Ratio Assurance:

More than just Flow Meters

Graco's multi-tiered system to prevent, detect and monitor off-ratio conditions

Table of Contents

Abstract

This document is intended to provide background on the value for ratio assurance with regards to the spray foam industry. It is also intended to provide details on Graco's Reactor ratio assurance system. This paper will detail the possible causes for off-ratio situations and the best methods of detection for each cause. Since no one detection method works for all possible causes, understanding the need for a multi-tiered prevention and detection system is important. This document will provide details on flow meters, pressure monitoring and the facts you need to know when calculating ratio.

The Need for Ratio Assurance

Today, using spray foam insulation is a widely accepted method of insulating both residential and commercial properties. The growth of spray foam as a commonly used method to provide insulation is due to the superior insulating benefits offered by the product, the push for homes and buildings to be more energy efficient and new building codes requiring tighter more energy efficient standards. Spray foam insulation is the perfect product to meet all these needs.

Spray foam is a unique product compared to other building products. Spray foam is actually manufactured on-site at the time of application. Most other building products are manufactured in a factory and delivered to the job site: sheetrock, fiberglass insulation, OSB, roof shingles, framing lumber, duct work, etc. The properties that make spray foam such a good insulator requires it to be manufactured on-site. Since it is being manufactured on-site, having the proper controls in place to assure it is manufactured correctly is important.

Spray foam is made from combining two liquid chemicals; an isocyanate (A) and a polyol resin (B). Once these chemicals are mixed they are sprayed onto a substrate. Mixing these two chemicals creates an instantaneous chemical reaction. The two liquids when mixed quickly expand typically between 10-50 times in size and fully cure to the touch within a few seconds resulting in the final spray foam product. The fact that spray foam is manufactured on the job-site allows for the materials to be spray applied as a liquid resulting in being able to better insulate by completely expanding to fill gaps, cavities, around pipes, wires, in tight spaces, etc.

The equipment needed to correctly mix and spray these chemicals must have the ability to heat and pressurize the materials and a robust mixing method that ensures a good homogenous mix is created. Properly mixing two components on-site requires professional equipment. Most spray foam chemistries today require a 1:1 ratio to mix properly and to obtain the optimal properties the material manufacturers design their chemistries to achieve.

As the use of spray foam continues to grow in order to meet new building codes and consumers demand for energy efficiency, the need to be sure the job gets done correctly becomes more important. Today the industry is growing quickly. One of the biggest problems facing the industry is finding and properly training new installers to keep up with demand. Spray foam when applied correctly is a product that offers many benefits, but if misapplied, may cause issues that become hard and expensive to remedy. The best course of action is to prevent issues from occurring. Therefore, relying on the installer alone to make sure the foam is being properly manufactured may

The Need for Ratio Assurance - continued

no longer be adequate. As more builders are adopting the use of spray foam in their homes and more homeowners become educated on spray foam they are looking for assurances that the spray foam applied in their homes was done correctly. This is where having spray foam equipment that is designed to mitigate the risk of spraying “bad foam” is important. Not only should the system have the capability of detecting possible issues with the equipment, process and chemicals, it should also save and provide the data in a usable format should customers request this information.

Graco’s spray foam equipment is designed to mitigate potential issues with a robust design and software that monitors and controls pressures and temperatures. It is also designed to alert the operator and shut down the machine if potential issues are detected.

Although Graco equipment is designed to help prevent spraying “bad foam” by detecting potential equipment issues many of the bad foam related issues are not due to equipment problems but rather things under the control of the insulation contractor: such as improperly conditioned chemical or using too large of a mix chamber for their feed system. The equipment is also mechanical and will require preventive maintenance over time and may experience issues that require repair. For all these reasons, having equipment that can detect potential off-ratio issues is important.

What are Single-Point Variables

It is important to understand the types of issues that may cause off-ratio foam to be sprayed. These types of issues are called *single-point variables*. *Single-point variables* can fall into several categories, that include:

- **Air in the fluid stream**
- **Undersized Feed Pump**
- **Poor material feed to the proportioner**
- **Proportioner pump issues**
- **Fluid leaks**
- **Fluid restriction in heated hose or spray gun**

By understanding the different *single-point variables*, detection methods can be designed for each. Once the variable type can be detected, it can be monitored. The goal is to monitor for each of these variables and shut the proportioner down if one is detected, thereby preventing off-ratio foam from being sprayed. The operator can then make the necessary updates or perform the necessary maintenance to eliminate the issue causing the off-ratio condition.

There are a number of individual *single-point variables* that may cause off-ratio dispensing. **Since no one detection method is best to detect all possible issues it is important to have a robust multi-tiered ratio assurance system that incorporates both pressure and flow meter monitoring**.

The detection method for each *single-point variable* uses a "Good, Better, Best" scale to identify the most accurate method of detection.

- **Best**: The device is the preferred method to detect the issue. This detection method will be the most sensitive so detection will be the fastest.
- **Better**: The device will detect the issue but detection may take longer. The issue may also have to become more severe to be detected.
- **Good**: The device will detect the issue but detection will take the longest. The issue may also have to become more severe to be detected. This detection method is the least sensitive method of detection and should not be relied upon as the primary detection method.
- **Not Applicable** (NA): Device cannot detect this type of issue.

What are Single-Point Variables - continued

BEST BETTER GOOD

Category Type	Single-Point Variables	Reactor Detection Method		
		Inlet Pressure Sensor *	Outlet Pressure Sensor	Flow Meters
Air in fluid stream	Run away feed pump/ Running out of chemical	NA	Better	Better
	Trapped air in the feed line and/or proportioner	NA	Good	Best
Undersized feed pump	Too large of a mix chamber being used	Best	Good	Better
	Too high of proportioner pressure setting	Best	Good	Better
	Too long of a trigger pull	Best	Good	Better
Poor material feed to proportioner	Cold material(s)	Best	Better	Good
	Feed pump pressure set too low	Best	Good	Better
	Damaged feed pump (seals, check ball, air motor)	Best	Good	Better
	No feed pump pressure	Best	Good	Better
	Plugging inlet filter	Best	Good	Better
Proportioner pump issue	Damaged proportioner pump foot valve ball/seat	Best	Good	Better
	Damaged proportioner pump piston ball/seat	NA	Better	Best
	Damaged proportioner pump seal	NA	Better	Best
Fluid leaks	Leak between proportioner pump and flow meter	NA	Better	Best
	Leak in heated hose	NA	Best	NA
Restriction after flow meter	Blockage in heated hose, build-up on ID of hose(s) **	NA	Best	NA
	Plugged gun filter **	NA	Best	NA
	Gun impingement port plugging **	NA	Best	NA

** Requires updated Reactor software (version 3.02 or newer) to properly detect the issue.*
*** May not cause off-ratio dispensing but may cause impingement mix issues.*

The final material quality is dependent on more than just understanding and controlling the single-point variables. A number of external factors also influence final material quality. These factors include but are not limited to: material formulations, environmental conditions and processing parameters.

Graco's Ratio Assurance System

No single method can easily and accurately detect each of the potential *single-point variables*. A robust ratio control system must be multi-tiered and more than just flow meters. The foundation of the system starts with mechanically linked pumps and then adds positive displacement piston pumps, pressure monitoring, and flow meters to provide a ratio assurance system with built in redundancies that will provide unsurpassed results in detecting off-ratio conditions.

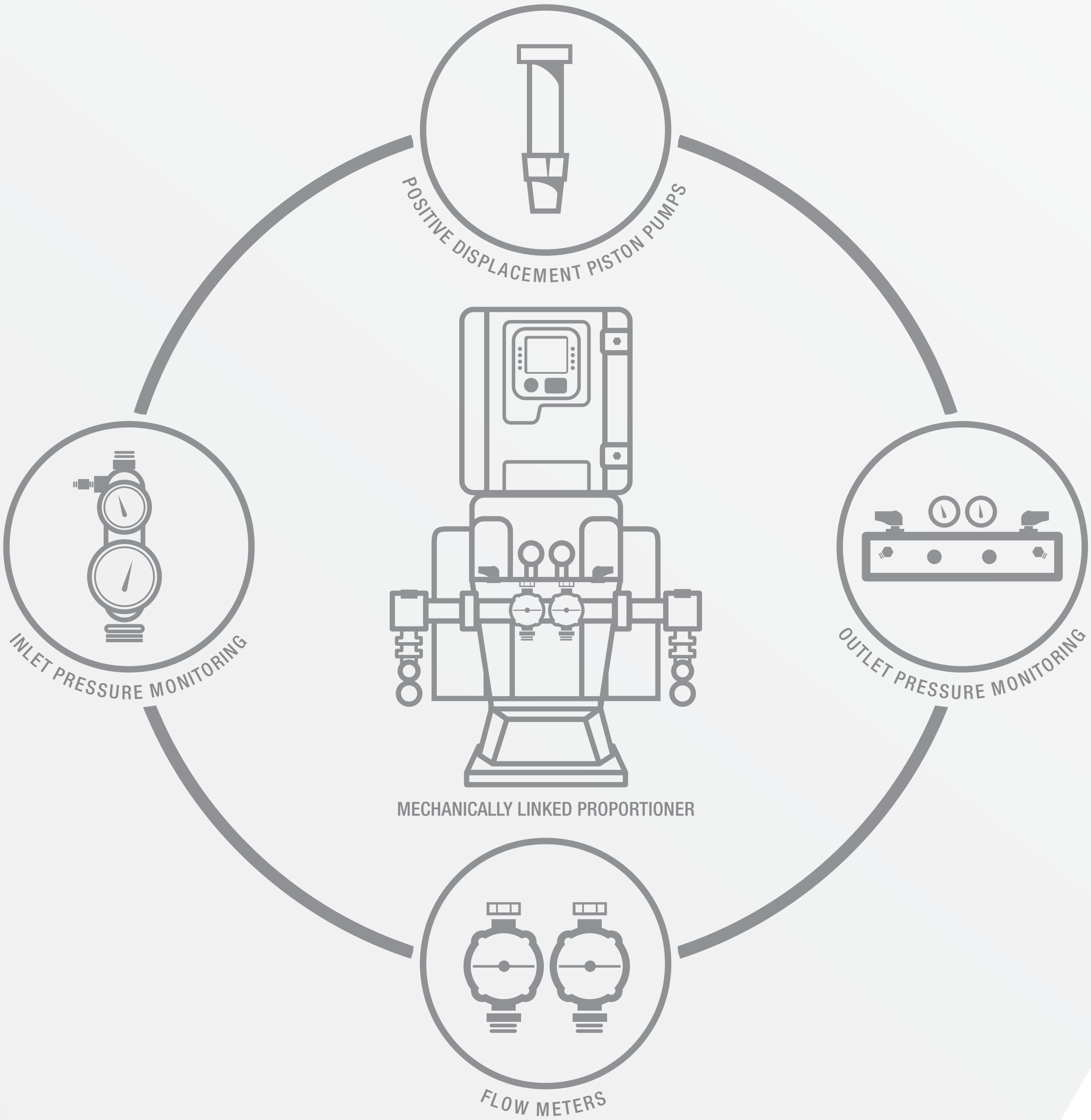
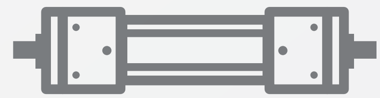


Figure 1*: Image represents the individual components of the Graco Ratio Assurance System.*

Mechanically Linked Pumps

At the foundation of every Reactor are mechanically linked pumps. This includes the pumps on all electric, hydraulic, and pneumatic Reactors. The term “mechanically linked pumps” simply means that both the A and B pumps are connected together either with a shaft or a yoke so that both pumps stroke evenly at the same rate. By mechanically linking the pumps each time the A pump is cycled the B pump must also cycle. This forces the pumps to cycle evenly and equally resulting in the pumps wanting to pump on-ratio.



Graco has always believed that mechanically linking the A and B pumps provides a robust system designed for 1:1 ratio spraying. In a sense, mechanically linked pumps are like built in flow meters, in that the pumps naturally dispense equal amount of A and B chemicals on each stroke.

Since ratio is fixed, mechanically linked pumps provide consistent ratio in a tight tolerance band. Mechanically linked pumps are also not dependent on flow meters to pump on-ratio. A mechanically linked pump is designed to automatically pump equal volumes of both A and B materials.

Non-Mechanically Linked Pumps

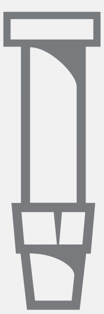
Alternatively, non-mechanically linked pumps are not forced to spray on-ratio. The volume of material from pump A can be different than the volume of material from pump B. When designed correctly, non-mechanically linked pumps are a good way to pump two-component materials that require different ratios from job to job but may not be the best method of pumping 1:1 fixed ratio chemistries day after day.

An example of a robust non-mechanically linked proportioner would be a proportioner using positive displacement piston pumps that are electronically linked to control the desired flow of both materials. In this system flow meters are not required but may be used as part a multi-tiered ratio assurance system to verify the desired ratio. In this type of system the volume of materials being pumped is not dependent on the flow meters but only using the flow meters as a way to verify ratio. Since piston pumps are being used in this design, an accurate volume of material is known for each pump stroke and/or portion of the pump stroke, therefore the desired ratio can be maintained.

Alternatively, a non-mechanically linked proportioner not using piston pumps often times must rely on flow meters to control ratio. In this design the A and B pumps are not directly electronically linked together but linked through the flow meter. Because pumps other than piston pumps may not be accurate enough to control ratio directly they must rely on the measurements of the flow meter to control the pump output. Potential issues with this design include:

Mechanically Linked Pumps - continued

- A system dependent on flow meters to measure the volumes of A and B materials and then controlling the pumps to match the desired ratio may create a situation of overshooting and undershooting the desired ratio as the pumps make adjustments to the flow. These types of machines will continually be making corrections to the ratio thereby always having variation to the product being dispensed. Frequently, these variations will be outside of the acceptable tolerance limits of the materials being dispensed (Ex. +/– 5%).
- A system dependent on flow meters to control volume is at risk of pumping severely off-ratio if there is an issue with the flow meters. Any flow meter issue, including not being calibrated correctly, may result in not reading the true ratio, but the system is making pumping decisions based on this faulty feedback from the meter. This may result in the proportioner spraying off-ratio without detection.
- A system dependent on flow meters is also at risk of a complete shutdown. If the flow meters are not working or not communicating with the controller then the proportioner is shut down and cannot pump.



Positive Displacement Piston Pumps

The type of pumps used for spray foam and coating applications is also important. There are many types of pumps. Positive displacement piston pumps are a proven design that Graco believes is the best type of pumps for this application.

Positive displacement piston pumps provide consistent volumetric performance over a large range of temperatures, pressures and viscosities. Piston pumps are more accurate for use in start and stop applications and for maintaining stall pressure. Piston pumps can maintain accurate volume per cycle over long periods of use even with aggressive fluids.

Graco's piston pumps are precision machined with state of the art CNC machining equipment and are held to very tight tolerances assuring consistency from pump to pump. This is important when depending on 2 pumps in a system for equal volumes of material. Graco's tolerance between pumps is held to less than 1%.

Inlet Pressure Monitoring

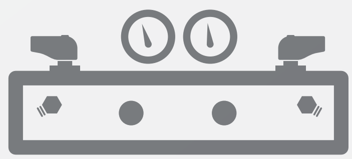
Monitoring changes in inlet pressure is a quick and reliable way to detect certain potential off-ratio causing issues.

Inlet pressure monitoring is a standard feature on Reactor 2 elite models. Inlet monitoring is the best way to detect most feed pump and material feed related issues. By monitoring when inlet pressure falls below an acceptable pressure a problem can be detected and the user alerted. Although flow meters and outlet pressure monitoring may also be able to detect feed related issues, inlet pressure monitoring is the most accurate and quickest responding method of detection.

Some of the most common ratio causing conditions including running out of chemical, cold chemical, or the feed pump(s) being undersized for the required demand are all best detected using inlet pressure monitoring.

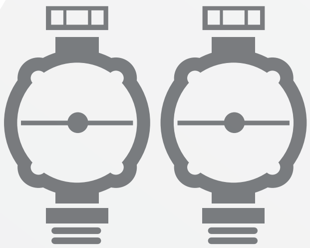
Outlet Pressure Monitoring

Outlet pressure monitoring is standard on all electric and hydraulic Reactors. Graco has always used the pressure differential between the A and B chemicals as a way to detect and prevent off-ratio spraying. Reactors have a pressure differential alarm default setting of 500 psi (customers have the option of changing this value to best suit their needs). Once the pressure differential between the A and B chemicals exceeds 500 psi the Reactor will shut down. Using pressure monitoring has always been the way to detect the majority of off-ratio conditions. Although this rule of thumb works in most cases, there are exceptions to the rule.



Outlet pressure monitoring can also help detect conditions that may cause poor impingement mixing of the A and B chemicals. Poor impingement mixing may occur even when chemicals are on-ratio. Possible causes of impingement mix issues include a plugged gun filter and/or plugged impingement port(s) in the side seals of the gun. These types of issues will cause the pressure of one of the chemicals to increase, thereby affecting impingement mixing. As the pressure differential between the A and B chemicals gets larger, complete impingement mixing becomes more difficult. Outlet pressure monitoring can detect these types of issues when the pressure differential exceeds the alarm threshold and will shut down the machine in an attempt to prevent improperly mixed materials from being dispensed.

Flow Meters



Flow meters can detect certain conditions that may cause off-ratio dispensing that may not be caught using inlet or outlet pressure monitoring alone. Flow meters are best at detecting issues related to the proportioner pumps, air in the feed lines/system and some fluid leaks. Adding flow meters to the strong Reactor foundation of mechanically-linked positive displacement piston pumps and inlet and outlet pressure monitoring provides an additional level of ratio assurance protection to the system.

Flow meters tie the complete system together with the ability to measure, monitor, and record true volumes of the A and B materials. By knowing the true volumes dispensed this data can be made available to the customer.

Understanding Flow Meters

Types of Flow Meters

A flow meter is an instrument used to measure volumetric flow rate. When deciding to measure flow there are a number of different technologies available including: oval gear, ultrasonic, electromagnetic, Coriolis mass, variable area, and differential pressure flow meters. Each type of flow meter comes with their advantages and limitations.

The Graco Reactor 2 ratio assurance system uses oval gear flow meters. Oval gear flow meters have a number of advantages including cost effectiveness, accuracy, ease of installation, and versatility.

Oval gear flow meters are generally regarded as one of the more cost effective options for liquid flow measurement. This type of flow meter is ideally suited for measurement of fluids having a range of viscosities and high flow rates. The gear meters used with Reactor, once calibrated have an accuracy of +/- 1%. Ease of installation is another advantage of the oval design. Because no straight pipe runs or flow conditioning are required, oval gear meters can be installed in tight areas where alternate technologies would fail. Oval gear flow meters are also an excellent choice for any number of industrial applications including chemicals, petrochemicals, water, oils, diesel fuel, paints, coatings, greases, and solvents.

Oval gear flow meters by design are simple and robust. Two interlocking oval shaped gears offset by 90 degrees rotate within a chamber of known volume. As these gears turn, they repeatedly fill and empty a very precise volume of fluid between the outer oval shape of the gears and the inner chamber walls. Each complete 180 degree rotation of the gears is called a pulse. The flow rate is then calculated based on the number of pulses recorded.

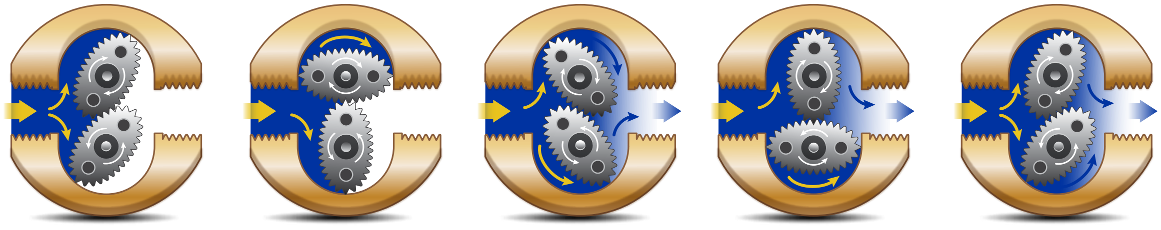


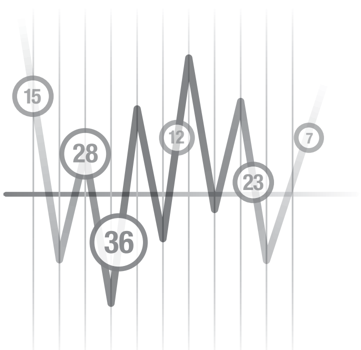
Figure 2: *Fluid flow is shown in the **oval gear flow meters** in the figure above. The flow meter has two oval-shaped gears. The rotation of the gears trap a precise amount of fluid between the gears and the housing. By monitoring the number of gear rotations, liquid flow rate is calculated.*

Understanding Flow Meters - continued

Flow Meter **Calibration** and Understanding K-Factor

Flow meters, like any other device used for measurement, require calibration to maintain accuracy. Flow meters are calibrated at the factory to precisely measure the fluid flow for each particular meter. Each flow meter has slight differences based on manufacturing tolerances of the components, so the volume of flow through each meter will vary slightly. In order to account for the slight difference in each meter a number known as the K-factor is used to calibrate the meter.

The K-factor is a number that represents the number of pulses which relates to a known volume of a material that passes through the flow meter. The volume of material is calculated by counting the number of pulses and then using the K-factor to account for differences in each meter. Changes to temperature, pressure, and liquid viscosity can all change the K-factor and effect the absolute accuracy of the volume measured.



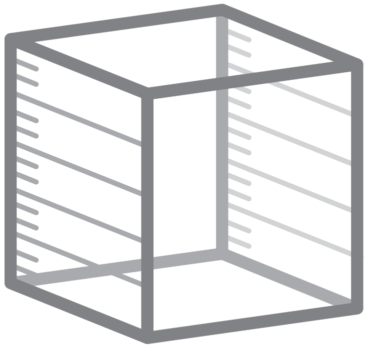
The flow meters being used with Reactor 2 units are calibrated in the Graco factory. Each flow meter will have a unique K-factor. The K-factor for each meter will be entered in the ADM (Advanced Display Module) and will be used to accurately calculate the ratio of materials recorded and displayed.

The Importance of Volume

When discussing ratio it is important to know how the ratio is being measured. Measuring ratio should always be calculated over an appropriate volume of material. Using too small of a volume may cause nuisance alarms and using too large of a volume may mask ratio issues.

Graco's goal is to keep you from spraying bad foam. Graco is calculating ratio using a small averaging volume, 1000 cc's, and constantly recalculating ratio on a rolling basis. Constantly refreshing the real-time ratio based on only the most recent small volume of material makes determining the current ratio very accurate. This differs for other equipment manufacturers that display ratio by using a running average of the total amount of chemical dispensed. Using a running average is susceptible to masking real-time ratio issues.

There is no rule or predetermined number to use for volume size when calculating ratio. Determining the correct volume is dependent upon a number of factors including: equipment, chemistry, application, and applicator. Through both lab and field testing, Graco has chosen a volume of material for measuring ratio that balances between being too sensitive and not being sensitive enough. The goal is to detect true off-ratio conditions within a short period of time but not be so sensitive that it will cause nuisance ratio alarms. Nuisance alarms may be caused by a variety of different factors including: the number of flow meter pulses counted, pump changeovers, a pump ball randomly not checking correctly, etc. These are events that will not affect the overall ratio of the material being dispensed so should not be the cause of a ratio alarm.



CONVERSION CHART		
cc's	gallons	liters
100	0.026	0.100
300	0.079	0.300
500	0.132	0.500
1000	0.264	1.000
1892	0.500	1.892
3785	1.000	3.785

The Importance of Volume - continued

Figure 3 demonstrates the importance of measuring ratio by averaging over the correct volume of material. As shown, when ratio is measured using too small of a volume, in this case 300 cc's, there are a few instances (minutes 25 and 55) with a single point outside of the tolerance window. If ratio were to be measured using this volume a ratio alarm would have occurred at these instances. But because these points do not continue to persist repeatedly, they are not indicative of a true off-ratio condition. By choosing a slightly larger ratio averaging volume, in this case 1000 cc's, the two points that would have caused a nuisance alarm are avoided, but the averaging volume is still sensitive enough to detect an issue when more than one point is outside of the ratio tolerance (minutes 101-116). These points represent a true ratio issue. Figure 3 also shows the inaccuracy of using a running average to measure ratio. Even after spraying just a few minutes the running average becomes a relatively straight line and does not show true fluctuations in ratio. The off-ratio condition shown in minutes 101-116 goes undetected.

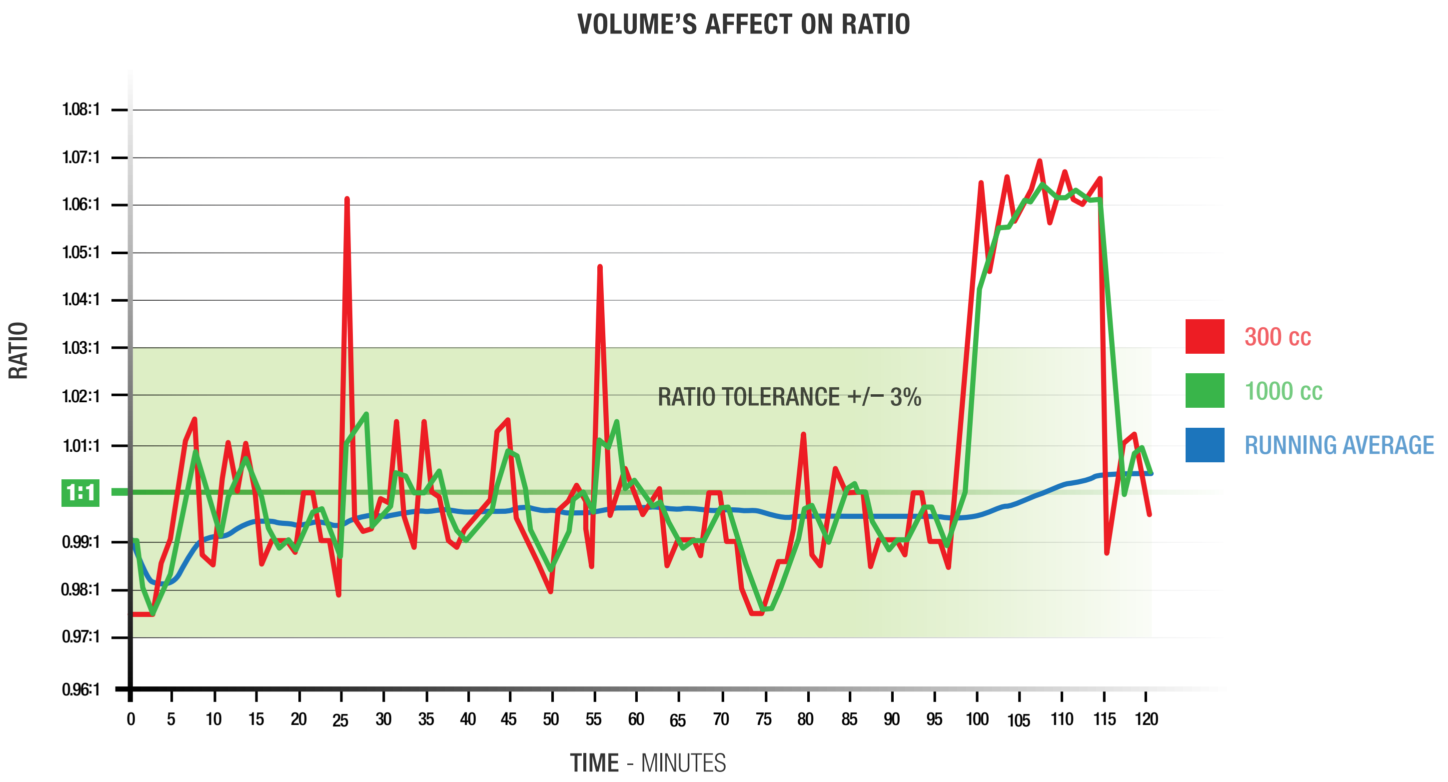


Figure 3: *Graph shows the importance of selecting the correct volume to measure ratio. The same data is displayed calculating ratio using 3 different volumes: 300cc, 1000cc, and a running average. At 300cc there would have been a few nuisance alarms and using a running average would not have detected a true ratio issue.*

The Importance of Volume - continued

Be cautious if your system is calculating ratio using a running average of the total material dispensed. Within just a few minutes, the ratio data becomes meaningless since true off-ratio conditions may no longer be detected. When too large of a volume is used to calculate ratio it may mask potential off-ratio conditions, the larger the averaging volume, the greater the chance of not detecting an off-ratio condition.

An example to better illustrate the issue of using too large of a material volume when calculating ratio can be seen in Figure 4 below. Figure 4 is actual spray data from a non-mechanically linked proportioner dependent on flow meters to control volume. This type of proportioner is constantly adjusting flows in an effort to stay on-ratio. As the A and B flows are adjusted there is overshooting and undershooting of the desired target and then constant re-correcting. This process of constant change allows material to be dispensed both A-rich and B-rich, at times severely outside of the desired tolerance window.

The data displayed in Figure 4 shows the variability in the ratio if it would have been calculated using a small material volume, in this case 1000 cc's. Because the machine used the running volume of materials dispensed, 59 gal A and 59 gal B, to average and display ratio it never alerted the user to a ratio issue. This system reported the material was sprayed at 1:1 ratio, yet it actually sprayed over 10% of the material off-ratio; that means over 11 gallons was sprayed outside of the desired tolerance window. Some of the material dispensed was as far as +/- 20% off-ratio.

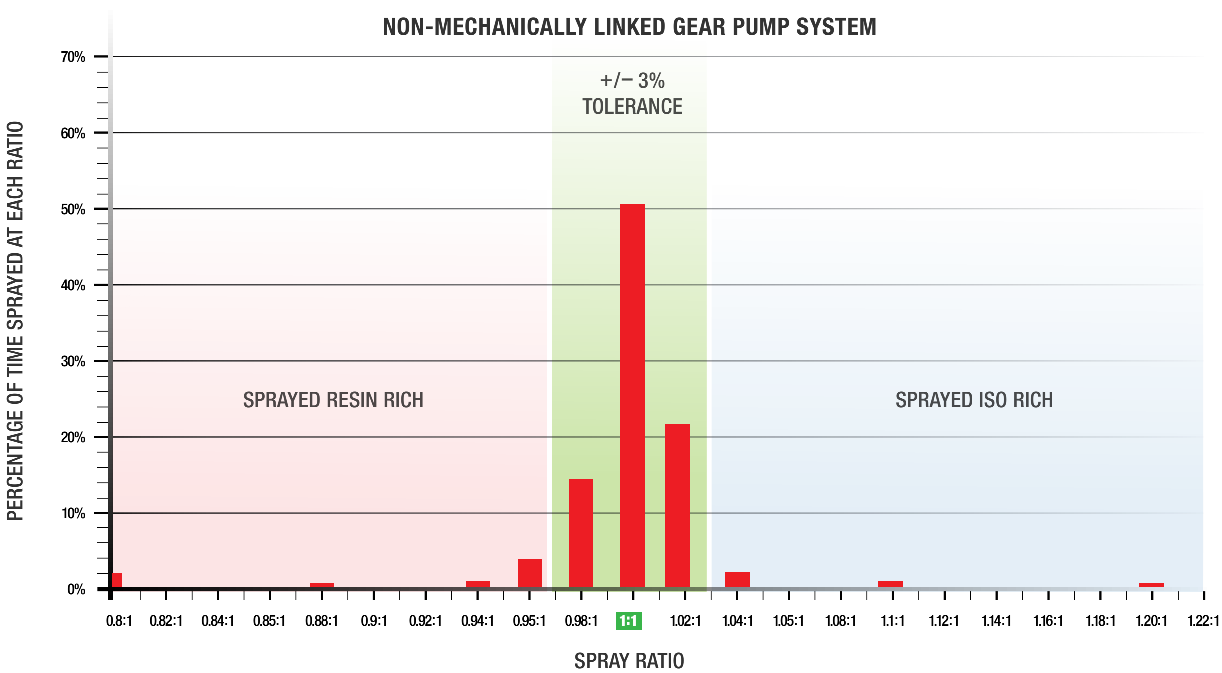
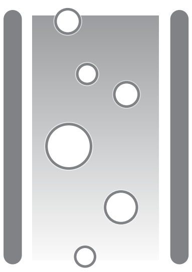


Figure 4: *Graph shows actual spray data of a non-mechanically linked gear pump proportioner. The system dispenses outside of the 3% tolerance over 10% of the time. The ratios were calculated using a 1000 cc averaging window.*

Understanding Single-Point Variables

Air in the Fluid Stream

Introducing air into your fluid stream is one of the most common reasons for being off-ratio. Once air is introduced into the fluid it may get trapped within the hoses, heaters, plumbing, etc. and may continue to cause ongoing ratio issues until all the trapped air is purged. The detection of air in the fluid stream is dependent on the situation.



Running Out of Chemical: When the material in the drum/tote is depleted and the feed pump continues to cycle it will introduce pressurized air into the fluid stream. The introduction of this air often allows the inlet fluid pressure to remain above the inlet pressure alarm threshold, thereby making this ratio issue undetectable using inlet pressure monitoring. The air in the fluid stream will ultimately affect outlet fluid pressure and fluid ratio as it makes its way through the proportioner. Outlet pressure monitoring and flow meters can both detect this issue. It is important to keep in mind that the detection method is for preventing an off-ratio condition, not for detecting a runaway feed pump. Therefore, there will likely be a short period of time from when the feed pump runs out of material to when this issue begins causing a detectable off-ratio fluid condition. A number of key factors will influence which detection method will be first to detect this issue, these factors include: pressure imbalance alarm value, ratio tolerance value, length of heated hose, material viscosities, pressure setting and triggering pattern.

Trapped Air in the Fluid Stream: A different problem occurs when air gets trapped in the fluid stream. Air is considered trapped when the empty drum/tote of material is replaced with a new drum/tote of material and the new material is fed into the fluid stream without properly purging the trapped air. In this situation, air is trapped between the new material and the remaining old material. When new pressurized material is added to the fluid stream the trapped air acts as an accumulator, thereby masking this issue from detection using inlet pressure monitoring and making outlet pressure monitoring detection more difficult. As the trapped air breaks apart it begins making its way through the fluid stream, continuing through the proportioner resulting in an off-ratio condition. Flow meters are the best method of detection for this issue.

Being able to troubleshoot and diagnose this issue may sometimes be difficult because the foam being dispensed may appear to be good. Once air bubbles are trapped in the feed hoses or proportioner system it may remain trapped even when using the traditional purge methods. Air bubble(s) trapped in the fluid stream may be a source of ongoing ratio issues as they slowly break apart and work their way through the system. The susceptibility of getting an air bubble and the ease of purging the air bubble depends on many individual circumstances including: the amount of air introduced into the fluid stream, the viscosity of the material being pumped, the cycles per minute of proportioner pumps, and the routing of the material hoses in the spray rig.

Understanding Single-Point Variables - continued

Air in the Fluid Stream - continued

The ratio issues caused by having air in the fluid stream can be resolved and avoided all together by properly purging all the air from the fluid stream. Graco has developed a simple procedure that should be followed to purge trapped air. The purge air procedure is as follows:

To Remove air trapped in the feed hoses

1. Power off proportioner motor
2. Remove air pressure to feed pumps by removing air line
3. Turn relief valves to re-circulation position
4. Turn feed air pressure line to 100 psi
5. Quickly add air pressure to the feed pumps by plugging in air line
6. Press Jog button on ADM, set jog speed to J20
7. Turn on Reactor motor. Listen for “spitting” sound from recirc lines; continue running until all spitting sound has stopped and there is a steady stream of fluid exiting the recirc hoses

To Remove air trapped in proportioner pump/heaters

8. Turn relief valves back to spray position
9. Remove air feed hose to feed pumps
10. Push motor power button to exit jog mode
11. Quickly turn relief valves to open position. Listen for “spitting” sound from recirc lines; continue running until all spitting sound has stopped and you have a steady stream of fluid exiting the recirc hoses.

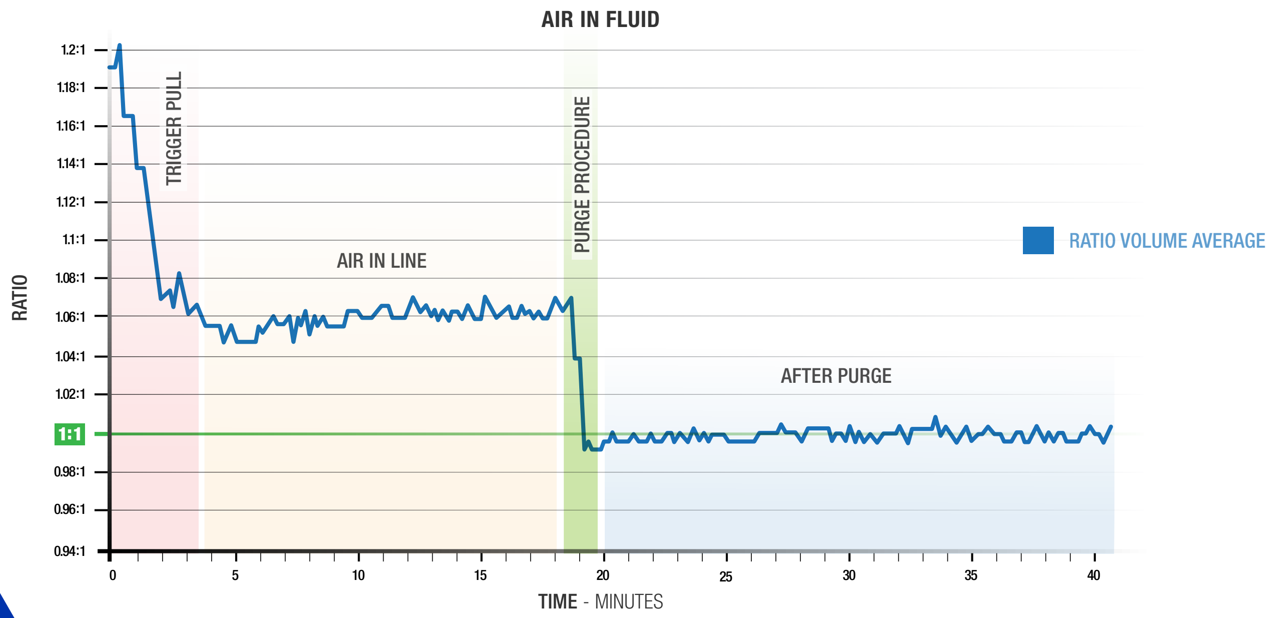


Figure 5: *Graph shows an off-ratio condition caused by having air in the fluid stream. When the trigger is pulled ratio quickly falls from 1.20:1 to about 1.06:1. Ratio remains high until a purge procedure is done to remove all air from the fluid stream. After purge procedure the ratio is nearly 1:1.*

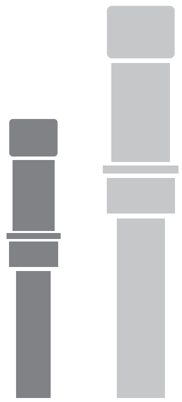
Understanding Single-Point Variables - continued

Undersized Feed Pumps

An off-ratio condition may occur when the desired fluid output at the gun is exceeding the volume of material the feed pump(s) can deliver. This may be caused by a number of conditions:

- Using too large of a mix chamber
- Using too high of a spray pressure
- Making long trigger pulls

Inlet pressure monitoring is the best method of detection for these types of issues.



These types of issues can be resolved several ways depending on the root cause of the issue:

- Utilize “Reactor Smart Control” mode: details on this tool are described in Updates to Reactor
- Use a smaller size mix chamber to reduce flow
- Reduce the output pressure of the proportioner
- Adjust triggering pattern if long trigger pulls are causing the issue
- Change feed pumps to a pump capable of delivering the desired volume of material

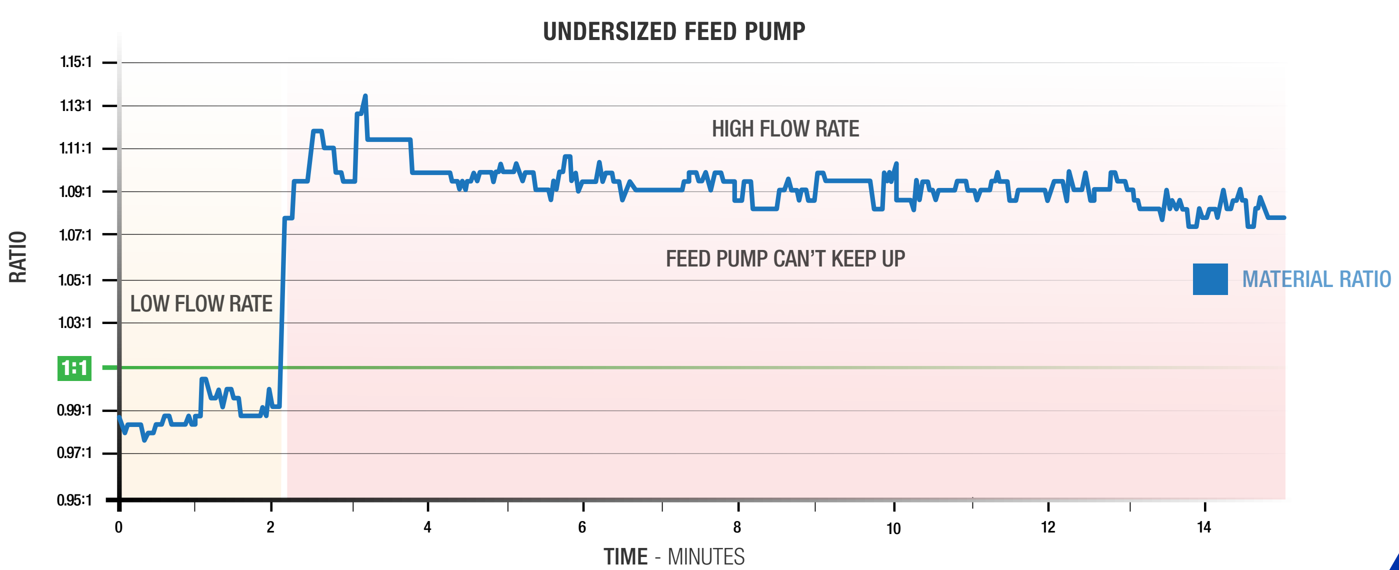


Figure 6: *Graph shows that when spraying at a low flow rate the ratio is close to 1:1, but when spraying at a high flow rate the feed pump cannot keep up causing off-ratio spray between 1.07-1.11: 1*

Understanding Single-Point Variables - continued

Poor Material Feed to Proportioner

An off-ratio condition may occur when material is not being properly fed to the proportioner. A number of issues may cause poor material feed. Possible causes include: cold material, feed pump pressure set too low, damaged feed pump, no feed pump pressure or a plugged inlet filter.

Inlet pressure monitoring is the best method of detection for these types of issues.

Issues caused by poor material feed to the proportioner can be resolved several ways depending on the root cause of the issue:

- Condition the chemical in the drum/totes/tanks to be sure the viscosity of the material is not too high
- Increase the air pressure to the feed pumps
- Repair the damaged feed pump components: seals, check ball, air motor
- Be sure compressed air is being properly supplied to the feed pump
- Clean the inlet filter in the Y-strainer

Understanding Single-Point Variables - continued

Poor Material Feed to Proportioner

Cold Chemical: Probably the most common issue causing poor material feed is the material in the drums/totes/tanks is too cold. For spray foam materials viscosity increases as material temperature decreases. As viscosity increases it becomes more difficult to pump. If the feed pump is undersized or not designed to handle viscous materials it may struggle to adequately feed the proportioner with the necessary volume of material to stay on-ratio.

This issue can be resolved by properly conditioning the chemical(s) prior to use or using a feed pump properly designed to pump more viscous materials. This issue is common in colder climates where the material temperature can fall below the recommended storage and pumping temperature. For common spray foam materials, viscosity increases exponentially as temperature decreases. Figure 7 shows how cold temperatures increase material viscosity.

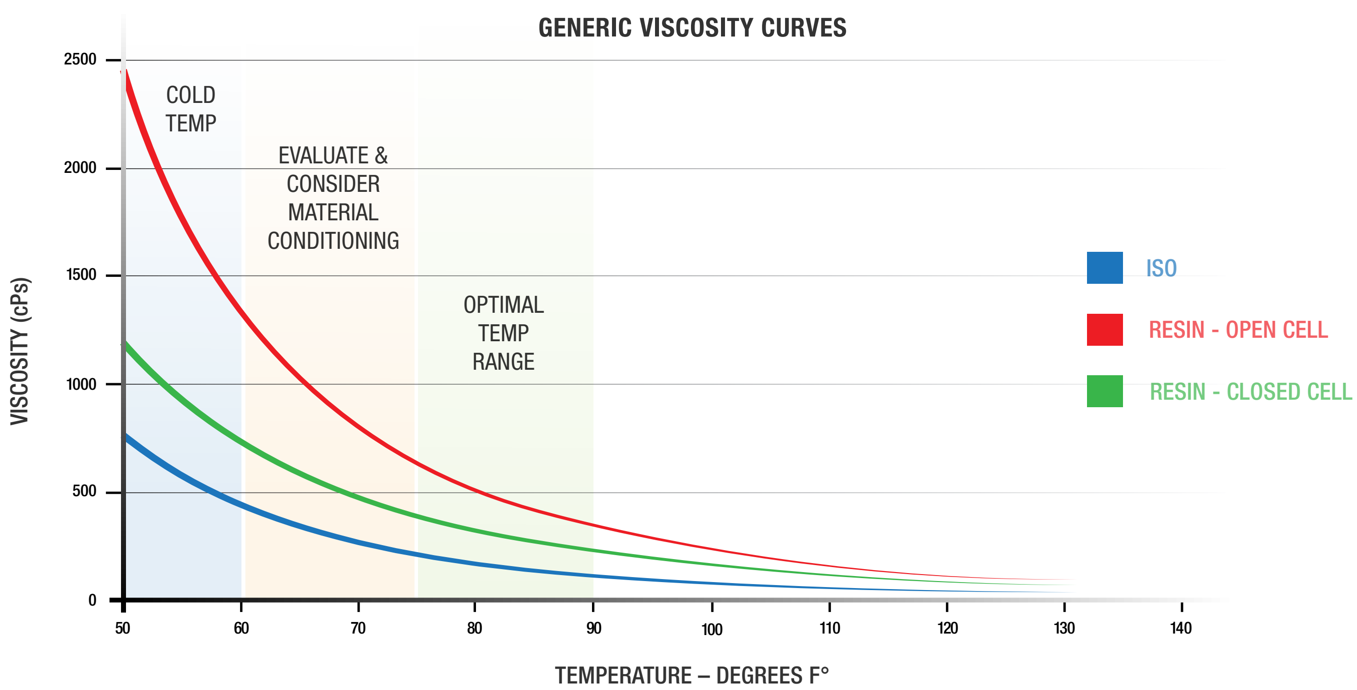


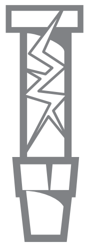
Figure 7: *Graph shows how viscosities are affected by temperature. At temperatures less than room temperature the viscosities quickly increase which may cause feed pump issues. The graph is a generic representation of spray foam chemicals. Viscosities of actual materials used should be verified with the chemical manufacturer.*

Understanding Single-Point Variables - continued

Proportioner Pump Issue

A number of issues with the proportioner pump may cause an off-ratio issue.

Damaged Proportioner Pump Foot Valve Ball/Seat: An issue with the proportioner pump foot valve ball/seat may cause high pressure fluid to leak past the ball/seat and into the feed hose. This may result in poor pumping efficiency and excessive pressure in the feed hose. Inlet pressure monitoring for a high pressure spike is the best method of detection for this type of issue. This issue can be resolved by repairing the damaged proportioner pump foot valve components.



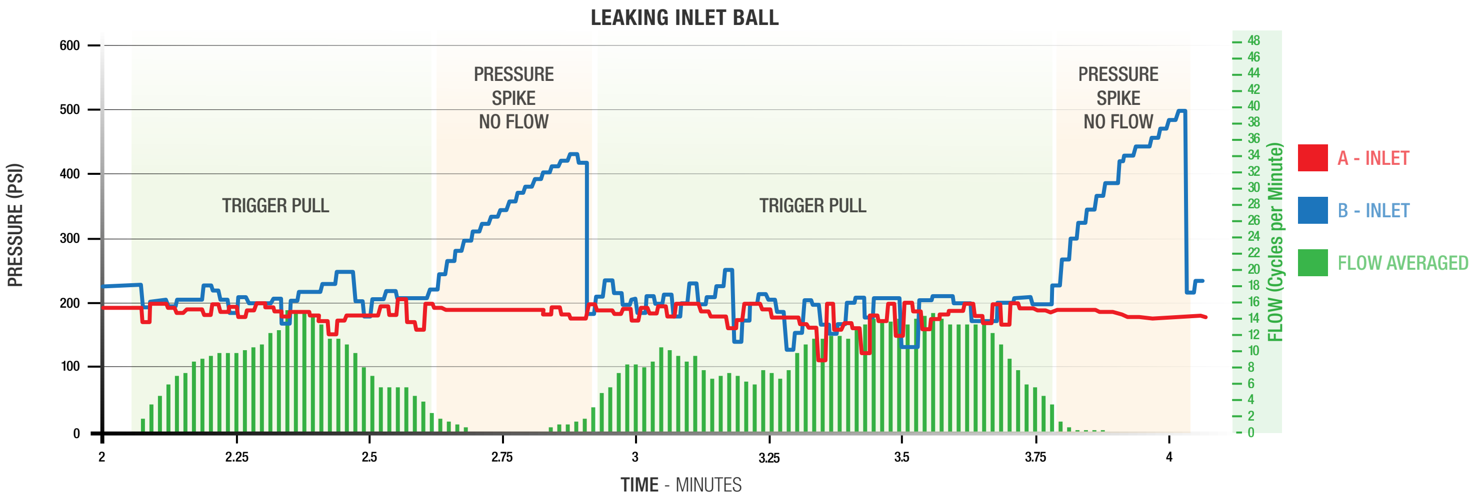


Figure 8: *Graph shows pressure spikes on the B inlet at periods of no flow. The pressure spikes indicate an issue with the proportioner pump foot valve not holding fluid pressure.*

Damage to Proportioner Piston Ball/Seat or Proportioner Pump Seal: An issue with a worn or damaged proportioner piston ball/seat or proportioner pump seal(s) may result in fluid leaking by the seal(s) or ball check, resulting in the pump not dispensing a full stroke of material, thereby possibly causing an off-ratio situation. Flow meters are the best method of detection for this type of issue. This issue can be resolved by repairing the damaged proportioner piston ball/seat and/or proportioner pump seal components.

Understanding Single-Point Variables - continued

Fluid Leaks

Fluid leaks, depending on location, may cause off-ratio dispensing. Large leaks may be obvious to detect due to visually being able to see the leaking material in the spray rig or on the job site. Smaller leaks may not be as easy to visually detect. For example, a pin-hole leak in a heated hose may be hidden under the hose construction materials. Being able to detect a fluid leak is important not only for detecting an off-ratio situation but also for reducing the potential for a large clean up.

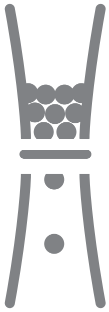
Leak between Proportioner Pump and Flow Meter: Flow meters are the best method of detecting a fluid leak between the proportioner pump and the flow meter.

Leak in Heated Hose: Outlet pressure monitoring is the best method of detecting a fluid leak in the heated hose.

These issues can be resolved by repairing/replacing the component(s) causing the fluid leak.

Fluid Restriction in Heated Hose or Spray Gun

Fluid restrictions after the flow meters may not create an off-ratio condition but may cause poor impingement mixing. Being able to detect conditions that may cause poor mixing is equally as important as catching off-ratio conditions.



Blockage or Buildup in Heated Hoses: Outlet pressure monitoring is the best method of detecting a material restriction in the heated hoses.

Plugged Gun Filter or Plugged Gun Impingement Port(s): Outlet pressure monitoring is the best method of detecting a material restriction due to plugging in the gun filter or in the gun impingement ports (side seals).

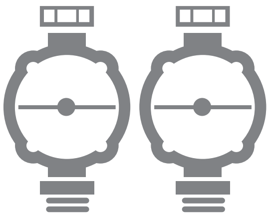
These issues can be resolved by removing the material causing the fluid restriction. If the restriction is in the heated hoses, the hose may need to be flushed or replaced. If the restriction is in the gun, the gun and/or gun components should be properly cleaned.

Updates to Reactor

A number of updates to Reactor 2 have been implemented as a result of studying and better understanding the types of *single-point variables* and the detection methods required to identify these conditions.

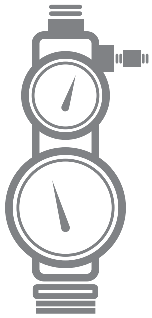
- **Flow Meters are standard on Reactor elite models:** All Reactor 2 elite E-30, H-30, H-40, and H-50 models will include factory installed flow meters.

The factory default settings for flow meters are as follows:



  - Ratio tolerance set at 5%. Customers can change ratio tolerance between 3%-20%.
  - Ratio alarms will be disabled. Customers can enable ratio alarms in the Advanced Display Module (ADM) System setup menu. Ratio alarms when enabled will shut down the Reactor when an out of tolerance ratio is detected. When alarms are disabled the ratio will still be shown on the ADM home screen and ratio data will still be collected and saved. Ratio reports will still be available using the Reactor app.

- **Pressure Monitoring Changes:** Due to the importance of pressure monitoring as part of the Reactor ratio assurance system, customers interested in being able to detect possible off-ratio conditions must be sure they have inlet pressure monitoring installed when adding flow meters to their system. The Reactor software was updated requiring both inlet pressure monitoring and pressure imbalance alarms to be enabled with the use of flow meters.



Reactor elite models include inlet pressure monitoring as standard but inlet monitoring will need to be added to non-elite models when using flow meters. For this reason five new flow meter kits have been created to provide flow meters and the necessary inlet monitoring hardware for each Reactor type: E-30, E-30 elite, E-30i, H-30/40/50, and H-30/40/50 elite.

The Reactor 2 software has been updated to optimize inlet pressure monitoring for low pressure alarms and now has added detection for high inlet pressure issues. Having inlet pressure monitoring installed without updating the Reactor 2 software will not properly detect some ratio issues. Reactor software should be updated to version 3.02 or newer.

An additional change on electric Reactor elite models is the location of the inlet pressure transducer in the Y-strainer. The location has been changed to optimize issue detection. For older electric Reactor elite models the location of the inlet pressure transducer will need to be moved to the new location after the Y-strainer inlet filter for optimal detection results. See manual 3A6738 for proper installation details.

Updates to Reactor - continued

- **Reactor Smart Control:** In order to minimize the frequency of being shut down for some off-ratio conditions caused by feed pump issues, Graco has developed new software for Reactor 2 electric models. This new software feature is called "Reactor Smart Control". Reactor Smart Control mode will automatically make adjustments to the Reactor to attempt to prevent off-ratio dispensing. Reactor Smart Control will be enabled as the default setting on new elite model electric Reactors. Customers can disable Reactor Smart Control in the ADM System setup menu.

  Reactor Smart Control works using the design of the electric Reactor to its advantage. Electric Reactor pumps are double-acting. This means chemical is pumped out on the UP and DOWN stroke of the pump. However, chemical is only taken into the pump on the fill stroke (UP direction). Graco's new Reactor Smart Control runs the pump at a speed needed to be properly fed. This is achieved by monitoring inlet pressure transducers. When the inlet pressure is insufficient to properly feed chemical into the pump, the Reactor will run slower on the UP stroke. To compensate for the loss of speed, the pump runs faster on the DOWN stroke. Overall, pressure at the gun will only be affected if the feed is severely restricted and unable to keep up. This feature can only be used on electric Reactors. Hydraulic Reactors require manually setting the hydraulic pressure to control the speed of the pump. Software cannot be used to compensate for feed pump issues on hydraulic models.

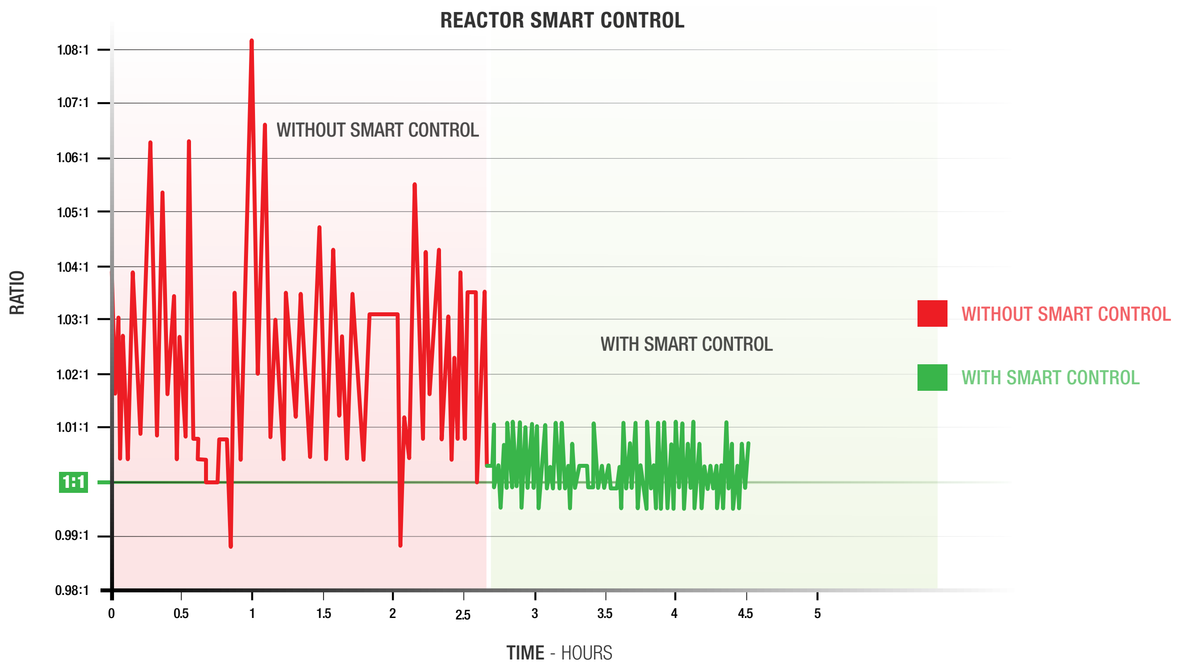


Figure 9: *Graph shows the benefit of using the Reactor Smart Control mode.*

Updates to Reactor - continued

- **ADM Updates:** The ratio will be displayed numerically using the format XX:1, representing the ratio of A:B. A ratio gauge will also display on the ADM home screen when flow meters are enabled.

  The system setup menus have been updated to include:

  - A drop down menu to select "Flowmeter"
  - Enabling ratio alarms
  - Adjusting ratio tolerance
  - Enabling Reactor Smart Control
  - K-factors for A and B flow meters
  - Easy enabling of pressure imbalance alarm
  - Inlet temperature removed as a deviation
  - Inlet pressure alarm threshold cannot be adjusted

- **Ratio Reports:** Through the use of flow meters, true volumetric flow data is now collected. This data is important in demonstrating the proper installation of materials. Through the use of the Reactor app customers can now view, save, send and print reports summarizing their spray data including ratio. There are a number of ratio reports available: a ratio summary report, and ratio detail report and a ratio graph.

Conclusion

As an insulation contractor, understanding the spray foam installation parameters including temperatures, pressures and ratio are becoming more and more important. Builders, homeowners and architects are continuing to request and specify more spray foam as their choice for insulation. Therefore they are becoming more educated on the process and are now asking for assurance the job is being installed correctly. Having the right equipment to monitor and detect possible issues and having the ability to collect the required information to provide proof of installation is important. A contractor that understands the potential issues, knows how to minimize the occurrence of issues and knows how to quickly resolve them if they do occur will set themselves apart from their competition.

Biography

Author:

- Nick Pagano: Nick is a Senior Marketing Manager and Worldwide Product Manager for the Applied Fluid Technologies Division at Graco Inc. and works in Minneapolis MN. Nick's focus is specifically with Graco's spray foam and polyurea equipment. Nick has over 20 years of experience in the spray foam industry. Nick holds a BS in Industrial Engineering from the Pennsylvania State University and a MBA from Monmouth University

Contributing Engineers:

- Mark Brudevold: Mark is an Engineering Manager for the Applied Fluid Technologies Division at Graco Inc. and works in Minneapolis MN. Mark has over 12 years of design engineering experience. Mark holds a BS in Electrical Engineering from the University of Minnesota

- Benjamin Godding: Ben is an Electrical Engineer for the Applied Fluid Technologies Division at Graco Inc. and works in Minneapolis MN. Ben has over 10 years of design engineering experience. Ben holds a BS in Electrical Engineering from St. Cloud State University

- Andrew Spiess: Andrew is a Senior Mechanical Engineer for the Applied Fluid Technologies Division at Graco Inc. and works in Minneapolis MN. Andrew has over 11 years of design engineering experience. Andrew holds an Engineering Drafting and Design degree from Dunwoody College of Technology

- Matthew Theisen: Matt is a Senior Mechanical Engineer for the Applied Fluid Technologies Division at Graco Inc. and works in Minneapolis MN. Matt has over 12 years of design engineering experience. Matt holds a BS in Mechanical Engineering from the University of Minnesota