Dosing pumps have evolved from the earliest generation of strictly mechanical machines to those that use robotic-like technology to preset standards of accuracy, reliability, efficiency, and, most important, simplicity.

By definition, a metering pump is a positive displacement pump that accurately delivers a controlled volume of liquid and that has an internal means of adjusting capacity. Applications for precise metering include the dosing of chemicals into water for pH adjustment or disinfection and addition of chemicals in process applications such as metering of colors, flavors, or vitamins into foods, drugs, or personal care products.

Tracing the evolution of the various technologies used in metering pumps highlights the changes that have been made to the drive and control functions. The inventors of metering pumps thought of them as instruments rather than pumps, envisioning dosing pumps of being capable of far more than flow inducement. However, it is likely that the pioneers in the metering pump field never imagined how robotic technology would contribute to the achievement of their vision. The latest generation of digital dosing pumps offers a whole host of benefits, allowing more accurate control over the process and lowering capital costs as well as operations and maintenance expenses.

**EVOLUTION OF METERING PUMP TECHNOLOGY**

Metering pumps began as rudimentary machines that relied on comparatively crude mechanical adjustments to control pump capacity. Every convenience wanted by early users of metering pumps, such as flow rate confirmation and pulsation dampening, had to be supplied as external accessories. As technology improved, many innovations were introduced to control capacity, control leakage, improve the handling of difficult liquids, and lower the cost of operation.

Although metering pumps were first introduced in the United States, many technology advancements were paralleled by concurrent engineering efforts in Europe and Asia. Today, users of metering pumps around the world are witnessing the introduction of an entirely new digital design platform that the first developers and users of this technology likely never imagined.

**1940s and 1950s—the first packed plunger metering pumps.** The first commercial metering pump was developed in the late 1930s by Milton Sheen and his son Robert. At the time, both were employees of what is now Betz Laboratories, a Philadelphia, Pa.–based manufacturer of specialty chemicals. The first metering pumps used a simple packed plunger, driven through a gear box by a foot-mounted motor and a slider crank mechanism. The Sheens added a method of changing the stroke length of the plunger by adjusting the crank arm, which in turn varied the pump’s capacity. With the addition of some easily serviceable check valves that Sheen designed to fit onto the pump head (he called them step valves), the first dosing pump was born. These early pumps, at that time called chemical feed pumps, were first produced commercially in the 1940s. The biggest improvements of the 1940s and 1950s were modifications in the way
the stroke length was mechanically adjusted.

1960s—diaphragms introduced to metering pumps. The packed plungers used on all metering pumps up to this point typically leaked around the packing, which ultimately reduced the accuracy of the metering pump as well as causing leakage of expensive and, in some cases, harmful chemicals. To actuate the diaphragm, designers used a closed volume of oil between the plunger and diaphragm. The oil, pressured by the plunger, actuated the diaphragm. PTFE diaphragms made the pumps leakproof and chemical-resistant.

A variation on hydraulically actuated diaphragm metering pumps was introduced to allow control of capacity by adjusting the amount of hydraulic fluid activating the diaphragm. This bypass is known as “lost motion” because it alters the effective stroke length without requiring expensive mechanical linkages.

In the 1960s, a less costly alternative to the hydraulic system came about—mechanically actuated diaphragm pumps—which mechanically attached the plunger to the diaphragm. Mechanical lost motion versions were eventually introduced for further cost efficiencies. Aside from pressure limitations, directly attaching the plunger and diaphragm created significant stress points and reduced diaphragm life. Despite these vulnerabilities, mechanically actuated designs met an important need of lowering cost, especially for lower-pressure applications.

1970s—solenoid-driven metering pumps significantly lower the cost of metering. The decade of the 1970s brought an important innovation to the world of metering pumps: the solenoid drive, which made metering pumps less complicated and considerably more affordable. This design still used a diaphragm, but the diaphragm 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 achieved accurate dosing of chemicals at a much lower cost than earlier mechanically and hydraulically actuated versions.

Hydraulically and mechanically actuated diaphragm metering pumps remained popular, though, because of several significant shortcomings of solenoid pumps. The movement of the diaphragm by means of the solenoid produced much higher diaphragm velocity than was the case with other designs. This significantly added to diaphragm stress, which reduced diaphragm life and increased the intensity of pressure pulsations. Upper limits of both pressure and capacity for solenoid metering pumps were considerably lower than those of other diaphragm dosing pump types. Solenoid pumps were not as accurate as the other metering pump types. Despite these shortcomings, the simplicity and lower cost of solenoid metering pumps spawned significant growth in the number of applications of diaphragm metering pumps.

1980s and 1990s—new designs accept electronic signals and utilize speed control. During the next two decades, dosing pump manufacturers introduced changes in their products that built on the improvements of the previous decade. These changes focused on remote metering pump controls, cost, and accuracy. One such innovation used a constant-speed AC motor and mechanically actuated diaphragm concept. Capacity could be adjusted by controlling the frequency at which the motor was turned on and off, and the pump could accept an external signal to control frequency of the stroke. All of these could be done in addition to adjustment of the stroke length.

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 accelerated the race for increased capacity variation in metering pumps. In early versions, however, stroke length could only be adjusted manually. When automatic stroke length adjustment came about, there was no software to seamlessly switch back and forth between stroke length adjustment and speed adjustment to reach higher turndown ratios. In fact, the usable turndown ratio was less than the combination of the two methods.

During these years, the holy grail of metering pumps—the ability to internally confirm that the capacity setting of the pump was indeed being achieved—was still elusive. Users of metering pumps that claimed high accuracy continued to rely on external monitors to confirm that the capacity they desired was being achieved.

A NEW DESIGN PLATFORM FOR METERING PUMPS—DIGITAL DOSING

The past five years have seen the introduction of an entirely new generation of diaphragm metering pumps, incorporating digital roboticlike technology to improve accuracy and process control, to save users money by lowering the amount of chemicals used, and to reduce the number of pump sizes required by large users of dosing pumps. All of this was achieved while simplifying the operation of metering pumps and opening up an almost unlimited number of potential new features and benefits. What started 70 years ago as a convenient form of capacity adjustment for a positive displacement pump evolved into the instrument that Sheen and other pioneers in the metering pump industry foresaw: a new level of intelligence within the dosing pump, where flow inducement is less important than controlling and measuring what is being dispensed.

Using state-of-the-art stepper or
brushless DC motors in combination with software to vastly improve the intelligence of the electronic control, the new generation of digital dosing pumps is able to always operate at 100% stroke length. Elimination of the need for stroke adjustment and the ability to vary capacity solely by means of a software-controlled speed adjustment, allow huge turndown ratios (e.g., 1,000:1). This is achieved without all of the accompanying complexity and inaccuracy of earlier versions of high-turndown metering pumps. This feature alone offers significant savings because the number of pump sizes needed to cover the entire range of flow is greatly reduced without any sacrifice in accuracy.

Precise speed control also allows easier priming, more accurate handling of difficult liquids such as sodium hypochlorite that tend to off-gas, and metering of more viscous fluids. 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 changes all result in lower costs.

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 accuracy of the pump 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 for 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.

WHERE WILL METERING PUMPS GO FROM HERE?

The new platform of digital dosing opens up a world of possibilities to designers of metering pumps and to the companies that use them, limited only by the imagination of the designers and users. Tomorrow’s metering pumps will be able to seamlessly monitor, troubleshoot, perform diagnostics, and appropriately adjust and recalibrate their operations both remotely and via wireless signals, to conform to process control variables, and, if necessary.

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. Metering pumps will become more user-friendly and costs will be further reduced as advances in control software continue and as economies of scale kick in for the new generation of digital dosing pumps.

—Klaus Müller is xxx with Alldos Pumps and can be reached at k.mueller@alldos.com. Hans Jorgen Andersen is product manager–dosing with Grundfos and can be reached at hjandersen@grundfos.com.
A Pump Expert’s View on the Metering Pump Technology Evolution

As an independent pump consultant and educator for the past 25 years, I’ve come in contact with thousands of people who use metering pumps, including water utility engineers, operators, and maintenance technicians. Metering pumps are found in almost every water treatment plant and are used in conjunction with most groundwater well pumps. The technology of these pumps has changed significantly over the past quarter century—much more so than many other pump types that have changed very little during that time frame.

When I first began my consulting career, almost all metering pumps were mechanically or hydraulically actuated, requiring a manual adjustment of stroke length to vary the flow. Invariably, the same issues and shortcomings with these metering pumps came up time and time again.

• **Too complicated.** The user had to make calculations by taking into account stroke length and maximum capacity in order to determine the proper stroke adjustment. Then the user had to mechanically adjust a dial on the pump to change the stroke length setting. Some owners found that improperly trained employees would fiddle with the adjustment dial and inadvertently change the flow setting. The solution to this problem for some owners was to tape off or otherwise disable the flow adjustment dial, rendering it useless for its intended function.

• **Not sufficiently accurate or repeatable.** Often a user would complain that the flow rate on the metering pump fluctuated over time or with variations in system pressure. This led to users not trusting the flow rate indicated by the stroke adjustment dial. Many users found they had to independently measure flow using a flow meter and had to constantly recalibrate the metering pump. These flow fluctuations caused wide swings in water quality and increased the amount of chemicals needed for water treatment.

• **Excessive maintenance costs.** The major causes of maintenance on metering pumps were the high-pressure pulsations that the pumps produced and the large number of parts in these pumps compared with other pump styles.

• **Problems handling off-gassing liquids.** Certain liquids commonly pumped with metering pumps, such as sodium hypochlorite, are prone to releasing gas, particularly when the pump is idle for a period of time. When the pump is restarted, this causes gas binding or erratic and inaccurate fluid delivery.

• **Inability to integrate with process control.** Metering pumps could be set to a particular flow rate, but they did not provide feedback regarding flow, pressure, or other variables that could be used to integrate process controls.

Solenoid metering pumps became popular in the 1980s. This pump style addressed the problem of excessive maintenance costs for metering pumps in a roundabout way. The initial cost of solenoid pumps was quite a bit less than those of hydraulically and mechanically actuated styles, but solenoid metering pumps still didn’t directly face the issue of excessive maintenance. In fact, solenoid pumps produced even higher stresses on the diaphragm and larger pressure pulsations because of the higher velocity of the diaphragm. They were limited in flow and pressure and didn’t address users’ concerns about complexity of use, inaccuracy, or off-gassing.

The digital dosing pumps introduced during the past several years have taken giant steps toward addressing the shortcomings of earlier generations of metering pumps. Stepper or brushless DC motors that incorporate electronic control software have eliminated the need for stroke adjustment, because the new generation of pumps run at 100% stroke and vary the flow only by speed adjustment. This means that users can directly input the desired flow rate, eliminating conversion calculations and complex mechanical stroke adjustment mechanisms.

Digital dosing pumps have the built-in capability to measure flow, pressure, and other variables such as amp draw to get a clear and accurate picture of how the pump is performing at all times and to compensate for changes in system pressure, presence of gas, and other process variables. This results in a metering pump system that has fewer parts, reducing both capital costs and maintenance expense. The measured variables can readily be incorporated into plant process control systems.

The feedback I recently received from Dennis Hall, Water System Operator II for the City of Fresno Water Department, exemplifies the enthusiasm with which digital dosing technology is being received. Fresno installed 40 Grundfos DME 8 digital metering pumps in chlorine injection service at some of their wells roughly two years ago, and an additional two pumps in fluoride treatment. The utility has more than 200 older-style metering pumps of various brands installed as well. The digital dosing pumps, according to Hall, are extremely simple to use. The stepper motors provide even flow with no pulsations, a big change from the high pulsations that their older solenoid pumps produce. He commented that setting the flow rate directly in units of gallons or litres per hour, without having to deal with stroke adjustment, greatly simplifies the setup for these pumps and allows the desired chlorine residuals to be reached more quickly.

Hall also commented that calibration of the digital dosing pumps is faster and easier and can be done with the pump working against no pressure or full system pressure, with equal accuracy. He also commented on the wide flow range the pumps are capable of and noted that the pumps can handle off-gas quite well. Hall mentioned that in the two years since the pumps have been installed, only two have come back to the repair shop, and he suspects these two were inadvertently dropped during handling.

I’m looking forward, as digital dosing technology continues to evolve, to seeing more innovations from suppliers to make metering pumps even easier to use, less expensive, and more valuable as a process system control element.

—Michael Volk is a registered professional engineer and has been an independent pump consultant and educator for 25 years. He is the author of Pump Characteristics and Applications (first published in 1996, with a second edition published in March 2005). In addition to serving as a consultant to pump users, Volk periodically offers short courses on pump applications, selection, system analysis, and maintenance. For information on his pump training courses and consultation, visit www.volkassociates.com.