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American National Standard for

Controlled-volume Metering Pumps

for Nomenclature, Definitions, Application, and Operation

Sponsor

Hydraulic Institute, Inc.

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Approved August 10, 2023

American National Standards Institute, Inc.

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Foreword [Not part of American National Standard (ANSI)]

Purpose and aims of the Hydraulic Institute

The purpose and aims of the Hydraulic Institute are to drive all Pump System stakeholders towards a sustainable future by:

a) Advancing Solutions for Pump System Performance and Efficiency

b) Developing Standards and Technical Resources

c) Educating the Global Marketplace

d) Advocating for the Industry

Purpose of Document:

Hydraulic Institute Standards and Guidelines may be published as American National Standards, and are adopted in the public interest to help eliminate misunderstandings between the manufacturer, the purchaser, and/or the user and to assist the purchaser in selecting and obtaining the proper product for a particular need. Use is completely voluntary and does not in any respect preclude a member from manufacturing or selling products which are not conforming.

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Comments from users of this standard will be appreciated, to help the Hydraulic Institute prepare even more useful future editions. Questions arising from the content of this standard may be directed to the Technical Director of the Hydraulic Institute. If appropriate, the inquiry will then be directed to the appropriate technical committee for provision of a suitable answer.

Revisions

American National Standards of the Hydraulic Institute are reviewed on a periodic basis and may be reaffirmed, revised, or withdrawn as appropriate. Errata or addenda may be issued between revisions to address limited changes. Should an errata or addenda occur, details of the changes can be found on the publication's product page at www.pumps.org.

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This document does not contain a complete statement of all requirements, analyses, and procedures necessary to ensure safe or appropriate selection, installation, testing, inspection, and operation of any pump or associated products. Each application, service, and selection is unique with process requirements that shall be determined by the owner, operator, or its designated representative.

Units of measurement

Metric units of measurement are used, and corresponding US customary units appear in parentheses. Charts, graphs, and sample calculations are also shown in both metric and US customary units. Because values given in metric units are not exact equivalents to values given in US customary units, it is important that the selected units of measure to be applied be stated in reference to this standard. If no such statement is provided, metric units shall govern.

Consensus

Consensus for this American National Standard was achieved by use of the canvass method. The following organizations, recognized as having an interest in the standardization of pumps, were contacted prior to the approval of this revision of the standard. Inclusion in this list does not necessarily imply that the organization concurred with the submittal of the proposed standard to ANSI.

Michael Cropper	Leistritz Advanced Technologies Corp.
Jim Elsey	Las Vegas Valley Water District
Randal Ferman, PE	Rotating Equipment SME

Committee list

Although this standard was processed and approved for submittal to ANSI by the canvass method, a working committee met many times to facilitate its development. At the time it was developed, the committee had the following members:

Chair – Peter Timpanelli, LEWA America, Inc.

Committee members	**Company**
Chris Distaso (Alternate)	PSG, a Dover Company
Rex Beach	PSG, a Dover Company
Douglas Purdy	Wanner Engineering, Inc.

7 Controlled-volume Metering Pumps

7.0 Introduction

7.0.1 Purpose

The purpose of this standard is to define common terminology, provide education, and prevent misunderstandings between manufacturers, purchasers, and users of controlled volume metering pumps. The standard can assist purchasers in the selection and acquisition of an appropriate pump for their needs. The standard can also assist pump users to operate their pumps in an efficient and trouble-free manner and avoid common mistakes.

7.0.2 Scope

This standard applies to controlled volume metering pumps. A controlled volume metering pump is a positive displacement reciprocating pump used for accurate liquid dispensing or dosing. This standard covers pumps driven by hydraulic, pneumatic or mechanical means. Liquid ends covered include plunger, piston, and diaphragm.

7.0.3 Units, symbols and subscripts

See tables 7.0.3a and 7.0.3b for units, symbols and subscripts.

7.1 Types and nomenclature

Controlled-volume metering pumps (also known as *metering pumps, proportioning pumps, chemical injection/feed pumps,* or *dosing pumps*) are reciprocating positive displacement pumps typically used for the injection of chemical additives, proportional blending of multiple components, or metered transfer of a single liquid. These types of pumps are used in applications requiring highly accurate, repeatable, and adjustable rate of flow.

The rate of flow of a controlled-volume pump is a function of the cross-sectional area of the plunger or piston, or displacement of the diaphragm; the stroke length; and the stroking speed. The pumping action is created by a reciprocating piston and controlled by suction and discharge check valves. The rate of flow is adjusted by changing the stroke length and/or the stroking speed.

Controlled-volume metering pumps are characterized by their ability to meet specific performance requirements concerning steady state accuracy, repeatability, and linearity.

Controlled-volume metering pumps are employed in a number of different environments and applications, several types have been developed with different liquid ends and drive and control mechanisms. The basic elements of the pumps are the driver, stroke-length adjustment, pumphead, and the gearbox. These are shown in Figure 7.1, which illustrates the general arrangement of these elements and how they are combined to form a controlled-volume metering pump. Detailed descriptions of these elements follow below.

7.1.1 Construction characteristics of controlled-volume metering pumps

NOTE: The following definitions and illustrations represent typical construction characteristics of controlled-volume metering pumps but do not necessarily represent recommended designs. Variations in design may exist without violating the intent of this standard.

Table 7.0.3a — Symbols

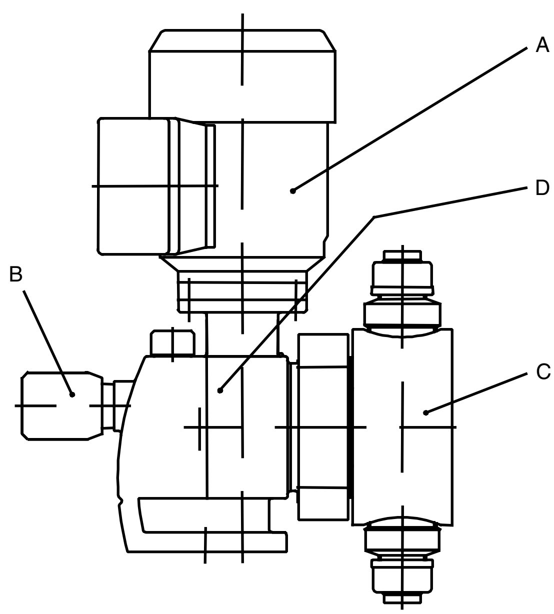
Symbol	Term	Metric unit	Abbreviation	US customary unit	Abbreviation	Conversion factor[a]
A	Area of piston/plunger	square centimeter	cm^2	square inch	in^2	6.45
β (beta)	Meter or orifice ratio	dimensionless	—	dimensionless	—	1
C	Coefficient for acceleration head	dimensionless	—	dimensionless	—	1
d	Diameter	millimeter	mm	inch	in	25.4
D	Displacement	cubic centimeter	cm^3	cubic inches	in^3	16.39
Δ (delta)	Difference	dimensionless	—	dimensionless	—	1
η (eta)	Efficiency	percent	%	percent	%	1
g	Gravitational acceleration	meter/second squared	m/s^2	foot/second squared	ft/s^2	0.3048
γ (gamma)	Specific weight	newton/cubic meter	N/m^3	pound/cubic foot	lb/ft^3	0.0064
H	Head	meter	m	foot	ft	0.3048
L	Pipe line length	meter	m	foot	ft	0.3048
L_m	Stroke length	millimeter	mm	inch	in	25.4
M	Number of pistons	dimensionless	—	dimensionless	—	1
n	Pump speed	stroke/minute	spm	stroke/minute	spm	1
N	Pump crankshaft speed	revolution/minute	rpm	revolution/minute	rpm	1
NPIPA	Net positive inlet pressure available	bar absolute	bara	pound/square inch absolute	psia	0.0689
NPIPR	Net positive inlet pressure required	bar absolute	bara	pound/square inch absolute	psia	0.0689
NPSHA	Net positive suction head available	meter absolute	m	foot	ft	0.3048
NPSHR	Net positive suction head required	meter	m	foot	ft	0.3048
ν (nu)	Kinematic viscosity	millimeter squared/second	mm^2/s	Seconds Saybolt Universal	SSU	0.216 @ 100° F and > 325 SSU[b]
π	pi = 3.1416	dimensionless	—	dimensionless	—	1
p	Pressure	bar	bar	pound/square inch	psi	0.0689
P	Power	kilowatt	kW	horsepower	hp	0.7457
Q	Rate of flow (capacity)	liter/hour	L/h	US gallon/hour	gph	3.7854
ρ (rho)	Density	kilogram/cubic meter	kg/m^3	pound mass/cubic foot	lbm/ft^3	16.02
sG	Specific gravity	dimensionless	—	dimensionless	—	1
S	Slip	percent	%	percent	%	1
t	Temperature	degree Celsius	°C	degree Fahrenheit	°F	(°F–32) × $^5/_9$
τ (tau)	Torque	newton-meter	N•m	pound-foot	lb-ft	1.356
μ (mu)	Viscosity, absolute	centipoise	cP	centipoise	cP	1
v	Velocity	meter/second	m/s	foot/second	ft/s	3.281
x	Exponent	none	none	none	none	1
Z	Elevation gauge distance above or below datum	meter	m	foot	ft	0.3048

[a] Conversion factor × US customary units = metric units (except temperature).

[b] Refer to ASTM D2161 for viscosity lower than 70 cSt.

Table 7.0.3b — Subscripts

Subscript	Term	Subscript	Term
a	Absolute	mot	Motor
A	Actual	ni	Net Inlet
acc	Acceleration	o	Outlet
atm	Atmospheric pressure	oa	Overall
b	Barometric	p	Pump
c	Piston or plunger	s	Suction
d	Discharge	t	Theoretical
D	Design	Δ (delta)	Differential
drv	Driver	v	Velocity
f	Friction loss	V	Volume
g	Gauge	vp	Vapor pressure
H	Total head	w	Hydraulic or water
i	Inlet	z	Fluid level delta
max	Maximum	1	Test condition
min	Minimum	2	Specific condition



A. Driver (motor)

B. Stroke-length adjustment

C. Pumphead (liquid end)

D. Gearbox (drive and control mechanism)

Figure 7.1 — Basic elements of a controlled-volume metering pump

Liquid end

- Plunger
- Piston
- Mechanical coupled disc diaphragm
- Hydraulic coupled disc diaphragm
- Hydraulic coupled tubular diaphragm
- Hydraulic coupled conical diaphragm

Drive and control mechanisms

- Electromagnetic drive (solenoid)
- Reciprocating air/gas drive
- Motor driven,[1] variable speed
- Motor driven,[1] mechanical lost motion
- Motor driven,[1] hydraulic lost motion
- Motor driven,[1] variable eccentric (non-lost-motion)

7.1.2 Description of liquid ends

The pump liquid end assembly (also called the *reagent head assembly, pumphead,* or *wet end*) includes all parts that contain or are in direct contact with the liquid being pumped.

7.1.2.1 Plunger

A plunger liquid end (see Figure 7.1.2.1) contains a reciprocating plunger in direct contact with the liquid being displaced. It uses packing within a stuffing box or seals to restrict leakage. This design is not inherently leak free. The plunger design allows for lower Net positive suction suction head required (NPSHR), limited by the vapor pressure of the liquid, and suction check valve losses. This design can be used in high-pressure applications. In operation the process liquid is admitted through the suction check valve as the plunger moves away from the wet end. As the plunger moves towards the wet end, the suction check valve closes and the discharge check valve opens discharging liquid.

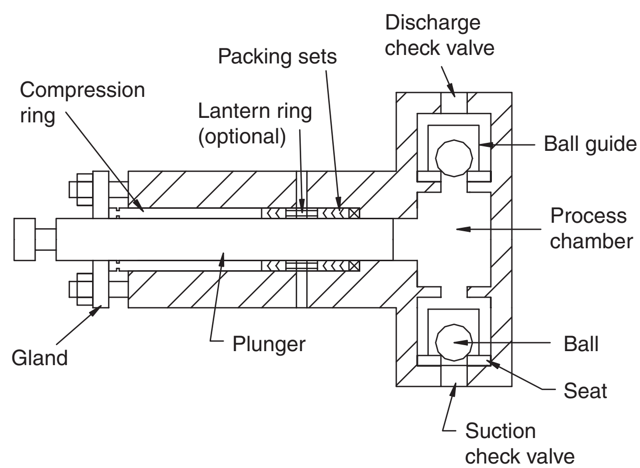
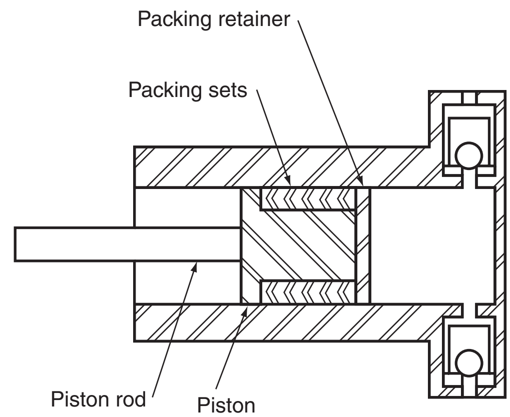


Figure 7.1.2.1 — Plunger pump

[1] Motor driven is understood to include electric, pneumatic, hydraulic turbine, gasoline, diesel, or hydraulic motors.

7.1.2.2 Piston

A piston liquid end (see Figure 7.1.2.2) contains a reciprocating piston in direct contact with the liquid being displaced. It uses packing or seals located on the piston to restrict leakage. This design is not inherently leak free. The piston design allows for lower Net positive suction suction head required (NPSHR), limited by the vapor pressure of the liquid, and suction check valve losses. This design can be used in high-pressure applications. In operation the process liquid is admitted through the suction check valve as the piston moves backwards. As the piston moves to the front, the suction check valve closes and the discharge check valve opens, discharging liquid.



Packed piston type

Figure 7.1.2.2 — Piston pump

7.1.2.3 Mechanical coupled disc diaphragm

A mechanically coupled disc diaphragm liquid end (see Figure 7.1.2.3) contains a flexible, round diaphragm, clamped at the periphery, that is in direct contact with the process liquid being displaced. This type of design is inherently leak free. The diaphragm material is typically a fluoropolymer, elastomer, or fluoropolymer-elastomer composite. A connecting rod is connected directly to the diaphragm. The diaphragm is not pressure balanced as the process pressure is acting on one side of the diaphragm and atmospheric pressure is acting on the other side. This results in higher stress levels in the diaphragm and therefore these pumps are typically used for lower pressure applications. In operation the process liquid is admitted through the suction check valve as the diaphragm/connecting rod assembly moves away from the wet end. As the diaphragm/connecting rod assembly moves towards the wet end, the suction check valve closes and the discharge check valve opens, discharging liquid.

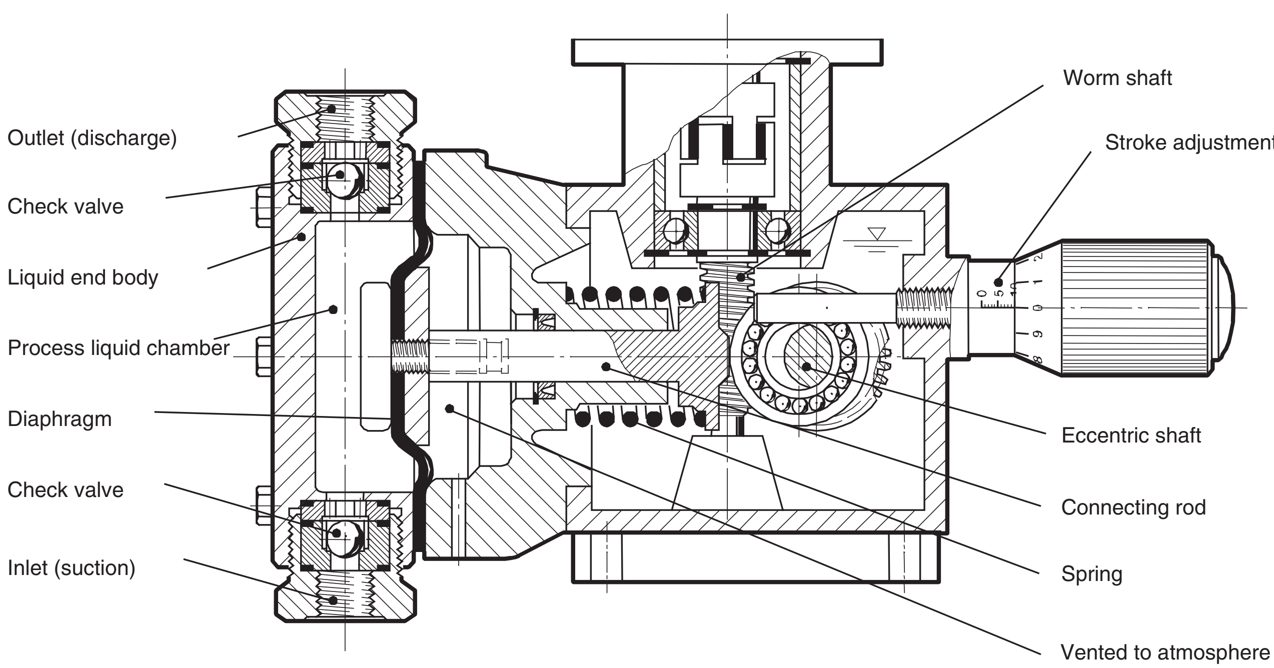


Figure 7.1.2.3 — Mechanically coupled disc diaphragm

7.1.2.4 Hydraulic coupled disc diaphragm

A hydraulic coupled disc diaphragm liquid end (Figure 7.1.2.4a) contains a flexible, single or double configuration diaphragm, clamped at the periphery, and is in direct contact with the process liquid being displaced. This type of liquid end design is inherently leak free. The diaphragm material is typically a fluoropolymer, elastomer, or fluoropolymer-elastomer composite. Liquid end designs featuring flexible metallic diaphragms are available and used in applications where severe operating conditions prohibit the use of fluoropolymer or other elastomers.

In operation, the diaphragm is moved by a hydraulic fluid, which is displaced by a reciprocating plunger or piston. The stresses in the diaphragm are minimal, as the process pressure acting on one side of the diaphragm is balanced by the hydraulic pressure acting on the opposite side. The process liquid is admitted through the suction check valves as the diaphragm moves rearward. As the diaphragm moves towards the wet end, the suction check valve closes and the discharge check valve opens, discharging liquid. Liquid end designs of this type may include provisions such as contour plates, springs, or diaphragm positioning hydraulic control valves (Figure 7.1.2.4b) to ensure the diaphragm does not move beyond its elastic limits.

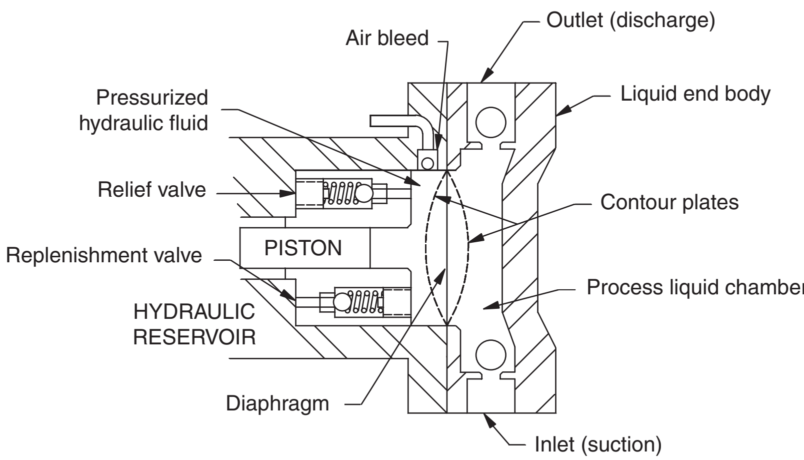


Figure 7.1.2.4a — Hydraulic disc with contour plates

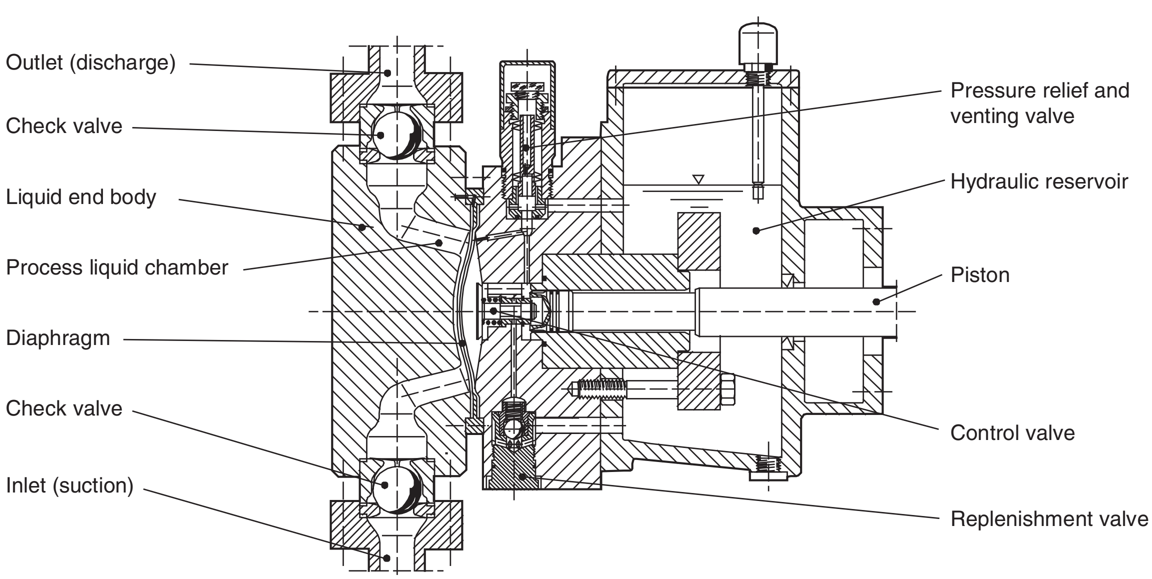


Figure 7.1.2.4b — Hydraulic disc with diaphragm positioning valve

7.1.2.5 Hydraulic coupled tubular diaphragm

A hydraulic coupled tubular diaphragm liquid end (see Figure 7.1.2.5) contains a flexible tube, clamped at both ends, that is in direct contact with the process liquid being displaced. This type of liquid end design is inherently leak free. The diaphragm material is either PFA or an elastomer. These liquid ends are typically used for viscous liquids or slurries. In operation, the plunger moves rearward and, through hydraulic coupling, expands the tube admitting liquid into the tube's cavity through the suction check valve. As the plunger moves towards the wet end, the hydraulic fluid constricts the tube moving the process liquid through the discharge check valve. A disc diaphragm constrained by contour plates may be used in series hydraulically. This disc diaphragm is used to ensure that the tube operates within its elastic limits.

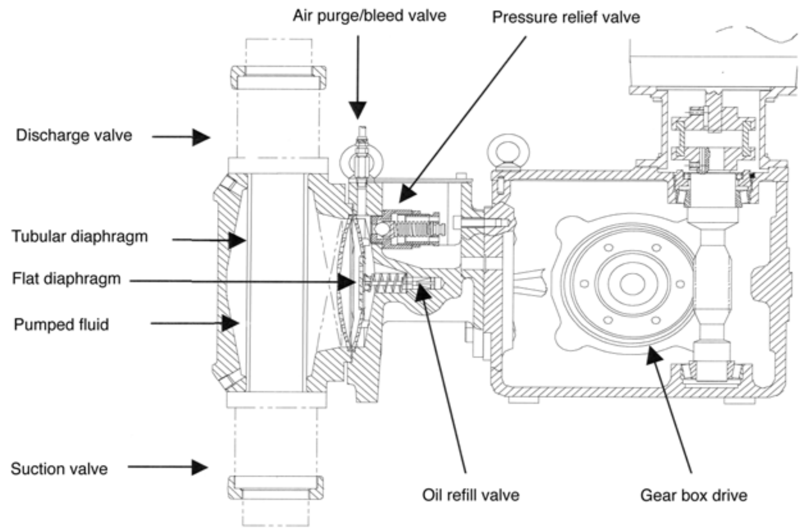


Figure 7.1.2.5 — Hydraulic tubular diaphragm

7.1.2.6 Hydraulic coupled conical diaphragm

A hydraulic coupled conical diaphragm liquid end (see Figure 7.1.2.6) contains a flexible conical diaphragm, clamped at the periphery, that is in direct contact with the process liquid being displaced. This type of liquid end design is inherently leak free. The diaphragm material is an elastomer. In operation, the plunger moves away from the wet end and process liquid is admitted through the suction check valve. As the plunger moves towards the wet end, the discharge check valve opens, allowing the process liquid to discharge and the conical diaphragm expands, storing elastomeric energy to return it to its original position.

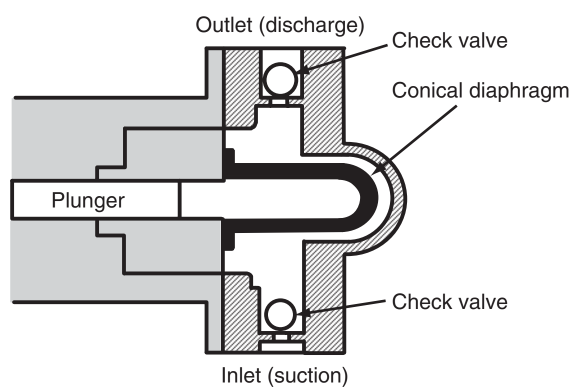


Figure 7.1.2.6 — Hydraulic conical diaphragm

7.1.3 Drive and control mechanisms

The drive and control mechanism is typically located between the driver and the liquid end. Its purpose is to create reciprocating motion of a piston, plunger, or push rod at a controlled frequency (stroke rate). As a controlled-volume metering pump, its secondary purpose is to allow controlled variation of the stroke length by means of its inherent stroke adjustment control mechanism (except in the case of the fixed stroke-length design, see Section 7.1.3.3).

7.1.3.1 Electromagnetic drive (solenoid)

The electromagnetic drive (see Figure 7.1.3.1) employs an electromagnet that, when pulsed, generates a linear motion transmitted to the liquid end. Each pulse results in one discharge stroke of the pump. The flow is controlled by changing the rate of pulses to the electromagnet and/or by varying the stroke length. These pumps can be run indefinitely in the stalled condition without damage to the pump or most systems. Typically used in lower flow and lower pressure applications. This type of design is inherently leak free.

7.1.3.2 Reciprocating air drive

A reciprocating air drive (Figure 7.1.3.2) uses an air cylinder to transmit linear motion to the liquid end. The flow is controlled by changing the pulse rate of the air entering and leaving the cylinder, changing the displacement by adjusting a physical stop, or by changing the rate of flow of air supplied to the air cylinder. These drives can be run indefinitely in the stalled condition without damage to the pump or pumping system. Most designs can be powered by air or other gases.

7.1.3.3 Fixed stroke-length drives

The stroke length is constant in a fixed stroke-length drive (see Figure 7.1.3.3). The stroking speed is changed to vary the flow. As the velocity and acceleration of the mechanisms used are typically sinusodal (see Figure 7.3.1b), the resulting velocity and acceleration of the process liquid is also sinusodal. Unlike the lost-motion drives, volume per stroke remains constant and flow rate is changed by speed adjustment.

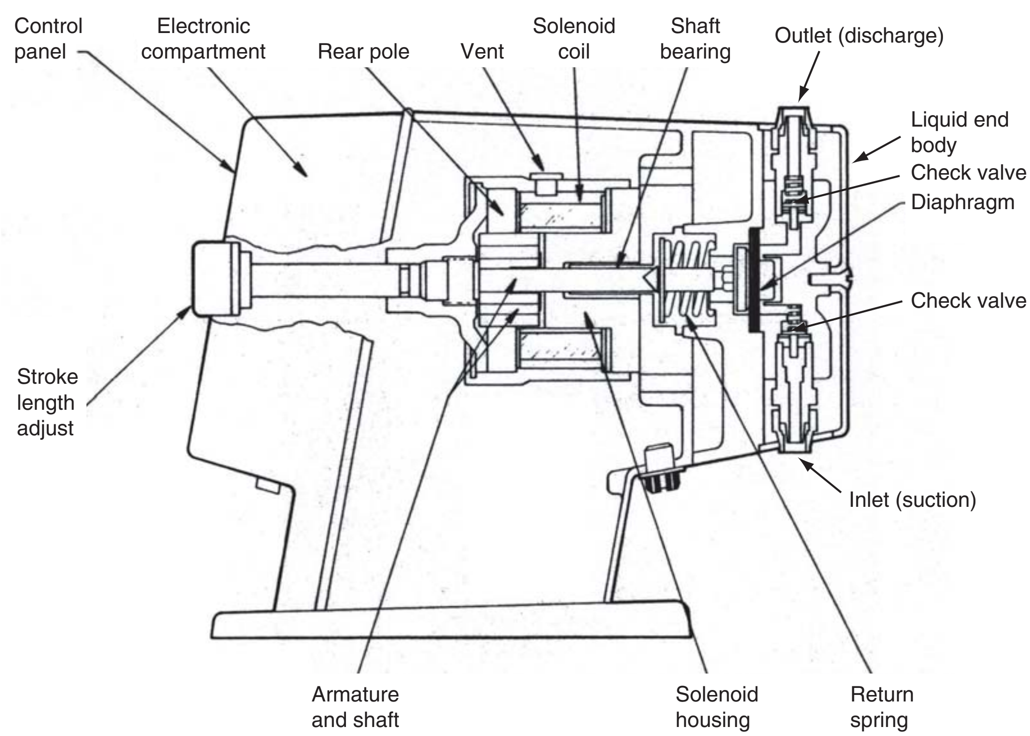


Figure 7.1.3.1 — Electromagnetic drive

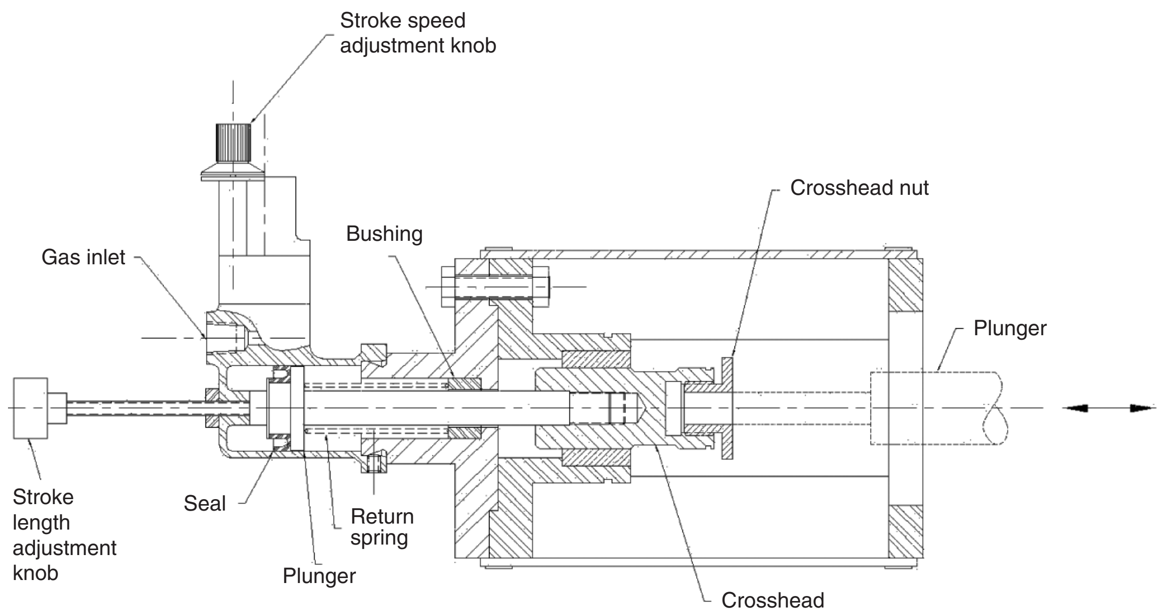


Figure 7.1.3.2 — Reciprocating air drive

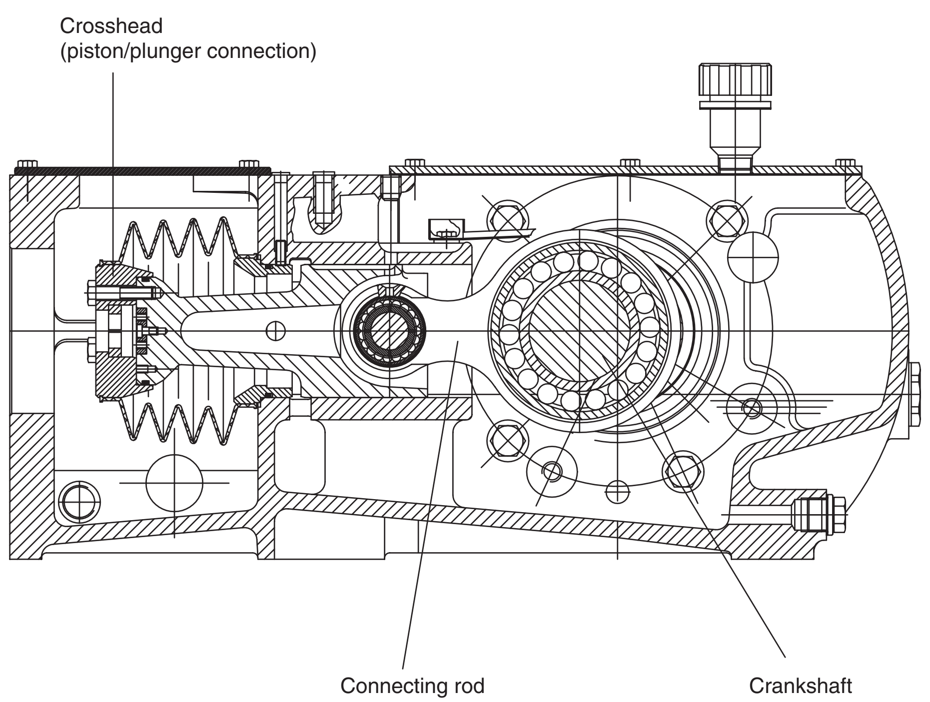


Figure 7.1.3.3 — Fixed stroke-length drive

7.1.3.4 Mechanical lost-motion drives

Mechanical lost-motion drives (Figure 7.1.3.4) have adjustable mechanical stops limiting the stroke length of the piston, plunger, or push rod to some portion of the total stroke. Rate of flow is controlled by the adjustment of the stop. These pumps are normally used at lower rates of flow. Figure 7.1.2.3 also illustrates the construction of a mechanical lost-motion drive in conjunction with a mechanically coupled diaphragm liquid end.

7.1.3.5 Hydraulic lost-motion drives

A hydraulic lost-motion drive (see Figure 7.1.3.5) uses a constant mechanical stroke length to pump hydraulic fluid to actuate a diaphragm. To adjust the rate of flow, a portion of the hydraulic fluid is bypassed so it imparts less motion to the diaphragm. These pumps are typically used at lower rates of flow.

7.1.3.6 Variable stroke-length drive mechanisms (non-lost-motion drive)

For typical design configurations, the effective radius of the crank arm is adjustable, varying the stroke length of the piston. The velocity and acceleration of the flow remains sinusoidal, but the volume per stroke can be reduced throughout the adjustment range. Sinusoidal output is similar to fixed stroke-length drives except that there is a mechanical means to change the effective stroke length, which changes the volume per stroke. Therefore, these non-lost-motion drives (see Figure 7.1.3.6) tend to be used in higher flow applications or when long pipe runs are required.

7.1.4 Nomenclature

The nomenclature and definitions in these standards were prepared to provide a means for identifying the various pump components covered by these standards and to serve as a common language for all who deal with this type of equipment.

7.1.4.1 Automatically controlled

The mechanism for varying the pump rate of flow is controlled by an external electronic or pneumatic signal. The external signal may control the stroke length and/or input speed to the pump.

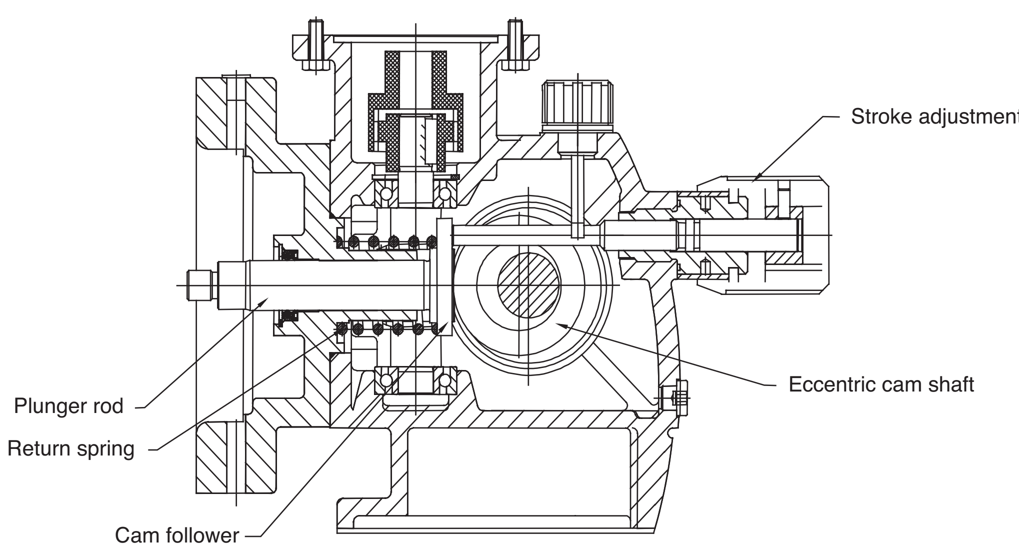


Figure 7.1.3.4 — Mechanical lost-motion drive

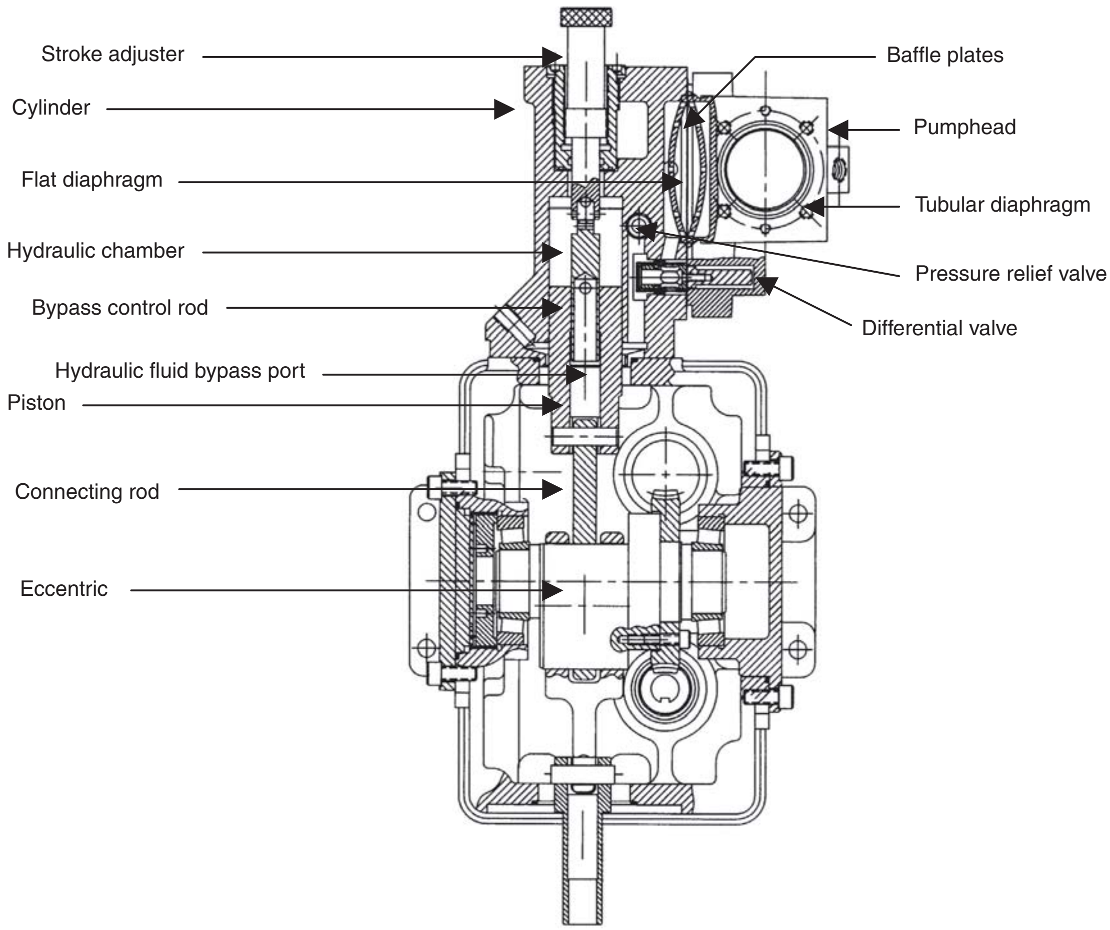


Figure 7.1.3.5 — Hydraulic lost-motion drive

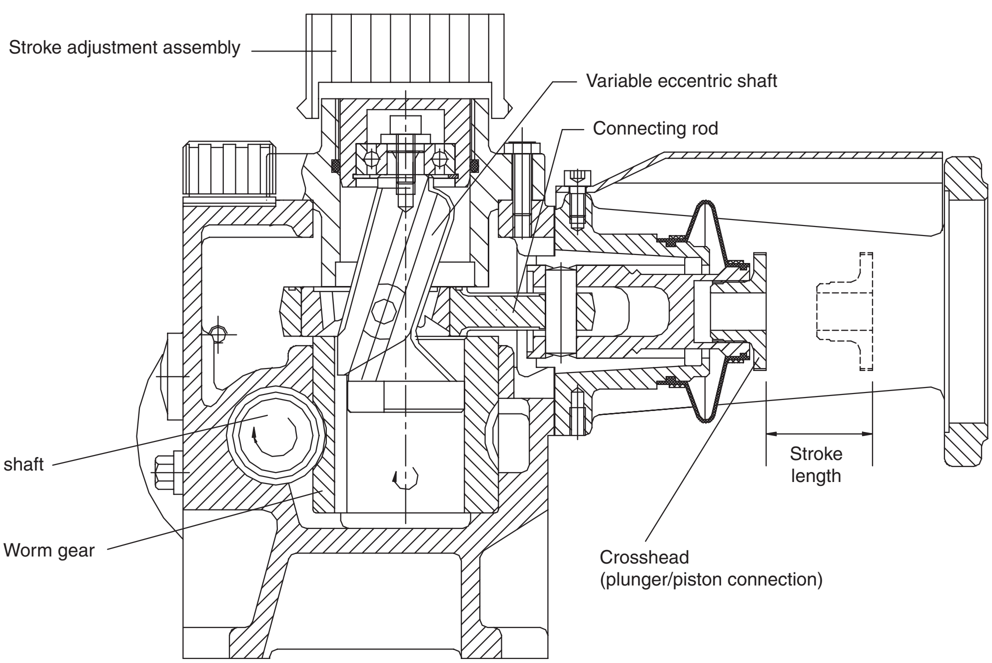


Figure 7.1.3.6 — Variable stroke-length drive (non-lost-motion)

7.1.4.2 Check valves

A controlled-volume pump uses suction and discharge check valves to produce directional flow of process liquid in the liquid head assembly. Various configurations of check valves are available for specific applications.

7.1.4.3 Diaphragm hydraulic system

Hydraulically actuated diaphragm pumps require hydraulic valves for proper operation. These valves are used to relieve, replenish, and/or bleed the hydraulic systems.

7.1.4.4 Diaphragm leak detection

Diaphragm leak detection systems are sensing systems that detect if a diaphragm has been compromised. These systems may detect reactions in barrier fluid, mechanical degradation of a diaphragm, changes in pressure/vacuum between diaphragms, or direct leakage of the process liquid by external means.

7.1.4.5 Diaphragms

Diaphragms provide isolation of the various liquids encountered in a diaphragm pump. Materials of construction shall be compatible with the specified process fluid and of a pre-determined thickness to resist degradation or permeation. Many diaphragm materials and configurations exist, but all perform the same basic function.

7.1.4.6 Liquid end assembly

The pump liquid end assembly (also called the *reagent head assembly* or *wet end*) includes all parts that contain the liquid being pumped.

7.1.4.7 Manually controlled

The mechanism for varying the pump rate of flow is manually adjusted.

7.1.4.8 Multiple diaphragm

A multiple diaphragm design uses two or more diaphragms operating in unison to provide secondary process liquid isolation. The diaphragms may be of similar or different design but must be synchronized to provide proper accuracy.

7.1.4.9 Simplex pump

Simplex pumps consist of a single liquid end and a single driver.

7.1.4.10 Multiplex pump

Multiplex pumps contain two or more liquid ends with the same or different capacities, powered by the same driver.

7.1.4.11 Remotely mounted liquid end

Most applications use liquid ends mounted directly to the drive mechanism. However, for extreme temperature services or a highly contaminating or explosive process, remotely mounted liquid heads may be specified to isolate the drive and/or control mechanisms.

7.2 Definitions

The purpose of this section is to define terms used in pump specification and applications. Symbols, terms, and units are shown in Tables 7.0.3a and 7.0.3b.

7.2.1 Accuracy and performance

The compound definition of metering performance, composed of steady state accuracy, linearity, and repeatability.

7.2.2 Accuracy, steady state

Steady state accuracy is the variation in rate of flow over a specified period of time, under fixed pump and system conditions, expressed as a percent of the maximum calibrated rate of flow. Steady state accuracy applies over a defined turndown ratio.

7.2.3 Capacity, rate of flow

7.2.3.1 Capacity, adjustment

The rate of flow produced by a reciprocating, controlled-volume metering pump may be controlled by varying stroke length (displacement per stroke) and/or the stroke speed (reciprocation rate or frequency).

7.2.3.2 Rate of flow (capacity) (Q)

The rate of flow of a pump is the total volume throughput per unit of time at suction conditions. It assumes no entrained gases at the stated operating conditions.

7.2.3.3 Design rate of flow (capacity) (Q_D)

The design quantity of liquid delivered per unit of time at the maximum capacity settings and a given set of operating conditions specified by the manufacturer.

7.2.3.4 Actual rate of flow (capacity) (Q_A)

The actual quantity of liquid delivered under installed conditions.

7.2.4 Displacement per stroke (D)

The volume swept by all pistons, plungers, or diaphragms in one stroke.

(metric) $$D = \frac{AL_m M}{10}$$

(US customary units) $$D = AL_m M$$

Where:

D = pump displacement, in cm^3 ($in.^3$)

A = area of piston/plunger, in cm^2 ($in.^2$)

L_m = stroke length, in mm (in.)

M = number of pistons or plungers

NOTE: The actual area for a diaphragm will vary based on design and construction but will be less than the area calculated based on the outer diameter of the diaphragm. This equation assumes identical area and stroke length. Multiplexed pump heads may vary in area and stroke length.

7.2.5 Efficiency, mechanical

The ratio of the pump power output to the pump power input, expressed as a percentage.

7.2.6 Efficiency, volumetric

The ratio of the actual pump delivery per stroke to theoretical displacement, expressed as a percentage.

7.2.7 Linearity

Linearity is an expression of maximum deviation (plus or minus) of a series of measured rates of flow versus capacity setting points to corresponding points on a theoretical straight line drawn through the points on a graph. The straight line is determined by the “least squares fit” method, applied to the measured points, obtained during a pump calibration test. Linearity is expressed as percentage of maximum calibrated rate of flow. See Figure 7.3.1c.

7.2.8 Net positive inlet pressure (NPIP)/Net positive suction head (NPSH)

7.2.8.1 Net positive inlet pressure available (NPIPA)/Net positive suction head available (NPSHA)

NPIPA is the total absolute suction pressure available from the system, determined at the pump inlet (suction) port, less the absolute vapor pressure of the liquid at pumping temperature.

$$NPIPA = p_{sTa} - p_{vp}\text{, in kPa (psi)}$$

Where p_{sTa} is the absolute total pressure at the pump inlet (suction) port.

NPSHA is the same concept expressed in units of meters (feet) of process fluid.

7.2.8.2 Net positive inlet pressure required (NPIPR)/Net positive suction head required (NPSHR)

NPIPR is the amount of net suction pressure (NPIP) required by the pump to obtain satisfactory volumetric efficiency and minimize the effects of cavitation. This is commonly established as the NPIP corresponding to a reduction in flow rate (capacity) of no more than 3%.

The pump manufacturer determines by test the net positive inlet pressure required by the pump at the specified operating conditions. NPIPR does not include system acceleration pressure, which is a system-related factor which may significantly affect dynamic pressures at the pump suction and discharge, as explained in Section 7.2.9 of this standard.

NPSHR is the same concept expressed in units of meters (feet) of process fluid.

To convert from NPSHA to NPIPA:

$$\text{NPIPA (kPa)} = \text{NPSHA (m head)} \cdot \left(\frac{9.804\text{ kPa}}{1\text{ m head}}\right) \cdot s$$

$$\text{NPIPA (psi)} = \text{NPSHA (ft head)} \cdot \left(\frac{0.4335\text{ psi}}{1\text{ ft head}}\right) \cdot s$$

Where:

s = specific gravity of liquid

7.2.9 Head, acceleration/pressure, acceleration

Acceleration head is a system phenomenon associated with reciprocating type metering pumps, due to the acceleration and deceleration of the liquid in the suction piping of these types of pumps. Due to the pulsating nature of metering pump flow, peak flow rates are about three times greater than the average flow. These peak rates add to the pressure in the discharge piping and subtract from the pressure in the suction piping.

Acceleration head is often thought of as being a loss, and it is treated as such when calculating NPSHA; but the pressure drop caused by the acceleration is offset by the increase in pressure when the liquid decelerates. Therefore, the average pressure in the suction line is calculated without consideration of acceleration head.

With higher pump speeds or with relatively long suction lines, the acceleration head must be considered if the pump is to fill properly without cavitation, pounding, or vibration of the suction line. If there is insufficient suction head to meet the minimum acceleration requirement of NPIP/NPSH, then the pump may experience cavitation resulting in a loss of volumetric efficiency.

The low speeds of metering pumps normally keep acceleration head low enough for satisfactory operation. However, it is desirable to perform an acceleration head calculation to ensure proper pump operation is obtained.

The head required to accelerate the liquid column is a function of the length of the suction line, the average velocity in this line, the pump speed, pump type, and the relative elasticity of the liquid and pipe and may be calculated as follows:

$$h_{acc} = \frac{l \cdot v \cdot n \cdot C}{K \cdot \mathrm{g}} \text{ (Generic form)}$$

$$p_{acc} = \frac{l \cdot v \cdot n \cdot C \cdot s}{0.102 \cdot K \cdot \mathrm{g}} \text{ (Metric units)}$$

$$p_{acc} = \frac{l \cdot v \cdot n \cdot C \cdot s}{2.31 \cdot K \cdot \mathrm{g}} \text{ (US customary units)}$$

Where:

h_{acc} = Acceleration head, in m (ft) of process fluid

p_{acc} = Acceleration pressure, in kilopascals (pounds per square inch)

l = Length of suction line, in m (ft)

v = Velocity in suction line, in m/s (ft/s)

n = Speed of pump crankshaft, in rpm

s = Specific gravity (dimensionless)

C = Constant depending on pump type

= 0.400 for single-acting simplex

= 0.200 for single-acting duplex

= 0.115 for double-acting duplex

= 0.066 for triplex

= 0.040 for quintuplex

= 0.028 for septuplex

g = Gravitational constant, 9.81 m/s^2 (32.2 ft/s^2)

K = constant depending on fluid compressibility

= 1.4 for noncompressible liquids such as deaerated water

= 1.5 for most liquids

= 2.5 for compressible liquids (such as ethane)

NOTE: This calculation provides a conservative estimate of acceleration head losses in piping lengths up to 15 m (50 ft).

7.2.10 Power, pump input

The mechanical power delivered to the pump input shaft at the specified operating conditions. Input power required is a function of the calculated pump output power and the manufacturer's stated efficiency.

7.2.11 Power, pump output power (hydraulic horsepower)

The hydraulic power imparted to the liquid by the pump at the specified operating conditions.

7.2.12 Pressures

Pressure is the force that the liquid exerts per unit area.

7.2.12.1 Atmospheric pressure (p_{amb})

The absolute pressure exerted by the weight of the air above it at any point on the earth's surface. It is also commonly referred to as barometric pressure.

7.2.12.2 Gauge pressure (p_g)

The pressure relative to atmospheric pressure. Its value is:

- Positive if this pressure is greater than atmospheric pressure
- Negative if this pressure is less than atmospheric pressure

7.2.12.3 Vapor pressure (p_{vp})

The pressure exerted when a solid or liquid is in equilibrium with its own vapor. The vapor pressure is a function of the substance and the temperature.

7.2.12.4 Absolute pressure (p_a)

Absolute pressure, which is defined as the sum of the gauge pressure and atmospheric pressure.

7.2.12.5 Total pressure (p_T)

$$p_T = p_v + p_z + p$$

The total pressure quantifies the total energy of the fluid in terms of pressure. The total pressure is the sum of the velocity pressure, elevation pressure and pressure.

7.2.12.5.1 Velocity pressure (p_V)

The kinetic energy of the liquid flow expressed in equivalent pressure. It is determined as follows:

$$p_v = \frac{v^2 \cdot \rho}{2} \quad \text{(Generic form)}$$

Where:

v is velocity

ρ is fluid density

$$p_v = \frac{v^2 \cdot s}{2} \quad \text{(Metric units)}$$

Where:

p_v is in kPa

v is in m/s

s is the unitless specific gravity

$$p_v = \frac{v^2 \cdot s}{149} \quad \text{(US customary units)}$$

Where:

p_v is in psi

v is in ft/s

s is the unitless specific gravity

7.2.12.5.2 Elevation pressure (p_z)

The potential energy of the liquid due to a difference in elevation between the liquid and the centerline of the pump inlet, expressed in terms of equivalent pressure. It is determined as follows:

$$p_z = z \cdot \rho \cdot g \quad \text{(Generic form)}$$

Where:

z is vertical distance

ρ is fluid density

g is gravitational acceleration

$$p_z = \frac{z \cdot s}{0.102} \quad \text{(Metric units)}$$

Where:

p_z is in kPa

z is in m

s is unitless specific gravity of fluid

$$p_z = \frac{z \cdot s}{2.31} \text{ (US customary units)}$$

p_z is in psi

z is in ft

s is unitless specific gravity of fluid

7.2.12.6 Pressure, differential

The difference between discharge pressure and suction pressure at a given operating condition.

7.2.12.7 Pressure, discharge (p_d)

The gauge pressure of the liquid at the centerline of the pump discharge port.

The liquid pressure at the pump discharge port.

7.2.12.8 Pressure, discharge, maximum allowable

The maximum allowable gauge pressure at the pump discharge that will not result in damage to the pump during operation as specified by the manufacturer.

7.2.12.9 Pressure, friction loss (p_f)

The loss of pressure energy in a liquid due to friction as it flows through pipe, fittings, instrumentation, and equipment.

7.2.12.10 Pressure, suction (p_s)

The gauge pressure of the liquid at the centerline of the pump suction port.

7.2.12.11 Pressure, suction, maximum allowable ($p_{s\ max}$)

The maximum continuous suction pressure for which the manufacturer designed the pump at a given set of operating conditions specified by the manufacturer.

7.2.12.12 Pressure, suction, minimum allowable ($p_{s\ min}$)

The minimum allowable pressure in absolute units at the pump inlet. This is governed by hydraulic considerations of the refill valve and is usually applicable to hydraulically actuated diaphragm-type pumps. It is determined by the pump manufacturer.

7.2.12.13 Pressure, total system discharge

The pressure the pump must generate to overcome system conditions. It is the sum of injection point pressure: the system pressure present at the pump discharge, including the static head pressure resulting from discharge elevation, pipeline and component friction losses, and liquid acceleration losses.

7.2.13 Repeatability

Flow repeatability is rate of flow variation, expressed as a percent of maximum calibrated rate of flow, resulting from an excursion from a rate of flow set point followed by a return to that set point.

7.2.14 Slip (S)

Slip of a reciprocating pump is the loss of flow rate, expressed as a fraction or percent of displacement, due to leaks past the valves (including backflow through the valves caused by delayed closing) and past double-acting pistons. Slip does not include liquid compressibility or leaks from the liquid end.

7.2.15 Stroke length (L_m)

The length of complete movement of a piston, plunger, or mechanical diaphragm in one direction. Stroke length is typically expressed in millimeters (inches).

7.2.16 Stroke speed (n)

The number of strokes per unit of time. Stroke speed is typically expressed in strokes per minute (spm) or revolutions per minute (rpm).

7.2.17 Stroke speed, maximum allowable

The highest stroke speed at which the manufacturer's design will permit accurate metering under a given set of operating conditions.

7.2.18 Stroke speed, minimum allowable

The lowest stroke speed at which the manufacturer's design will permit accurate metering under a given set of operating conditions.

7.2.19 Suction lift, static

Under suction lift conditions, the pressure at the inlet of the pump is less than 1 atmosphere while the liquid is at rest. Suction lift may be thought of as "negative" static suction head.

7.2.20 Suction lift, total

The difference between the absolute operating inlet pressure at the pump inlet port centerline and atmospheric pressure. It is the sum of suction system frictional losses and the static suction lift.

7.2.21 Temperature, maximum rated (t_{max})

The maximum continuous temperature for which the manufacturer has designed the equipment when handling the specified liquid at the specified pressure.

7.2.22 Temperature, minimum rated (t_{min})

The minimum continuous temperature for which the manufacturer has designed the equipment when handling the specified liquid at the specified pressure.

7.2.23 Turndown ratio

Turndown ratio is the maximum rate of flow divided by the minimum rate of flow that can be obtained while maintaining the specified steady state accuracy, linearity, and repeatability.

7.2.24 Specific gravity (*s*)

Specific Gravity is the ratio of density of a liquid relative to the density of water. The reference density for liquid used in Hydraulic Institute Standards is based on water at 20 °C (68 °F), which is 998.2 kg/m^3 (62.31 lb^m/ft^3).

7.3 Design and application

7.3.1 Typical uses and industries

Controlled-volume metering pumps are used in many industrial, commercial, and municipal applications. They are used where the process requirements and/or cost of the chemical additives dictate accuracy, consistency, and repeatability. In general, most applications can be categorized as one of the following:

- Single-point injection, used for:

  Examples: pH adjustment; boiler feed treatment; process additive injection

- Controlled transfer, used for:

  Examples: reactor feed; point-to-point transfer; filling operations

- Multistream proportioning, blending and mixing, used for:

  Examples: resin blending; mayonnaise production; continuous dye addition

The controlled-volume metering pumps are used in a wide range of industries, including the following:

- Agriculture
- Boiler and cooling water treatment
- Chemical and petrochemical processing
- Food and beverage processing
- Gas odorization
- Heating, ventilation, and air conditioning (HVAC)
- Mining and ore extraction
- Oil and gas production and transmission
- Personal care products
- Pharmaceuticals
- Plastics and foam production
- Potable water treatment
- Power generation
- Pulp and paper
- Refining
- Soap and detergent

- Textiles
- Wastewater treatment

7.3.2 General principles

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

Rate of flow = Displacement × Cycles per unit of time × Volumetric efficiency

Figure 7.3.1a illustrates how the rate of flow from a reciprocating, controlled-volume metering pump is minimally affected by changes in discharge pressure.

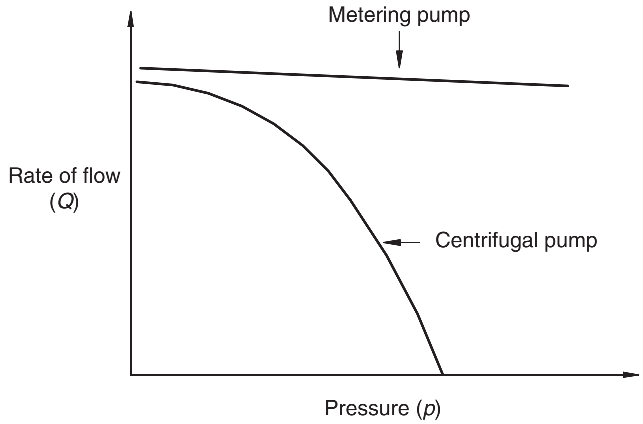


Figure 7.3.1a — Rate of flow versus pressure

Figure 7.3.1b illustrates how the average flow from a reciprocating controlled-volume metering pump is determined over several complete cycles.

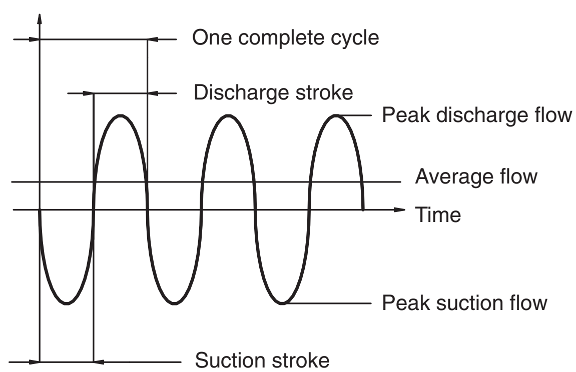


Figure 7.3.1b — Flow profile for reciprocating pump

Figure 7.3.1c shows rate of flow versus stroke-length setting for a controlled-volume metering pump at a given pressure and stroking speed. The curve is linear. The curve is not necessarily proportional in that 50% stroke setting may not equal 50% flow. This is because the curve may not pass through zero on both axes simultaneously. By measuring flow at two rate-of-flow settings, plotting both points, and drawing a straight line through them, other rates of flow versus stroke length settings can be accurately predicted.

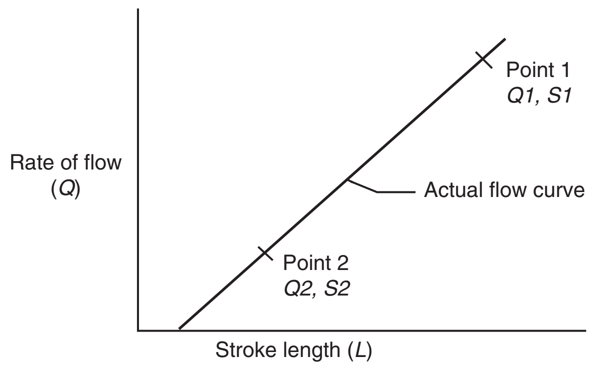


Figure 7.3.1c — Actual flow curve, rate of flow versus stroke length

Figure 7.3.1d illustrates the relationship between the theoretical and actual rate of flow of a controlled-volume metering pump. The difference between the theoretical and actual curves represents the volumetric efficiency (*VE*) as defined in Section 7.2.6.

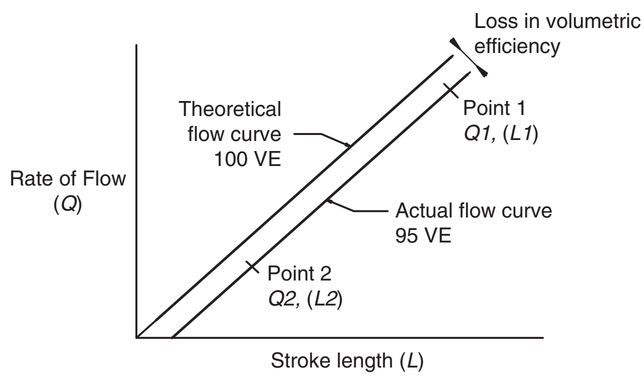


Figure 7.3.1d — Theoretical and actual flow curve, rate of flow versus stroke length

7.3.3 Sizing and selection

The manufacturer requires the following information to ensure the proper selection and operation of the controlled-volume metering pump.

7.3.3.1 Application data requirements

To begin the process of selecting the appropriate pump and its configuration, the end user must furnish detailed information regarding its process requirements, such as:

- Minimum, maximum, and normal operating rate of flow
- Minimum, maximum, and normal operating temperature
- Minimum, maximum, and normal operating suction pressure
- Minimum, maximum, and normal operating discharge pressure
- Material compatibility at process conditions
- Required accuracy and performance

- Basic liquid properties at operating conditions (viscosity, vapor pressure, solids characteristics, temperature, specific gravity)
- Special liquid properties (toxicity, flammability, reactivity, rheology)
- Utilities available, operational environment, and area classification
- Type of pump (refer to Section 7.1)
- Type of driver
- System control requirements
- System piping configuration and requirements

The criteria listed above is required by the manufacturer to select a pump that best meets the end user's needs.

7.3.3.2 Rate of flow and turndown

Controlled-volume metering pumps with stroke-length adjustment typically have a rate-of-flow (capacity) adjustment range between 10 and 100% of rated flow, expressed as a turndown ratio of 10:1. Below the stated turndown, accuracy cannot be guaranteed. The pump should be sized such that the entire flow range falls between 10 and 100% of the pump rate of flow.

Controlled-volume metering pumps may also use stroke frequency adjustment with turndown ratio dependent on the stroking speed of the pump and turndown capability of the driver.

Greater turndown range can be achieved in some applications by using both stroke-length adjustment and driver speed control when maximum rate of flow is greater than 10 times minimum flow. Extended turndown range must be confirmed with the pump manufacturer.

For optimal performance and most economical operation, a pump should be sized to operate at the top 30% of its rated flow rate. Operation in this range promotes the highest accuracy.

7.3.3.3 Materials of construction

The materials used in the construction of a controlled-volume metering pump must be compatible with the liquid being pumped. This includes all wetted components of the liquid end, such as seals, gaskets, diaphragms, and elastomers. The effects of corrosion, erosion, and reactivity at operating conditions must be considered when selecting or specifying equipment.

7.3.3.4 Environment

Special protection or material may be required if the pump is exposed to temperature extremes, high humidity, high salt content, or ultraviolet light (sun). Corrosive atmospheres may indicate a need for a special finish or coating. The purchaser/end user must know the area classification of the intended installation. Hazardous environments, including fumes or combustible dust, will affect pump, driver, accessory, and control configuration.

7.3.3.5 Choice of driver

The purchaser/end user may select electric motor, air/pneumatic or gas motor, or internal combustion engine, etc., depending on the application, the utilities available, and environmental concerns.

7.3.3.6 Control methods

- Manual adjustment of speed and/or stroke length
- Automatic adjustment of stroke length by electronic or pneumatic input signal
- Automatic adjustment of stroke speed by use of variable-speed drive, variable air pressure, or other means

7.3.3.7 Optional pump features

Accessory options are available for special applications, including, but not limited to:

- Gas vent valves to purge the liquid head when handling chemicals that off-gas
- Double diaphragms with leak detection systems; used where contamination of the process liquid must be prevented or when pumping hazardous or toxic chemicals and even the remote chance of leakage must be prevented
- Impulse/stroke counters
- Pressure and temperature sensors

7.3.4 System components

After pump selection, the balance of the installation must be defined. Plan the entire installation from the supply tank to the injection point and consider the necessary accessories. The manufacturers have experience in selecting and sizing the components associated with metering pump installations and can assist with selection of these components.

7.3.4.1 Suction piping

Suction pipe systems must be designed to satisfy the NPIP (NPSH) requirements of the pump. As a general rule, the pump should be located as close to the liquid supply as possible. An inlet stabilizer or standpipe may be mounted in the suction line, near the pump, to improve the suction inlet condition to the pump (i.e., increase NPIPA [NPSHA]). See ANSI/HI 7.8 *Controlled Volume Metering Pump Piping Guideline* for more detailed information on metering pump piping and system accessories.

- When appropriate, a “Y” strainer or similar device should be installed in the suction line to prevent particles from clogging the pump check valves
- A volumetric flow calibration column with isolation and vent valves installed in the suction line, near the pump, will provide a means to verify pump output under actual operating conditions
- As an option, a flush line can be added to facilitate cleaning

7.3.4.2 Discharge piping

Discharge piping systems must be designed to accommodate peak flow and pressure conditions. System components typically used in discharge line design include:

- Safety relief valve – to protect pump, piping, and components.
- Backpressure valve – to provide necessary pressure to ensure proper pump check valve operation and to prevent siphoning when pumping to a low discharge pressure or when the differential between suction and discharge pressure is not sufficient.
- Pulsation dampener – to minimize flow and pressure variations in the discharge piping, if required.

- Pressure gauge and snubbers (or diaphragm seal for viscous, corrosive chemicals or slurries) to monitor the pump operation. Gauge block and test valves may or may not be desirable depending on application. A gauge test valve may also be used as a vent for ease of start-up.
- Injection check valve – installed at the injection point provides separation of the chemical and the fluid into which the chemical is injected. Addition of an injection quill at the injection point aids in more rapidly dispersing the injected chemical into a process stream.
- Other valves to consider – priming, isolating, draining, sampling, and flushing.

7.4 Installation, operation, and maintenance

With proper installation, care, and regular maintenance, controlled-volume metering pumps will operate satisfactorily for many years. The following paragraphs discuss the general principles that must be considered to ensure trouble-free operation.

Controlled-volume metering pumps are built in a wide variety of designs for many different services. The manufacturer's instruction book furnished with each pump should be carefully studied and followed as there may be specific requirements of a particular application that cannot be covered in a general discussion.

7.4.1 Safety

The following precautions should be taken when working with controlled-volume metering pumps to ensure safety of personnel:

- Follow all safety requirements per operating instructions, codes, and regulations.
- Electrical power should be turned off. All valves to liquid end should be closed and the liquid end drained.

CAUTION: Care should be taken to dispose of toxic or flammable liquids or vapors properly.

- The work area should be kept clear and all unnecessary items removed.
- All lifting devices should be checked for condition and weight limits before using.
- Before dismantling, assembling, or performing maintenance on the pump, the proper tools, correct parts, and manufacturer's instruction book shall be reviewed and available for consultation.
- Eye protection and appropriate protective gear must be worn.

7.4.2 Storage

All controlled-volume metering pumps are inspected and protected against corrosion for the period of shipment and installation only.

If the pump is not to be installed at once, then the pump and parts, such as packing, special wrenches, etc., should be stored in a clean, dry location, free from temperature extremes, in an approximately level position. Coat all machined surfaces with heavy, noncorrosive preservative. Inspect frequently to see that the surfaces are free of corrosion. Renew the preservative when necessary. Before putting unit into operation, inspect and clean thoroughly.

When it is known that a pump will be in storage or taken out of service for more than three months, such as for a relocation, plant shutdown, etc., follow manufacturer's instructions. Inspect periodically for possible leakage. In severe storage conditions, such as salt-laden marine environments or subfreezing temperatures, consult the manufacturer for a recommendation or for additional procedures.

7.4.3 Location of pump

Locate the pump as close to the liquid supply as possible. The location should be clean, protected from seepage or flood, and have adequate clearance to facilitate any repair, maintenance, or inspection activity.

7.4.4 Foundation

Depending on size and weight, controlled-volume pumps can be located on the floor or supporting structure. The purchaser/end user should consider ease of access for maintenance and the recommendations of the manufacturer.

7.4.5 Installation

Most pumps are aligned with the driver before leaving the factory. It is important the entire pump be properly supported and leveled. Use care not to spring the pump out of alignment when fastening it to the foundation. Alignment must be rechecked after piping has been completely installed.

7.4.5.1 Piping

Pipes must line up naturally. They must not be pulled into place with flange bolts, as this may force the pump out of alignment. Pipes should be supported independently of the pump so as to produce minimum strain on the pump.

7.4.5.2 Forces and moments

The most desirable arrangement is one in which suction and discharge piping line up naturally with the respective pump connections. When this is done, no force or moment is exerted on the pump that could result in stresses in the pump or its foundation. Thermal expansion, when handling hot or cold liquids, must also be considered. When the piping tends to expand or contract, it exerts a force and often a twist (torque or moment) on the point of restraint, such as the pump piping connection. Pipe strains are a common cause of process leakage, misalignment, hot bearings, worn couplings, and vibration. When requested by the purchaser/end user, the pump manufacturer shall advise the maximum allowable forces and moments that may be applied to the pump connections.

Variations in flow and pressure, changes in direction of flow, cavitation, worn pistons, pump valves, etc., all contribute to piping vibration. Therefore, suction and discharge piping must be adequately fixed and not just lightly strapped down. Flush, clean, and blow out all piping before connecting to the pump. Use thread sealant and tape sparingly on male threads only.

7.4.5.3 Flanges and fittings

Flange fittings, unions, and flexible connectors should be located close to the pump in all pipelines, so as to facilitate removal of the pump. Alignment must be rechecked after suction and discharge piping have been bolted to the pump for testing the effect of piping strains. When handling hot or extremely cold liquids, disconnect the nozzle flanges after the unit has been in service to check the direction in which the piping expansion is acting. Correct for strain effect as required to obtain true flange alignment.

7.4.5.4 Priming

Controlled-volume metering pumps operating with a flooded suction will typically self-prime. Under suction-lift conditions, controlled-volume metering pumps are not necessarily self-priming and must be purged or may require a foot valve installed at the base of the suction pipe. Providing a vent port in the discharge piping makes some pumps self-priming at a reasonable suction lift. Other suction-lift installations may require priming by filling the pumphead chamber and suction pipe with liquid.

7.4.5.5 Safety relief valve

A safety relief valve should be installed in the discharge piping of a controlled-volume metering pump to protect the pump and system piping from overpressure. Pressure relief valve installation should be in accordance with local end user requirements or applicable code.

The final set pressure must be below the lowest rated working pressure component in the discharge system. The relief valve must be set sufficiently above the operating discharge pressure to prevent opening due to the discharge pressure peak. This causes decreased output rate of flow from the pump and diminished relief valve life.

NOTE: Hydraulically coupled diaphragm pumps are provided with internal hydraulic relief valves. These valves are designed to protect the pump drive mechanism and driver only. Do not use this internal valve for system protection.

7.4.5.6 Drive alignment after piping installation

After the piping has been installed, the pump and driver alignment should be checked again and corrected as required.

7.4.5.7 Gaskets, thread sealant, and pipe tape

The gaskets, thread sealant, and pipe tape used in the system piping are exposed to the same conditions of high or low temperatures, pH values, etc., as the pump wetted parts. Careful selection is necessary to avoid joint failure and the air and liquid leaks that follow.

CAUTION: Care must be taken to prevent any of these materials from contaminating the suction line, and fouling the pump check valves.

7.4.5.8 Flexible coupling

Controlled-volume metering pumps may use high-speed/low-torque or low-speed/high-torque flexible couplings. Proper alignment of coupling and driver is critical for satisfactory operation. Consult and follow the manufacturer's recommendations.

7.4.5.9 Lubrication

The power ends of controlled-volume metering pumps may use pressure, splash, or gravity lubrication. Grease-fed lubrication is also used. It is very important that the manufacturer's specific instructions or nameplate data be carefully followed as to choice of oil and the frequency of lubricant changes. The oil must be checked periodically for contamination.

7.4.6 Inspection

The pump should be inspected regularly. Leaky valves should be corrected as soon as they are discovered. Most pump troubles can be traced to worn valves, packing, rods, plungers, or bushings; grooved liners; improper suction conditions; or to faulty conditions outside the pump itself. There is no substitute for regular, thorough preventive maintenance.

7.5 Troubleshooting

Table 7.5 provides guidelines for troubleshooting some of the most common conditions encountered in controlled-volume metering pump installations.

Table 7.5 — Locating trouble: controlled-volume metering pumps

Trouble	Possible Cause	Remedy
Pump rate of flow too low or no flow	Liquid end air-bound	Vent liquid cylinder and/or diaphragm chamber.
	Hydraulically coupled system vapor-bound	Allow pump to operate at low pressure through bypass valve to eliminate vapor.
	Dirty or worn check valves	Clean or replace check valve balls (or poppet parts) and seats.
	Restricted or clogged discharge/suction line	Clean suction strainer. Blow down discharge/suction line. If suction trouble occurs often, use larger size strainer.
	Excessive suction lift	Decrease suction lift condition.
	Insufficient suction head	Increase suction pipe diameter and/or decrease length. Check NPIPA calculation. Consider use of suction stabilizer if necessary.
	Leaking pressure relief valve (internal or external)	Replace or reset relief valve. Measure discharge pressure spike.
	Incorrect pump setting	Increase stroke length or stroke speed.
	Restricted diaphragm support holes	Clean.
	Liquid viscosity too high	Reconfirm NPIPA vs. NPIPR. Review pump/check valve selection.
	Cavitation occurring	Reconfirm NPIPA vs. NPIPR.
Pump rate of flow too high	Insufficient discharge pressure or low differential pressure	Install backpressure valve to provide higher discharge/differential pressure.
	High liquid inertia due to suction acceleration	Use pulsation dampener to absorb pipe hammer. Or install backpressure valve to provide higher discharge/differential pressure.
	Incorrect pump setting	Decrease stroke length or stroke speed.
Speed reducer (gearbox) overheating (see manufacturer's instruction book for guideline)	Low oil level	Fill to proper level.
	Too viscous or too much oil	Fill to proper level with correct viscosity and grade.
	Dirty, contaminated oil (water or process contaminated)	Replace oil with fresh per instruction book.
	Excessive load caused by high operating pressure or high packing friction	Reduce pressure. Check packing condition.
	Bearings dirty or worn	Clean or replace. Flush and replace oil.

Table 7.5 — Locating trouble: controlled-volume metering pumps (*continued*)

Trouble	Possible Cause	Remedy
Overheating, pumphead housing (liquid end)	Low oil level	Fill to proper level.
	Internal hydraulic relief valve is bypassing (for hydraulically coupled diaphragm pumps)	Check discharge pressure vs. set pressure of internal relief valve. Check condition of relief valve. Measure discharge pressure spikes if any.
	Oil viscosity or level too high	Fill to proper level with correct viscosity and grade per instruction book.
	Excessive operating pressure	Review pump selection.
Failure to start	Electrical/pneumatic circuit open	Correct electrical/pneumatic problem. Consult manufacturer's instruction book.
	Discharge line static pressure too high for pump to overcome and motor does not have enough horsepower/torque to deliver.	Ensure all valving is open, verify, and if necessary, reduce discharge line static pressure.
Pump stops (no mechanical motion)	Electrical/pneumatic circuit fault (circuit tripped)	Correct electrical/pneumatic problem.
	Pump internal mechanical problem	Inspect the pump. Consult manufacturer's instruction book.
	Discharge line static pressure too high for pump to overcome and motor does not have enough horsepower/torque to deliver.	Ensure all valving is open, verify, and if necessary, reduce discharge line static pressure.
	Control system shut down the pump	Check external control inputs.
Excessive or unusual noise during operation	Cylinder only partially filled during suction stroke	Clean suction strainer. Blow down suction line.
	Worn parts	Inspect internals and replace bearings or other worn parts.
	Cylinder packing too tight	Check packing gland.
	Relief valve bypassing (relieving)	Inspect relief valve and check discharge pressure.
Leaking gland packing	Packing worn	Replace.
	Plunger scored	Replace.

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