SECTION 9.15
METERING

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METERING OR PROPORTIONING

Conventional reciprocating pumps can be adapted to function as metering or proportioning devices in the transfer of liquids. The principal adaptation is the addition of a means of varying the pumping rate and predicting what that rate will be, which makes the modified units suitable for use as final control elements in continuous-flow processes. Metering pumps are often employed where two or more liquids must be proportioned or where mixture ratios must be controlled. These effects are achieved by changing the displacement per stroke (by moving the crankpin by special linkages or by partial stroking) or by changing the stroking speed through the use of variable-speed transmissions or electric motors. Accurate cyclic volume compensation can also be performed using electronic calibration.

Four basic types of positive displacement reciprocating pumps, and several variations, are used for this service: packed plunger pumps, pumps with a mechanically actuated diaphragm, pumps with a hydraulically actuated diaphragm, and pumps with hydraulically actuated pistons.

Packed Plunger The packed plunger pump is the most commonly used type because of its relatively simple design and wide range of pressure capability. It is an adaptation of the conventional reciprocating transfer pump (Figure 1). Its advantages are

1. Relatively low cost
2. Pressure capability to 50,000 lb/in^2 (345 MPa) gage
3. Mechanical simplicity
4. Wide capacity range, from a few cubic centimeters per hour to 20 gpm (4.5 m^3/h)
5. High accuracy, better than 1% over a 15:1 range
6. Only slightly affected by changes in discharge pressure

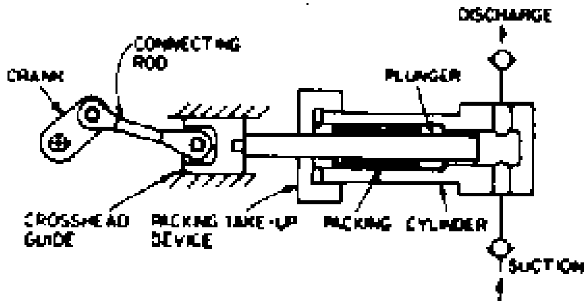

FIGURE 1 Packed plunger pump

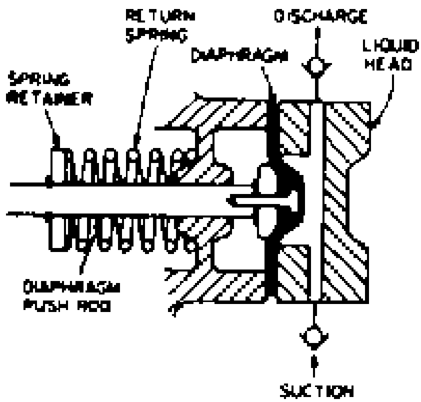

FIGURE 2 Mechanically actuated diaphragm pump

Its disadvantages are

1. Packing leakage, making it unsuitable for corrosive or dangerous chemicals
2. Packing and plunger wear and the resulting need for gland adjustment
3. Inability to pump abrasive slurries or chemicals that crystallize

Mechanically Actuated Diaphragm The mechanically actuated diaphragm pump is commonly used for low-pressure service where freedom from leakage is important. This pump utilizes an unsupported diaphragm, which is moved in the discharge direction by a cam and returned by a spring (Figure 2). Its advantages are

1. Relatively low cost
2. Minimum maintenance at 6- to 12-month intervals
3. Zero chemical leakage
4. Ability to pump slurries and corrosive chemicals

Its disadvantages are

1. Discharge pressure limitation of 125 to 150 lb/in^2 (860 to 1030 kPa) gage
2. Accuracy in 5% range and as much as 10% zero shift with change from minimum to maximum discharge pressure
3. Capacity limit of 12 to 15 gph (0.045 to 0.057 m^3/h)

Hydraulically Actuated Diaphragm The hydraulically actuated diaphragm pump is a hybrid design that provides the principal advantages of the other types. A packed plunger is used to pulse hydraulic oil against the back side of the diaphragm. The reciprocating action thus imparted to the diaphragm causes it to pump in the normal manner without being subjected to high pressure differences. A flat diaphragm design is shown in Figure 3 and a tubular diaphragm design in Figure 4.

The advantages of the hydraulically actuated diaphragm pump are

1. Pressure capability to 5000 lb/in^3 (34.5 MPa) gage
2. Capacities to 20 gpm (4.5 m^3/h)
3. Minimum maintenance
4. Zero chemical leakage
5. Ability to pump slurries and corrosive chemicals
6. Accuracy around 1% over 10:1 range

Its disadvantages are

1. Subject to predictable zero shift of 3 to 5% per 1000 lb/in^2 (6.9 MPa) gage
2. Higher cost

Hydraulically Actuated Pistons This type of design is used when high accuracy at relatively low pressure is required. Figure 5 shows the complete pumping and metering unit, whereas Figure 6 shows a sectioned view of the metering unit. The pumping unit shown in Figure 6 can be a gear or vane type, driven by an electric motor. This is integral to a dual-measuring unit (Figure 5), mounted on top of the pumping unit. Alternatively, a centrifugal pump located remotely in the product storage tank can provide the pumping function. The pumping unit is run at a constant speed of about 850 rpm. A bypass valve in the pumping unit varies the output from 0 to 100% in response to a control valve located downstream of the meter.

The metering unit shown in Figure 5 is a dual unit providing two separate measured outputs. Each meter unit has two pistons and three chambers. Scotch yokes that drive a

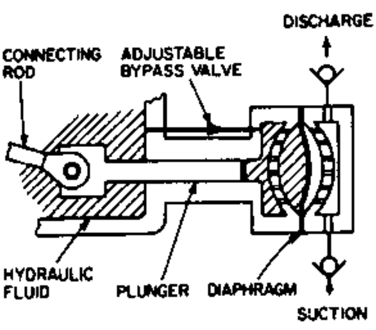

FIGURE 3 Hydraulically actuated diaphragm pump with flat, circular diaphragm

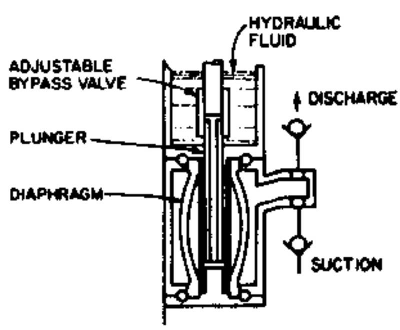

FIGURE 4 Hydraulically actuated diaphragm pump with tubular diaphragm

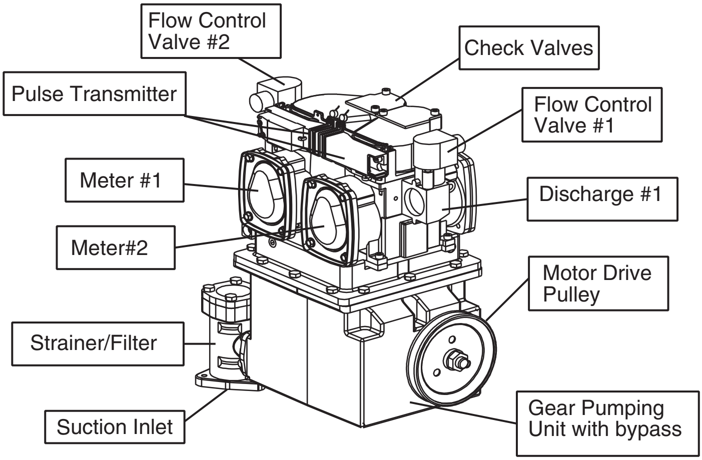

FIGURE 5 "Duplex" metering pump (Dresser-Wayne)

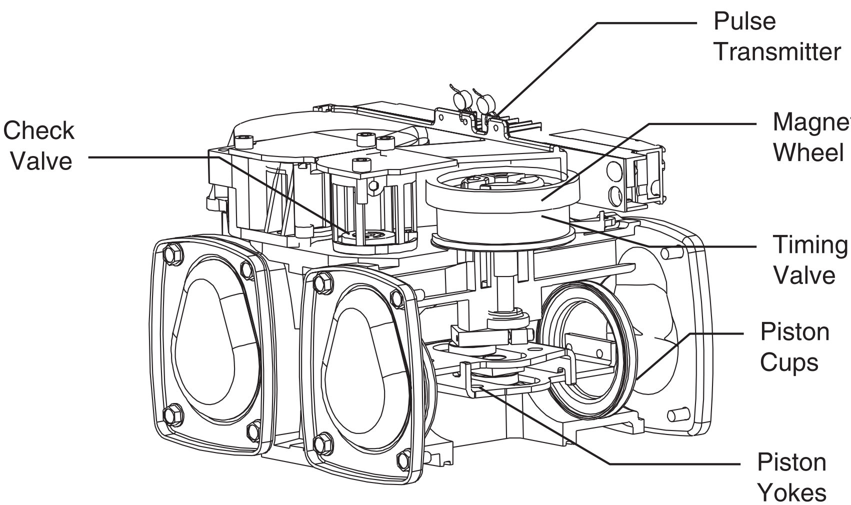

FIGURE 6 "Duplex" meter (Dresser-Wayne)

rotary valve that ports the fluid in and out of the measuring chambers connect the pistons. A shaft encoder and calibration unit is integral to the meter to provide accurate adjustment of the pumped volume together with batch and running volume totals. The advantages are

1. High accuracy (0.25%) across complete flow range to 25 gpm (6 m^3/h)
2. Compact, totally integrated multi-function design.

3. Minimum maintenance every 1.3–1.5 million gallons (5000–6000 m^3)
4. Low initial and ownership cost

Its disadvantages are

1. Pressure limitation of 100 lb/in^2 (700 kPa).
2. Maximum flow rate of approximately 25 gpm (6 m^3/h)
3. Only suitable for low viscosity noncorrosive products.

CAPACITY CONTROLS

There are five methods commonly used to adjust the capacity of metering pumps. The choice of which method to use is determined by the application for which the pump is intended.

Manually Adjustable While Stopped This control is generally found on packed plunger pumps of conventional design. Capacity changes are effected by moving the crankpin in or out of the crank arm while the pump is not in motion. This is the least expensive method and is used where frequent changes in pump displacement are not required.

Manually Adjustable While Running This feature is most frequently found on mechanically actuated diaphragm pumps, where it is accomplished by limiting the return stroke of the diaphragm with a micrometer screw. On packed plunger pumps, stroke adjustment while the pump is running is relatively complicated. Stroke length is set by some type of adjustable pivot, compound linkage, or tilting plate, which is manually positioned by turning a calibrated screw. On hydraulically actuated diaphragm pumps, relatively simple control is provided by manually adjustable valving that changes the amount of the intermediate liquid bypassed at each stroke.

Pneumatic Meeting pumps used in continuous processes must be controlled automatically. In pneumatic systems, the standard 3- to 15-lb/in^2 (21- to 103-kPa) gage air signal is utilized to actuate air cylinders of diaphragms directly connected to the stroke-adjusting mechanism.

Electric On electric control systems, stroke adjustment is through electric servos that actuate the mechanical stroke-adjusting mechanism. These accept standard electronic control signals.

Variable Speed This method of adjusting capacity is achieved by driving a reciprocating pump with a variable-speed prime mover. Because it is necessary to reduce stroke rate to reduce delivery, discharge pulses are widely spaced when the pump is turning slowly. Surge chambers or holdup tanks are used when this factor is objectionable.

In control situations involving pH and chlorinization, two variables exist at once; for example, flow rate and chemical demand. This is easily handled by a metering pump driven by a variable-speed prime mover. Flow rate can be adjusted by changing the speed of the pump, and chemical demand by changing its displacement.

CALIBRATION

Calibration, which is a fine adjustment of capacity, can be performed in the same way as the capacity controls previously discussed by using a fine stroke adjustment mechanism. It can better be achieved using electronics linked to the pumped volume display. A shaft encoder is connected to the meter that outputs pulses proportional to the volume pumped.

The number of pulses is selected relative to the display resolution required. If $\frac{1}{100}$ th of a liter were required on a nominal cyclic volume of 1 liter, 105 pulses would be provided per revolution. The pulses are fed into counting and processing electronics. The electronics are put in calibrate mode and a fixed measure pumped into a calibrated vessel. The electronics counts the number of pulses received for the known volume pumped, compares that to the number of pulses it should have received, and calculates a calibration factor for that meter. This factor is stored in nonvolatile memory, and used by counter to "discard" extra pulses when the pump is in normal delivery mode. The 105 pulses per revolution is used to make sure that there are always extra pulses to discard allowing a ±5% manufacturing variation on the nominal cyclic volume. The calibrating electronics can also store batch and lifetime volumes pumped totals, and supply this information to a local or remote display.

SERVICE AND MAINTENANCE

Proportioning pumps utilizing manual capacity controls can be installed, serviced, and operated by plant personnel. Pneumatic capacity controls are more sophisticated, but after their construction and function are understood, maintenance and service should become routine. Electric capacity controls require a basic understanding of electric circuits for installation, operation, and routine service. Modular construction allows repair service by replacement of component groups, thus diminishing the task of trouble-shooting.

All proportioning pumps utilize suction and discharge check valves. These require regular maintenance and service because they are used frequently, encounter corrosion, and must be kept in good working order to ensure accurate pump delivery. Service periods are greatly dependent on liquids pumped, pump operating speed, and daily running time. Usual service periods run from 30 days to 6 months or longer. Check valves are designed to facilitate service with a minimum of downtime, thus allowing replacement of wearing parts at minimum expense. Good design allows this service to be accomplished without breaking pipe connections to the pump.

Packed plunger pumps require periodic adjustments of the packing takeup device to compensate for packing and plunger wear. Packing has to be replaced periodically, and regular lubrication of bearings and wear points is required.

The lubricating oil in speed-reduction gearing, either separate integral units or built in, must be changed at six-month intervals.

Diaphragm pumps usually require replacement of the diaphragm as part of routine service at six-month intervals. On hydraulically actuated diaphragm pumps, the hydraulic fluid must also be changed.

Pneumatic and electric controls generally present no special maintenance problems. The frequency of routine cleaning and lubrication is dependent on environmental conditions and should be consistent with general plant maintenance procedures.

INSTALLATION

Proper installation of metering pumps is very important if reliable pump operation is to be obtained.

NPSH must be kept as high as possible, and the manufacturer's recommendations as to pipe size and length, strainers, relief valves, and bypasses must be observed.

MATERIALS OF CONSTRUCTION

With the tremendous variety of liquid chemicals used in industry today, an all-inclusive guide to suitability of materials for pump construction is virtually impossible. For the great majority of common chemicals, pump manufacturers publish data on materials of construction. In general, packed plunger and hydraulically actuated diaphragm pumps are available as standard construction in mild steel, cast or ductile iron, stainless steel, and plastic. Mechanically actuated diaphragm pumps are usually available as standard construction in plastic and stainless steel. Almost any combination of materials can be furnished on special order.

Diaphragms are available as standard construction in Teflon, chemically-resistant elastomers, and stainless steel from various manufacturers.

See also Section 3.6, "Diaphragm Pumps," and Section 3.5, "Displacement Pump Flow Control."