Digital Dosing and the Evolution of Metering Pump Technology:

A look back at 70 years of engineering achievement

A Brief History by Grundfos Pumps

A metering pump (sometimes called a dosing or controlled-volume pump) is a positive displacement pump capable of precise dosing of a desired volume of liquid, incorporating an integral means of capacity change. Applications typically include the metering of chemicals to render water suitable for drinking or for a particular use; blending of chemicals in process applications; and the accurate addition of colors, flavors, or vitamins into foods, drugs, or personal care products.

These dosing pumps are usually injecting expensive additives, so their accuracy is critical to maintaining product quality. Their ability to dose chemicals precisely at all times and with predictable repeatability is of primary importance. Over the past 70 years, the demand for accuracy has driven metering pump design, but so has the need to make the devices as user friendly and cost-effective as possible.

Today, metering pumps have come a long way from their earliest mechanical machine forms, to the digital dosing technology that is used in advanced products today, to meter liquids more accurately, reliably and economically.

This article discusses the major changes in metering pumps since their invention in the late 1930s. Inventors of metering pump technology considered the devices instruments, rather than pumps, because they envisioned them doing much more than simply pumping.

But the combination of robotics and metering pumps brought more power than even they could have imagined, to the technology. The newest generation of Digital Dosing pumps offers a whole host of benefits, permitting more accurate control over the process, and lowering capital costs as well as operation and maintenance expense.

The Early Stages

Metering or dosing pumps began as simple reciprocating pumps that relied on comparatively crude mechanical adjustments to control pump capacity. Every convenience that their original users required, such as flow rate confirmation and pulsation dampening, had to be supplied as an external accessory. As technology improved, many innovations were introduced to control capacity, control leakage, improve the handling of difficult liquids, and lower the cost of operation.

Packed Plunger Metering Pumps: State of the Art in the 1940s

The first commercial metering pump was developed in the late 1930s by two employees of Betz Laboratories. These first metering pumps used a simple packed plunger, driven through a gear box by a foot-mounted motor and a slider crank mechanism. The first defining evolutionary step was to add a method of changing the stroke length of the plunger by adjusting the crank arm, which in turn varied the pump's capacity.

These early pumps, at that time called *chemical feed pumps,* were first produced commercially in the 1940s. The next decade saw many improvements, including improved check valve design, as well as a better way to adjust the stroke length, mechanically.

Metering pumps were and are unique in that they permit the length of the stroke to be changed, and thus allow the amount of material dispensed to be adjusted. The next 50 years of innovation improved the way that both were achieved.

Diaphragms End Leaking

About the beginning of the 1960s, a significant innovation was introduced into the world of dosing pumps: the diaphragm. Until this point, the packed plungers used on all metering pumps experienced wear, and the packing deteriorated over time, resulting in leakage, which reduced metering accuracy, but could also cause the loss of expensive or even harmful chemicals.

The introduction of a reciprocating diaphragm in the pump head changed all of that. The diaphragm eliminated the need for the plunger to be exposed to the chemical being pumped, making the pump sealless. In order to actuate the diaphragm, metering pump designers introduced a closed volume of clean hydraulic oil located between the plunger and the diaphragm. The plunger and the many moving parts of its drive system were lubricated by this oil, and the oil pressurized by the plunger in turn actuated the diaphragm.

The importance of this *hydraulically actuated diaphragm* for metering pumps included the fact that the diaphragm could be made of a corrosion resistant material (e.g., Teflon), and that the pump was leak-proof. Also, the pressure on both sides of the diaphragm could be equalized, which meant that diaphragm life was independent of the back pressure against which the pump operated. Finally, the intermediate hydraulic oil system could be internally protected, eliminating the need for the external pressure relief device required by most positive displacement pumps.

As a more cost effective alternative to the hydraulic system, *mechanically actuated diaphragm* pumps were also developed, in which the reciprocating plunger was mechanically attached to the diaphragm. There were direct-drive versions of the mechanically actuated pump which changed stroke length by adjusting mechanical linkages in the pump.

Mechanically actuated diaphragm simplified diaphragm metering pump design, although the mechanically actuated designs were somewhat less durable than their hydraulically actuated cousins. Direct attachment of the reciprocating plunger to the diaphragm created significant stress points on the diaphragm, reducing diaphragm life. Also, mechanically actuated designs had pressure limitations, since the pressure was no longer balanced on both sides of the diaphragm as was the case with the hydraulically actuated designs. Though much more limited in application, these mechanically actuated designs met an important need of lowering the cost of metering pumps, especially for relatively low-pressure applications.

Solenoid Drives for Metering Pumps: An entirely new cost point

The 1970s brought the solenoid drive to dosing pumps, making the devices simpler and less expensive to use. This design still used a diaphragm, but it was actuated by energizing and de-energizing a solenoid. The result was a dosing pump that was relatively simple, had few moving parts, accepted an electronic signal, and which achieved accurate dosing of chemicals at a much lower cost than earlier mechanically and hydraulically actuated versions.

This innovation was based upon a simple way to adjust capacity by changing the *frequency*, rather than the length of the stroke. However, when the pump was operating at the lower quadrant of its performance range, chemicals were dosed so infrequently that the devices often didn't meet their goals. Thus, new designs were developed that incorporated a way to adjust stroke length.

However, solenoids suffered from some performance problems. For one thing, the solenoid produced much higher diaphragm velocity than did the other designs, adding to diaphragm stress and reducing diaphragm life expectancy and increasing the intensity of pressure pulsations. At the same time, solenoids had lower pressure and capacity limits than hydraulically and mechanically actuated diaphragm metering pumps. In addition, they were not as accurate as the other types, so hydraulically and mechanically actuated diaphragm metering pumps remained popular.

Nevertheless, their shortcomings aside, solenoid metering pumps' simplicity and lower cost permitted the use of diaphragm metering pumps to increase significantly in commercial sectors where alternatives would be too expensive. Commercial and light industrial processes that heretofore couldn't justify the expense of a metering pump could now easily incorporate such pumps into their chemical feed systems. The number of users grew exponentially during this period.

Control Improvements and Turndown Ratios

In the 1980s and 1990s, manufacturers of dosing pumps focused on broadening the ways that metering pumps could be controlled, and on lowering the overall device cost while using control to improve accuracy.

In the 1980s, another low cost alternative to the solenoid metering pump employed a constant speed synchronous A.C. motor and a mechanically actuated design concept. It incorporated electronic controls that could have power to the pump simply turned on or off, could accept a pulse signal such as a water meter would put out, or could accept a 4-20 mA signal to cause the pump to turn on or off. All of these could be in addition to traditional stroke length adjustment. This generation of pumps was the first to use a synchronous motor that accepted an electronic signal.

Late in the 1980s and throughout the 1990s, manufacturers began to incorporate variable frequency drives, stepper motors, and servo motors into metering pump designs. These variable speed technologies permitted the capacity of the pump to be controlled two different ways, by varying the stroke length and the pump speed. This combination of the two methods of capacity adjustment significantly increased the capacity range for a metering pump, referred to as the pump's *turndown ratio*. This broadened the application capabilities of a single pump, which in turn reduced the number of pump sizes that a manufacturer needed to offer, while also reducing the number of models that a large user of metering pumps needed to carry.

Early versions that incorporated the combination of stroke-length control and speed control still required that stoke length control be done manually. Even after automatic stroke-length adjustment mechanisms were introduced, they were still hampered by the fact that these pumps didn't incorporate software control to seamlessly switch back and forth between stroke length adjustment and speed adjustment. If the pump user or the process called for an increase in pump capacity, this increase of flow didn't follow a smooth curve, but rather ramped up in a series of uneven steps. Thus, the advertised high turndown ratios were, practically speaking, much narrower than the theoretical limits of speed and stroke adjustments would suggest. Also, the holy grail of metering pumps, the ability to confirm, internally, that the capacity setting of the pump was indeed being achieved, was still elusive. Users of metering pumps that claimed high accuracy still relied on external flow meters to confirm that desired capacity was being achieved.

A New Design Platform for Metering Pumps – Digital Dosing

The last five years have seen the merger of control interface and accuracy with simplicity of operation and dependability, culminating in the introduction of a new generation of diaphragm dosing pumps incorporating digital robotic technology. This technology is changing how value is defined in a metering pump, and it has been achieved while establishing a platform for an almost limitless number of potential new features and benefits. What started decades ago, as a convenient form of capacity adjustment for a positive displacement pump, has finally evolved into the instrument that the pioneers in the metering pump industry foresaw: *a new level of intelligence within the dosing pump, where flow inducement is less important than measurement of what is being dispensed.*

Gone is the dependence on changing the effective stroke length that has been at the heart of metering pumps for the past 70 years. Using state-of-the art electric motors, in combination with proprietary software to vastly improve the intelligence of the electronic control, the new generation of digital dosing pumps is able to always operate at full stroke length.

Elimination of the need for stroke-length adjustment, and the ability to change capacity very accurately, solely by means of automatic speed adjustment, also permitted turndown ratios (e.g. 1000:1) far beyond what metering pump users had been accustomed to. And today's models achieve this without the complexity or inaccuracy of yesterday's metering pumps, reducing the number of pump sizes required to cover the entire range of flow, without sacrificing accuracy.

The precise speed control also permits easier priming, more accurate handling of difficult liquids such as sodium hypochlorite, which tends to off-gas, and the metering of more viscous fluids. Naturally eliminating the need for stroke control also means the pump has fewer parts and doesn't require knobs or other forms of mechanical adjustment. These all result in easier use and improved value.

Key innovations that are being incorporated into the new generation of digital dosing pumps include the ability to precisely monitor pressure, flow, and amp draw on the motor on a continuous basis. Monitoring pressure allows the user to determine when the pump's accuracy is being compromised because of air or gas bubbles, cavitation, or leaking check valves. It also permits the pump to self-adjust to compensate for these effects. Monitoring flow continuously within the pump gives the feedback needed to adjust pump speed as system conditions change or as air or gas is introduced into the pump.

Combining dosing, measuring, and regulating into one machine means that the user doesn't have to make any calculations to determine the pump's flow setting, but merely inputs the desired flow rate. The flow rate that is programmed in is what the pump delivers, without the need of costly independent flow measurement. This new generation of digital dosing pumps has lower pressure pulsations and higher accuracy than its predecessors, even at extremely low flow rates.

A Look at the Future

The new platform of Digital Dosing opens up a whole new world of possibilities to industrial users, limited only by their imaginations. Tomorrow's metering pumps will be able to monitor, troubleshoot, perform diagnostics, and appropriately adjust and recalibrate their operation to conform to process control variables, all done seamlessly, and, if necessary, remotely and via wireless signals.

Use of metering pumps as precise control instruments will allow more concentrated chemicals to be used, and will allow many accessories such as flow meters, back pressure valves, and pulsation dampeners to be eliminated. As the technology continues to evolve, together with advances in control software, we expect metering pumps to become even more user friendly, and cost effective.