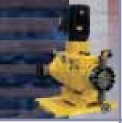




# A Primer on Metering Pumps (Part One)

Laurel Bloch, Milton Roy

**A review of traditional metering pump designs, along with a look at some of the new technologies that are being introduced.**

The metering pump is a positive displacement chemical dosing device with the ability to vary capacity manually or automatically as process conditions require. It features a high level of repetitive accuracy and is capable of pumping a wide range of chemicals, including acids, bases, corrosives or viscous liquids and slurries.

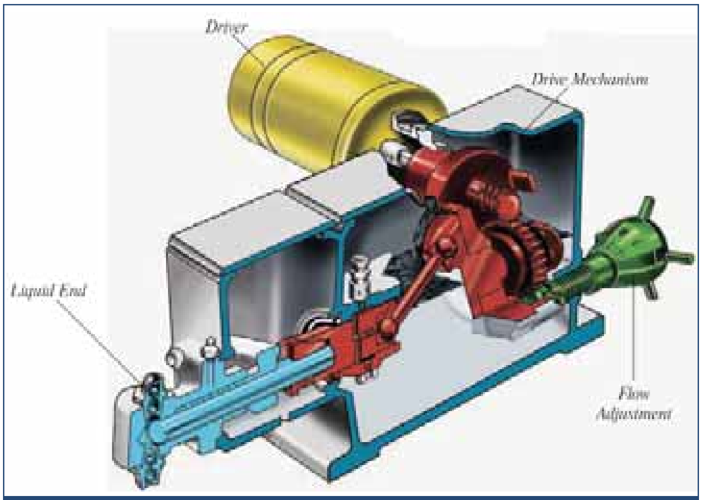



Diagram showing the basic components of a metering pump.

## Basic Components

The pumping action is developed by a reciprocating piston which is either in direct contact with the process fluid, or is shielded from the fluid by a diaphragm. Diaphragms are actuated by hydraulic fluid between the piston and the diaphragm. Metering pumps are generally used in applications where one or more of the following conditions exist:

- Low flow rates in ml/hr or gph are required
- High system pressure exists
- High accuracy feed rate is demanded
- Dosing is controlled by computer, microprocessor, DCS, PLC, or flow proportioning
- Corrosive, hazardous, or high temperature fluids are handled
- Viscous fluids or slurries need to be pumped

The metering pump is usually driven by an AC constant speed motor. Variable speed, pneumatic, and hydraulic drivers are also utilized. The liquid end design and materials of construction are determined by the service conditions and the nature of the fluid to be handled. Temperature, flow rate, fluid viscosity, corrosiveness and other factors are considered.

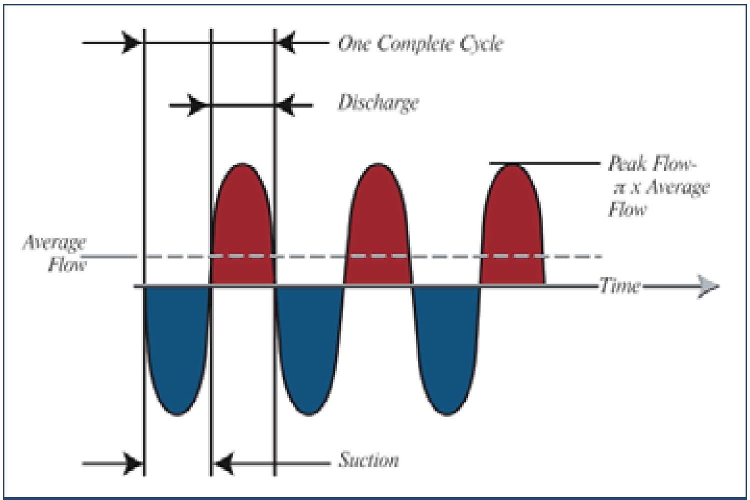
The drive mechanism translates the rotary motion of the driver into reciprocating movement. Industrial duty pumps will submerge this portion of the pump in an oil bath to assure reliability during continuous operation. Pump flow rate is adjustable by varying stroke length, effective stroke length, or stroking speed. Most metering pumps are supplied with a micrometer screw adjustment. The micrometer can also be replaced by an electronic or pneumatic actuator to adjust pump flow rate in response to process signal.

## Metering Pump Characteristics

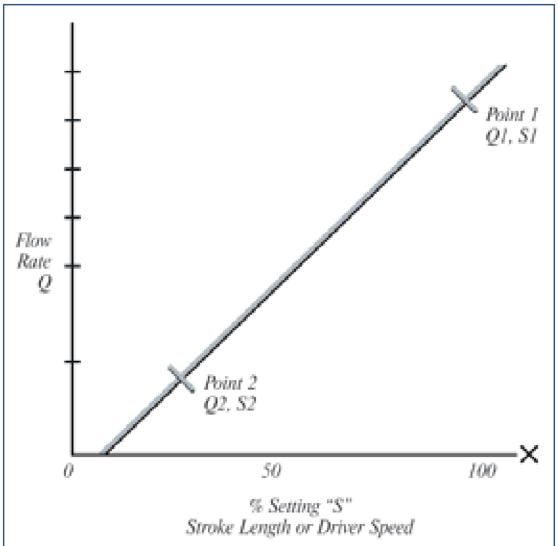
The pumping action is developed by a reciprocating piston. This reciprocating motion develops a flow easily represented by a sine wave. Actual flow rate is determined by the following formula:

Flow rate = Displacement x Cycles per unit of time

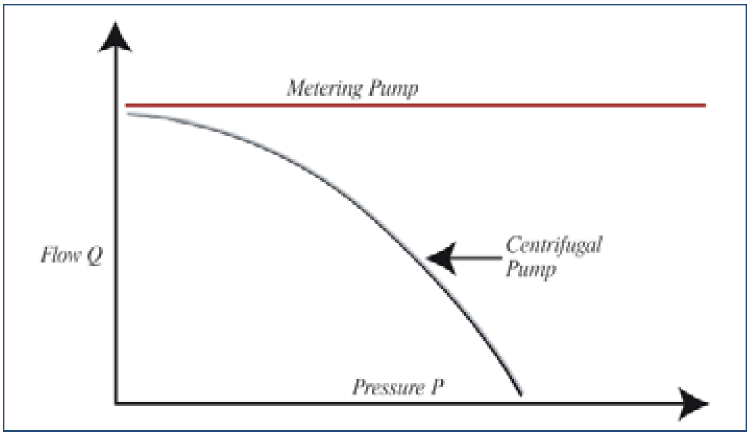
The metering pump flow vs. stroke characteristic curve is linear. It is not, however, necessarily proportional, in that 50 percent stroke setting may not equal 50 percent flow. This



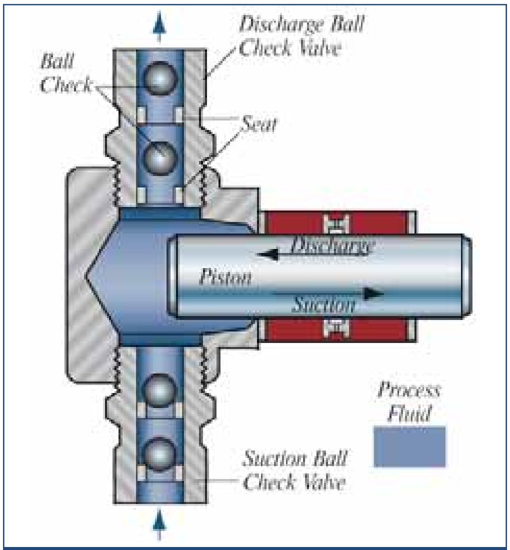

The reciprocating motion of the piston develops a flow represented by a sine wave.




Flow rates vs. stroke can be accurately predicted by measuring flow at two stroke settings, plotting both points and drawing a straight line through them.




Unlike centrifugal pumps, flow rate is not greatly affected by changes in discharge pressure.




The liquid draws into the wetted end by the rearward motion of a piston, and expels by the forward motion.

is due to the fact that the calibration line may not pass through 0 on both axes simultaneously.

By measuring flow at two stroke settings, plotting both points and drawing a straight line through them, other flow rates vs. stroke can be accurately predicted. The steady state accuracy of a correctly installed industrial grade metering pump is generally ± 1.0 percent or better. Although a metering pump can generally be adjusted to pump at any flow rate between 0 and its maximum capacity, its accuracy is measured over a range determined by the pump's turndown ratio.

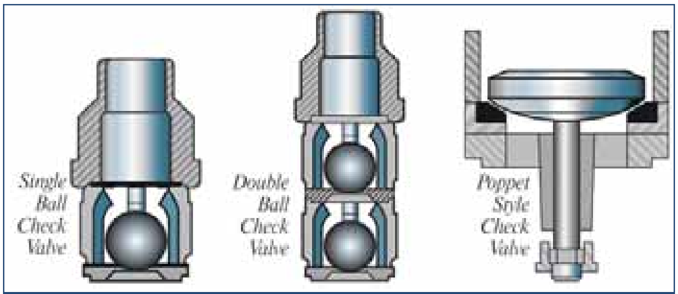
Most metering pumps have a turndown ratio of 10:1, which means that the pump is within its accuracy rating anywhere between 10 percent and 100 percent of capacity. New generation metering pumps have been introduced that feature higher accuracy, and a greater turndown ratio of 100:1. Some of these new designs will accurately dose anywhere between 1 percent and 100 percent of capacity.

The maximum capacity of a metering pump is determined by gear ratio, piston diameter, and motor RPM.

## Liquid End Designs

The liquid end, which is referred to as the *wetted part* of the pump, is selected to meet the specific service conditions of the application. Required flow and pressure ratings are considered, as well as the physical and chemical properties of the liquid. The liquid end's ability to protect the environment is also a major consideration when dealing with toxic or hazardous chemicals.

All liquid ends have several features in common. First, the liquid is drawn into the wetted end by the rearward motion of a piston, and expelled by the forward motion. To achieve this, the metering pump is supplied with check valves at the suction



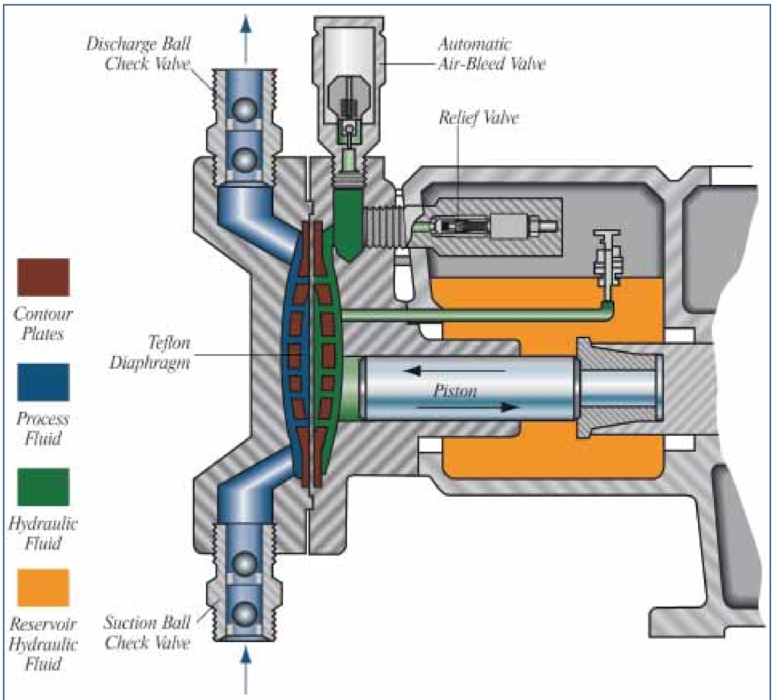

**Check valves come in several different designs and configurations.**

and discharge connection points. The check valves contain and release the chemical based on system conditions and gravity.

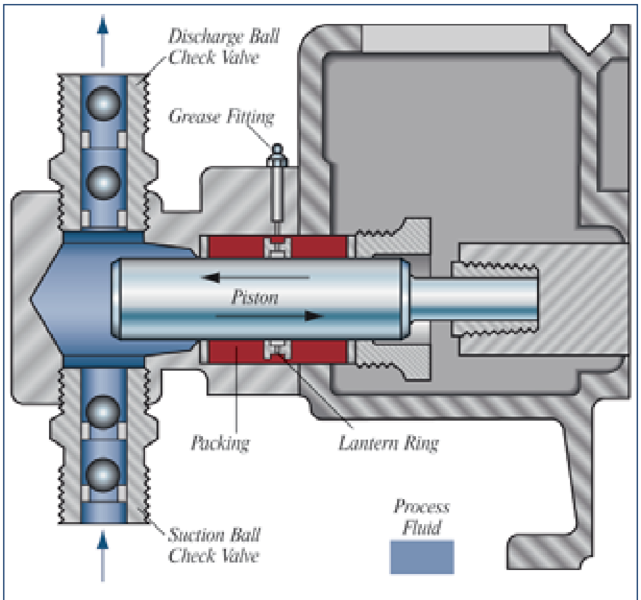
During the suction portion of the stroke, the motion of the piston lifts the suction ball check from its seat, allowing liquid into the pump. At the same time, the piston's motion and system back pressure hold the upper check valve (discharge) closed. This is then reversed during the discharge stroke.

Check valves are available in several different designs and configurations. There are single or double ball configurations and poppet style check valves. Selecting which type to use can be determined by the manufacturer based on capacity required of the specific pump.

For example, slurries or liquids with large fibers or particles can cause a single ball to leak if particles are trapped between the ball and seat. Therefore, a double ball check offers more stability and accuracy. On the other hand, since each check valve causes some resistance in the flow path even when open, viscous fluids are better handled with a single ball suction check valve.




**The disc diaphragm liquid end can use a teflon diaphragm as a barrier between the piston and the process fluid.**




**The packed plunger style liquid end is the only liquid end in which the piston is in direct contact with the process fluid.**

***Packed Plunger***

The packed plunger style liquid end is the only liquid end in which the piston is in direct contact with the process fluid. This direct contact offers a number of advantages, including: high suction and discharge pressure capabilities; high temperature resistance, and lowest NPSH requirements.

The reciprocating piston requires packing to seal the wetted parts from the atmosphere. This simple design is effective, but places limitations on the use of packed plunger pumps in certain applications. Because a small amount of controlled leakage past the packing must be expected, this style liquid end should not be used with hazardous or toxic chemicals.

Additionally, the friction between the piston and the packing results in wear that increases leakage. Periodic packing adjustment is necessary to maintain volumetric efficiency. To avoid problems associated with leakage, consider a diaphragm style liquid end. The packed plunger can handle pressures up to 15,000-psi, and temperatures to 600-deg F (with special modifications).

***Disc Diaphragm***

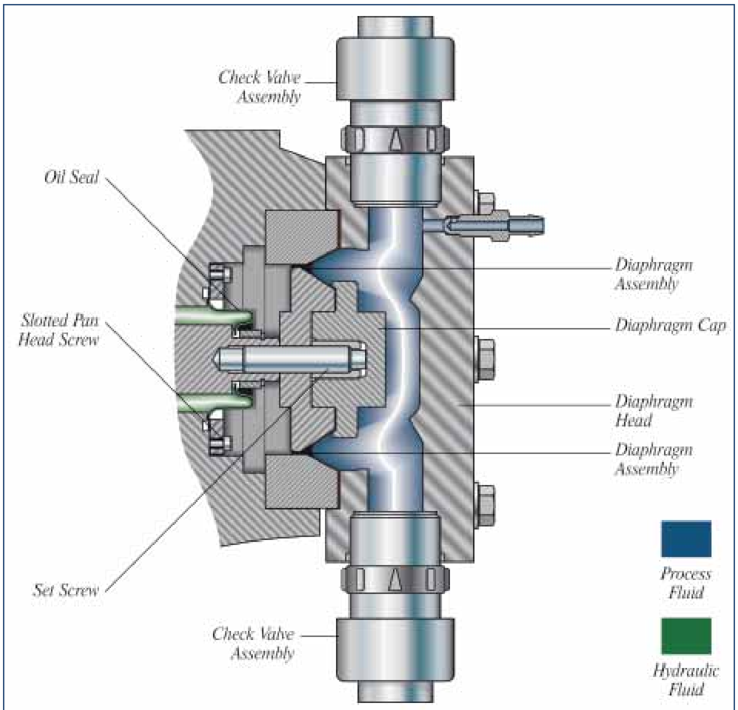
Certain disc diaphragm liquid ends use a teflon diaphragm to act as a barrier between the piston and the process fluid. The piston's pumping motion is applied to hydraulic fluid which causes the diaphragm to flex back and forth as the piston reciprocates.

The hydraulically actuated diaphragm operates with equal pressure between the hydraulic and process fluids. This eliminates diaphragm stress, since the pressure is essentially equal on both sides at all times. Two contour plates encase the diaphragm to contain its travel.

The hydraulic and process fluids pass through carefully engineered holes in the contour plates in order to come into contact with the diaphragm. Relief and refill valves control the volume of hydraulic fluid. An automatic air bleed valve continuously purges air from the hydraulic fluid.

The diaphragm style pump is sealed, making it an excellent choice for hazardous, toxic, or corrosive chemicals. For extra protection, double diaphragm and leak detection modifications are available, although they are considered redundant since this design is extremely durable.

Because the process fluid must pass through relatively small holes in the contour plate, the disc diaphragm liquid end is not the best choice for slurries. With a few exceptions, disc diaphragms are usually not the best choice when pumping viscous fluids. The disc diaphragm is capable of handling fluids where the required injection pressure is 3500-psi or greater and the fluid temperature exceeds 250-deg F.




**Because a mechanically-actuated diaphragm pump has zero diaphragm leakage, it is ideal for critical and otherwise expensive chemicals or where environmental issues are involved.**

***Mechanically Actuated Diaphragm Design***

A mechanically-actuated diaphragm pump represents the best balance between low pump cost and high quality performance. Because it has zero diaphragm leakage, it makes a great pump for critical and otherwise expensive chemicals or where environmental issues are involved.

The mechanically-actuated series is an excellent choice where slurries and abrasive chemicals are required up to the pump's maximum flow and pressure ranges. They are also well tolerant of high viscosity liquids, providing an economical solution for a variety of difficult applications.

Mechanically-actuated pumps operate with a plunger directly attached to the diaphragm. This attachment generally takes place from a bolt and clamp being placed through the plunger and through the diaphragm. The direct attachment of the piston to the diaphragm connects the pump's drive and motor to the liquid end. The motion of the pump drive moves the plunger back and forth, thereby causing suction from the supply tank and pumping the fluid of choice through the attached conveyance infrastructure.

This type of pump generally finds pressure peaks at 175-psi, but is only limited to flow as a matter of wetted end volume. Maximum life of the pump can be achieved by replacing the diaphragm at the recommended service interval. Leak detection can be easily found from the air-filled chamber residing generally at atmospheric pressure on the drive side of the liquid end.

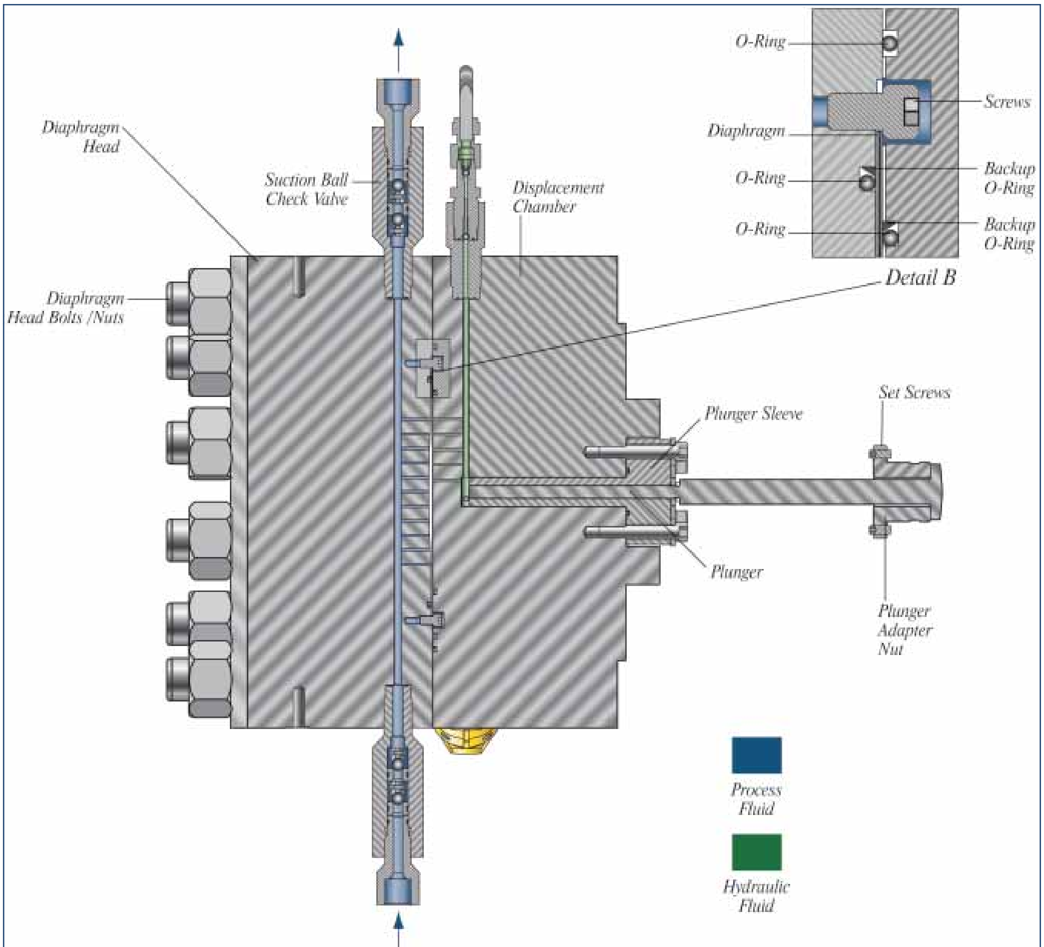
As with any chemical where gas binding can be a problem, it is recommended that a degassing valve be used to release off-gases from the agitation or pressure changes experienced by a liquid having off-gas characteristics. Some of these liquids that can generate off-gases as a result of pressure losses are NaOCl, $H_2O_2$, and some specialty chemicals.

Mechanically-actuated pumps work well in these applications, providing 10:1 turndown as a standard. The addition of VFD technology and remote stroke control will bring the turndown as high as 100:1. Mechanically-actuated diaphragm pumps are easily maintained and provide years of service for little effort.

***Metallic Diaphragm Liquid End and Critical Head Service***

Metallic diaphragm metering pumps are ideal for use in critical, high pressure applications such as oil and gas platforms and specialty industrial applications. They are especially useful where temperatures and pressures of both the environment and the process chemical can be variable or otherwise difficult. These pumps are known for their longevity and durability in many difficult applications.

Metallic diaphragm metering pumps are hydraulically-actuated in the same manner and style as a standard hydraulically-actuated drive liquid end. However, the teflon or other usual diaphragm material is replaced with a special metal alloy particular to the application to produce higher pressures than more traditional materials. The metal design of the diaphragm also manages difficult chemicals such as abrasives, slurries and



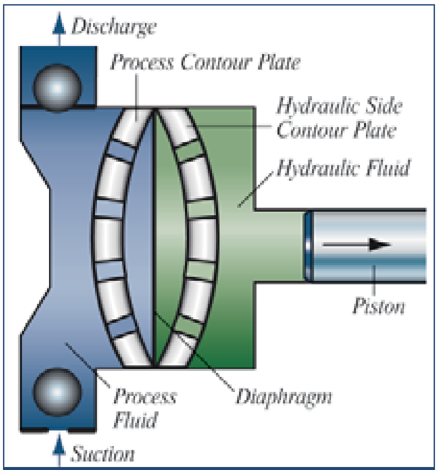

**Metallic diaphragm metering pumps are ideal for use in critical, high pressure applications such as oil and gas platforms and specialty industrial applications.**

other special requirement compounds easily and more efficiently than its more standard version.

Many oil and gas offshore drilling platforms require metallic diaphragms because of their high reliability and longevity.

***Advanced Liquid End Technology: High Performance Diaphragm***

A high performance diaphragm (HPD) liquid end operation is similar to a disc diaphragm in that it is hydraulically actuated and utilizes the same shape and diaphragm. It is similar to a tubular diaphragm in the respect that the process fluid has a "straight through" path through the liquid end. Its low NPSH requirements are similar to that of a packed plunger liquid end.



**Traditional liquid end with process and hydraulic contour plates (refill system not shown).**

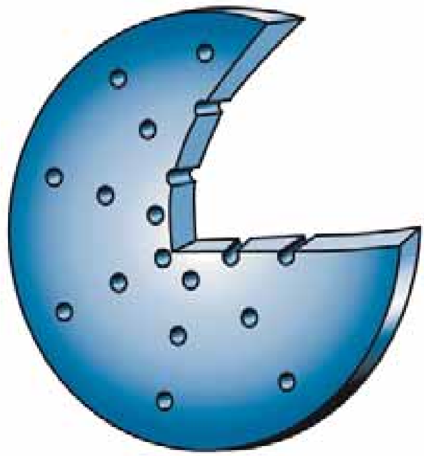
The primary advantages of a HPD are the unique design features that separate it from traditional design.

A hydraulically actuated diaphragm liquid end design requires a refill system to compensate for hydraulic fluid that bleeds past the piston or through an air bleed valve during normal operation. Hydraulic fluid is also expelled from the chamber through the internal relief valve when the system experiences excess pressure, and therefore must also be replenished. A HPD features a mechanically actuated refill system (MARS) that offers a number of advantages over traditional refill systems. To understand the advantages of a MARS, traditional refill systems must first be explored.

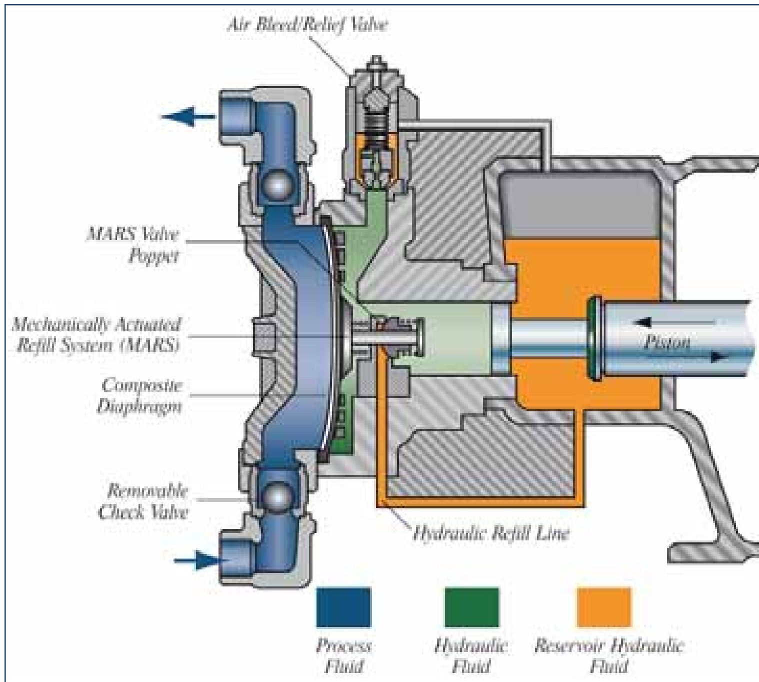
***Traditional Designs***

Traditional designs use a system that refills the chamber when a vacuum is created by the inability of the diaphragm to move beyond the hydraulic contour plate. It also refills when the suction is momentarily or permanently starved by accidental valve closure, insufficient NPSH, or other similar occurrences. When this happens, the hydraulic fluid chamber is overfilled because a vacuum has been created even though the diaphragm has not been able to travel rearward.

To avoid diaphragm rupture due to overfilled hydraulic oil, a process side contour plate stops the diaphragm's forward



Typical contour plate (section cutaway).




A HPD preshaped composite diaphragm.

travel, and forces the hydraulic relief valve to open, thus expelling the excess fluid. The contour plate is a concave (actually, concavo-convex) disc that supports the diaphragm and limits its travel. The plate has a series of holes bored through it to permit the fluid to come into contact with the diaphragm. The pattern and size of these holes requires careful engineering to maintain the contour plate strength required to withstand the force of the diaphragm experienced at operating pressure.

The hydraulic contour plate does not cause any problems in pump operation since the hydraulic fluid passes easily through the contour plate holes. However, a process contour plate, required by traditional disc diaphragm liquid ends, places limitations on the types of process fluids the pump can handle (such as slurries) since the process fluid must also pass through contour plate holes. The process contour plate also creates a pressure loss which raises the NPSH requirement of the liquid end.

### *MARS Design*

A MARS eliminates the need for a process contour plate by assuring that the hydraulic fluid can only be refilled when the diaphragm has traveled all the way back to the hydraulic contour plate. The diaphragm presses against the MARS valve, which only then permits a poppet valve to open from the vacuum created by insufficient hydraulic fluid. Hydraulic overfill is therefore impossible.

With the process contour plate gone, the straight through path of the process liquid makes a HPD a perfect choice for slurries and viscous materials. It also lowers the NPSH requirements of the pump, since pressure loss through a process contour plate is eliminated.

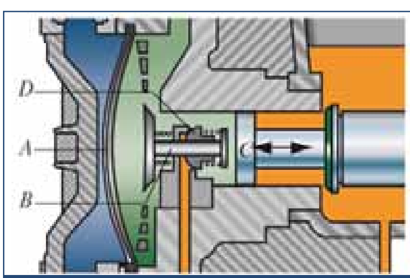



Figure 1. Diaphragm (A) and piston (C) are full forward. MARS valve (B) in forward position holds poppet valve (D) closed, preventing refill line hydraulic oil from entering the chamber.

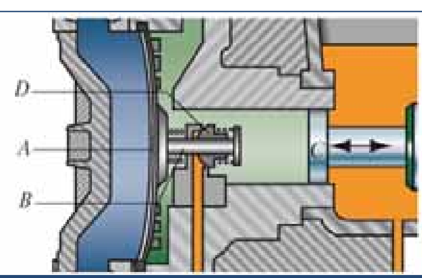



Figure 2. Diaphragm (A) and piston (C) are full rearward. MARS valve (B) is also rearward due to diaphragm position, thus freeing poppet (D) to open if required. Poppet (D) is shown closed, indicating hydraulic oil refill is not required.

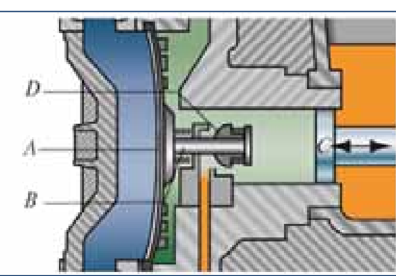



Figure 3. Diaphragm (A) and piston (C) are full rearward, once again forcing MARS valve (B) to its rearward position, which allows poppet (D) to open if required. Low oil volume creates a vacuum and opens poppet, permitting hydraulic fluid to enter the chamber from the refill line.

A MARS also simplifies HPD start-up. Unlike other hydraulic liquid ends, the refill valve does not need adjustment. Additionally, since a HPD hydraulic fluid cannot be overfilled, there is no need to perform delicate procedures to synchronize hydraulic fluid balances (a difficult task required for tubular and other double diaphragm liquid ends). With a HPD, just fill the reservoirs and turn it on.

***HPD Preshaped Composite Diaphragm***

A HPD features a preshaped PTFE/elastomer composite disc diaphragm. On the process side, the chemical resistance of PTFE is utilized. On the hydraulic side, the elastomer imparts favorable elastic and mechanical factors.

A composite diaphragm eliminates the inherent problems of pure PTFE diaphragms. PTFE tends to cold flow when compressed between two metal parts (such as those required to seal the hydraulic side from the process side). A HPD composite diaphragm features an integral O-ring seal around the perimeter of the diaphragm, which provides a better seal between hydraulic and process fluids than conventional diaphragm materials. A HPD is capable of handling pressures up to 3025-psi and temperatures up to 300-deg F (with special modifications).

Next month we'll conclude our discussion by reviewing drive mechanisms and other metering pump system components.

P & S

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