Positive displacement proportioning of two-component epoxy intumescent coatings for passive fire protection

WHITE PAPER

In today's protective coating industry, there is a growing demand to proportion and spray 100% solids coatings that are high viscosity and composed of materials that make them compressible during processing. Epoxy intumescent fireproofing is one such material that starts as somewhat compressible in the pail, and becomes more compressible when heated and agitated under air pressure. This can be a problem for a proportioning machine that meters by volume. When using plural component equipment, if a material is compressible, equipment parameters may have an impact on the spray-applied mix ratio. Factors include agitation, feed pressure, spray pressure, temperature, material composition and compressibility. These factors are not often understood and for most high solids coatings, compressibility has subtle to no impact. But, when a material is viscous enough to entrap air, equipment design and set-up factors may have an impact on coatings performance and end properties. This paper will explain different portioning technologies that exist and their ability to handle these materials.

Positive displacement proportioning by volume

For decades the standard method of proportioning and pumping coating materials has been positive displacement pumps. They are ideal because they displace a fixed amount of material on each stroke and handle a variety of materials, including epoxies and urethane coatings. Although the pumps are simple in their operation, there are several things that need to happen correctly to make them accurate in metering applications. First, each metering displacement pump must be fully loaded (Figure 1). If the pump is not fully loaded, it will not displace the correct volume.

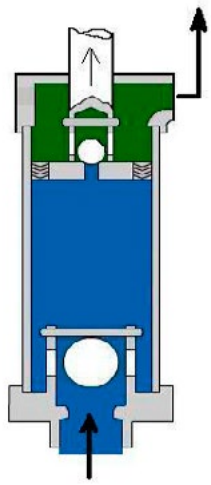

Figure 1.
Fill stroke. Lower ball check is open, piston ball check is closed. The pump must be fully loaded on the up-stroke in a positive displacement pump for metering applications. Green is high pressure, blue is low pressure.

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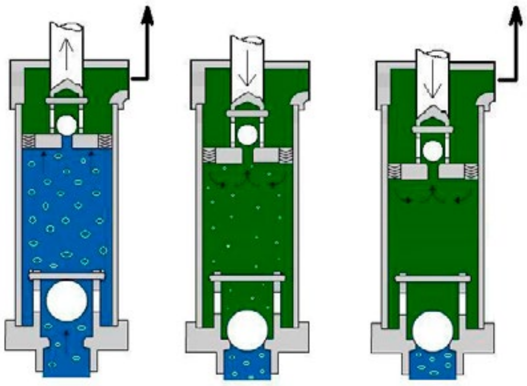


Figure 2.
Metering by Volume
Fluid must be incompressible or fully compressed. The middle picture shows part of the stroke being used to compress the fluid up to outlet pressure.

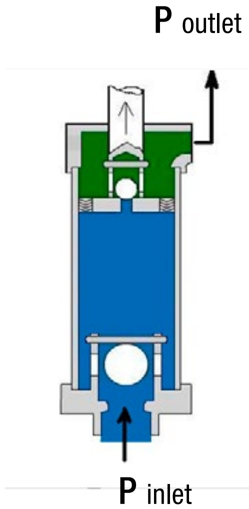


Figure 3.
Inlet fluid pressure shouldn't exceed 25% of the outlet pressure to prevent sluggish ball checking in metering applications.

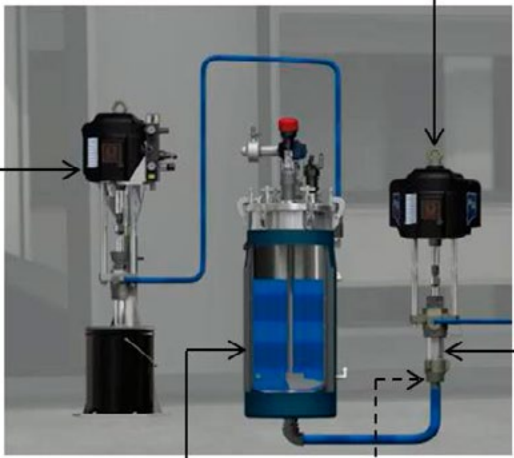
Second, the fluid must be a known volume. This means it is non-compressible or fully compressed (Figure 2). If part of the stroke is used to compress the material, ratio errors may occur.

Third, the feed pressure should not exceed 25% of the spray pressure. Two-check pumps depend on significant pressure difference to positively close the ball checks. As the feed pressure approaches the outlet pressure, the ball checks become sluggish and may not close properly, resulting in an incomplete dispense on either stroke (Figure 3).

Why are compressible materials hard to proportion?

For most coating applications, the coating materials are low enough in viscosity and the chemical make-up is such that the material will not entrap enough air when it is heated and mixed to become compressible. It is rare that it becomes a topic of discussion or concern. Some materials such as intumescent epoxy coatings are solvent-free and may contain small fibers and other components that make them thick enough to entrap air. It has been demonstrated that some of these materials are compressible directly from the 20 liter (5 gallon) pails. When handling intumescent epoxy materials, shovel-style ram pumps are required just to load the material from the pails into heated pressure tanks. At ambient temperatures, the materials are too thick to pour from the pails. In order to condition the material to properly feed the metering pump, the material must be both heated and agitated under pressure (see Figure 4).

Figure 4.
Material feeds from ram pumps into a heated, agitated, pressurized tank for conditioning. This process is necessary for metering and spraying without interruptions, even when changing pails.



The compressibility of these materials when heated and agitated under pressure can easily be shown by measuring the level in the tank when air pressure is changed. Test results indicate that the material volume in the tank can change by as much as 20 liters (5 gallons) when compressed from 0 to 5.5 bar (0 to 80 psi) (see Figure 5). This can pose a potential problem in metering applications because the volume dispensed on each stroke of a metering pump can change if the tank pressure is manually tweaked or changed.

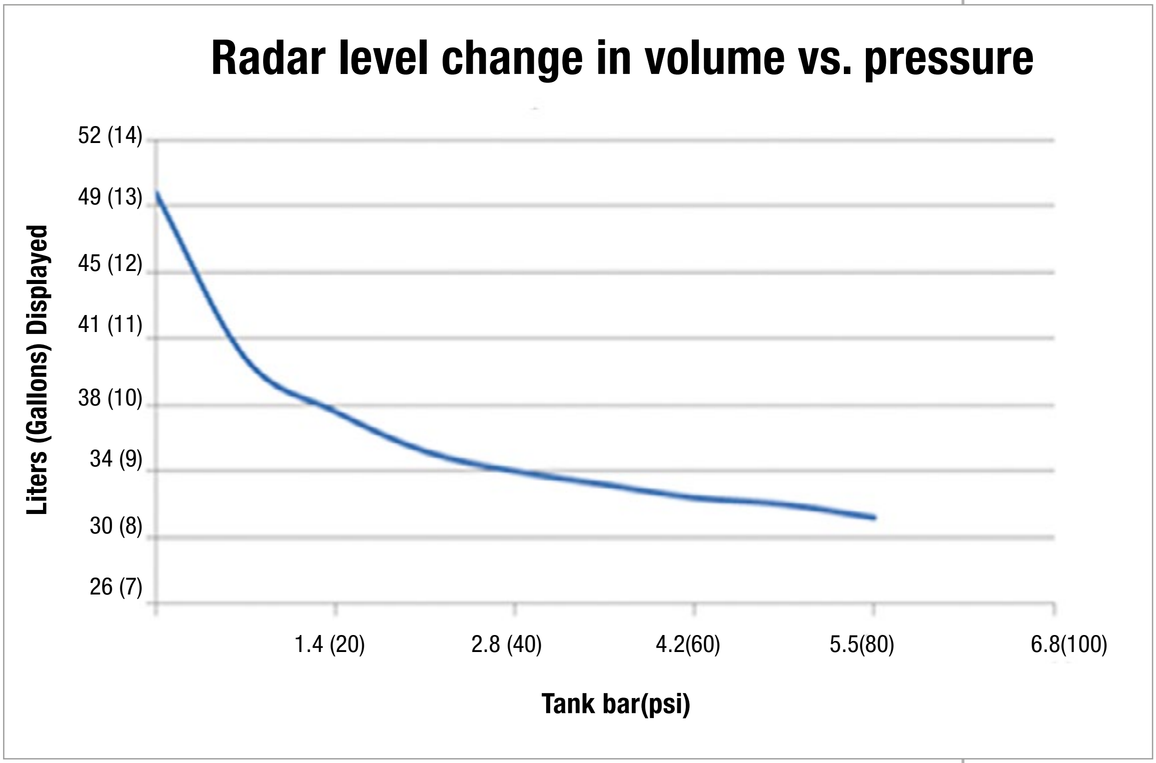


Figure 5.
Chart reads liters(gallons) of resin as feed tank pressure increases. After being agitated under pressure, the level of material in the tank can change by over five gallons after air is mixed in under pressure. The change in fluid volume is a result of the compression of the air which has been mixed in with the fluid.

How do compressible materials affect mechanically linked proportioners?

On mechanically linked or fixed or variable ratio proportioners, ratio is determined by linking fixed volumetric strokes proportionally between the A and B (see Figure 7). This has been, and will continue to be, a very useful method for proportioning materials in the protective coatings industry. On these systems the assumption is that there is full displacement on each metering pump regardless of diving or compressibility. In reality, the “effective” stroke can be different between A and B, and the mix ratio is not consistent. When mechanically linked systems are used on compressible fluids, it is common that very specific instructions are needed on the tank pressure settings and temperature settings to make the system perform as well as the technology allows; however, the compressibility between A and B, with all variables taken into account, is unpredictable. An indication that compressibility is changing active spray ratio may be that the A and B fluid pressure gauges don’t react together at the top change-over, however, the fluid outlet hoses often dampen the pressure gauges so that they appear normal.

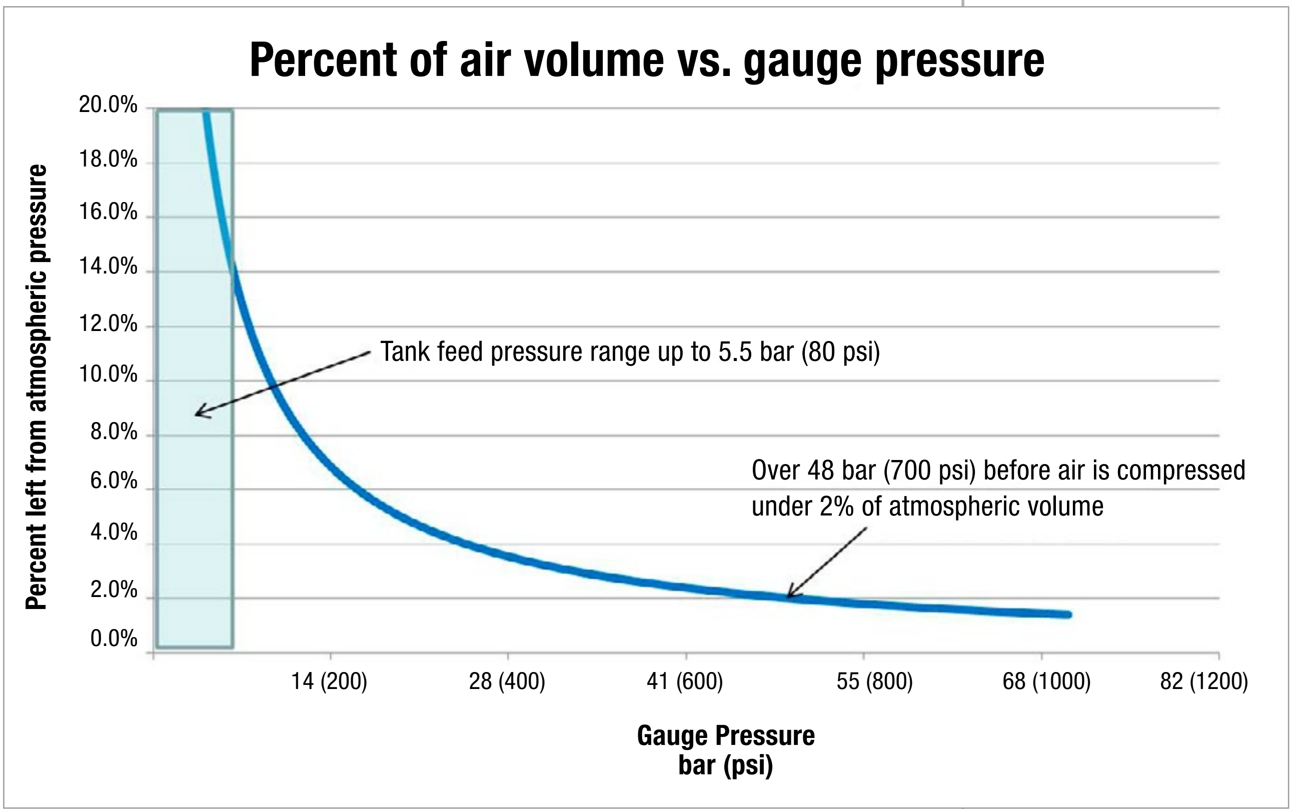


Figure 6.
Percent of air volume left from atmospheric pressure as gauge pressure is increased. Based on standard volumetric compression of air under pressure according to Boyle's Law.

How much pressure is required to compress air?

Figure 4 shows that the material is compressed both in the pressure tank and also in the metering pump. Ideally, all of the entrapped air would be fully compressed prior to the metering pump, but this is not possible since the inlet feed pressure must remain below 25% of the outlet pressure in order for proper checking of the metering pump. Feed tank pressure minus the pressure drop of flowing into the pump leaves an unpredictable yet significant amount of compression to happen in the metering pump before the fluid gets up to outlet spray pressure. This compression can steal a significant portion of the displacement stroke before attaining outlet spray pressure. This compression does not happen equally or predictably between the A pump and B pump. Over 48 bar (700 psi) of pressure is required before air is compressed to under 2% of atmospheric volume (see Figure 6).

Ratio checking and spray process using mechanically linked proportioners

The ratio checking process for mechanically linked ratio equipment when handling epoxy fireproofing materials has been defined for decades as measuring the volume of A and B fluid dispensed at low pressure at the outlet of A and B fluid hoses. The application of epoxy fireproofing is one of the only applications that require this method of checking prior to each spray period. Most of the time, with incompressible materials, the pressures of A and B are monitored and since the materials are not compressible, it is a very good indicator of a balanced, on-ratio system.

With epoxy intumescent materials, ratio checks are not always accurate and can be tweaked by modifying pressures and temperatures during the checking process. The checks are also taken at low pressure out of the hoses and the metering pumps no longer have high outlet pressure to work against. This slows the action of the pump ball checks and steals even more stroke. Temperatures are tweaked to adjust viscosity and this adds or subtracts pressure drop when the pump is loading. Tank pressures are tweaked to adjust flow through the sluggish ball checks–lower on one tank and higher on the other to dial in the ratio check. If the tank pressure is lowered to dial in a ratio check, it leaves even more compression that needs to happen in the displacement pump while spraying. All of these adjustments to dial in ratio checks have an unknown effect on the ratio while running at spray pressures. The machine is spraying at an unknown ratio.

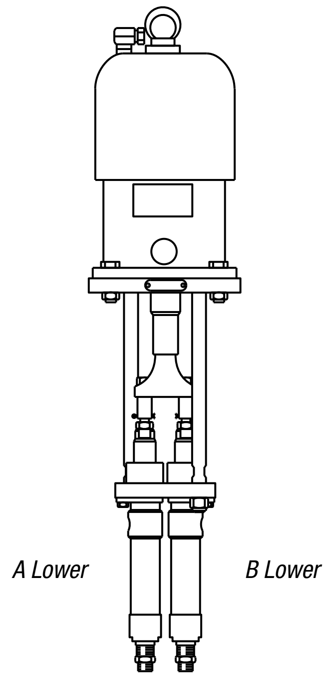
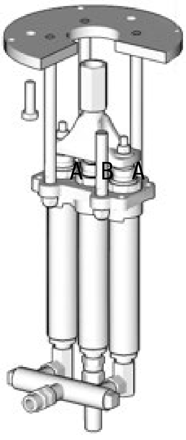
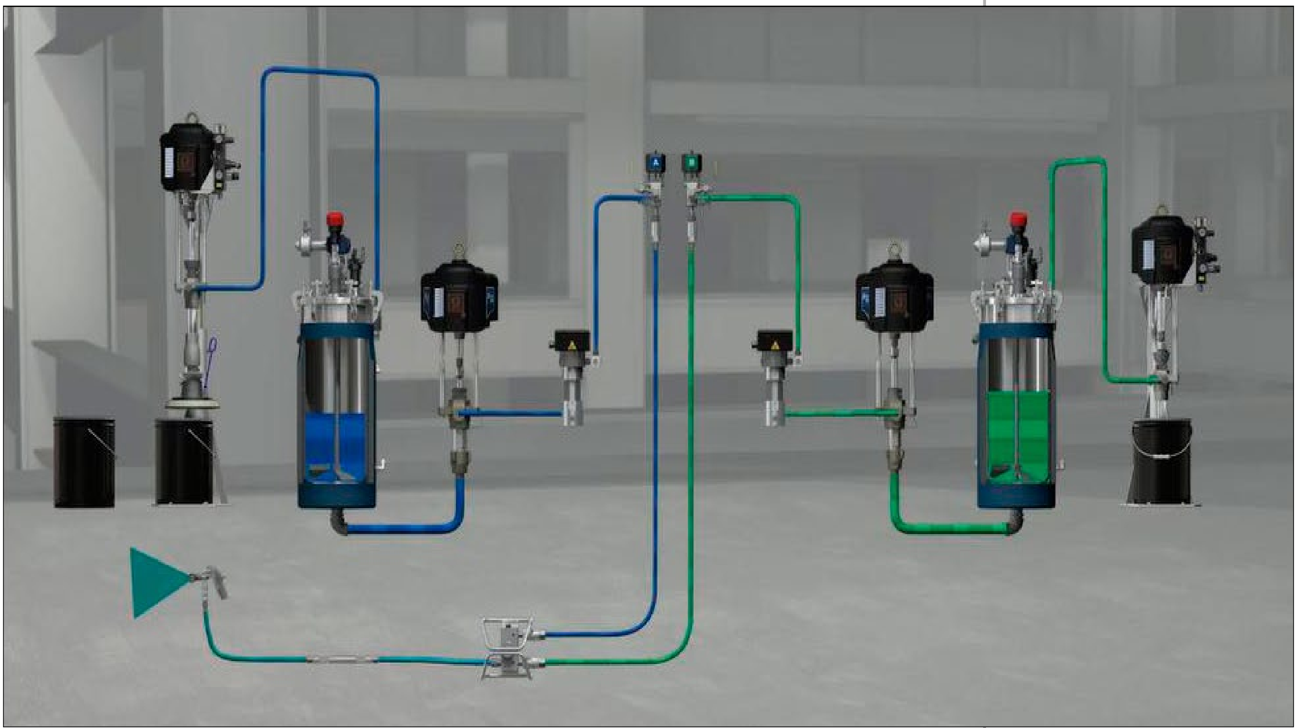


Figure 7.
Fixed ratio (mechanically linked) proportioner. For 1:1, there are often two lowers. For odd-ratios, three lowers are common.

Benefits of dosing technology – "How does it cope with compressibility?"

A new method of proportioning within the past five years is continuous injection dosing. It is a technology that is also based on positive displacement, but with the use of linear position sensors and pressure sensors on each metering pump. These linear sensors measure displacement, and metering valves open and close to control the ratio (see Figure 8). The main difference is that the A and B pumps run independently of each other (not mechanically linked) and cavitation or "dive" on one pump doesn't affect the other pump. Since the pumps are not linked, each pump can fully compress the material and the system can count the material after the fluid has been pressurized to near spray pressure. The control knows the exact volume per micro inch of rod movement and has the capability to measure actual displacement on each pump and subtract the portion of the stroke that is used to compress the material. Accurate ratio is a result of knowing the actual output of each pump at spray pressure.





Ratio assurance using dosing proportioners

Ratio checking on dosing proportioners is often unnecessary since the system has built-in ratio assurance, but it is easily done. To account for compressibility, the ratio checks are taken at a minimum of 172 bar (2500 psi). This assures that the fluids are fully compressed at or near spray pressure. The ratio is not affected by how much air has been mixed into the fluid from the supply system. The ratio check is also performed right at the machine outlets, which eliminates errors due to hose expansion. Changing a parameter such as temperature or tank pressure does not have significant effect on the spray ratio or the ratio check samples. Systems will provide the same spray ratio unless they are adjusted beyond the point of the system's ability to compensate. At this point, the system shuts down to prevent material from being applied to the substrate. High-speed dosing maintains accurate ratio at all times while spraying. The B material injects into the A stream at higher pressure as needed to maintain the exact mix ratio. Because the systems are electronic, more capability is built into the system before each spray period. Pump stall tests are automatic before each spray period to ensure there are no leaks in the system.

Figure 8.
On dosing proportioners, separate pumps with linear sensors and pressure transducers are used for A and B materials.

Metering valves open and close to control ratio. Material can be pre-compressed in each pump before creating the ratio.

The electronic controls check to find any leaks in the metering pumps or dosing valves.

Summary

When handling high viscosity materials for spray applications, such as epoxy fireproofing, there are two basic methods for volumetric proportioning–mechanically linked proportioning and dosing proportioning. Material compressibility is often not fully understood, but is a real factor when these materials are sprayed. Epoxy intumescent fireproofing is one of the only plural component applications that requires equipment and applicator certifications. The requirement for certification is an indicator that challenges do exist. Both proportioning methods are used in the industry and real world variables can have unknown or negative impact on spray performance.

Dosing proportioners have advanced the method to handle these materials for several reasons. First, the equipment measures displacement accurately despite changes in fluid density, pressure, temperature, flow or viscosity. Secondly, the systems are capable of monitoring all functions including off-ratio material or leaks while spraying, automatic alarm or shut-downs for running out of material, pressures out of range, pump run-away, pump leaks, valve leaks and sensor problems. Dosing proportioners allow for simple ratio and pump tests to verify output by weight. Lastly, data is recorded on flow, pressure, temperature and ratio for all material that is sprayed. Applicators, material suppliers, inspectors and clients should all be aware of the pros and cons of each type of system to verify that materials are being sprayed to manufacturer's specifications and to improve overall quality for these types of applications.

Graco XM™ PFP Plural-Component Sprayers use continuous injection dosing for accurate ratio control.

BIOGRAPHY

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