

Accurate Tank Pressurization The Easy Way!

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The ancient Romans knew a good thing when they saw it. Realizing how important it was to have a good water supply, but finding insufficient sources close to Rome to satisfy a growing population, they didn't struggle for long before finding a gravity-based solution to their problem.

Around 310 BC, they began to build an incredible system of aqueducts to bring fresh water from the mountain lakes and springs into the city. Some aqueducts were several miles long, and were capable of delivering over 38 million gallons of water per day - more than enough to quench a Roman emperor's parched thirst. While they didn't know the physics behind the process, (it wasn't until 1687 that Sir Isaac Newton first proposed his Law of Gravitation to the world), they knew how to take advantage of the earth's gravitational pull to deliver water from its source to the local point of use.

Very little has changed in the ensuing centuries. The city of Los Angeles has one of the most extensive systems of aqueducts, bringing fresh water to the City of Angels from the Colorado River, 242 miles away. A second aqueduct supplies water from the Sacramento River, over 440 miles away! As long as the force of gravity remains constant, the flow of water is pretty reliable.

The Conventional Gravity-Based Method

In filling operations, we rely on gravity to move liquid product from a product fill tank to final product containers or bottles in much the same way we move potable water by gravity from its source to its point of use. Typically known as a gravity-based time/fill process, the two constants are the force of gravity and a predetermined fill time.

A critical variable in this system is the head pressure of the liquid in the product fill tank. The delivery pressure, or head pressure of the liquid product is greatest when the tank is full. As the tank is emptied, the head pressure drops. The change in fill volume dispensed into each bottle is directly proportional to the head pressure in the product fill tank.

Typically, this filling process is one of averages. The actual desired volume is dispensed only when the tank is half-full. Theoretically, then, the bottle is overfilled when the product fill

tank is full (highest head pressure) and underfilled when the product fill tank is nearly empty (lowest head pressure). We call this an open-loop control scheme, as there is no confirmation of the actual fill volume to a mechanism capable of compensating for the changing head pressure.

This method of filling bottles is relatively inexpensive to design, build, and use, but it has several profit-robbing drawbacks. First, overfilled bottles directly translate to lost profits. If the overfill is too great, then product is spilled outside of the bottle, adding to cleanup time and waste disposal costs. Underfilling is equally costly, as bottles with less than the minimum allowable volume are pulled off the packaging line and scrapped. This too, adds to waste disposal costs as well as lost revenue for the product that gets thrown away. Variations in excess of 20% are possible if the liquid level in the tank varies substantially.

Reduced Variation

A variation of the gravity head-pressure, time-based filling system is to seal the product fill tank, and pressurize it with nitrogen using a spring-loaded pressure regulator. This type of delivery system is shown in Figure 1. The spring-loaded pressure regulator maintains a low positive pressure on the product in the tank. The gas pressure adds to the product head pressure, and therefore reduces the variation of the dispense volume as the liquid level in the tank changes. While an improvement over the gravity head-pressure system, this is still an open-loop control scheme, as changes in delivery pressure are not sensed directly by the spring-loaded pressure regulator, for which they cannot be completely compensated.

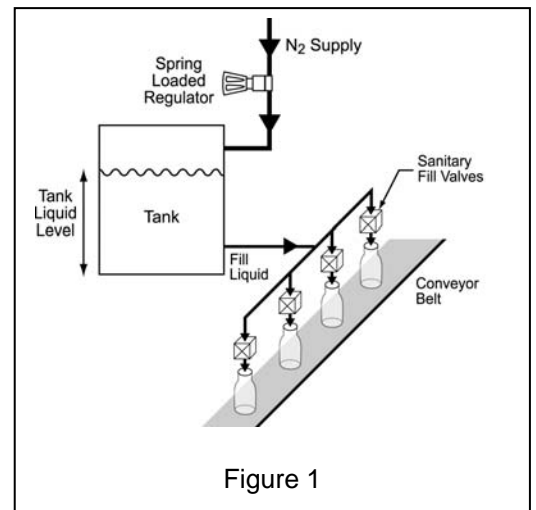
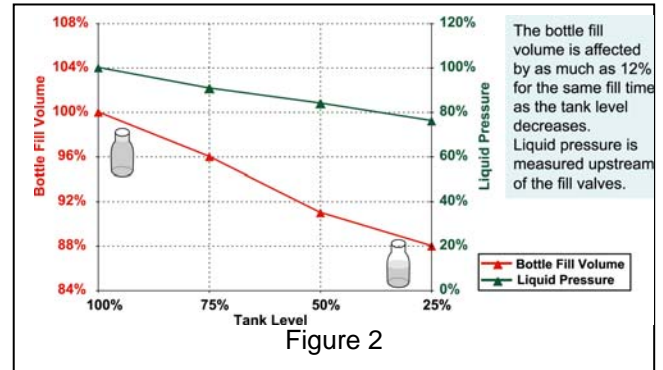


Figure 2 provides a graphic depiction of the change in bottle fill volume as the liquid pressure in the tank changes. In this example, we see that the fill volume of the bottle varies by up to 12% as the liquid pressure changes in the product fill tank. Upgrading the basic time/fill operation with the addition of nitrogen tank pressurization incurs the additional cost of the

spring-loaded pressure regulator and a nitrogen gas source. This is still a relatively low-cost process.

Enter Electronic Technology

Modern electronics have made it possible to control gas pressures to within .01 PSIG of a desired set point. If we employ a digital pressure regulator to control the nitrogen pressure in the product tank, we can maintain the actual delivery pressure with a level of precision not previously possible!



The dispensing system in figure 3 is a closed-loop system. Here, a digital pressure regulator controls the nitrogen pressure in the product fill tank. An analog pressure transmitter is installed in the dispensing nozzles that fill the bottles. The transmitter senses the pressure in the dispensing nozzle, and provides the electronic pressure controller with this 'feedback'. The pressure controller is constantly monitoring the feedback from the transmitter, and comparing it to a reference value, or 'setpoint'. If there is any difference, or 'error', between the 'setpoint' and 'feedback', the pressure controller will adjust the nitrogen pressure in the product fill tank to compensate for, or eliminate the error. Assuming that the controller monitors or 'updates' the evaluation of set point and feedback every 25 milliseconds, then the pressure in the product fill tank is essentially held constant. Now the time/fill process becomes extremely accurate.

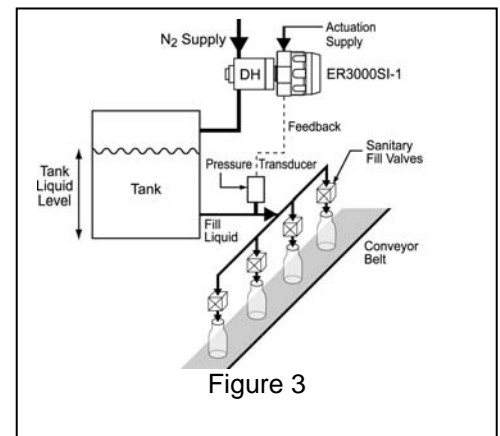
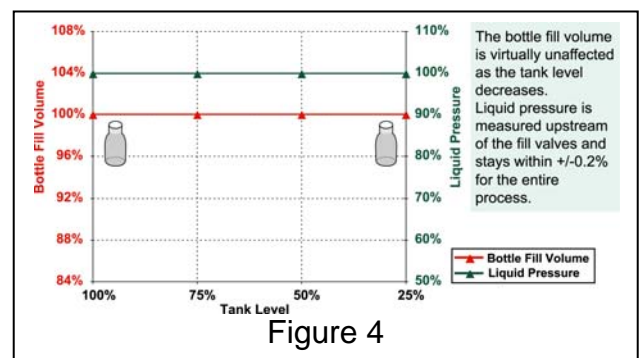


Figure 4 demonstrates the consistency of the fill volume relative to the fill pressure. Essentially, there is no variation in the fill volume as the liquid pressure is maintained as a constant. This translates into higher profits for the owner, as there are no overfills. It also



eliminates any underfilled containers, which could lead to customer dissatisfaction, or scrapping of severely underfilled product containers.

Small Investment, Big Payback

Upgrading the time/fill system by employing a closed-loop pressure control scheme may cost a couple of thousand dollars or more upfront. Considering the increased profits that result from employing a closed-loop control scheme, the additional cost is amortized in a very short period of time. In some cases, the additional cost of a closed loop dispensing system is paid for within months of going into service. This fill system has the added benefit of making changes to fill volumes relatively easy. Changing the nitrogen pressure while keeping the fill time the same results in greater dispense volumes without increasing fill cycle time. More throughputs, more profit!

Who knows, if the Romans could have controlled the pressure in their aqueducts with a closed-loop control scheme, they probably could have cut their construction costs by designing smaller, more efficient aqueducts, coming in under budget and ahead of schedule!