SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 17
Pulse width modulation systems

How they work and set-up considerations

Tom Wolf

Key points

- Pulse width modulation (PWM) controls the flow rate produced by nozzles by causing them to pulse, that is, turn on and off rapidly
- PWM systems maintain constant pressure in the spray line so droplet size does not change when flow rate (pulsing) changes in response to changes in speed
- The time that the system is 'on' compared to 'off' is referred to as the 'duty cycle'
- PWM has on/off control at the nozzle, allowing for options such as single nozzle section control and turn compensation, and boom recirculation
- Nozzle selection requires careful consideration in order to avoid the duty cycle from becoming too low for the speed and application volume being used

1. Introduction

The majority of modern sprayers, whether self-propelled or tractor or truck-drawn, all experience fluctuations in travel speed. All spray operators speed up or slow down as the conditions or situation requires.

To be able to maintain a constant application volume per hectare, the spray liquid flow rate must change in direct proportion to travel speed. The sprayer achieves this with a rate controller, a device standard on most sprayers.

The rate controller uses four pieces of information to ensure a constant application rate:

- the user enters the **width of the boom** (metres) and the desired **water application rate** in litres per hectare (L/ha); and
- the sprayer provides **travel speed** information (kilometres per hour, collected from a GPS signal or a radar or wheel-based speedometer) and **liquid flow rate** (L/minute, collected from a flow meter on the main sprayer pressure line).

Using a simple mathematical formula, the rate-controller knows what the required liquid flow needs to be for any given travel speed. It changes the flow by adjusting the pump pressure.

The sprayer operator should keep an eye on the spray pressure to ensure it doesn't exceed the capabilities of the nozzle, the plumbing or the pump.

2. Rate-control options

There are currently about five options for rate control on the market, and all but one rely to a degree on spray pressure to manage flow rate.

2.1 Pressure-based rate control

This is the most common system. It changes spray pressure as required by the travel speed. It is limited by the flow rate capacity of the spray nozzles installed on the sprayer.

2.2 Variable-rate spray nozzles

Commercial systems, such as the VariTarget nozzle, use a plunger in the nozzle assembly that pushes down on and deforms a flexible nozzle cap with spray pressure. Higher pressures result in the cap's orifice becoming larger, facilitating more flow. This system is capable of a wider range of flows than a conventional nozzle system over the same pressure range.

VariTarget nozzles allow for a wider range of flow rates than standard hydraulic nozzles when operated over a similar pressure range.

Photo: http://www.spraytarget.com/varitarget.htm

One of the VariTarget nozzle bodies

2.3 Dual-boom systems

The rate controller still functions as described above, but a second boom fitted with different flow nozzles is activated when the flow-rate requirements can no longer be met with a single set of nozzles. For example, if the second boom contains larger nozzles, once the boom with larger flow nozzles is activated, the spray pressure drops significantly and additional speed capacity can be realised.

2.4 Dual, triple or quadruple-nozzle bodies

A similar approach to the dual boom is available from ARAG (Selectron) or Hypro® (Duo React).

These systems use a single boom (no duplicate boom is required) and direct the flow through one of any two or four (ARAG Selectron only) nozzles, or two nozzles simultaneously. Individual nozzle section control is also possible with this approach. Similar pressure fluctuations as a dual boom would be experienced, requiring careful selection of nozzle flow rates to avoid large pressure jumps. The same system can also be used to manually change from one nozzle to another as conditions require.

For more information about multi-step spray systems see Module 18: Single line and multi-step systems

3. Pulse width modulation

Pulse width modulation (PWM) uses conventional plumbing with a single boom line and a single nozzle at each location.

The liquid flow rate through each nozzle is managed via an intermittent, brief, shut-off of the nozzle flow at the diaphragm check valve which is activated by an electric solenoid that replaces the spring-loaded check valve.

A Case AIM Command® PWM unit on the boom

The model shown is an earlier version, where a standard nozzle body is mounted in front of the PWM solenoid. Newer versions may not be plumbed this way.

Photo: Case

Typical systems pulse at 10 hertz (the solenoid shuts off the nozzle 10 times per second. The duration of the nozzle in the 'on' position is called the duty cycle or pulse width. When the duty cycle is 100 per cent this means the nozzle is fully on. 20 per cent duty cycle means the solenoid is open 20 per cent of the time resulting in the nozzle flowing at approximately 20 per cent of its capacity. The ability to control the duty cycle is referred to as pulse width modulation.

3.1 The pros and cons of PWM

There are two primary features of a pressure-based approach that affect the spray operation.

- **Pressure affects spray quality and spray patterns.** Higher pressures (the result of faster travel speeds) result in finer, more drift-prone sprays, and lower pressures may, in addition to producing a coarser spray, reduce the spray's fan angle. The resulting narrow patterns can result in less overlap and poor pattern uniformity.
- **Pressure is not a very effective way of changing flow rates.** Increasing the travel speed by a factor of 2 requires a four-fold pressure change, as predicted by the square-root relationship between flow rate and pressure. As a result, a system capable of pressures ranging from a low of 2.0 bar to a high of 6.0 bar (a three-fold change in pressure) results in only a 1.73-fold change in flow rate (and travel speed the square root of 3 is 1.73).

By comparison, PWM systems do not rely on pressure changes to affect new flow rates. Instead, the duty cycle of the system affects nozzle throughput (flow rate, L/min).

With PWM systems the boomspray pressure stays constant throughout the duty cycle and, as a result, so does spray quality and spray fan pattern angle.

In practice, the lowest duty cycles increase droplet size and reduce fan angle somewhat. These effects are minor and do not impact overall performance.

Most manufacturers claim that the PWM system can therefore change travel speeds by about a factor of 5 (from 20 to 100 per cent duty cycle). Duty cycles of 20 per cent or less, although possible, are not recommended.

The majority of spray operators using this system in Australia operate with a minimum duty cycle above 30 to 40 per cent, and try to maintain the system well above 70 per cent for most spraying operations.

CapstanAg monitors show the duty cycle on screen so the operator can maintain the optimum spraying speed for the nozzle and situation.

Source: CapstanAg

CapstanAg SharpShooter monitor

3.2 Commercial PWM systems

The original inventor of PWM for spraying, Dr Ken Giles of the University of California, Davis, worked with CapstanAg Systems to produce the SharpShooter (the first PWM system on the market). The CapstanAg product was licensed to CaseIH sprayers and named AIM Command. It has been commercially available on Case sprayers since about 1998, manufactured by CapstanAg. The system featured a separate monitor, permitted PWM to range from 100 per cent down to 15 per cent, with an alternating pulse in which every second nozzle pulses identically, and alternating nozzles work in a 180° offset. In other words, in a system operating at 50 per cent duty cycle, when any given nozzle is on, the adjacent nozzles are off. This results in a 'blended pulse' that minimises the likelihood of skips.

In recent years, CapstanAg has entered the retro-fit marketplace and the SharpShooter has been installed on many brands of sprayers at the dealer level. The hardware is identical, with some minor differences in how the software interacts with the rate-controller.

Since 2012, Case has offered an enhanced version called AIM Command Pro (CapstanAg calls its version PinPoint). This system offers individual nozzle sectional control, as well as turn compensation. In addition, the enhanced system offers individual nozzle diagnostics that provide operational details to the sprayer operator.

In 2014, Raven® introduced a system called the Hawkeye®. Targeted at the retro-fit market, the system uses a Controller area network bus approach that works well with the Viper 4 monitor. The electric solenoids are the same as those on the CapstanAg systems. The system features turn compensation but not individual nozzle sectional control. Section resolution is determined by the limits of the monitor, for example, 16 sections on the Raven Viper 4. Raven claims that the Hawkeye® can be installed on a sprayer in about four hours.

TeeJet® has its own system called the DynaJet®. It is intended as an original equipement manufacturer product that would be factory-installed. Its specifications are similar to those of other products but the product is not yet available in the marketplace.

3.3 System capabilities

Only extended-range fans and pre-orifice nozzles are recommended for use on PWM systems.

Source: Raven

Spray quality

Since PWM systems can alter flow rate without affecting spray pressure, the user can select a spray pressure that meets their spray-quality goals and expect the spray quality to remain constant throughout the paddock, regardless of travel speed.

Table 1 Spray quality for various nozzle types and pressures for the Raven Hawkeye® system

Tip Info		Wilger www.wilger.net				TeeJet® www.teejet.com			Hypro www.hypropumps.com						
Office size	PSI	ER	SR	MR	DR	XR/XRC	TT/2XTT	TTJ60	TR	F	VP	AXI	GRD	LD	VPT
	Gauge	110	110	110	110	110	110	110	110	110	110	110	120	110	110
03	20	M	-	C	-	M	VC	VC	M	-	M	M	M	C	M
	30	M	C	VC	XC	F	C	C	M	M	F	M	M	C	F
	40	F	C	VC	XC	F	C	C	F	F	F	M	M	M	F
	50	F	C	C	VC	F	M	C	F	F	F	F	M	M	F
	60	F	C	C	VC	F	M	C	F	F	F	F	M	M	F
04	20	C	-	-	-	M	VC	VC	M	-	M	M	C	C	M
	30	C	C	VC	XC	M	C	C	M	M	M	M	C	C	M
	40	M	C	VC	XC	M	C	C	F	M	F	M	C	M	F
	50	M	C	C	XC	F	M	C	F	F	F	M	M	M	F
	60	M	C	C	VC	F	M	C	F	F	F	M	M	M	F
05	20	C	-	-	-	M	VC	VC	C	-	M	M	C	C	M
	30	C	VC	XC	XC	M	VC	C	M	M	M	M	C	C	M
	40	M	C	XC	XC	M	C	C	F	M	F	M	C	C	F
	50	M	C	VC	XC	F	C	C	F	M	F	M	M	M	F
	60	M	C	VC	XC	F	M	C	F	M	F	M	M	M	F
06	20	C	-	-	-	M	VC	XC	C	-	M	C	VC	VC	M
	30	C	VC	XC	XC	M	VC	VC	C	M	M	M	C	C	M
	40	C	VC	XC	XC	M	VC	C	M	M	M	M	C	C	M
	50	C	C	XC	XC	M	C	C	M	M	F	M	C	C	F
	60	C	C	VC	XC	F	C	C	M	M	F	M	C	C	F

3. Spray-drift control

Play a YouTube video on PWM systems: www.youtube.com/watch?v=MXCEQ0YzwAI and www.youtube.com/watch?v=RI3ht3eGMLk

Although PWM does not by itself have any unique capabilities to reduce spray drift, it does make spray-drift management easier. For example, the most accessible tool for reducing spray drift is to increase droplet size by reducing spray pressure. In a conventional system, the reduction of spray pressure can only be achieved with a reduction in travel speed because the lower spray pressure also reduces the overall flow rate.

With PWM, the loss of flow that normally comes with a reduction in spray pressure can be compensated for by an increase in duty cycle (DC), provided the range is available at your operating speed and nozzle choice. As a result, lower pressures do not require a reduction in travel speed, provided there is sufficient DC capacity in the system.

Potential for variable-rate control

A PWM system can be used for variable-rate application. The spray volume, as determined by DC, can vary as desired within its operational range without a change in travel speed.

Turn compensation

Ag AIM Command Pro, CapstanAg SharpShooter PinPoint and Raven Hawkeye® feature turn-compensation capabilities. During a turn, the outside boom moves faster than the inside boom, resulting in under and over-application. A turn-compensated system can deliver additional flow to the outside, reducing the flow towards the boom end on the inside of the turn. In practice, there are limits to this feature.

For example, the system's average DC needs to be about 70 per cent to offer the maximum flexibility. Second, the diameter of the object being turned around must not exceed the width of the boom, otherwise the inside boom will move too slowly in relation to the outside boom. The system's lag must also be minimal to avoid a counteracting effect during turn initiation and completion.

Section control

In a PWM system, sectional configuration is determined by wiring, not plumbing. All section valves remain open during operation, and sectional shut-off is affected directly at the nozzle solenoid. Individual nozzle sectional control is only offered by the AIM Command Pro and CapstanAg SharpShooter PinPoint. This feature may provide product savings when field margins are not straight or fields feature obstacles resulting in significant overlaps.

Shut-off response

The traditional nozzle-check valve is designed to prevent nozzle dripping on boom shut-off. However, due to the presence of air pockets in most booms, as well as the elastic nature of rubber hoses leading to the boom, the shut-off is delayed until the boom pressure reaches about 1.0 bar. This can take up to 10 seconds, resulting in unintended overspray and other safety concerns. In a PWM system the solenoid shuts off the flow to the nozzle instantly and, conversely, it also turns them on instantly.

The boom remains fully pressurised while the nozzles are shut off, allowing the spray patterns to be fully developed upon flow resumption.

PLAY VIDEO

Nozzle selection and duty cycle for pulse width modulation

3.4 Nozzle options

A pulsing solenoid creates short durations of low pressure inside the nozzle body, which can result in poor performance of some air-inducted nozzle tips. PWM manufacturers have recommended that air-induction nozzles be avoided, and pre-orifice nozzles or extended-range flat-fan nozzles be used instead.

Case sprayers are equipped with a proprietary nozzle body manufactured by Wilger. This company offers four nozzles for PWM. In order, from finest to coarsest these are:

- **Combo-Jet ER;**
- **Combo-Jet SR;**
- **Combo-Jet MR; and**
- **Combo-Jet DR.**

The ComboJet is one of the p-re-orifice nozzle types used on some PWM systems.

One of the Combo-Jet range used on Case PWM systems

Source: Wilger

In practice, the Combo-Jet DR is rarely used in PWM systems. The Combo-Jet MR is typically suited to lower water volume rates (30 to 60L/ha achieved with the MR110-03 or SR110-04), whereas higher volumes (60 to 150L/ha) are typically delivered using the Combo-Jet SR tip (usually the SR110-05 or SR110-06), depending on average travel speed. In some cases, the Combo-Jet ER nozzle is used when flow rates require 110-08 and larger. Spray pressures are typically about 3.0 bar.

PWM systems operating on TeeJet®-style bodies are well served by Turbo TeeJet® nozzles. These wide-angled tips are available in sizes up to 110-08 and generate suitable spray qualities at pressures ranging from 1 to 4 bar. Many operators use the TurboTwinJet, another good option, which is available in a large selection of flow rates to 110-10.

Hypro has a pre-orifice tip similar to the Turbo TeeJet®, called the Hypro Guardian. Most other manufacturers, including Lechler®, Hardi®, ARAG and others, have traditional pre-orifice flat-fan nozzles that may also work. It is important to always select 110 degree fans to ensure that 100 per cent overlap is achieved to maintain the concept of blended pulse.

Limitations are in the maximum flow rates available in a specific model; many nozzles are not available in sizes larger than 05 or 06.

Some PWM users have used air-induction nozzles successfully, but this approach is not currently supported by PWM manufacturers. Some air-induced nozzles blow spray liquid out the air-induction intakes one a pulse is applied, so caution is advised.

3.4.1 Suggested nozzle selection process for PWM

Selecting the most appropriate nozzle size requires some additional calculations when compared to selecting nozzles for a standard boomsprayer. Follow the steps outlined below:

Target a duty cycle above 80 per cent for your average spraying speed, and a minimum above 35 per cent.

Be aware that operating at higher duty cycles may limit the ability of the turn compensation feature to fully compensate for speed variations in turns.

Step 1

Determine desired application rate – for example, 70L/ha.

- **Measure the sprayer's nozzle spacing in metres – for example, 0.508m.**
- **Select the optimum operation pressure that delivers the required spray quality – for example, 3.0 bar with Combo-Jet MR 110-04 nozzles.**

When assessing spray quality, allow for a pressure drop across the solenoid. The pressure drop depends on the total flow through the solenoid. It varies from 0.2 to 0.3 bar for 04 flow rates through to 0.3 to 0.9 bar for 08 flow rates for the Case, CapstanAg and Raven products. If targeting 3.0 bar spray pressure, set the pressure to 3.0 bar plus these values.

For an 04 orifice at 3.0 bar, the nozzle should achieve a flow rate of 1.6 litres per minute per nozzle at 100 per cent duty cycle, with a droplet size of 370 micron volume median diameter (VMD), which is equivalent to a coarse to very coarse spray quality.

Calculate the spraying speed at 100% duty cycle

Inputs:
Litres per minute per nozzle = 1.6L/min at 3.0 bar pressure at the nozzle
600 is a conversion constant
Litres per sprayed hectare =70L/ha
width (w) nozzle spacing in metres = 0.508m

Calculation:
Maximum spraying speed (kilometres per hour)

Formula:
Speed = L/min/nozzle x 600 ÷ litres per sprayed hectare ÷ width (m)

Calculation:
Speed = 1.6 x 600 ÷ 70 ÷ 0.508 = 26.99km/h

The maximum operating speed for an 04 orifice nozzle to achieve 70L/ha is 26.99km/h

Step 2

Calculate the minimum speed – based on the preferred minimum duty cycle.

Assume the spray unit is to be operated at a minimum duty cycle of not less than 35 per cent.

Example:
Litres per minute per nozzle at 100% duty cycle = 1.6 litres per minute
Calculate 35% of 1.6L/min = 0.56L/min

Inputs:
L/min/nozzle = 0.56L/min at 35% duty cycle at 3 bar
600 a conversion constant
L/sprayed hectare =70L/ha
width (w) nozzle spacing in metres =0.508m
total number of nozzles on the boom = 72

Minimum spraying speed (kilometres per hour)

Formula:
Speed = L/min/nozzle x 600 ÷ litres per sprayed hectare ÷ width (in metres)

Calculation:
Speed = 0.56 x 600 ÷ 70 ÷ 0.508 = 9.44km/h

Minimum operating speed is 9.44km/h

Step 3

Determine the speed range using the same formula as in steps 1 and 2 to determine the speed for the flow rates at various percentages of the flow rate for operating at 100 per cent of the duty cycle.

Table 1 Pulse width modulation duty cycles based on an 04 orifice nozzle at 3 bar to achieve 70L/ha with a 0.508m nozzle spacing.

Duty cycle	Min* 35%	50%	70%	75%	80%	85%	90%	95%	Max 100%
Litres per minute per nozzle	0.56 L/min	0.8 L/min	1.12 L/min	1.2 L/min	1.28 L/min	1.36 L/min	1.44 L/min	1.52 L/min	1.6 L/min
Litres per minute for all nozzles (72 nozzles)	40.32 L/min	57.6 L/min	80.64 L/min	86.4 L/min	92.16 L/min	97.92 L/min	103.68 L/min	109.44 L/min	115.2 L/min
Speed	9.44 km/h	13.49 km/h	18.89 km/h	20.24 km/h	21.59 km/h	22.94 km/h	24.29 km/h	25.64 km/h	26.99 km/h
Performance	Least favourable range		Satisfactory range		Optimum range				

*Note that by limiting the duty cycle to a minimum of 35%, an actual speed ratio of 2.85:1 has been achieved for this example.

4. Common questions about PWM

As PWM systems are still relatively new to many spray operators there are usually many questions about how the system works and the maintenance required. The following sections address many of the common questions.

4.1 Will the pulsing of the spray create skips in control?

This can occur when a mistake in nozzle selection has been made where the duty cycle is too low. Skips are more likely with a combination of low duty cycles, fast spraying speeds, very low booms, narrow fan angles and extremely coarse sprays.

At high speeds, the system is usually operating at a high duty cycle unless a nozzle size that is far too large has been selected. At booms above 50cm and medium to very coarse sprays there is usually enough blending of the spray cloud from the nozzle to the target to remove any skips in coverage.

Skips can be seen on the outer edge of the boom during a sharp turn when duty cycle is taken from the tractor unit speed (slow during a turn) and the outer edge of the boom is travelling at two to three times that speed.

4.2 Does the droplet size really stay constant throughout the duty cycle range?

At low duty cycles we have seen a slight increase in the droplet size and also a slight decrease in the fan angle. This could be because the longer off-phase reduces the internal pressure in the nozzle body, resulting in an effectively lower pressure. These changes are not alarming in their magnitude. It remains important to avoid the lowest duty cycles (travel speeds) for prolonged periods.

4.3 Can I do all my spraying with one nozzle?

A PWM system offers the advantage of maintaining consistent pressure over a wide range of travel speeds for any given water volume. When moving to a new water volume that is different by more than 25 to 30 per cent another nozzle orifice size is recommended. Keeping the same nozzle type and size for two different application volumes can technically work, but at the cost of limiting the travel speed range for one or both volumes. It may also limit spray quality choices, particularly when trying to maintain a reasonable duty cycle.

A typical PWM user should have three different nozzle sizes and models, one each for low, intermediate and high water volumes, assuming similar spraying speed ranges. Some operators choose to use the same nozzle for intermediate and high water volumes based on the assumption that the high volumes is applied to maturing canopies or used in pre-emergent herbicide application, where spraying speeds are typically reduced as a result.

4.4 Does PWM reduce drift?

The PWM system is no different to a conventional spray system when it comes to drift reduction. Drift potential is related to the weather conditions at the time and release height and droplet size (which is controlled by nozzle choice and operating pressure).

A conventional system will use low-drift nozzles that maintain a reasonable percentage of drift-prone droplets over most of their pressure range. But at high speeds, high pressures will result in increased drift potential. In a PWM system, higher spraying speeds do not increase pressure, provided the machine stays within the duty cycle range.

However, even at the same pressure, higher speeds increase drift potential because more drift-prone droplets are pulled from the spray plume. Some users of PWM may drive faster than they should simply because they are able to avoid the pressure spike associated with conventional pressure-based systems. Higher spraying speeds can still increase drift potential.

4.5 Is the system prone to breakdowns?

PWM has been on the market for about 15 years with Case and CapstanAg and has proven to be robust. The solenoids themselves have a good wear life, but do require replacement from time to time. Inside the solenoids, a poppet seal can wear over time, requiring fairly inexpensive and easy replacement. As with all electronics, regular inspection of the wiring harness to ensure no abrasion or pinching is required.

Disassembling the PWM solenoid for regular cleaning is critical to maintaining the system.

Source: CapstanAg

The CapstanAg solenoid

4.6 Additional help and information

One of the more useful tools for PWM users is the 'Tip Wizard' on the Wilger website (www.wilger.net).

The Tip Wizard is geared towards selecting the right nozzle for Case AIM Command, which uses the proprietary Wilger nozzle bodies and caps. The website helps users to select nozzles that match their volume, speed and droplet-size requirements.

Once a user understands the basic principles of the system, any conventional nozzle chart can be used, providing the nozzle spacing matches the machine. A conventional chart will show when the system is operating at 100 per cent of the duty cycle.

A user simply needs to choose a nozzle that is no more than 30 per cent larger in flow rate to allow the system to run at approximately 70 per cent of the duty cycle or more at the selected volume and spraying speed.

Wilger also produces a smartphone app called 'Tip Wizard', which offers many of the same tip-selection features as its website.

Nozzle-selection tools can only work on the parameters entered. It is important to consider the full range of spraying speeds, and the duty cycle that will occur with various nozzles at different spraying speeds.

Source: Wilger

An example of the TipWizard output

1. Target Application Rate	select	or	70	Liters/Hectare
2. Target Droplet Size	250	or		VMD
3. Maximum Sprayer Speed	20	or		KPH
4. Nozzle Spacing	select	or	50	cm
5. Spray Tip Angle	80	Degrees		

These are our spray tips that best match your input information. For applications where a uniform spray pattern is required, the minimum recommended opera
Tip-Caps are: ER Series - 20 psi; SR Series - 25 psi; MR Series - 25 psi; DR Series - 30 psi.

COMBO-JET® SR80-03
Part No. 40288-03
Part Colour Blue

Gage Press. BAR	Press. PSI	Speed Range KPH	Drop VMD	% <200	% <600
1.38	20	3.4 - 13.8	400	9	86
1.73	25	3.8 - 15.1	374	13	88
2.07	30	4.1 - 16.6	349	17	89
2.42	35	4.5 - 17.9	329	20	90
2.76	40	4.8 - 19.2	312	22	91
3.11	45	5.0 - 20.2	301	24	91
3.45	50	5.3 - 21.3	289	26	92
3.80	55	5.6 - 22.4	279	28	92
4.14	60	5.9 - 23.4	269	30	93
4.30	62	6.0 - 23.8	266	31	93

Pre-orifice No. R03
Part No. 40285-03

Screen Mesh/Color: 50/Red
Part No. 40250

COMBO-JET® SR80-04
Part No. 40288-04
Part Colour Red

Gage Press. BAR	Press. PSI	Speed Range KPH	Drop VMD	% <200	% <600
1.38	20	4.6 - 18.4	399	11	83
1.73	25	4.9 - 19.7	379	14	85
2.07	30	5.4 - 21.7	353	18	86
2.42	35	5.9 - 23.6	332	21	88
2.76	40	6.3 - 25.3	316	23	89
3.11	45	6.6 - 26.6	304	25	89
3.45	50	7.0 - 28.1	292	27	90
3.80	55	7.4 - 29.6	282	29	91
4.14	60	7.7 - 30.7	274	30	91
4.42	63	7.9 - 31.3	267	32	92

Pre-orifice No. R06
Part No. 40285-06

Screen Mesh/Color: 50/Red
Part No. 40250

COMBO-JET® ER80-05
Part No. 40270-05
Part Colour Brown

Gage Press. BAR	Press. PSI	Speed Range KPH	Drop VMD	% <200	% <600
1.38	20	5.7 - 22.9	296	24	95
1.73	25	6.2 - 24.6	286	27	95
2.07	30	6.7 - 26.7	274	29	95
2.42	35	7.3 - 29.0	263	32	95
2.76	40	7.7 - 30.8	255	34	95
2.97	43	8.0 - 32.0	249	36	95
3.11	45	8.2 - 32.8	247	37	95
3.45	50	8.6 - 34.4	241	38	95
3.80	55	9.1 - 36.3	235	40	95
4.14	60	9.4 - 37.7	230	41	95
4.49	65	9.9 - 39.4	225	43	95

Pre-orifice No. Not Req'd
Part No. Not Req'd

Screen Mesh/Color: 50/Red
Part No. 40250

CapstanAg produces a useful calibration table that identifies the pressure drop for various nozzles and pressures, as well as travel-speed ranges for these nozzles when applying a range of water volumes.

For more information, visit www.capstanag.com

4.7 Troubleshooting and maintenance

The main hazard for the PWM solenoids is contaminants. Granules can become lodged on the poppet seal surface, reducing the metering accuracy. Regular inspection of screens and occasional removal and disassembly of the solenoids to expose the poppet are recommended.

TIPS FOR OPERATING A PWM SYSTEM

- Avoid duty cycles below 35 per cent. This will help to determine your minimum speed.
- Avoid sharp turns when spraying as an increase in boom speed will overrun the duty cycle. Later machines are equipped with turn compensation, which will only be effective if the machine's duty cycle is operating below 100 per cent. Boom whip will still lead to potential spray misses in corners if the boom speed exceeds the operating parameters for the nozzle selected.
- Back into corners.
- Square up headlands.
- Drive in opposite directions on AB lines to reduce the repeatability of potential spray misses.
- Have a range of nozzle types for spray quality and application.
- Don't use air-induction nozzles.
- Anticipate the pressure drop across the solenoid when choosing an operating pressure and spray quality

5. Summary

PWM systems can offer spray applicators many advantages over standard spray systems, which rely on pressure regulation to adjust flow rates for maintaining a constant application rate.

Operators need to be aware of the limitations as well as the strengths of the system, and carefully consider how it will fit into their farming system. The additional expense of purchasing a PWM system may not be required by some operators, particularly those who can maintain a relatively small variation in their spraying speed for particular jobs.

NEXT MODULE

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 18 Single line and multi-step systems How they work and set up considerations

GRDC GROWNOTES

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION