10.4271/891836.
- [2]Butts et al., 2019. Biosyst. Eng. 178:52-69. DOI: 10.1016/j.biosystemseng.2018.11.004.

10 htz Valve Animation
1/20 Speed (0.1s → 2.0s)



0.005 s

Courtesy of Brian Finstrom, Capstan Ag Systems, Inc.

PWM Basics

Scan me

For more detailed information on operating PWM sprayers, please scan the QR code to the left.

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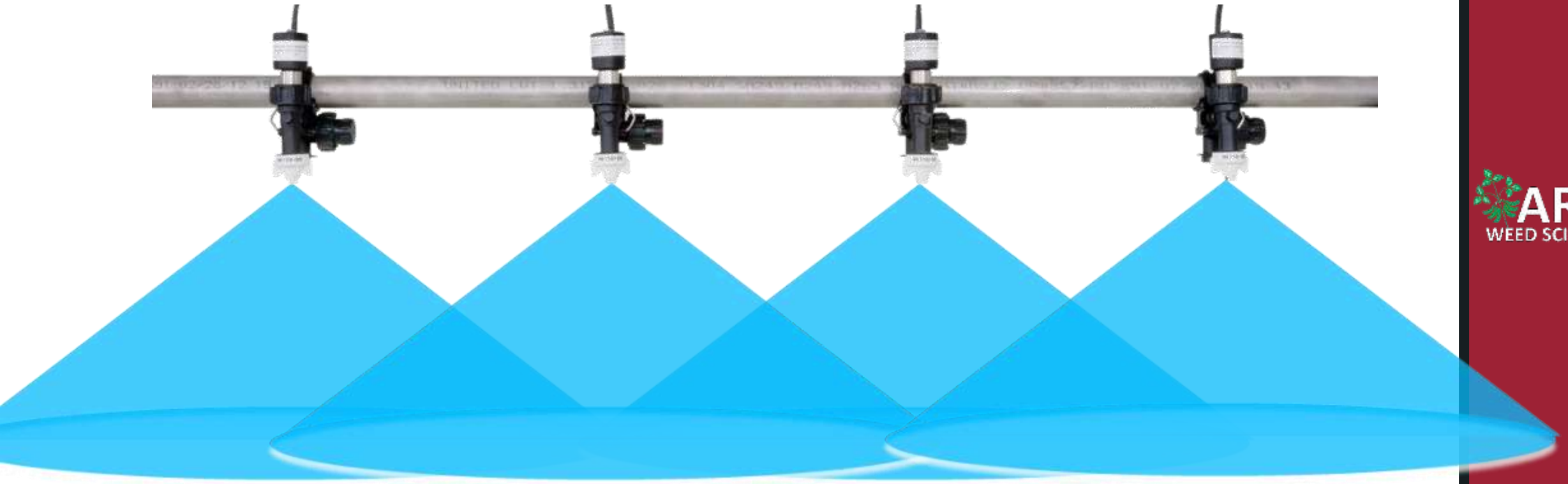
With all this pulsing wouldn't PWM leave skips in the field?

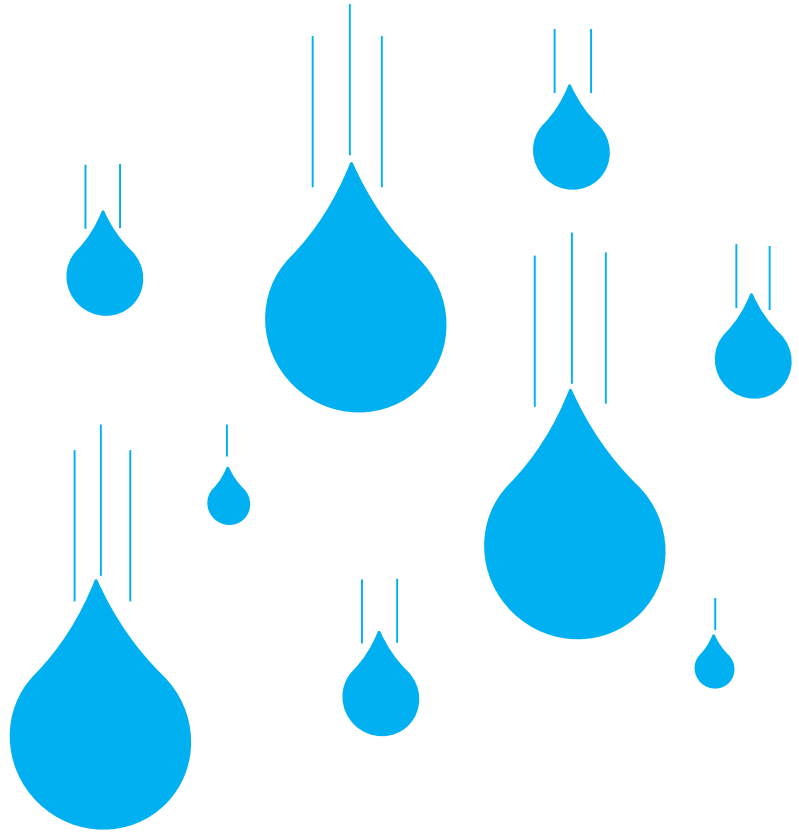


Through Alternating (Blended) Pulse We Maintain 100% Overlap

Courtesy of Brian Finstrom, Capstan Ag Systems, Inc.

Objectives:

- **Evaluate the effect of PWM duty cycle, current nozzle technology, and boom pressure on:**
  - Spray droplet size
  - Nozzle tip pressure
  - Droplet velocity
  - Spray pattern uniformity



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Importance of Droplet Size, Velocity, and Pattern Uniformity

- **Particle Drift –**
  - Greater droplet size = reduced drift
  - Higher velocity = reduced drift[1]
- **Spray Coverage –**
  - Increased spray pattern uniformity maintains appropriate spray coverage[2]
  - Collapsed, non-uniform patterns can lead to underapplication areas thereby selecting for herbicide resistance[3]
- **Herbicide Efficacy –**
  - Generally, increases in droplet size decreased herbicide efficacy[4]

[1]Farooq, M, Balachandar, R, Wulfsohn, D and Wolf, TM, "Agricultural sprays in cross-flow and drift," *J Agr Eng Res*., Vol. 78, No. 4, 2001, 347–58.

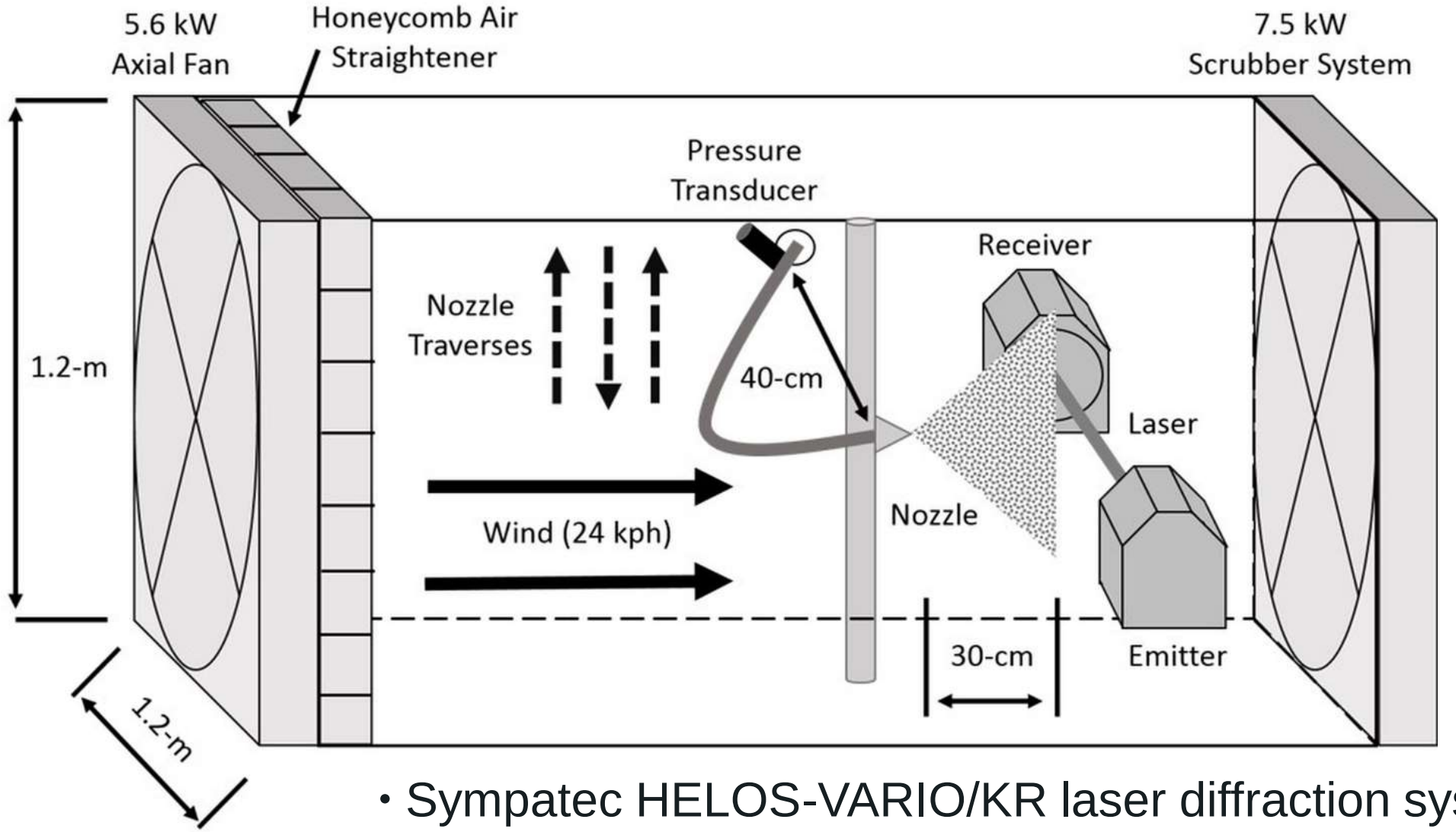
[2]Matthews, G., Bateman, R., Miller, P., 2014. Pesticide Application Methods, 4th Edition, 4th ed. Wiley-Blackwell.

[3]Gressel, J., 2011. Low pesticide rates may hasten the evolution of resistance by increasing mutation frequencies. Pest Manag Sci 67, 253–257. https://doi.org/10.1002/ps.2071

[4]Knoche, M. 1994. Effect of droplet size and carrier volume on performance of foliage-applied herbicides. Crop Prot 13(3): 163–178. doi: 10.1016/0261-2194(94)90075-2.

1. PWM Effect on Droplet Size & Nozzle Tip Pressure

Low Speed Wind Tunnel – PAT Lab



- Sympatec HELOS-VARIO/KR laser diffraction system

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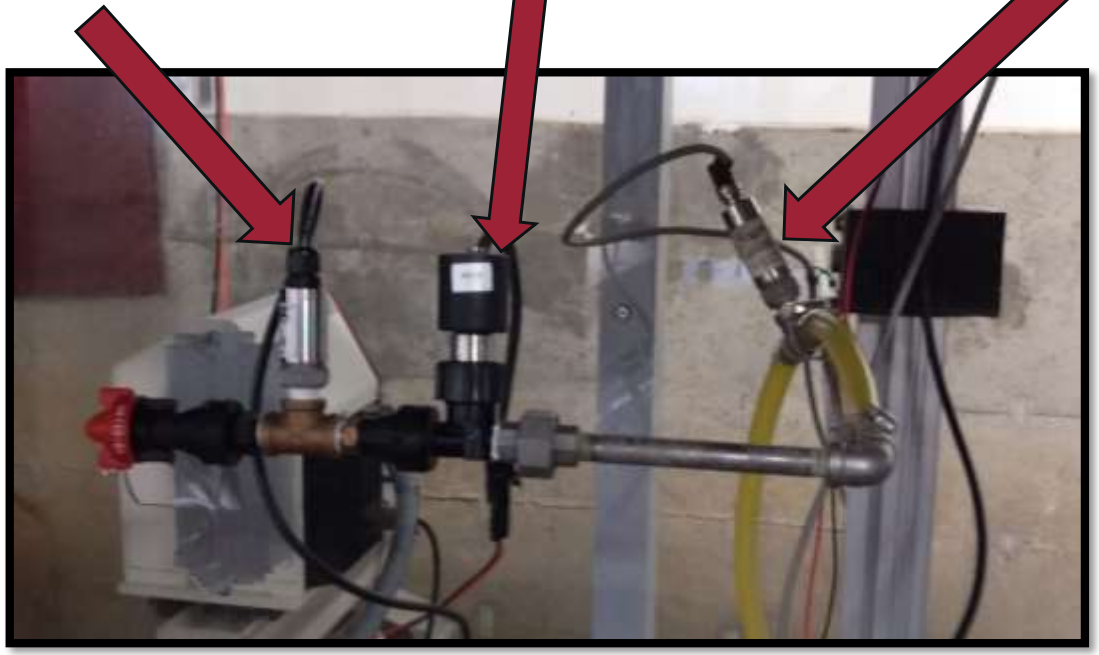
1. PWM Effect on Droplet Size & Nozzle Tip Pressure

Nozzle Tip Pressure Measurements

Nozzle Pressure

Solenoid Valve

Boom Pressure



2. PWM Effect on Droplet Velocity

Low Speed Wind Tunnel

- Aerial Application Technology Laboratory
  - USDA Southern Plains Agricultural Research Center, College Station, TX
- 2.2 mph wind speed
- Capstan SharpShooter PWM System
- Solenoid valve = 10 Hz frequency

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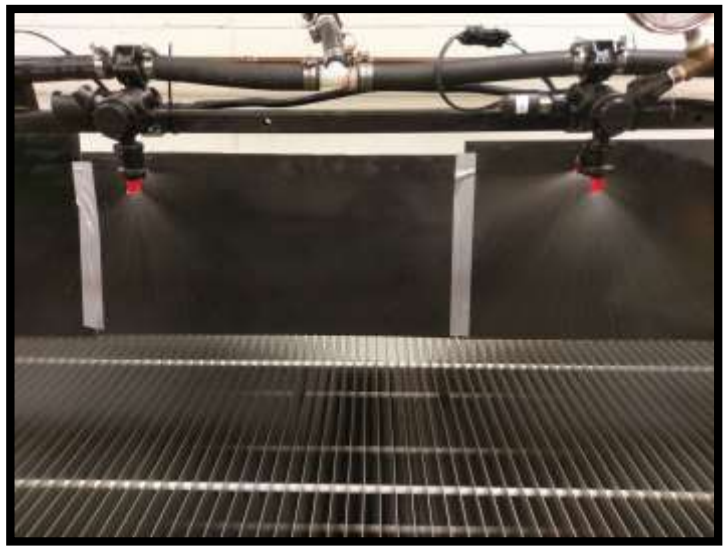
2. PWM Effect on Droplet Velocity

LaVision SprayMaster

- Pulsed laser to backlight images
- Paired images recorded 10 µs apart
- Droplet size and velocities recorded 6 inches from the nozzle
- Droplet size measurement range between 60 and 2000 µm
- 300 paired images collected
- Nozzle traversed for two complete revolutions, four samples of the entire spray plume

3. PWM Effect on Pattern Uniformity

Patternator



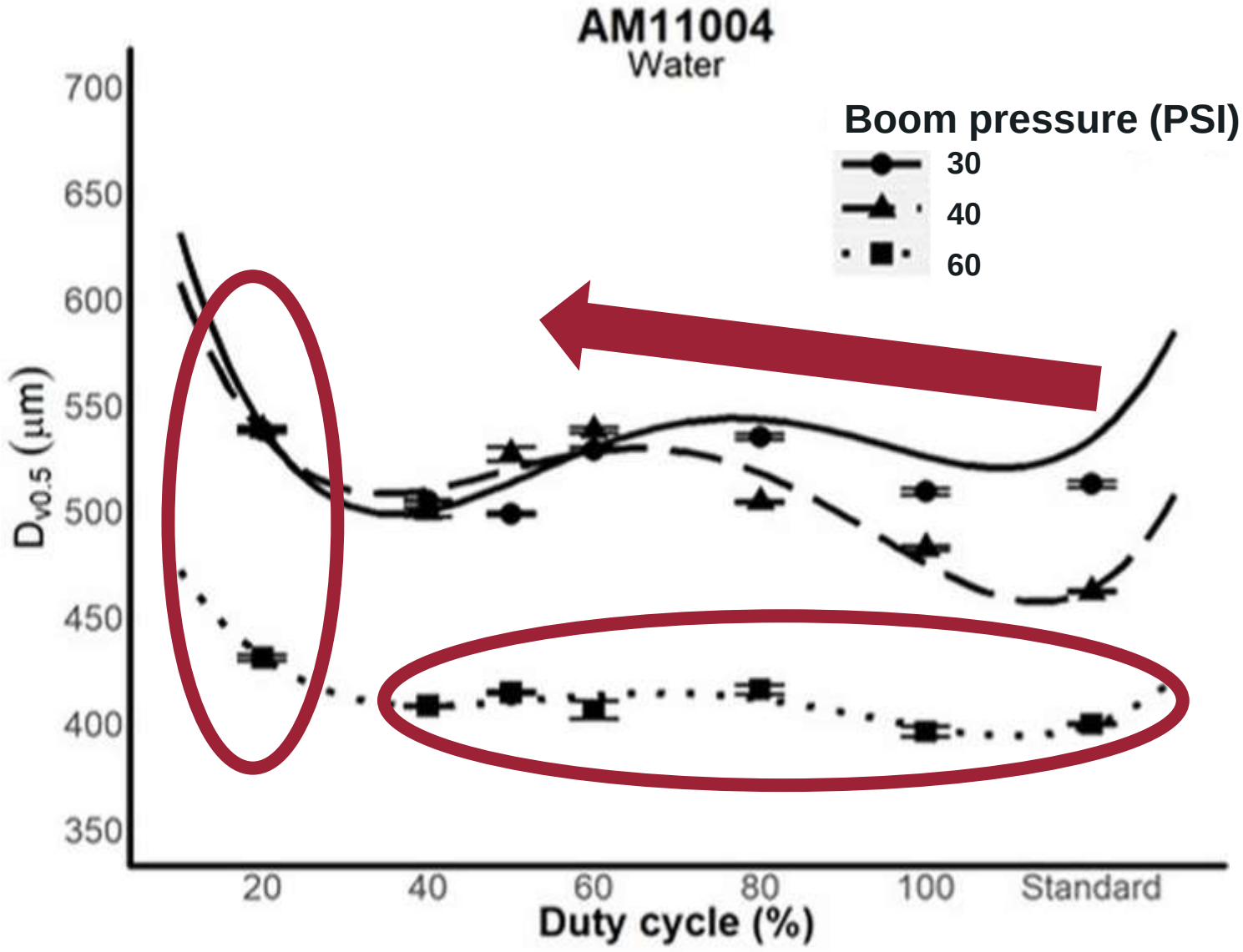
- Measures amount of time needed to fill 166 mL collection tubes
- Collection tubes spaced 1 inch apart
- Nozzle spacing = 20 inches
- Boom height = 20 inches
- Three nozzles
- Two-20 inch collection widths were taken (40 inches total pattern width)
- Three replicates (40 inches)

Treatments

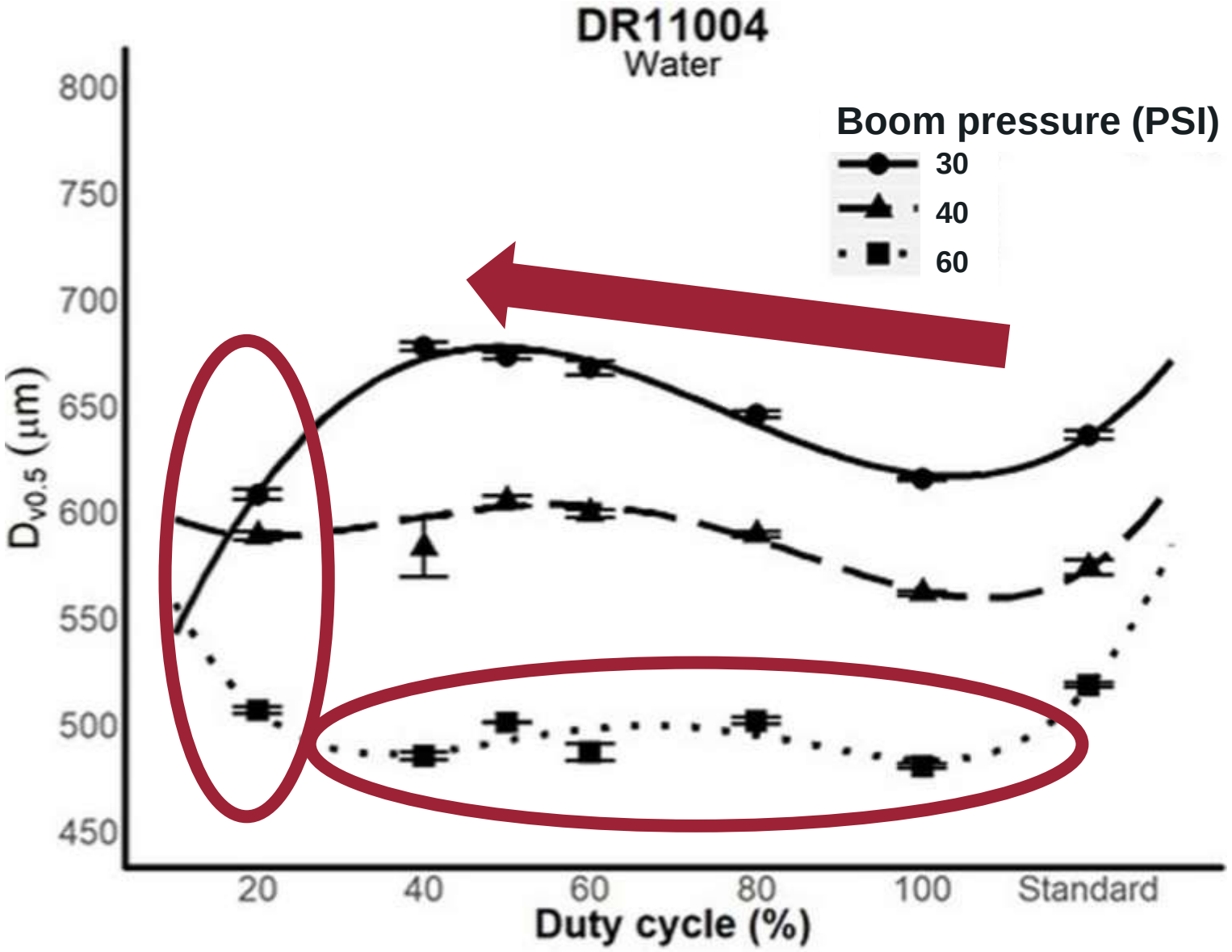
- **6 PWM Duty Cycles:**
  - 20%
  - 40%
  - 60%
  - 80%
  - 100%
  - Standard (No Solenoid)

- 1
- 04,

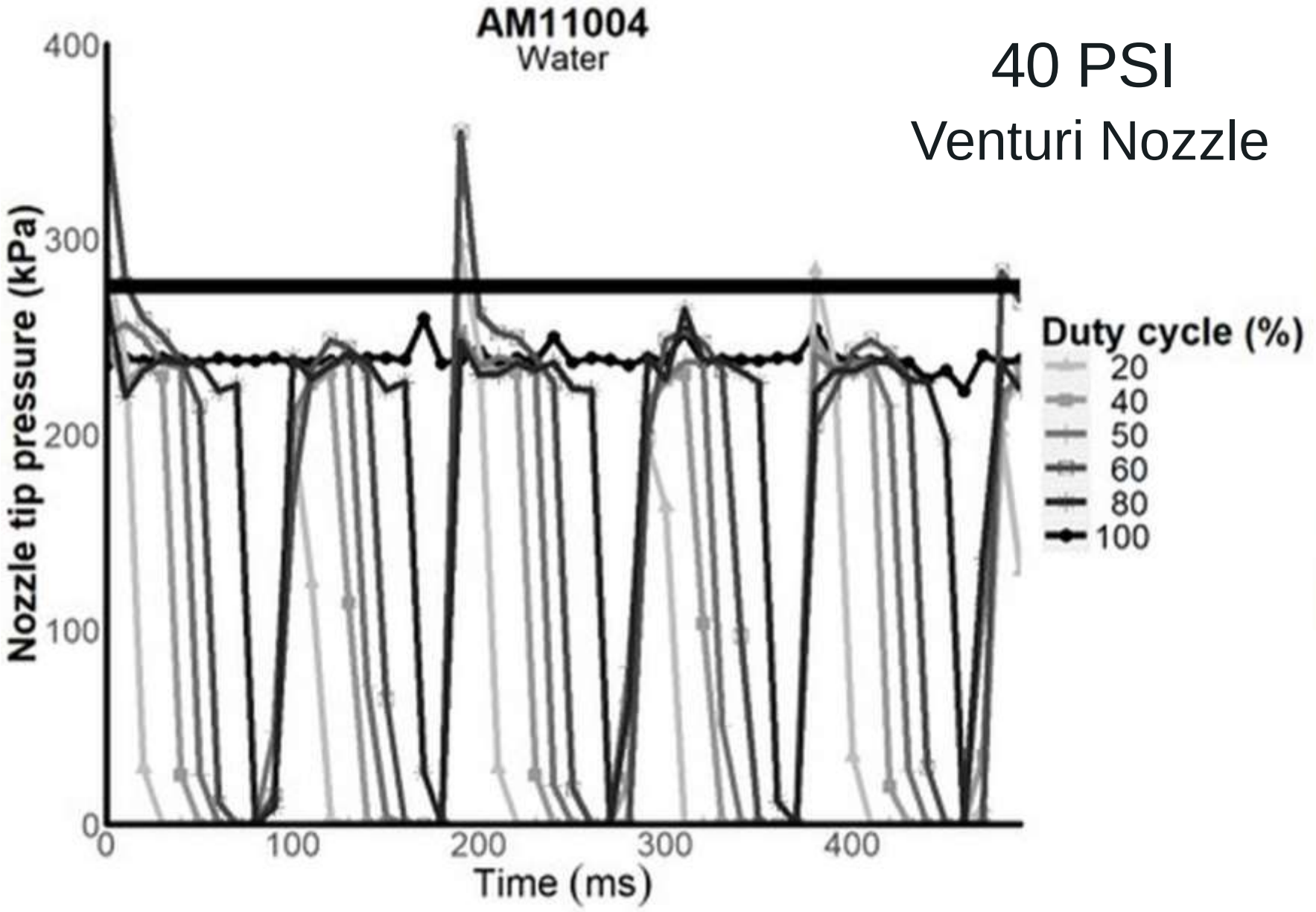
Droplet Size Results



Droplet Size Results



Nozzle Tip Pressure Results



40 PSI

Venturi Nozzle

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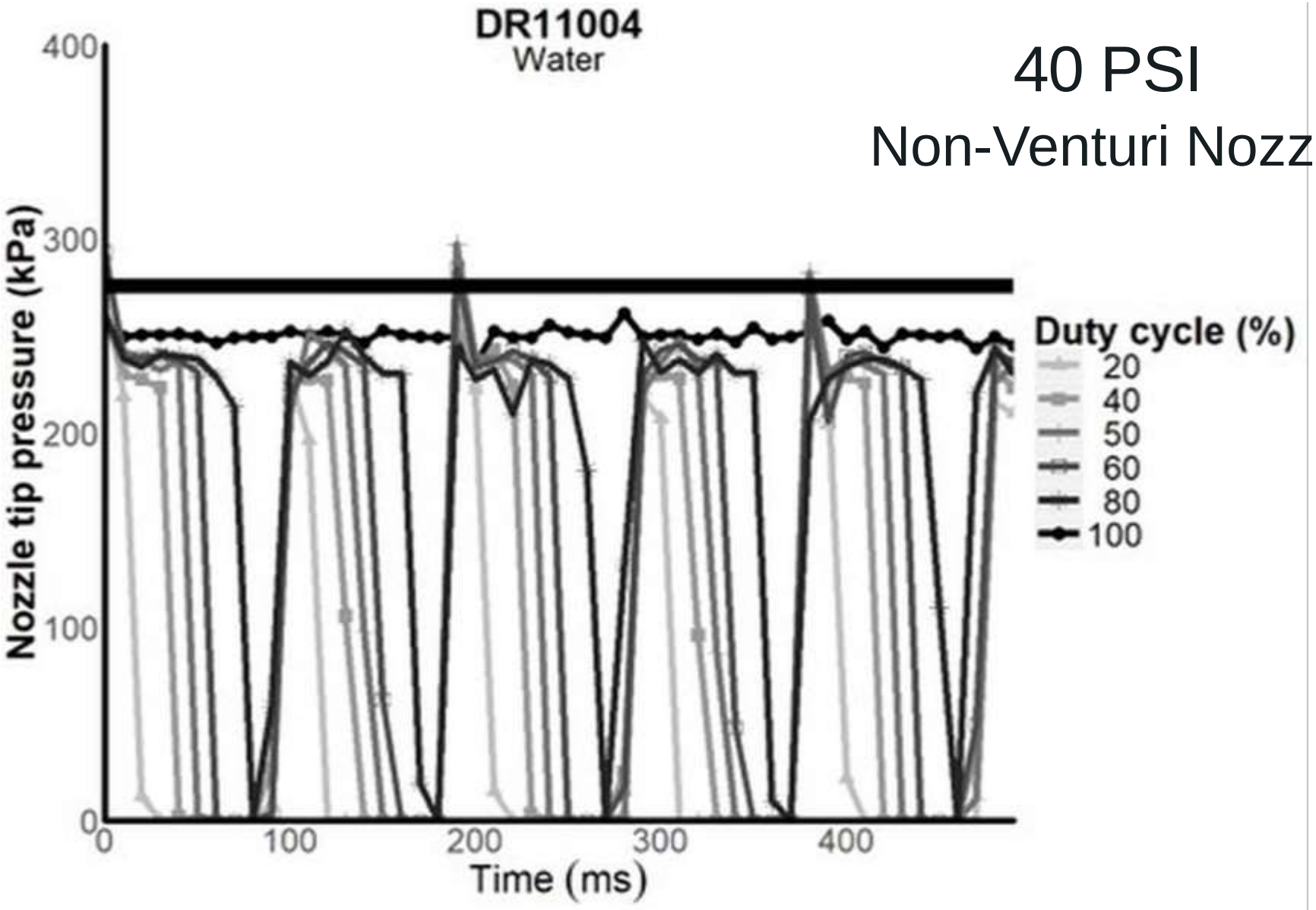
Nozzle Tip Pressure Results



40 PSI

Non-Venturi Nozzle

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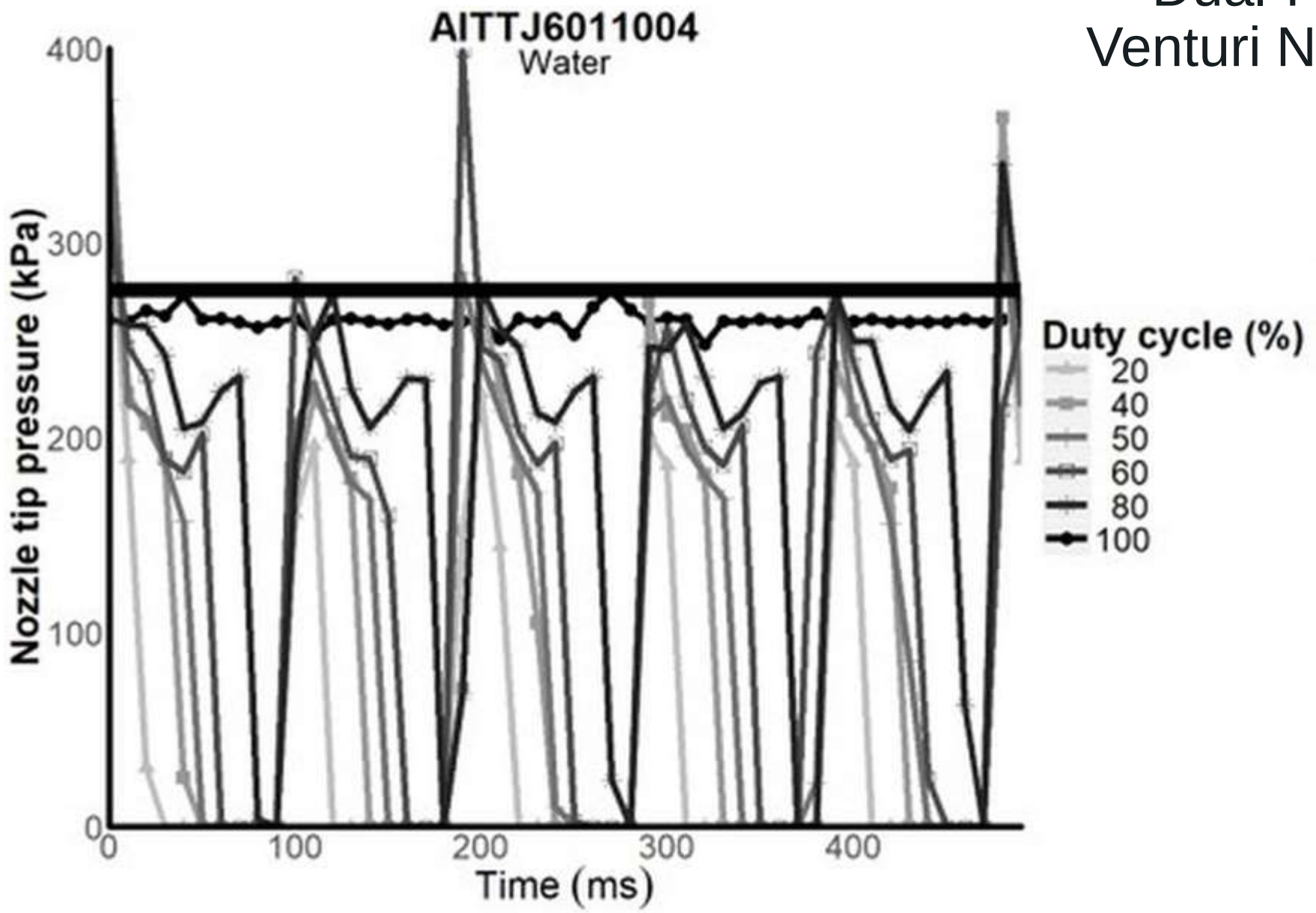
Nozzle Tip Pressure Results

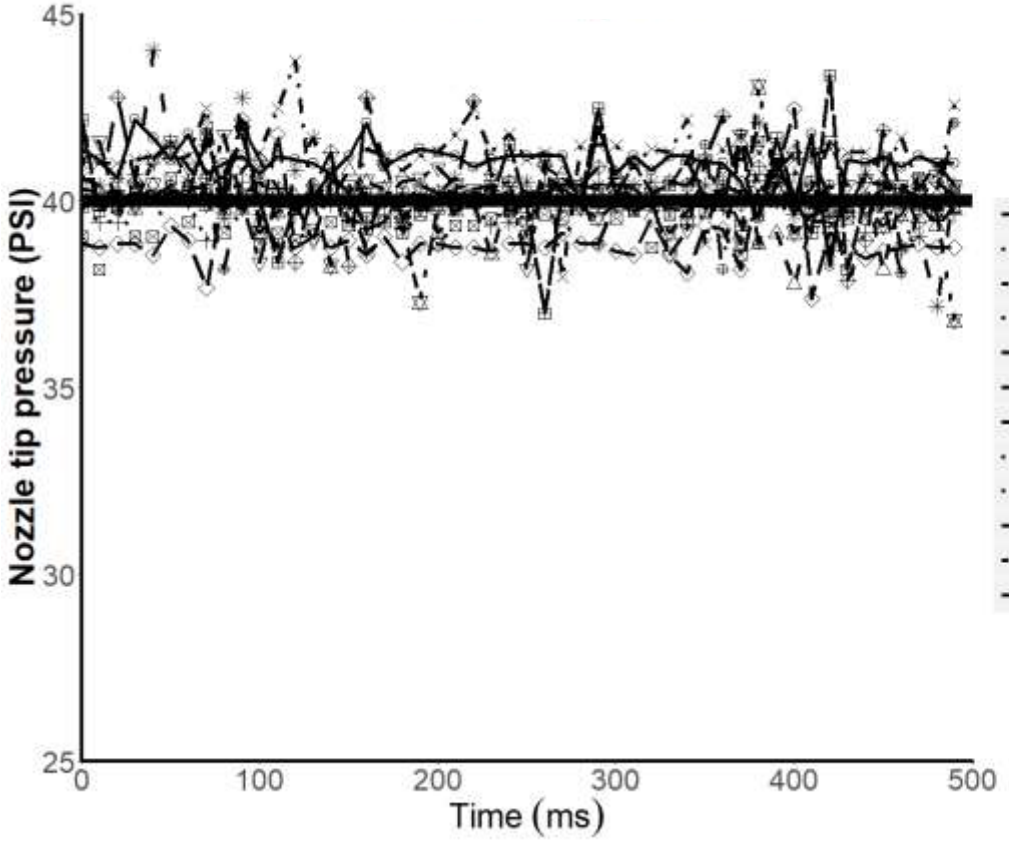
40 PSI
Dual-Fan
Venturi Nozzle

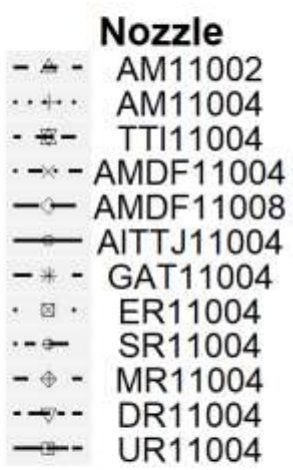


PWM Best Use Practices

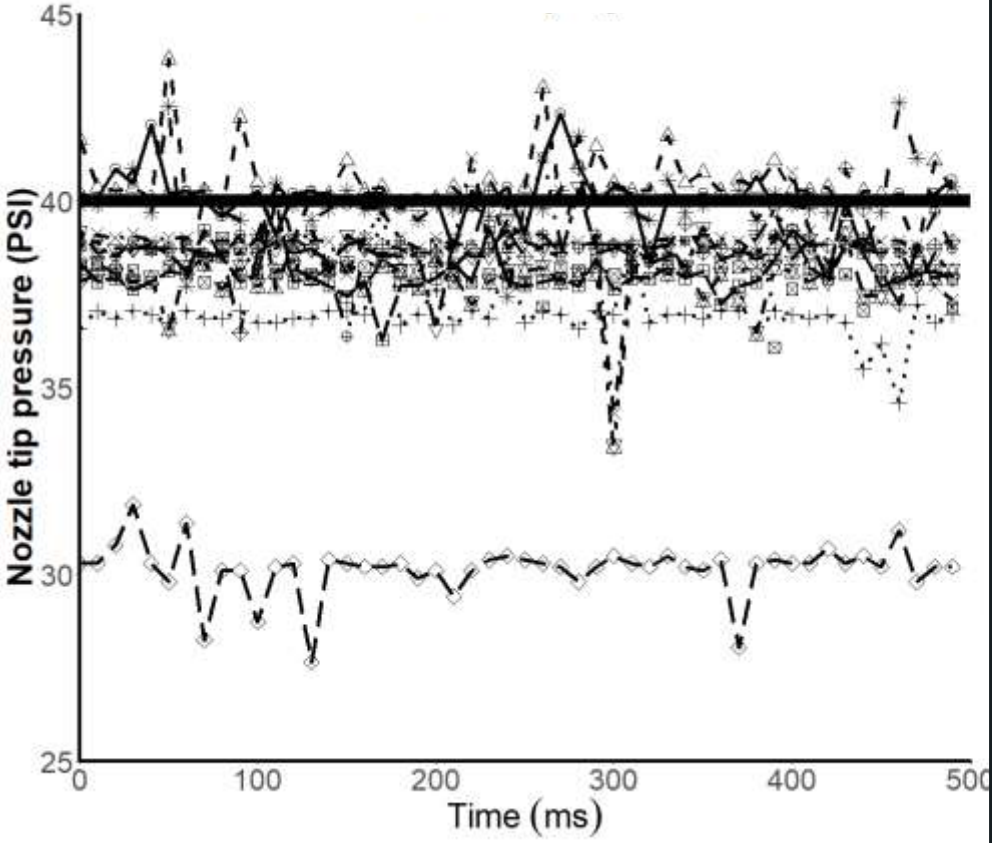
40 PSI

— Solenoid Valve





+ Solenoid Valve



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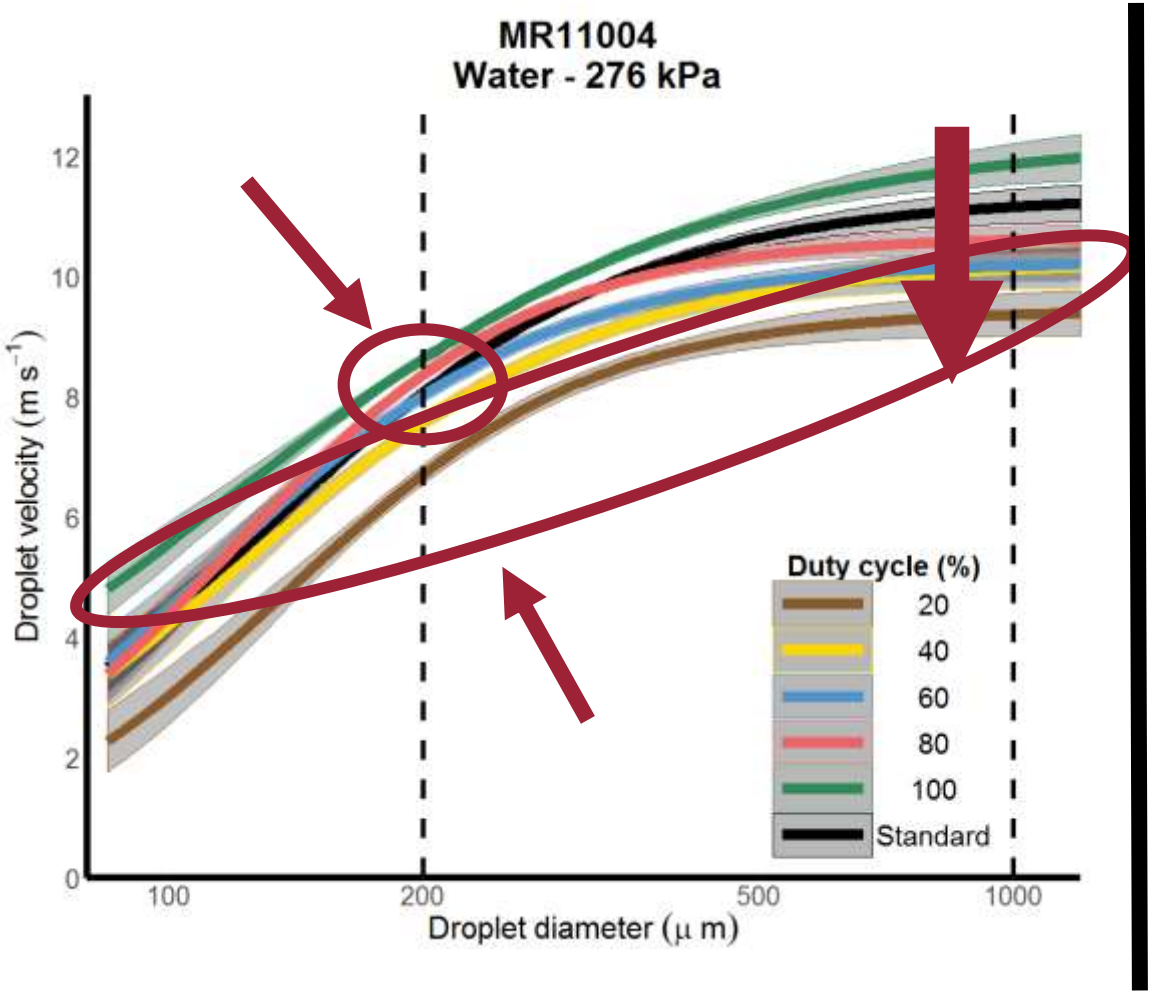
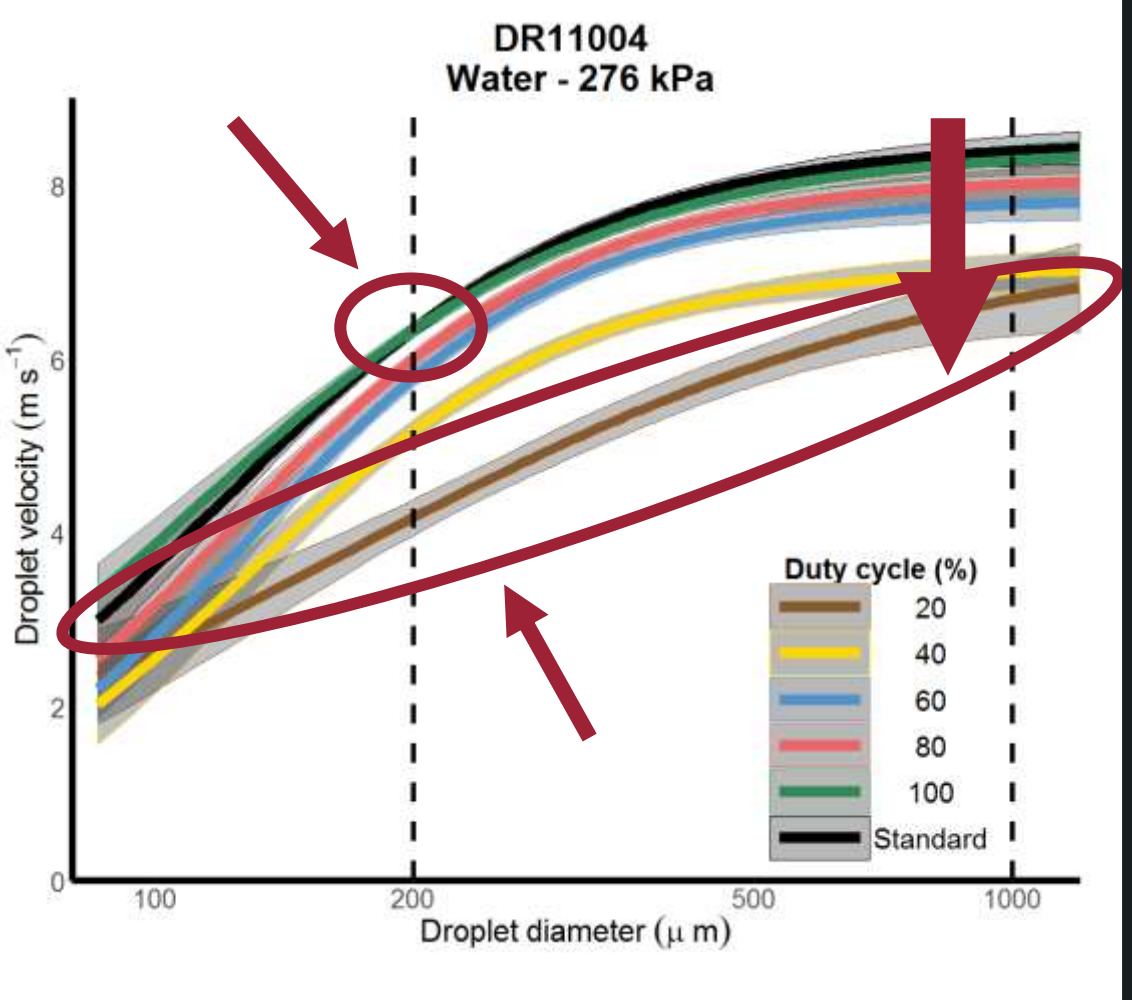
Droplet Velocity Results

Non-Venturi Nozzles





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Droplet Velocity Results

Non-Venturi Nozzles

		Average spray velocity[a]			
		Duty cycle (%)			
Nozzle	Gauge pressure	100	Standard	Reduction from 100-40% duty cycle	Reduction from 100-20% duty cycle
	PSI	——m s^{-1}——		%	%
UR11004	40	5.8 ab	5.9 a	6.8	13.8
DR11004	40	7.0 a	7.0 a	15.7	25.7
MR11004	40	8.9 b	9.4 a	7.9	16.9
SR11004	40	12.3 a	12.2 b	22.0	26.8
ER11004	40	13.8 a	13.8 a	15.2	16.7

[a]Means within a nozzle (row) with the same letter are not significantly different (P ≤ 0.05).

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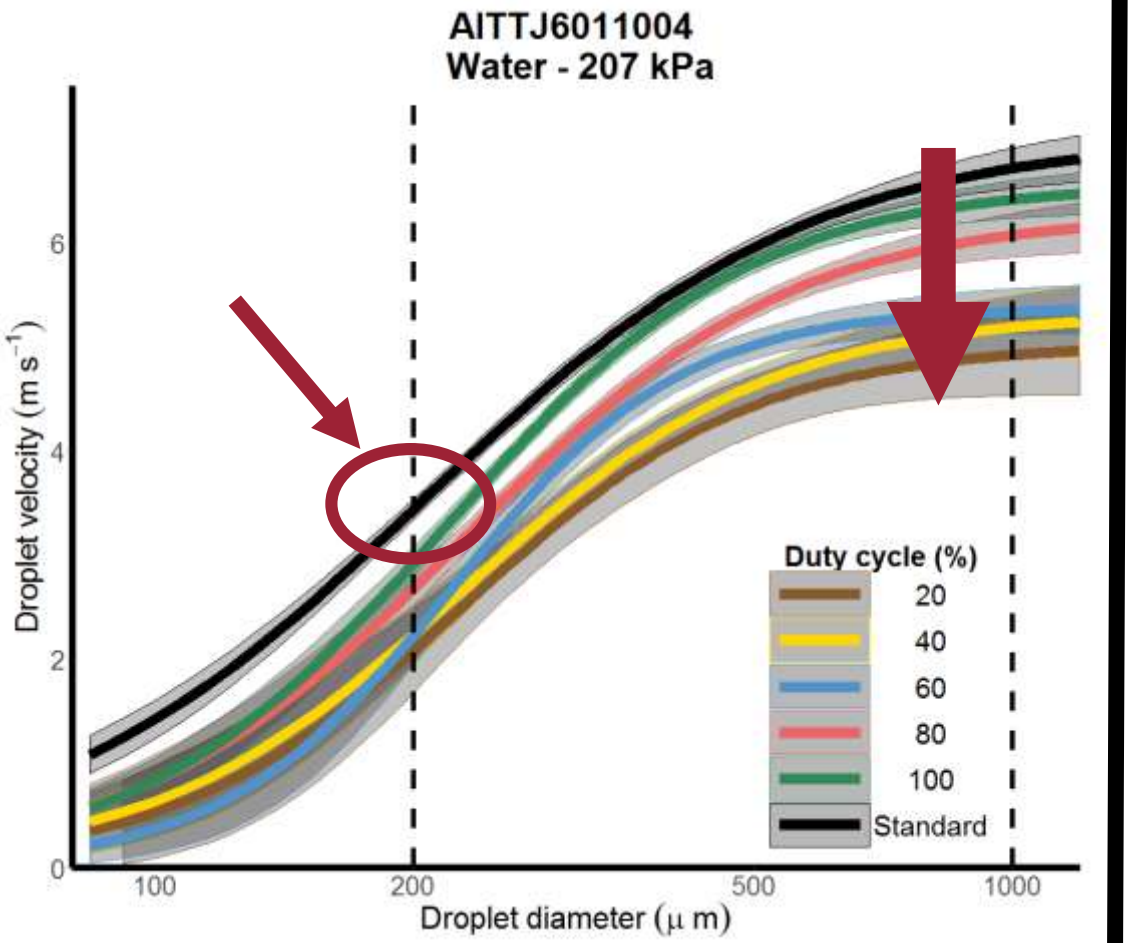
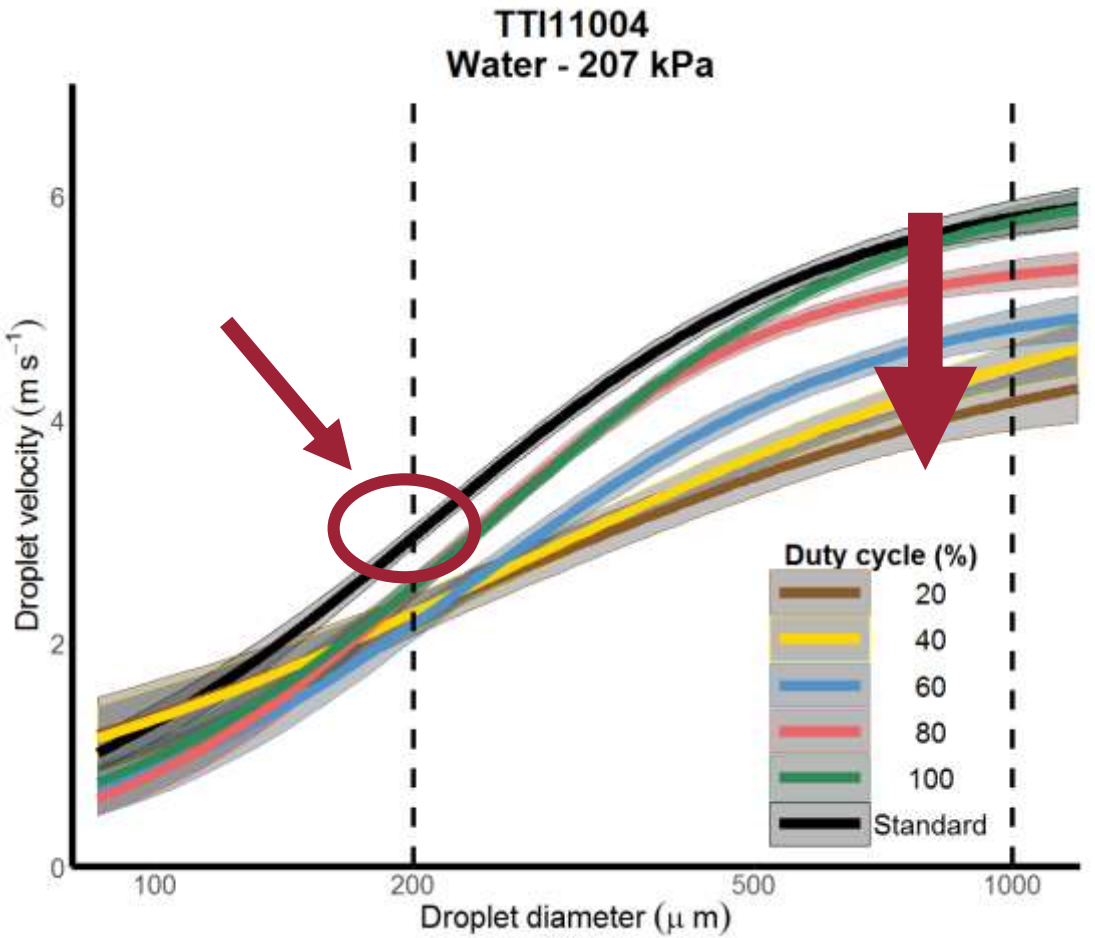
Droplet Velocity Results

Venturi Nozzles





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Droplet Velocity Results

		Average spray velocity[a]			
		Duty cycle (%)			
Nozzle	Gauge pressur	100	Standard	Reduction from 00-40% duty cycle	Reduction from 100-20% duty cycle
	PSI	——————m s^{-1}——————		%	%
TTI11004	40	4.3 b	4.7 a	18.6	18.6
AITTJ6011004	40	5.7 a	5.2 b	15.8	14.0
AMDF11004	40	6.3 b	6.8 a	31.7	38.1
AM11002	40	7.6 a	7.5 a	11.8	23.7
AMDF11008	40	8.3 b	9.2 a	33.7	41.0
AM11004	40	8.3 a	8.4 a	14.5	30.1

[a]Means within a nozzle (row) with the same letter are not significantly different ($P \leq 0.05$).

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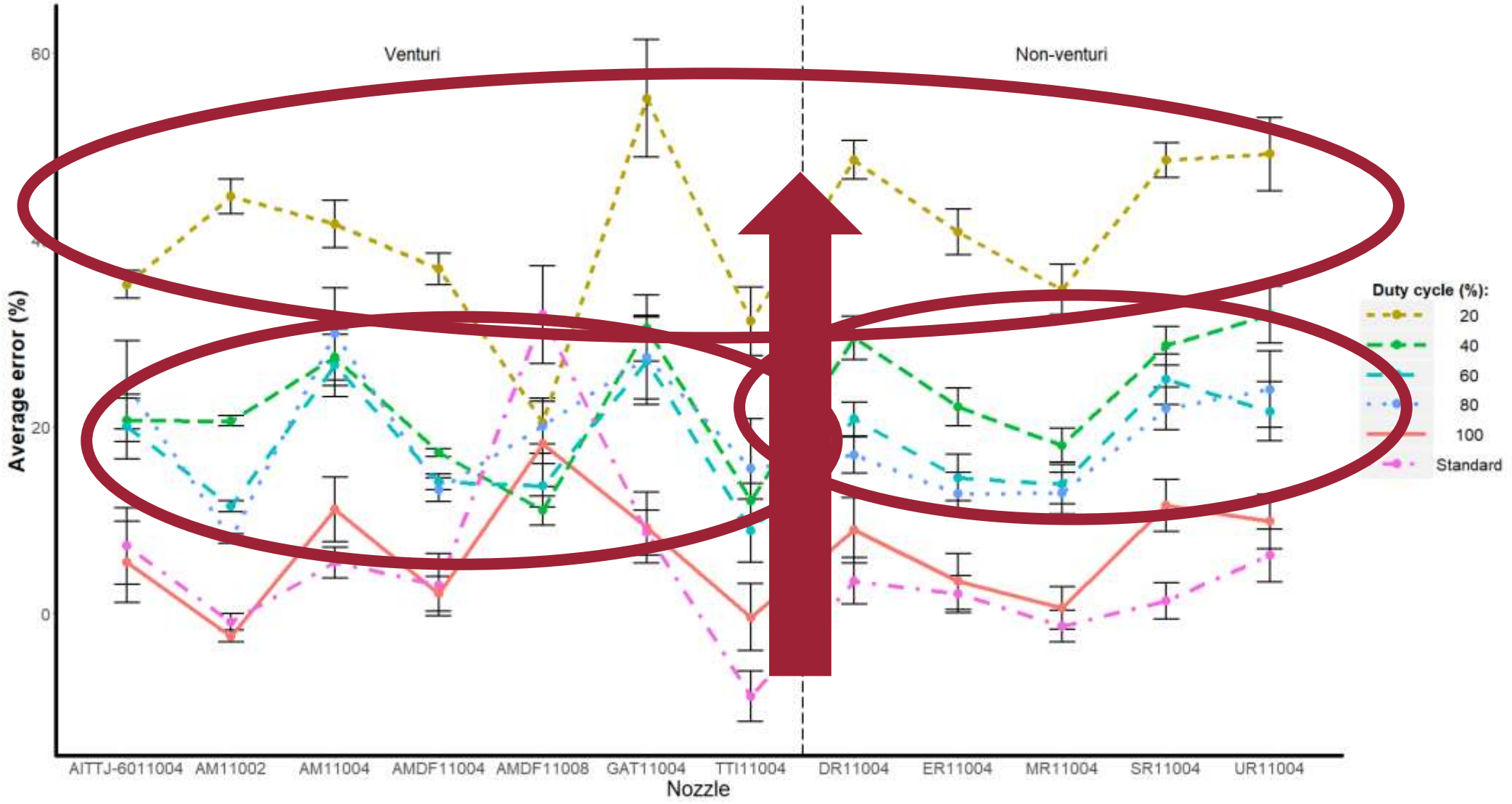
Pattern Uniformity Results



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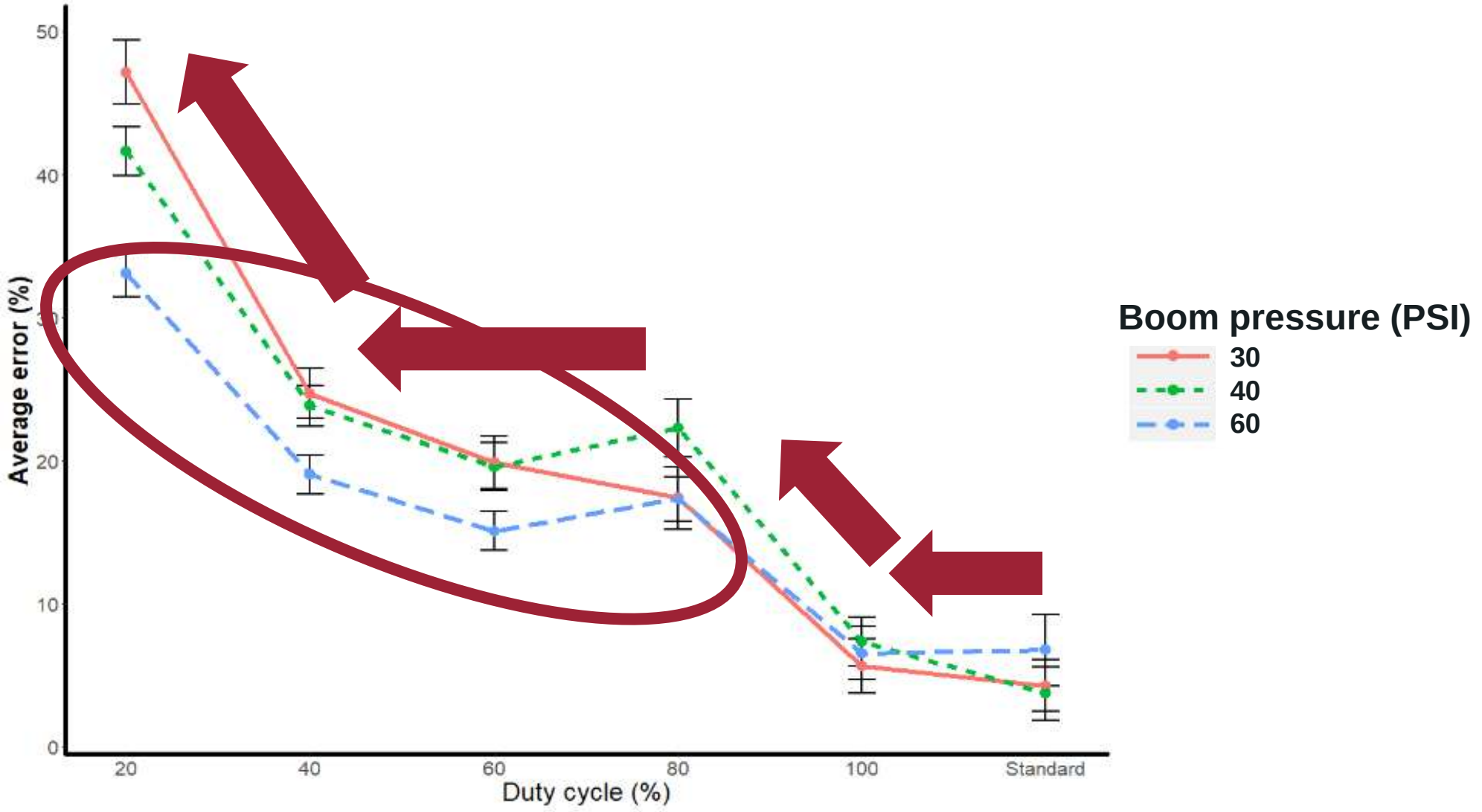
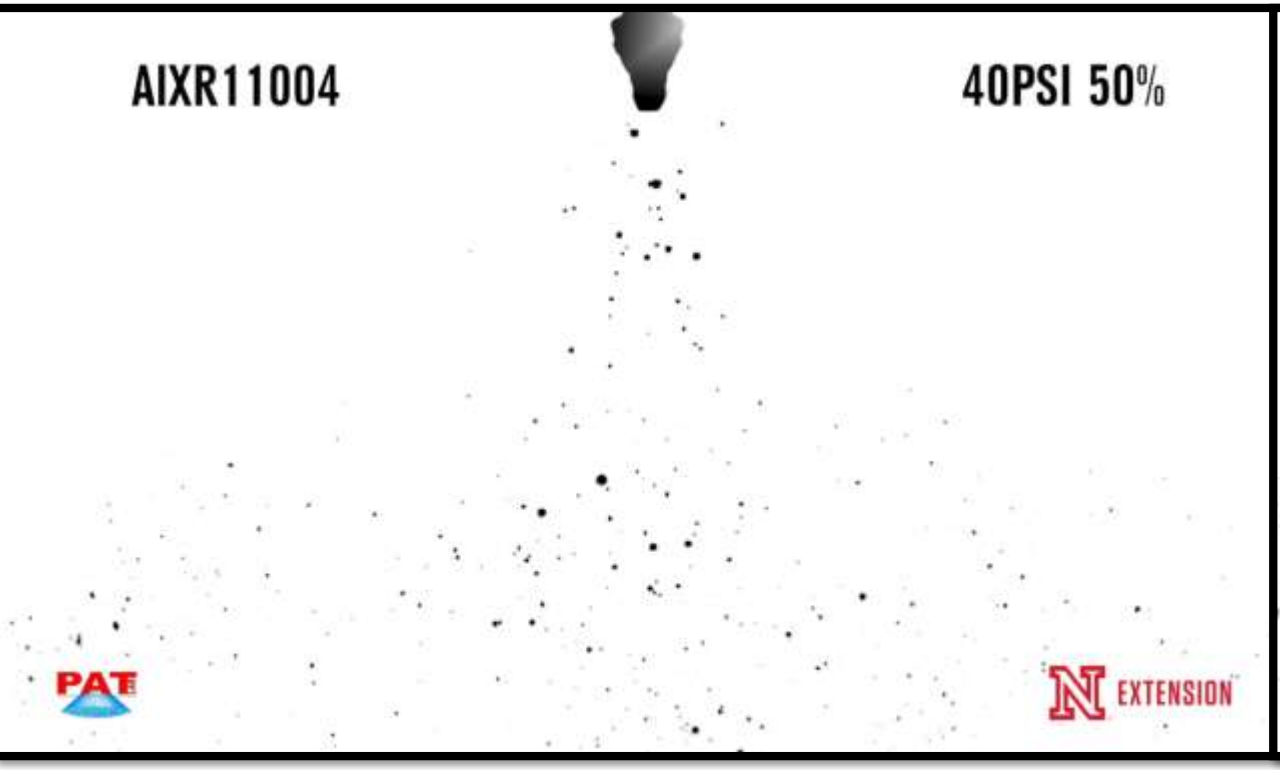
Pattern Uniformity Results



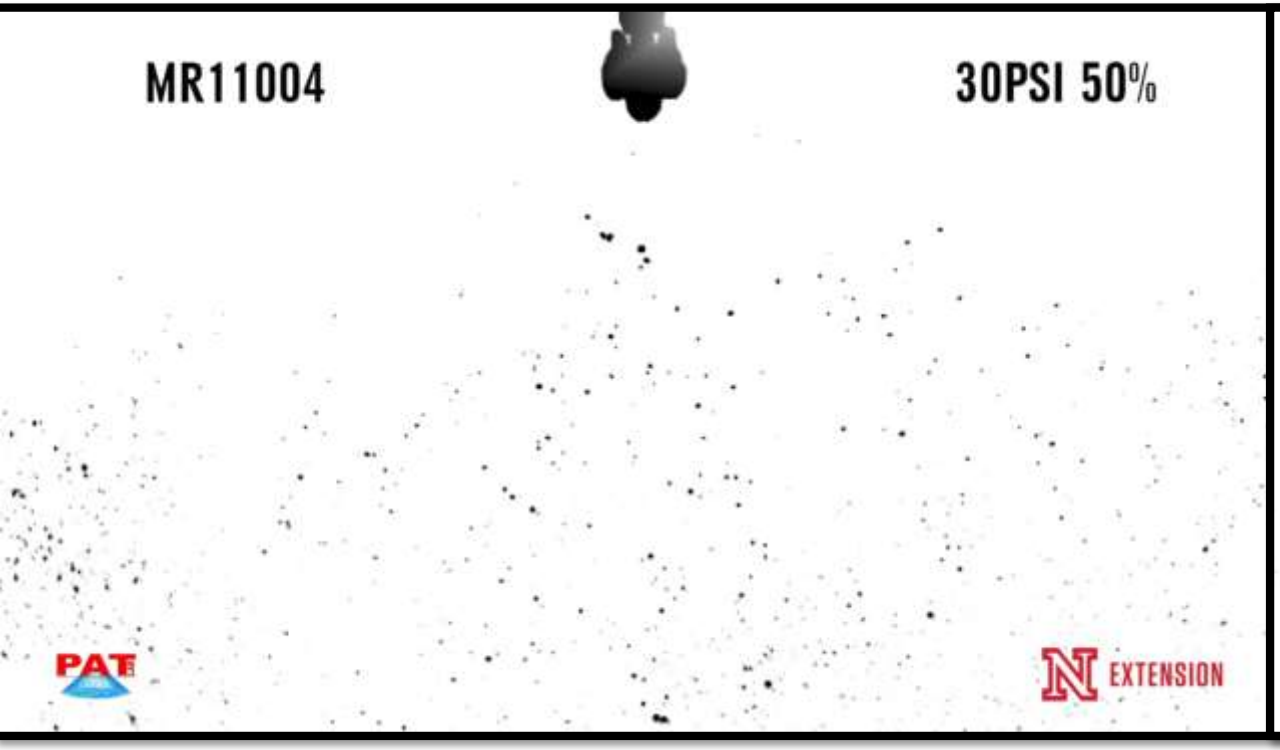
Nozzle Comparison



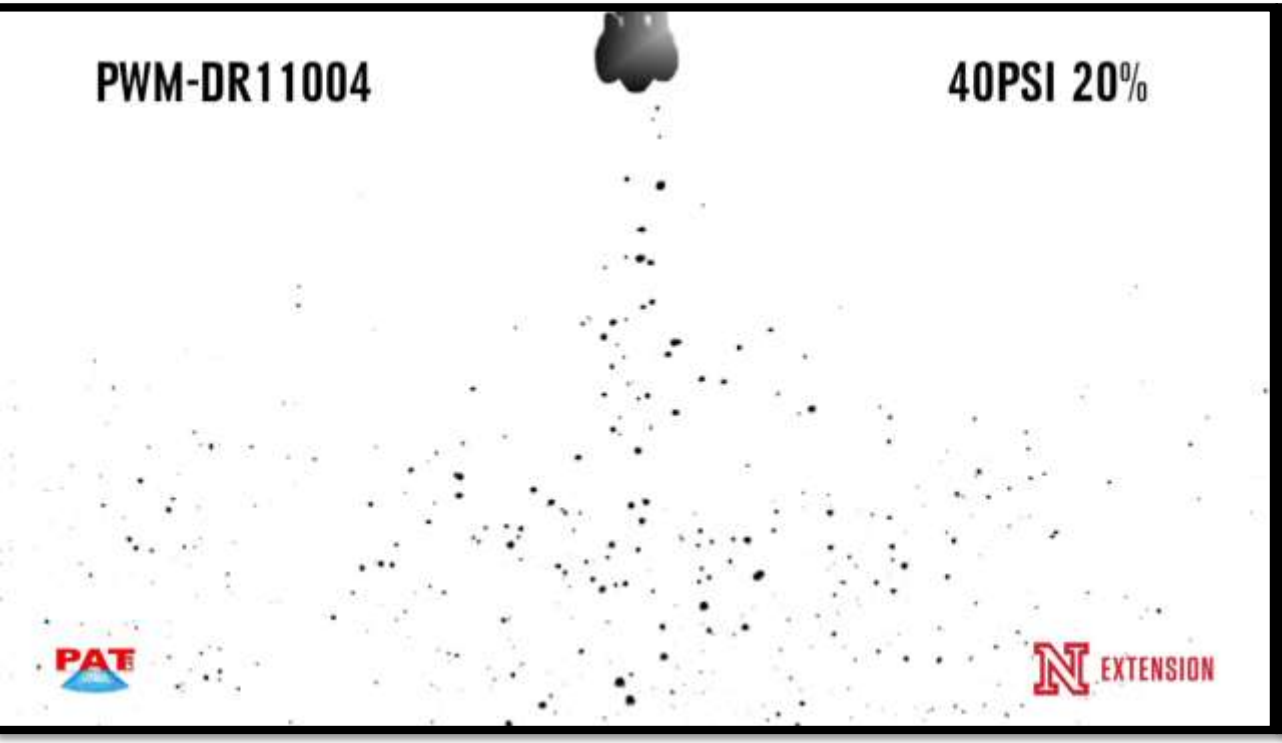
Venturi

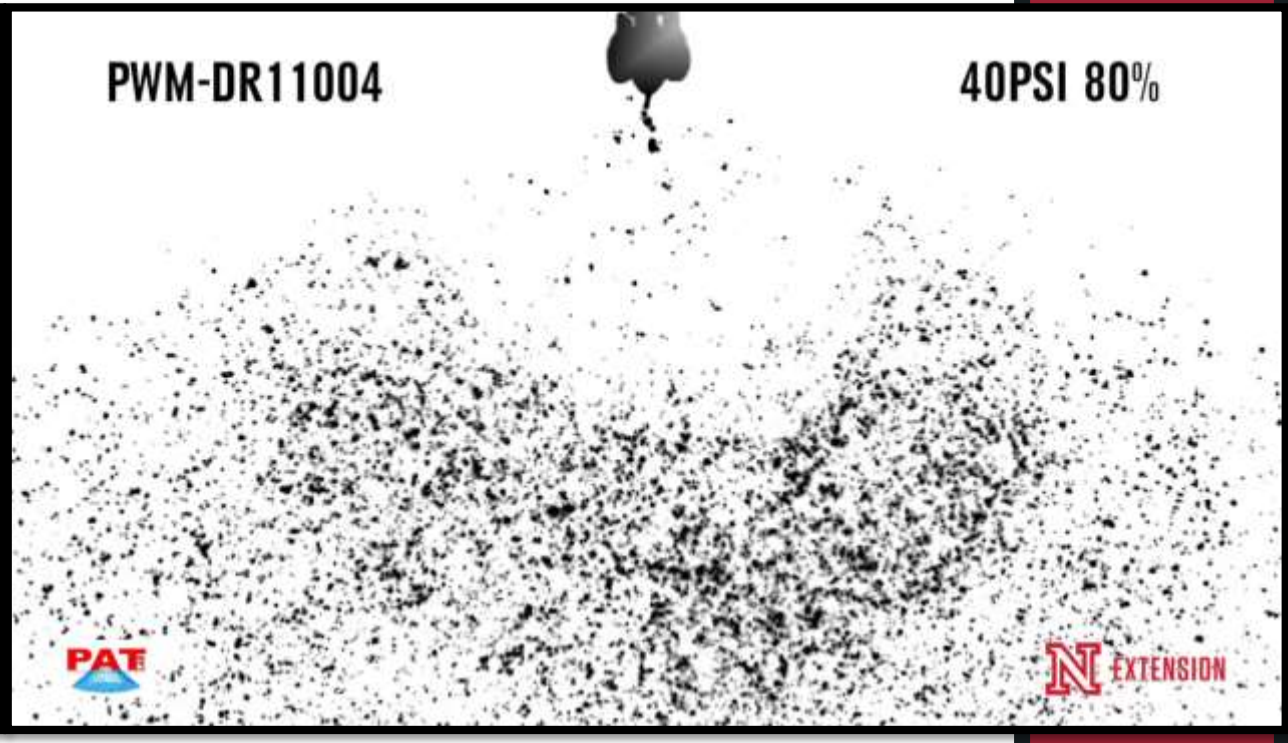
Non-Venturi

Pressure Comparison



Duty Cycle Comparison






ER110-04

PWM Best Use Practices

uction)

100%
n 80 – 98%

tained,
(≥ 40 psi)

h the

Where can PWM help?

- **Around field borders**
  - Reduce speed
  - Don’t have to change nozzles
  - Assist with drift reduction strategies
- **Site-specific applications**
  - Maintain precise droplet size (reduce drift but maintain efficacy)
  - Minimize overlap and output errors
- **Application flexibility**

Newer PWM Technologies

"Switch spraying between nozzles with the push of a button from inside the cab."

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- The ability to switch spraying between two pre-selected nozzles with the push of a button from inside the cab. This capability also increases the range of application to achieve consistent droplet size.
- The ability to automatically vary the rate across the entire boom, ensuring the correct amount of material is applied to the right area of the field, even while turning.
- Reduces the number of nozzles needed because of range increases on each nozzle.
- Alerts the operator if a single nozzle is plugged.
- Includes LED lighting on each individual nozzle for improved visibility of spray pattern in low-light conditions.

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“Good, bad, or indifferent, if you are not investing in new technology, you are going to be left behind.”

- Anonymous

“The farmers who succeed are the ones who are going to incorporate new technologies.”

- Stan Blade, University of Alberta

Questions? Thank-you!