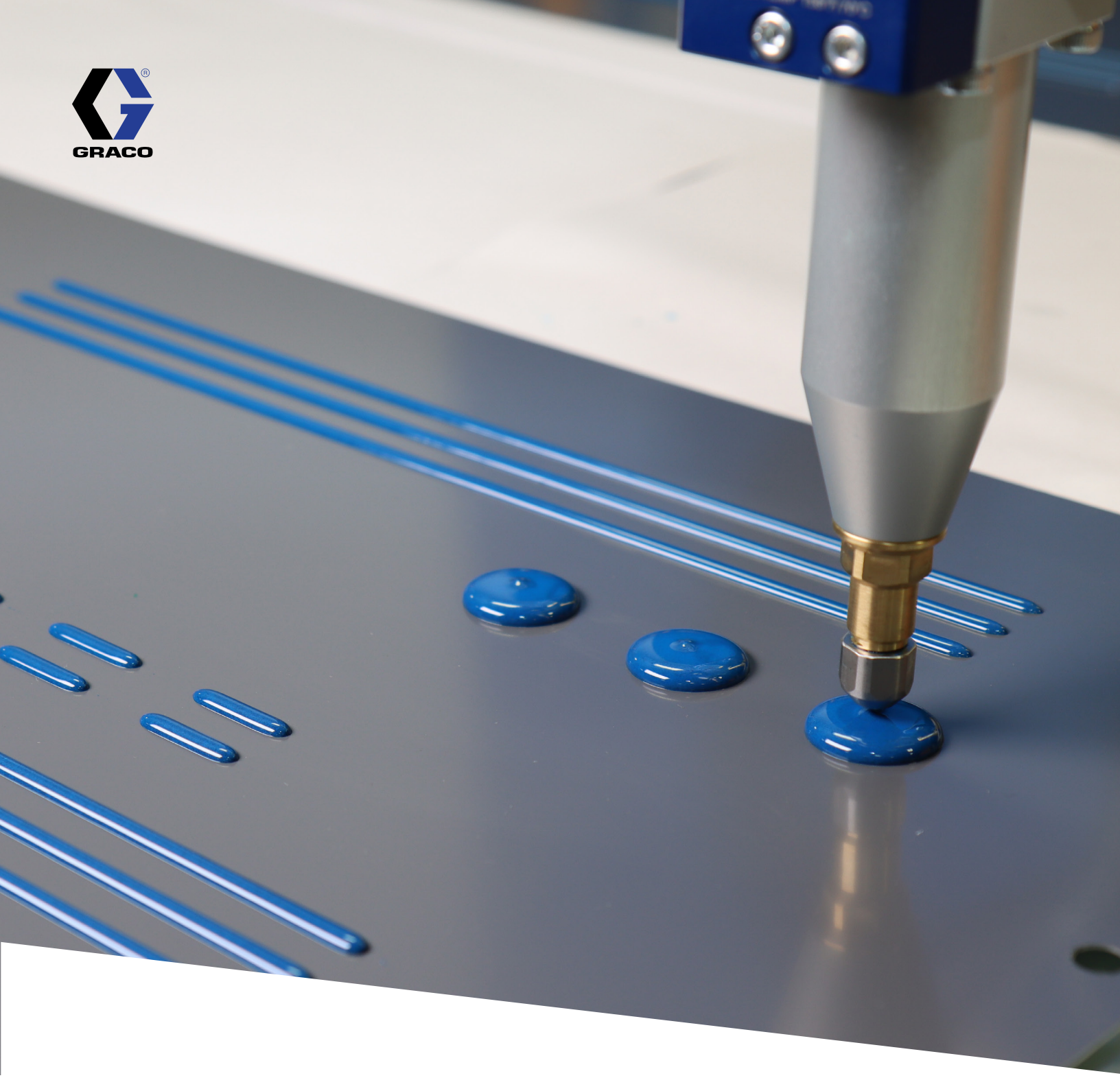

ONE COMPONENT METERING SYSTEMS PERFORMANCE EVALUATION

FOR SEALING APPLICATIONS

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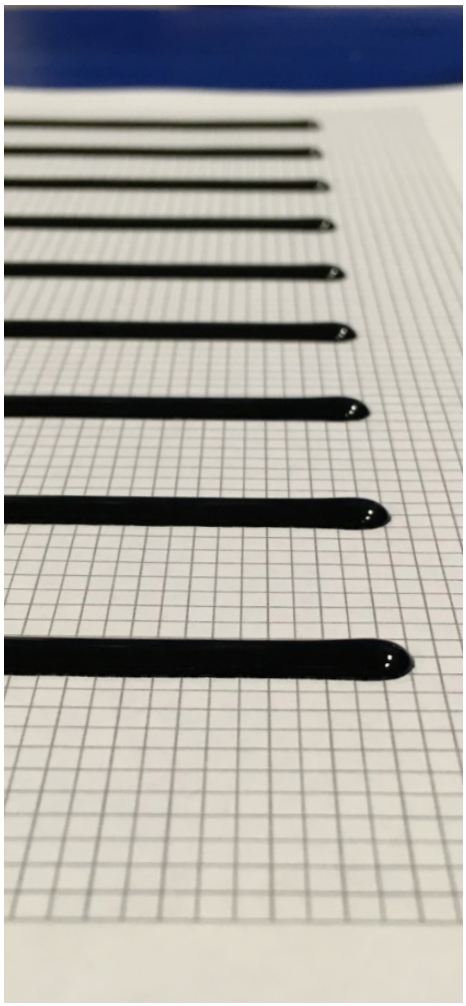
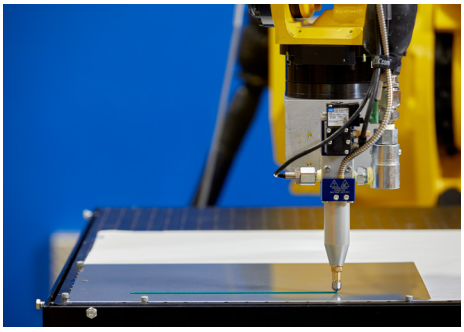
Abstract:
Graco has three primary solutions for continuous single component dispensing applications in industrial factory applications; E-Flo® iQ, Precision Continuous Flow (PCF) and Precision Gear Meter (PGM). In order to understand the benefits and performance of each system, our engineering team conducted a series of system comparisons tests including a shot study, bead study, and additional auxiliary testing. All systems were compared equally to each other by running the same target flow rates for both shot repeatability and bead analysis studies.

Material:
A single component, oven-cured epoxy adhesive, was used in each system for the entire testing process. According to the material supplier, this material exhibits excellent adhesion to oily surfaces of galvanized and cold rolled steel that is typically used in automotive applications. This adhesive is specifically designed for hem flange and lap joint bonding but can also be used in general assembly of product.

Test Setup and Details:
Typical applications of this material utilize a robot to provide the motion for the dispense path. A robot was used and integrated with each metering system in order to provide the motion path for the beads and timed shots, and interfaced using discrete input/outputs. Scales were used to record the shot weights, and a DATAQ data collection device was used to record pressure readings from calibrated pressure transducers installed at key test points within each system. The same supply pump lower section was used for every equipment configuration, including the supply/metering pump on the E-Flo iQ test. All configurations used the same 200cc Check-Mate® lower pump, whether on the supply pump for the PCF and PGM, or the supply/metering pump for the E-Flo iQ.





E-Flo iQ

Precision Continuous Flow (PCF)

Precision Gear Meter (PGM)

Graco Systems Background:

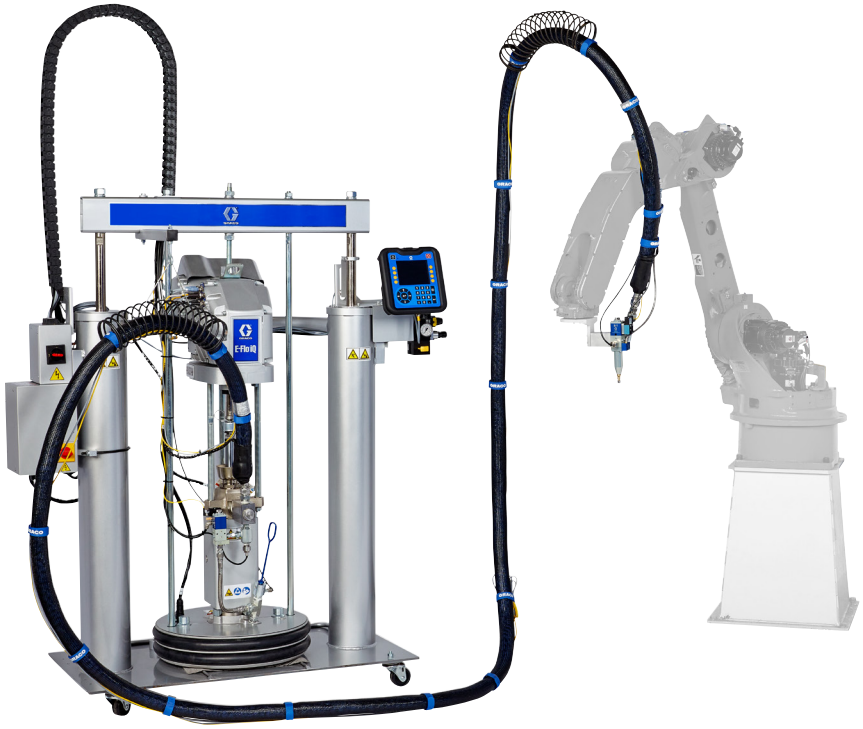
It is important to understand the principle of how each system functions before reviewing the results of this test.

E-Flo iQ:

The E-Flo iQ system is both the supply pump and metering device controlled by an electric motor that translates rotational velocity to linear velocity through a rack and pinion gear system. An encoder on the motor is used to calculate the position of the pump based on the motor position. A standard Check-Mate 200 pump is used as both the supply and metering pump. The principal operation of a Check-Mate pump is drawing material into the pump with an upward stroke. During this upward stroke, material is also dispensed out of the top section of the pump. On the downward stroke, material is simultaneously dispensed out of the pump and loaded into the top section of the pump. The cylinder and piston are sized in such a way so that 50% of the pump volume is dispensed on the upward stroke and 50% is dispensed on the downward stroke.

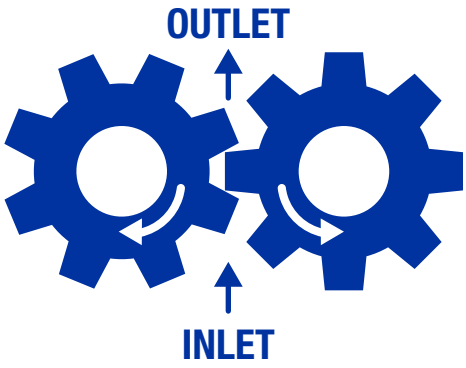
The system is tuned to how much volume every millimeter of stroke is equivalent to so that the electric motor can regulate flow rate by controlling the linear speed of the pump. The addition of pressure transducers on the pump outlet and dispense valve makes it possible to incorporate a “pre-charge.”

The pump will compress the material in the lines until the set “pre-charge” value is observed. Since the metering pump is also the supply pump, the effects of a pump changeover are dampened only by the hose between the pump and dispense valve. This effect is partly mitigated by changeover logic that tells the pump to change over at the end of a dispense cycle if the pump position is within the set changeover band. In theory, this metering system could be defined as positive displacement.



Precision Gear Meter (PGM):

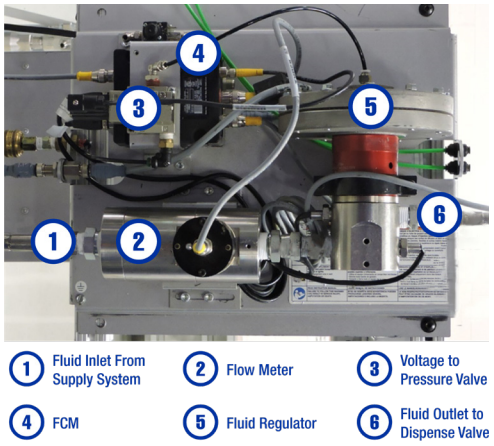
The PGM utilizes a servo motor and a gearbox. Working together, these two components can offer a high level of accurate metering. The gearbox is the principal metering device for this particular system. As material enters the gearbox, it fills up the volume between each gear tooth. Based on the machining and manufacturing of the gear assembly, this volume is very consistent from tooth to tooth. The gear is driven by a servo motor so that the material that enters the gear then exits on the opposite side and as the gears mesh together the material becomes metered to a set volume at a desired flow rate. The controller is calibrated so that the desired set flow rate can be achieved by adjusting the rotational speed of the servo motor driving the gear. This is considered a positive displacement metering device as material enters and flows through the system at a fixed incremental volume.



PGM Gear Operation

Precision Continuous Flow (PCF):

The PCF system utilizes a feedback system between pressure transducers and a flow meter to regulate flow or pressure. Material coming from the supply system enters the flow meter, where it drives augers that spin a gear. A sensor counts the gear teeth, and the information is used to communicate how fast the material is flowing—all feedback from the pressure transducers and flow meter feed into the Fluid Control Module (FCM). Flow rate and pressure readings are monitored on the Advanced Display Module (ADM) screen on the controller and are updated continuously. As material exits the flow meter, it then enters the fluid regulator. If the system is set to control flow rate, the voltage to pressure valve will regulate the air pressure to the top of the fluid regulator to create more or less restriction based on the feedback from the flow meter. In some applications, it may be desirable to incorporate a “pre-charge” operation where the material going to the dispense valve is charged to a set pressure before dispensing. In this case, the voltage to pressure valve will regulate the air pressure to the fluid regulator so that the outlet fluid pressure matches the target.



PCF Fluid Plate

Evaluation Testing:

Shot Repeatability Test:

In order to observe the repeatability, how the flow rate affects shot repeatability and how shot size affects performance for each system, a procedure was recorded that applied to all three systems. This procedure began with programming flow rate into the system controller and then purging the system to ensure pressures are consistent. Then, the proper sequence program was set up in the robot and the shot duration needed was calibrated in order to maintain the desired shot size. From there, sample shots were dispensed, weighed, and recorded.

System	PROS	CONS
E-FLO iQ	• Performed well and amongst the top in the smaller shot sizes (<1.31cc) • Least limited by flow rate. Could have performed at much higher flow rates than the other systems	• Performance decreased significantly as the shot size increased • Pre-charge time was 5-10 seconds • Combination of valve off delay timer and pre-charge made for a more complex setup
PCF – 1/2”	• Performed best at larger shots • Predictable performance with consistent trends as shot size increased • Minimal supply pump changeover effects • Pre-charge was <2 seconds	• Did not perform well at smaller shot sizes • Dwell time between shots significantly affected the weight of the next shot • Shot mode did not work well when utilizing pre-charge
PCF – 3/8”	• Minimal supply pump changeover effects • Pre-charge time was <2 seconds	• Did not perform well at smaller shot sizes • The 3/8” hose used more pressure drop, limiting the overall rate to under 200cc/min • Dwell time between shots significantly affected the weight of the next shot
PGM – REMOTE	• All shot sizes performed among the best compared to the other systems • Minimal supply pump changeover effects • No pre-charge or valve delay were required	• Dwell time between shots reduced the weightof the next shot • Greater repeatability was seen if the first shot on each data set was ignored
PGM – DIRECT	• Least effected by dwell time between shots • Higher flow range than the PGM Remote due to no hose • Minimal supply pump changeover effects • No pre-charge or valve delay were required	• Larger shot sizes started to decrease the Cpk

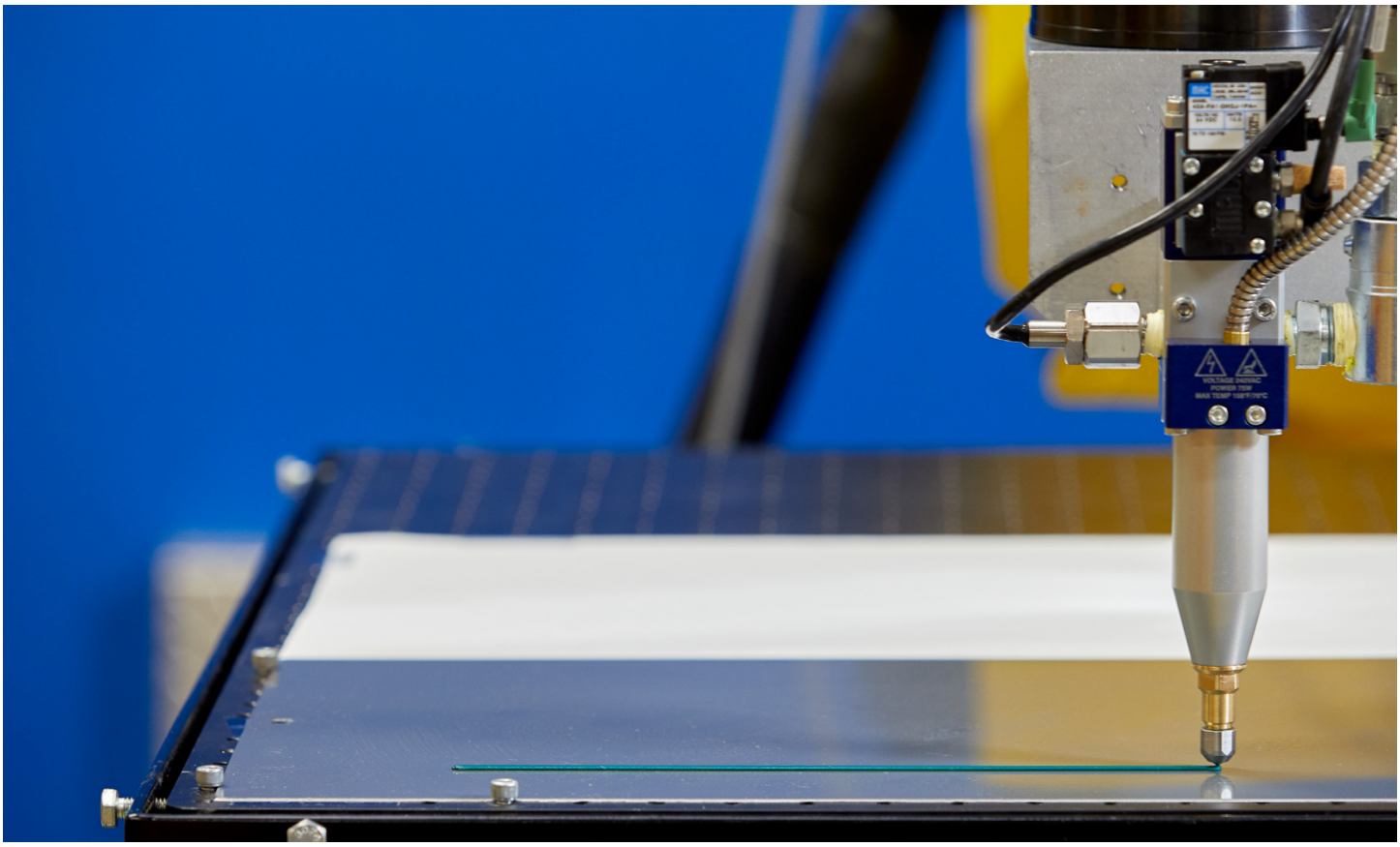
Linear Bead Repeatability Test:

For this test, beads were dispensed on a substrate at lengths of 350mm and a series of 9 beads per set. The samples were then cured and measured at defined increments and recorded for comparison. This study measured consistency within each bead and consistency from bead to bead. The primary testing was done on four standard system configurations. These systems were all configured with the same valve and the same tip (1.7mm) to get a direct one-to-one comparison keeping as many variables as possible the same.

NO DEVIATION

DEVIATION WITHIN BEAD

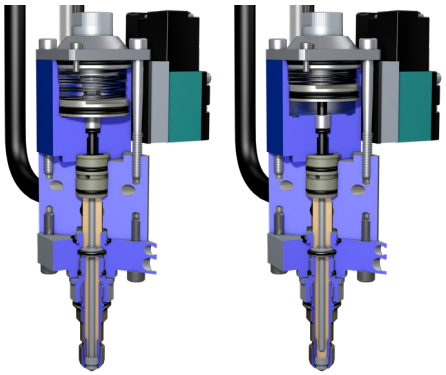
BEAD TO BEAD DEVIATION



Linear Bead Repeatability Test:

	Setup Considerations	Performance Observations
E-FLO iQ	• 3/4" x 40' hose between the metering pump and dispense valve • Used a tip seal valve with a 1.7mm tip • Utilized pre-charge function • Dispense pressures of over 2000 psi for optimal repeatability *Valve turns: see note below*	• For optimal repeatability, adjust dispense pressure to at least 2000 psi • Pre-charge is critical for producing more repeatable beads • More valve turns will result in a more consistent bead dispensing process
PCF REMOTE	• 1/2" x 10' Hose • Used a tip seal valve with a 1.7mm tip • Utilized pre-charge function • Valve on/off delay for 46ms *Valve turns: see note below*	• Pre-charge is critical for producing more repeatable beads • Valve on/off delay is effective in increasing performance and monitoring pressure • Performed well in bead to bead comparison
PCF REMOTE	• 3/8" x 10' Hose • Used a tip seal valve with a 1.7mm tip • Pre-charge function not utilized • Optimal delay time at 150ms *Valve turns: see note below*	• Valve on/off delay timers are most effective in order to produce repeatable beads • Consistent performance regardless of flow rate and motion speed • Performed best in bead to bead comparison *Note: The highest flow rate tested (236cc/min) was unable to be reached*
PGM REMOTE	• 3/8" x 10' Hose • Used a tip seal valve with a 1.7mm tip • Pre-charge function not utilized • Valve off delay of 50ms and valve on delay of 60ms significantly decreased bead deviation	• Lower flow rates increase performance and decrease bead deviation • Valve on/off delay timers significantly decrease bead deviation

Valve Turns:
Valve turns are the dimensional gap between the needle and seat of the dispense valve. There is an adjustment to control how far the needle pin unseats when the valve opens. This was found to be an important variable depending on the bead size. For smaller beads, the valve was adjusted to a smaller opening and adding orifice restriction so that when the pin would seat inside the valve it did not squeeze out excessive material that would cause a "snake head" at the end of the bead. For the larger beads, the valve opening could be larger as the relationship between the amount of material squeezing out at the shut off and the bead width was larger.



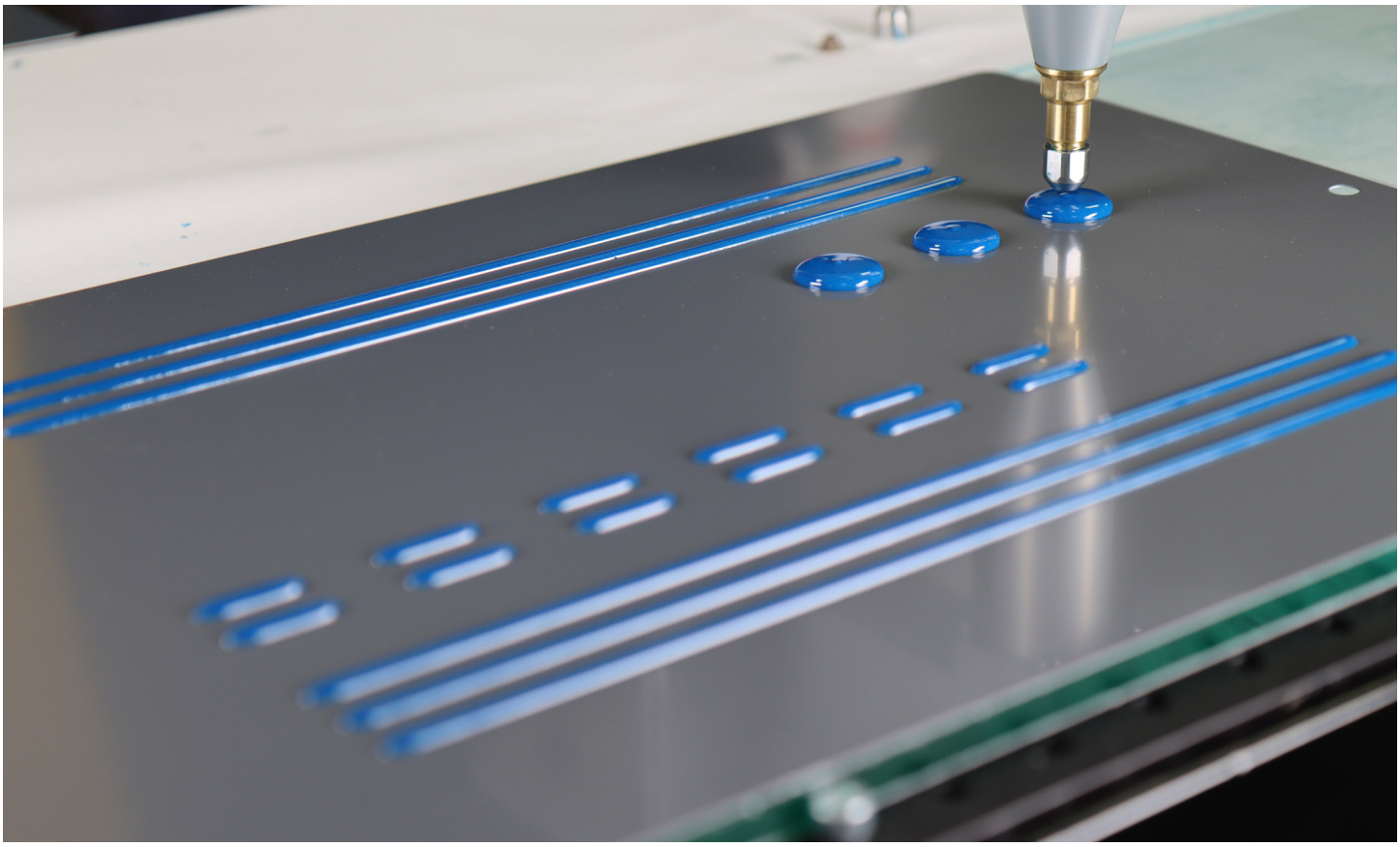
Valve Turn Comparison

Auxiliary Tests:

An additional two tests were conducted to analyze pressures and speed responses within each system. Pump changeovers and analog beads were the final items to be tested and observed and tested for each system.

Supply Pump Changeovers:
The aim of this study was to analyze pressures within the system during a supply pump changeover to see the effects. In this application testing, pump changeovers were not seen as an issue in any system that was tested.

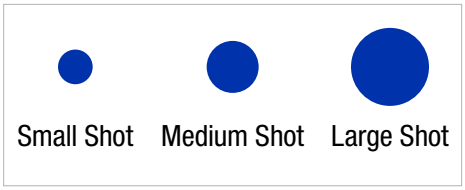
Analog Beads:
The PGM and PCF have the ability to instantaneously change flow rate based on an input voltage. This study looked at the speed of response to see which system performed the best. Both the PGM and PCF performed well at transitioning from one flow rate to the next.



Conclusion:

Repeatability Testing: Shots and Beads

This application testing was focused on comparing our One Component Metering Systems head-to-head. Based on the system setups for the E-Flo iQ, PCF, and PGM, and observing their performance in the shot and bead tests, we recommend a specific application. It is important to note that each system can be configured in a number of additional ways that can be useful for other applications not mentioned.

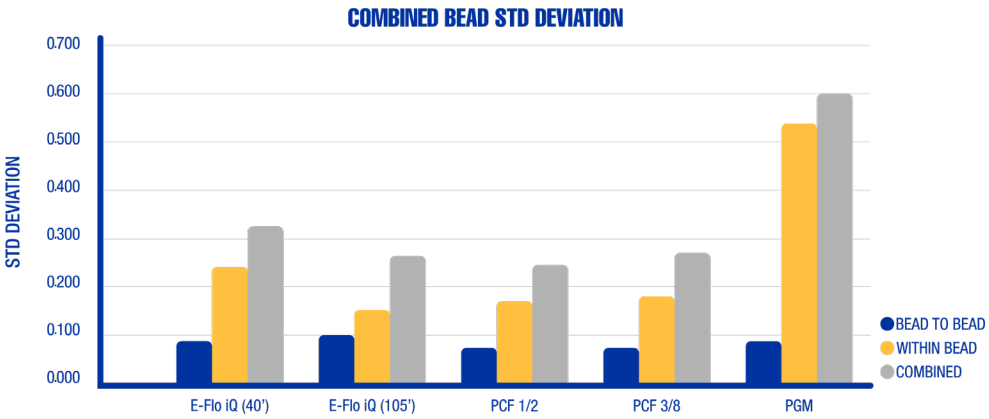


System	Ideal Shot Size	Ideal Flow Rate	Pre-charge Feature	Recommended Application
E-FLO iQ		240cc/min	Yes	Medium to high flow bead applications
PCF REMOTE (1/2” x 10’ HOSE)		120cc/min	Yes	High flow beads and shots
PCF REMOTE (3/8” x 10’ HOSE)		120cc/min	Yes	Medium flow beads and shots
PGM REMOTE (3/8” x 10’ HOSE)		120cc/min	No	Shot-based and cavity-filling applications
PGM DIRECT (NO HOSE)		120cc/min	No	High viscosity material applications of shots or beads

Linear Bead Repeatability:

In all instances, all systems had less deviation from bead to bead than within the bead meaning all systems are very capable of reproducing consistent beads. In most if not all applications, this is an important characteristic.

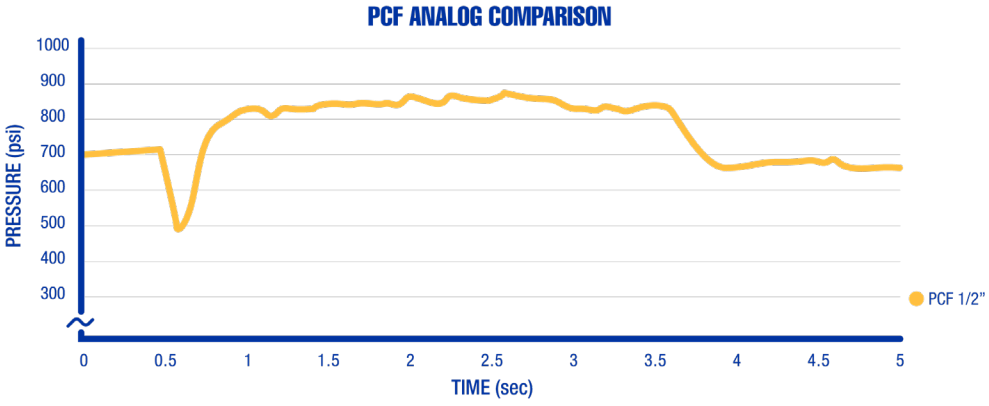
The distinguishing calculation is the standard deviation within a bead. The PCF and E-Flo iQ performed at a much higher degree than the PGM.



Auxiliary Testing:

Supply Pump Changeovers:
In this application testing, pump changeovers were not seen as an issue in any system that was tested. Some factors as to why this may be are material properties, flow rates (all our tests were at or below 240cc/min), and supply system configuration. Note that the changeovers in the shot study occurred at the end of the shot.

Analog Beads:
Both the PGM and PCF performed well at transitioning from one flow rate to the next. Hoses located between the metering device and the dispense valve do show a significant increase in time to transition from one flow rate to the next. The following graph shows how well the PCF 1/2" performed at transitioning from one flow rate to the next. The PCF 1/2" configuration's ramp up time was 0.40 seconds shorter (than PCF remote), and the ramp down time was approximately 0.80 seconds shorter (than PCF remote). Overall, both PGM and PCF both performed extremely well in the analog bead test.



Graco One Component Metering System Summary:

E-Flo iQ:

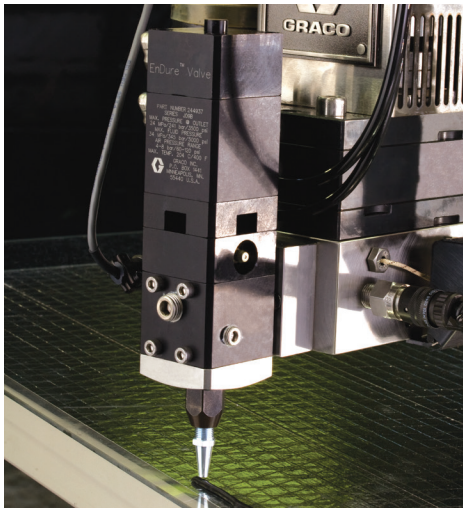
E-Flo iQ is a complete tank-to-tip solution for intelligent metering and optimal flow control—without the hassle and expense of an external metering device. Some performance benefits include the ability to drop pressure before the next dispensing cycle, the built-in changeover logic, and the long-lasting, high-quality components that make maintenance needs extremely low.

The E-Flo iQ has the easiest setup and fewest components given that the system is both the supply pump and metering device. Additionally, it can perform at the highest flow rate out of our one component metering systems. Its main application focuses around bead types.

PCF:

The PCF system can perform a variety of applications for shots and beads. It can handle a wide range of material viscosities. Finally, it offers the highest flexibility and pre-charge options.

Our PCF Metering Systems provide a precise, continuous flow for sealant and adhesive dispensing without costly reload times. Some performance advantages include the ability to handle a wide range of material viscosities, flexible pre-charge options, and an intuitive interface that shows active feedback on exact usage as well as flow rates.



PGM:

The PGM system is most effective in shot-based applications. It is also the most immune to supply/metering pump changeovers. It has the ability to meter accurately at the entire range of flow rates and is primarily limited by the capability of the servo motor controlling it.

Precision Gear Metering and Dispense Systems provide precise metering control for single-component bead, ribbon or extrusion applications. The PGM delivers smooth, consistent bead dispense every time. Precision dispense combined with high flow rates, even with high viscosity materials, means you can dramatically improve production rates and ROI within your operation. Some performance advantages include the positive continuous displacement gear meter that experiences little impact from supply/metering pump changeovers, and the ability to accurately meter at the entire range of flow rates.

ABOUT GRACO

Founded in 1926, Graco is a world leader in fluid handling systems and components. Graco products move, measure, control, dispense and apply a wide range of fluids and viscous materials used in vehicle lubrication, commercial and industrial settings.

The company's success is based on its unwavering commitment to technical excellence, world-class manufacturing and unparalleled customer service. Working closely with qualified distributors, Graco offers systems, products and technology that set the quality standard in a wide range of fluid handling solutions. Graco provides equipment for spray finishing, protective coating, paint circulation, lubrication, and dispensing sealants and adhesives, along with power application equipment for the contractor industry. Graco's ongoing investment in fluid management and control will continue to provide innovative solutions to a diverse global market.

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