



Spraying Systems Co.[®]
Experts in Spray Technology



A Guide to Pulse Width Modulated Flow Control



Spray
Nozzles



Spray
Control



Spray
Analysis



Spray
Fabrication

Pulse Width Modulation

Pulse Width Modulation (PWM) is a common technique for controlling an electrically-actuated device by turning the device on and off – or “pulsing” it – very quickly.

The speed at which the device is pulsed is called the FREQUENCY and is expressed in cycles per minute or hertz (Hz).

The proportion of time during which the device is “on” during each full cycle is the DUTY CYCLE and is expressed as a percentage.

A very simple analogy for PWM is riding a bicycle.

You can maintain speed by pedaling and then coasting, allowing your momentum to carry you forward. As you slow down due to wind resistance, friction or changes in terrain, you pedal to speed up and then coast again. Duty Cycle = The ratio of pedaling time to the total time (pedaling time plus coasting time)



100% duty cycle means you are pedaling all the time



50% duty cycle means you are pedaling only half the time

What is PWM Flow Control?



Pulse Width Modulated (PWM) Flow Control

involves switching an electrically-actuated spray nozzle on and off very quickly in order to control the flow rate of the nozzle. This cycling takes place so quickly that the flow often appears to be constant and the coverage remains reasonably uniform.

Controlling flow rate by adjusting duty cycle and cycling frequency of an electric nozzle while maintaining a constant pressure provides distinct advantages over controlling flow by adjusting pressure.

Refer to pages 10 and 11 for more details on PWM flow control.



Why is PWM Flow Control Important for Spray Applications?

PWM flow control enables the electrically-actuated PulsaJet® automatic spray nozzle to provide several important advantages:



- **Adjustable flow at a single pressure provides flexibility.** To increase the flow rate, you normally need to increase pressure, which can dramatically change the spray angle and drop size. PWM flow control provides an extremely wide range of flow rates from a single nozzle, maintaining a consistent spray angle and drop size without adjusting pressure.
- **Flow rate can be changed almost instantaneously.** Electrically-actuated nozzles can be controlled much more quickly and accurately than pneumatically-actuated spray guns or standard hydraulic nozzles.
- **Reduced clogging improves reliability.** PWM flow control can maintain low flows even with large spray orifices, reducing clogging.
- **Reduced misting improves safety and transfer efficiency.** Generating low flows using larger orifices at lower pressures reduces or eliminates the misting that often results at higher pressures. The risk of worker inhalation of chemicals is reduced and overspray is minimized or eliminated.





- **Decreased fluid consumption saves money.** Improving transfer efficiency and controlling flow rate more precisely can reduce costly chemical usage while maintaining or even improving product quality.
- **Uniform coating improves quality.** Because flow is controlled with duty cycle instead of pressure, drop size and spray angle remain constant. This results in more consistent coating over a wide range of flow rates.
- **Eliminating atomizing air saves energy.** Using PWM flow control, low flow rates that are normally only possible using air atomizing nozzles can often be achieved with hydraulic nozzles. The expense of compressed air can be eliminated along with the associated misting.
- **Simple controls make implementation easy.** Using PWM flow control to maintain consistent performance of low flow applications is much less complex than managing air atomizing systems.



How and Where is PWM Flow Control Used?

PWM flow control can be used in many different spray applications. In general, PWM flow control may prove useful anywhere a repeatable dose or consistent coating weight is required. Below are just a few examples of applications where PWM flow control has significantly improved efficiency.

- **Spraying food ingredients onto products or into trays**
- **Spraying flavors or oils onto bread and pastries**
- **Spraying ascorbic acid onto meat for food safety**
- **Surface coloring with milk protein, egg or caramel**
- **Spraying oil to improve mold release**
- **Applying adhesive to tire treads before re-treading**
- **Spraying extremely small volumes of silicone on plastic blanks prior to a blow molding process**
- **Applying a uniform coating of silicone across a web of paper machine clothing**
- **Spraying water on hamburger patties prior to freezing to maintain proper weight**
- **Spraying water to act as a catalyst for glue in door manufacturing**
- **Spraying water on a cellulose strip to reduce electrostatic charges while manufacturing incontinence pads**

A closer look at the benefits of PWM flow control

EXAMPLE 1

Manual PWM flow control regulation

An industrial bakery needs to slightly moisten bread to make it sticky prior to sesame seed application. The conveyor belt speed is stable and cycles are repetitive and identical – ideal for manual regulation using the AutoJet® PWM Spray Control Panel*. The frequency is preset to match the speed of the product and to be compatible with the desired duty cycle range.

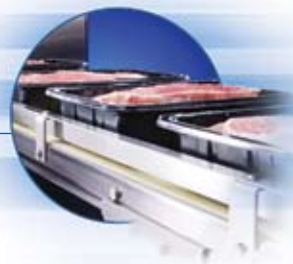
The PWM Spray Control Panel modulates the signal according to the turning of a potentiometer on the front of the panel or according to a 4-20mA signal. This method is simple and efficient and ensures uniform coating consistency.

* AutoJet Technologies is the systems division of Spraying Systems Co. The AutoJet PWM Spray Control Panel activates PulsaJet® electronic nozzles at a specific frequency and duty cycle. For complete product details see Bulletin AT162B, AutoJet PWM Spray Control Panel.



EXAMPLE 2

A food processor needs to apply flavoring uniformly to one of its products. A variable speed conveyor complicated the situation but the use of automated PWM flow control proves to be an efficient solution.



- Target product measures 220 x 110 mm (0.0242 m²) [8.7" x 4.3" (0.260 ft²)]
- Product needs a uniform coating of 0.5 ml (0.0169 ounce) flavoring (20.66 ml/m² or 0.0649 oz./ft²)
- The minimum line speed is 15 m/min (49.2 ft/min); maximum line speed is 35 m/min (114.8 ft/min)
- The permissible distance between pulses on the target is 5 mm (0.197")
- A UniJet[®] tip** on a PulsaJet[®] nozzle provides the necessary flow of 20.66 ml/m² (0.0649 oz./ft²) at a pressure of 0.5 bar (7.25 psi)
- The PWM function of the AutoJet[®] Model 2250 Spray Controller*** regulates the flow rate within the desired range:
 - Minimum duty cycle of 21% 3000 cycles/min, i.e., 50 Hz
 - Maximum duty cycle of 49% 7000 cycles/min, i.e., 116.67 Hz
 - The flow rate will vary between 2.05 l/h (0.542 gph) and 4.77 l/h (1.26 gph) according to the speed

With PWM flow control, a single nozzle operating at a single pressure can be used by varying the duty cycle. Without PWM flow control, a spray nozzle with 1/3 the flow of the specified tip would be needed for the slower line speed and the pressure would need to increase by a factor of five to produce the required flow rate for the faster line speed.

** Spraying Systems Co.'s. UniJet TPU flat spray tip was used in this application. PulsaJet nozzles can be used with a wide range of spray tips. For more information, see Catalog 70, *Industrial Spray Products*.

*** AutoJet Model 2250 Spray Controller provides real-time control of spray processes. Using patented software, the controller accurately monitors and automatically adjusts spray performance based on process conditions. See Bulletin AT164B, *AutoJet Model 2250 PulsaJet Panel*.



What is Needed for PWM Flow Control?

A fast electrically-actuated spray nozzle

The PulsaJet® family of automatic spray nozzles is ideal for PWM flow control. PulsaJet nozzles can achieve cycle speeds up to 10,000 cycles per minute, are available with hydraulic or air atomizing spray tips and operate at flow rates up to 59.8 l/min (15.8 gpm) and fluid pressures up to 24 bar (350 psi).



Electrically-Actuated Nozzles +
Spray Controller + Spray Knowledge =
PWM Flow Control

Spray knowledge

As with all spray control methods, designing an effective PWM flow control spray system also requires a strong knowledge of how liquids flow and how spray nozzles work. The ability to turn an electrically-actuated spray nozzle on and off very quickly is not enough.





A spray controller plus software

A fast automatic spray nozzle does not provide PWM flow control on its own – it must be controlled.

AutoJet® Technologies offers a wide range of spray control options. For manual PWM flow control regulation, the PWM Spray Control Panel should be used. For automated operation in applications requiring precise dosing or coating, use the Model 2250 PulsaJet® Panel.

PWM flow control can also be managed with standard or custom software which can provide on/off control of PulsaJet spray nozzles. However, an AutoJet Spray Controller will cycle PulsaJet nozzles more quickly and more precisely than a PLC.

Controlling Flow Rate by Adjusting Duty Cycle

In PWM flow control, the nozzle's flow rate is controlled by changing how long the nozzle sprays during each cycle. This "spray time" is called the "duty cycle" and is expressed as a percentage of total time.

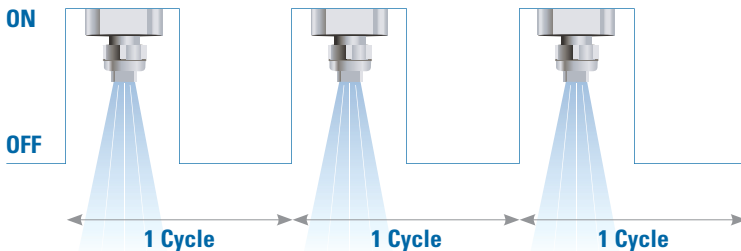
In the example below, the duty cycle of 50% results in a nozzle that sprays half the time and is off half the time. A 50% duty cycle produces a flow rate that is half the maximum flow for the nozzle.

With duty cycles possible from 5% to 100%, PWM provides great flexibility for precise flow control.

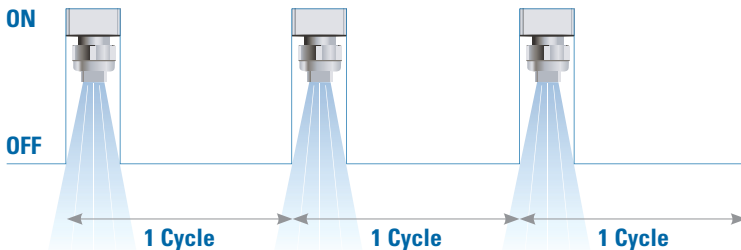
Why Control Flow Rate So Precisely?

Although there are many reasons to adjust flow from a single nozzle, the most common is to compensate for variations in line speeds. For example, to provide uniform coating weight, an increase of 50% in flow rate is required if the conveyor speed increases 50%. While that's an extreme example, increases and decreases in line speed are common and can greatly affect product quality if flow rate adjustments are not made.

Adjusting the duty cycle controls the volume of liquid per unit of time.



Higher line speeds require more flow and a higher duty cycle.



Lower line speeds require less flow and a lower duty cycle.

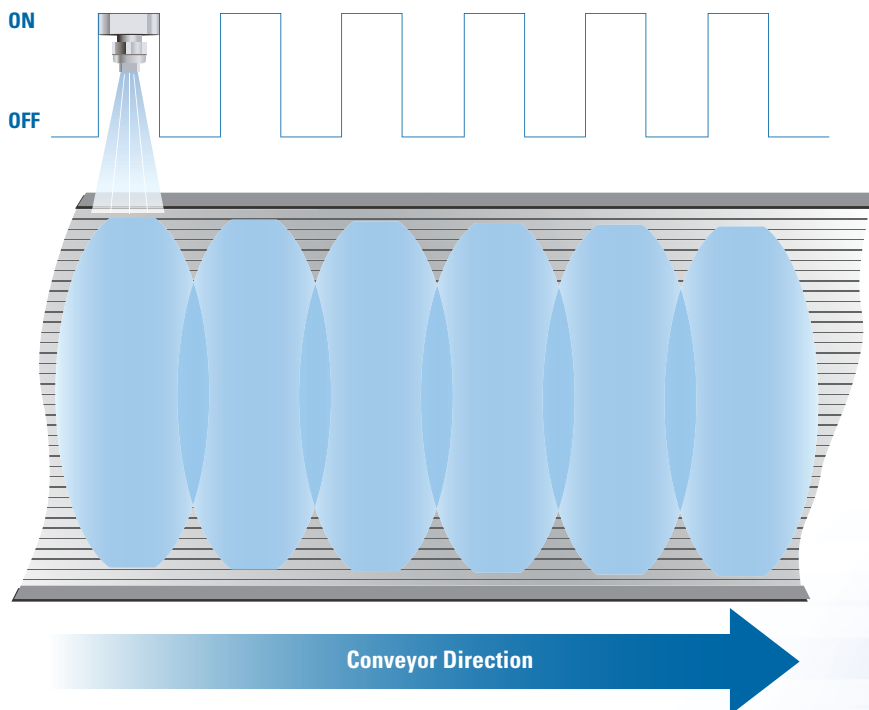
Ensuring Even Coverage by Adjusting Frequency

Because PWM is often used to compensate for variations in line speed, it's critical that even when spraying intermittently on a moving object, the PulsaJet® nozzle is able to produce acceptably uniform coverage.

Adjusting the cycle speed of the nozzle – also called the frequency – provides this capability.

To understand how this is possible, consider how motion pictures create a “smooth” appearance from a series of still pictures moving very rapidly. The more frames per second, the more uniform the movie appears.

In the same way, an electrically-actuated spray nozzle operating at a very high frequency – thousands of cycles per minute – can produce uniform coverage on a moving object, as shown in the image below.



Spray patterns from a single PulsaJet nozzle cycling at high frequency generate even coverage on a moving conveyor belt.

Other Helpful Resources

- Pulse Width Modulation
Video Demonstrations
www.spray.com/pwm
- *PulsaJet® Automatic Spray Nozzles*
Bulletin 603
- *AutoJet® PWM Spray Control Panel*
Bulletin AT162B
- *AutoJet® Model 2250 PulsaJet® Panel*
Bulletin AT164B



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