

Analysis of Metering Pump and Problem Solution during Work

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Abstract: Metering Pump is introduced here with its various key features and benefits. Manufacturing process and testing procedure for metering pump are described in brief. Detailing of the problems encountered while working and its possible solutions are also mentioned here. An inefficient pump will use more energy than normally required so this paper additionally highlights the procedure to increase the efficiency of metering pump up to certain level. This paper addresses pertinent issues involved in metering pump and associated working problems with solutions.

Keywords: Metering Pump, Manufacturing, Problem Solutions, Efficiency

1. Introduction

A metering pump moves a precise volume of liquid in a specified time period providing an accurate flow rate. Delivery of fluids in precise adjustable flow rate sometimes called metering. The term “metering pump” is based on the application or use rather than the exact kind of pump used, although a couple types of pumps are far more suitable than most other types of pumps. Although metering pumps can pump water, they are often used to pump chemicals, solutions, or other liquids. Many metering pumps are rated to be able to pump into a high discharge pressure. They are typically made to meter at flow rates which are practically constant (when averaged over time) within a wide range of discharge (outlet) pressure. Manufacturers provide each of their models of metering pumps with a maximum discharge pressure rating against which each model is guaranteed to be able to pump against.

The metering pump is a positive displacement liquid 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. The pumping action is developed by a reciprocating piston, which either is 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. The basic principle of working of metering pump is similar to working of the heart of human being. Both almost perform same functions. Sized to fit the system conditions, Flow rate adjustable for varying conditions, adjustable for varying pressures, pulsing or reciprocating action, check valves, Leak proof, built in safety features, rugged in construction.

1.1 Characteristics of Metering Pump

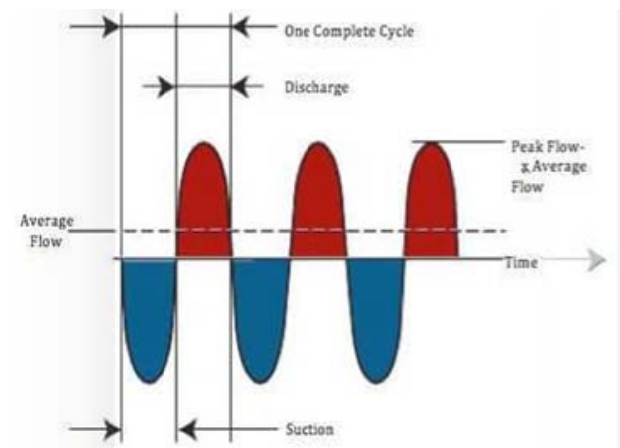
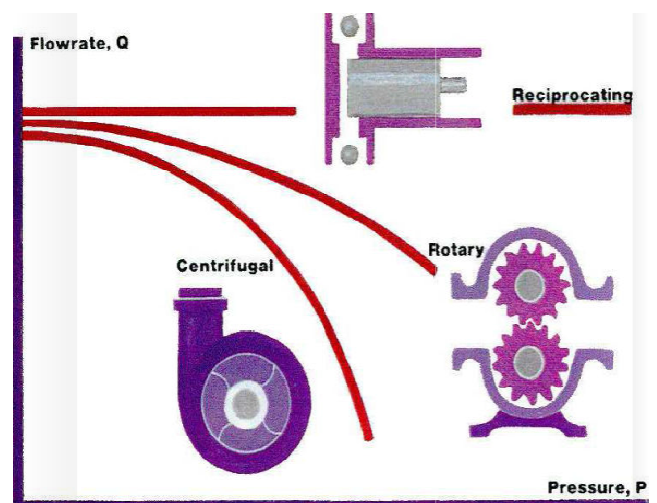


Figure 1: Key Feature of Metering Pump

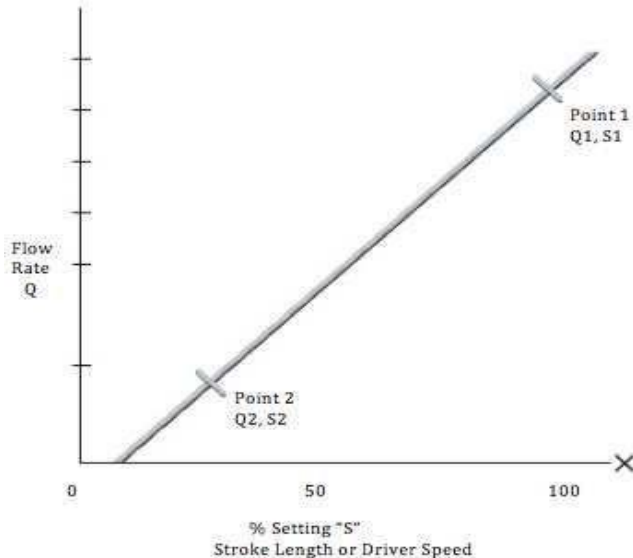
The pumping action is developed by a reciprocating piston. This reciprocating motion develops a flow easily represented by a sine wave. Actual flow rate is determined by the following formula:

Flow rate = displacement x cycles per unit of time



Graph 1: Flow Rate vs. Pressure for different pumps

Unlike centrifugal pumps, flow rate is not greatly affected by changes in discharge pressure. It tends to remain unchanged neglecting minor losses.



Graph.2: Flow Rate to %Setting Graph

Characteristic curve is linear. It is not necessarily proportional in that 50% stroke setting may not equal 50% flow. This is due to the fact that the calibration line may not pass through 0 on both axes simultaneously. By measuring flow at 2 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 $\pm 1.0\%$ or better. Although a metering pump can generally be adjusted to pump at any flow rate between zero 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 simply means that the pump is within its accuracy rating anywhere between 10% and 100% of capacity.

1.2 Problem Summary and Literature Survey

The present invention is related to study of metering pump and solving different problems during work. Locating the Best Efficiency Point for Metering Pump, Best Efficiency Point is the point where the maximum efficiency can be achieved. An engineer, designer, or user should ensure that the pressure, temperature ratings and wetted pump materials are compatible for the application and the type of liquid being pumped. Most metering pumps have a pump and a motor. The liquid being pumped goes through the pump head, entering through an inlet line and leaving through an outlet line. The motor is commonly an electric motor which drives the pump head.

Giovanni Mimmi [1] invented the membrane to separate the process fluid from the oil circuit in metering diaphragm pumps, it is the critical component of these machines. Sometimes, depending on the operating conditions, the membrane may crack and it is necessary to disassemble the pump and replace this component part. Design improvement was done to avoid the crack. The behavior of a membrane mounted in a metering diaphragm pump has been simulated by using FEM. An accurate analysis of the result has allowed

the membrane to be redesigned in a more rational way to improve its performance.

Donelle Capriotti [2] of Wanner Engineering suggested that a new definition is required for metering pump, with recent technical developments and additional capabilities.

Robert S. Ruggeri and **Royce D. Moore** [3] investigated a method for prediction of pump cavitation performance for various liquids, liquid temperatures, and rotative speeds. Both experimental and theoretical data was obtained.

Peter Woias [4] investigated the Problems related to micro pumps during running. As the past, progress and future aspects of micro pump were studied.

Dennis Parker [5] studied about the metering pumps and about cavitations in a fluid metering pump. The system is having reciprocating pumps as first fluid displacer and a second reciprocating pump as second fluid displacer. The invention also provide a metering pump including a three-dimensional, variable profile conjugate cams with a transmission stroke modulation assembly that permits conversion between simplex and duplex pump configurations. The system prevents fluid flow across the pump during non-operational periods.

Barron Dan [6] worked in bosch gmbh robert his invention relates to a metering pump made of plastic, with two rotors coupled to one another via gears and drivable in opposite directions, which are placed in a pump housing equipped with suction ports and outlet ports. Each rotor has two rotor blade walls arranged diametrically on the rotor shaft. A partially cylindrical rotor blade shoe being formed at each of the peripheral ends of rotor blade walls, wherein the rotor blade shoes on the one hand contact the cylindrical inside wall regions of the pump housing and on the other contact the rotor blade shafts of the adjacent rotor in a sliding and sealing manner.

Eric C. Van bork [7] who worked in pulsafeeder inc. has studied about computer operated metering pump. The displacement of a metering pump is accurately monitored using a position sensor connected to a piston. A control computer receives the sensor signal as well as a desired pumping volume rate. The pumped volume is continuously monitored by the computer as a function of the piston displacement and compared with the desired rate. The metering pump is controlled to bring the pumped volume rate into agreement with the desired volumetric pumping rate.

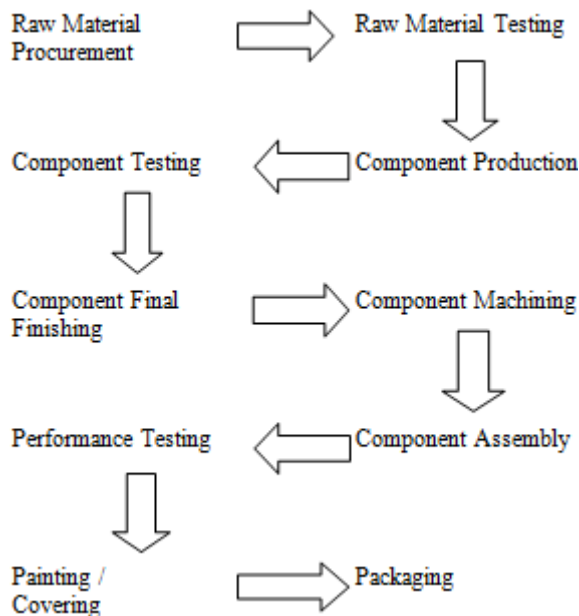
Lonnie G. Wood [8] invented an anti-cavitation device for centrifugal pumps and more particularly to a device for allowing air bubbles contained in the liquid in the pipe line connected to the suction side of the pump to escape from while maintaining a positive head of liquid on the suction side of the pump. In the pumping of solutions or slurries, such as aqueous slurry of phosphate ore, air bubbles sometimes become entrained in the liquid being pumped. Moreover, the pressure drop within the pipe line connected to the suction side of a pump often causes cavities of air bubbles to form in the liquid in the pipe line due to the

release of dissolved air, this well-known phenomenon being termed cavitation. Moreover, cavitations results in impeller vane pitting and corrosion-fatigue failure of metal pump parts. The elimination of cavitation within the pipe line and pump casing greatly increases pump efficiency and greatly reduces pump wear and pump maintenance. Moreover, as anti-cavitations device maintains a positive liquid pressure on the suction side of the pump at all times. Pump efficiency is increased and the pump never loses its prime.

Carl L. Hammonds [9] of Hammonds Technical Services' invention is to provide a large, very slow operating mechanically operated valve with submerged suction that allows a pump to operate at virtually any speed from zero to maximum while eliminating loss of efficiency of prior valves due to cavitation or leakage through their poorly seated valves. The invention is about a pump with much greater control of the delivered fluid by powering the pump with a motor with precise control of its speed of rotation and to provide a pump with pumping chambers of any stroke length or diameter. Another object of the invention is to reduce or eliminate the problem of various fluids becoming air-locked within the pumping head due to boiling, off gassing, or entrained gas within the fluid being pumped. The objects identified above as well as other features and advantages are incorporated in a positive displacement pump designed to accurately meter various liquids of widely varied viscosities.

Jay Joshi, Manthan Thakkar and Sahil Vora [10] researched about production processes with grey relational analysis. MINITAB16 software was used to find out regression equation and analysis graphs.

2. Production Process for Metering Pump



2.1 Testing Procedure for Metering Pump

Quality assurance department assure following areas in each and every metering pump:

- 90% of calculated flow rate at 10,25,75 and 100 percentage of stoke length with respect to working pressure of pump
- Linearly of flow rate at different stoke length
- Repeatability of flow rate at different stoke length
- Zero flow at zero stoke length
- Number of stoke per minute
- Leakages
- Noise of power end and non-return valve mainly

3. Efficiency Test for Different Model of Metering Pump

For the practical purpose calculation was done for pump capacity with the pump model

1125 having plunger diameter = 20 mm

Stroke length= 20 mm

Pressure Setting =38 kg/cm²

Vessel size = 100 litre

The pump was attached with the vessel of 100 litre. This got filled in 2 hour 56 minute. That means per hour capacity of above specified pump is 34.2 litre/hr = 34 litre/hr. By this practical Capacity of any pump can be measured. Then the company provided the catalogue which had capacity of different models of pump included in it. Hence as a research task calculation for different pump was done with the formula as below,

$$V_{stroke} = \frac{\pi}{4} \times d^2 \times L$$

$$\eta_{Vol} = \frac{Flow(LPH)}{V_{stroke} \times N \times 60}$$

Where, V_{stroke} = Stroke volume in litre

N = Strokes per minute

d = Plunger diameter

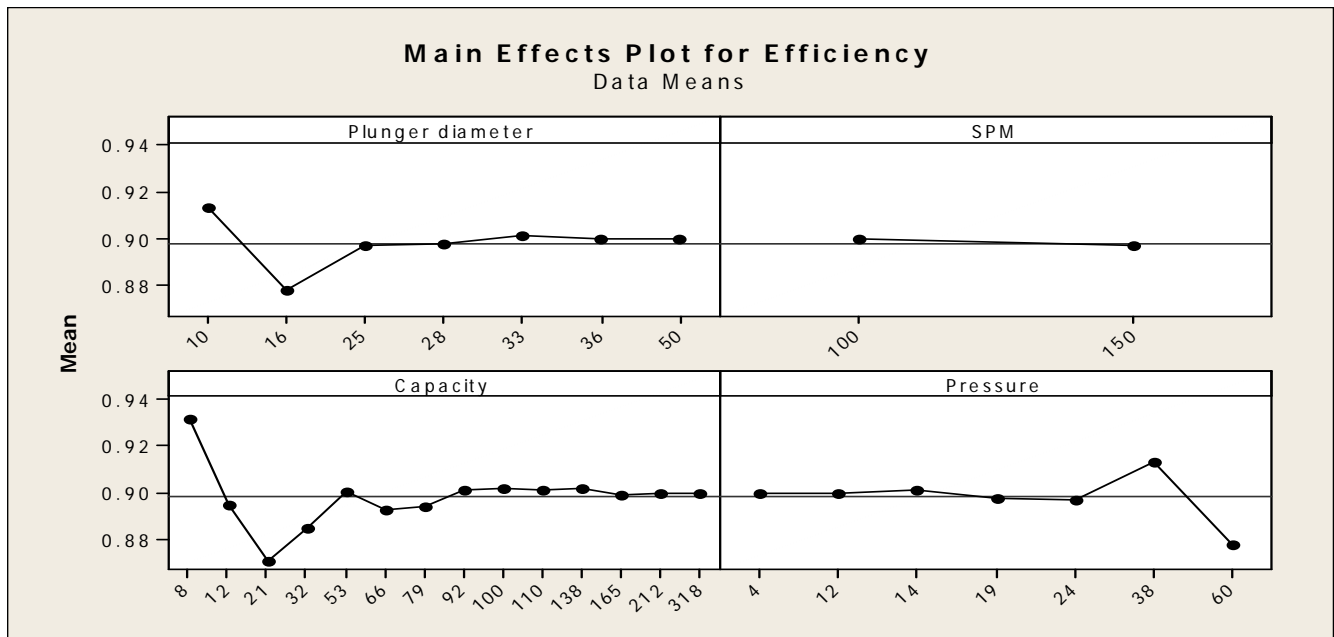
L = Stroke length

η_{vol} = Volumetric efficiency

3.1 Efficiency of Metering Pump

Table.1: Efficiency Test for 1125 Model

1125 (Low Capacity)				
Plunger diameter	SPM	Capacity	Pressure	Efficiency
10	100	8	38	93.23%
10	150	12	38	89.46%
16	100	21	60	87.08%
16	150	32	60	88.46%
25	100	53	24	90.04%
25	150	79	24	89.44%
28	100	66	19	89.30%
28	150	100	19	90.20%
33	100	92	14	90.10%
33	150	138	14	90.23%
36	100	110	12	90.10%
36	150	165	12	89.90%
50	100	212	4	90.02%
50	150	318	4	90.02%



Graph 3: Main Effect Plot for efficiency (1125 Model)

Table 2: Efficiency Test for 1750 Model

1750 (High Capacity Pump)				
Plunger diameter	SPM	Capacity	Pressure	Efficiency
10	100	10	290	94.20%
10	150	15	290	94.20%
16	100	27	112	89.31%
16	150	39	112	92.75%
30	100	95	32	89.24%
30	150	137	32	92.82%
36	100	137	22	89.11%
36	150	197	22	92.95%
44	100	205	15	88.96%
44	150	295	15	92.73%
56	100	332	11	88.97%
56	150	478	11	92.70%
60	100	381	8	89.00%
60	150	549	8	92.65%

Efficiency (1125 Model) = $1.00067 - 0.00248717 (\text{Plunger diameter}) - 0.000232029 (\text{SPM}) + 0.000211383 (\text{Capacity}) - 0.000993553 (\text{Pressure})$

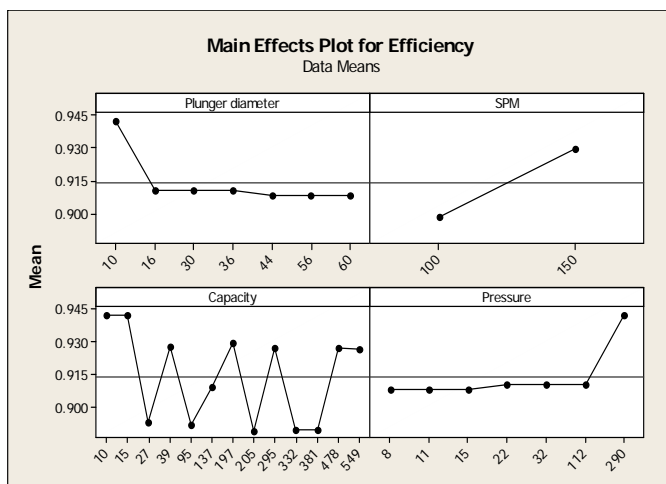
Efficiency (1750 Model) = $0.838236 - 0.000337488 (\text{Plunger diameter}) + 0.000558273 (\text{SPM}) + 4.72361e - 005 (\text{Capacity}) + 0.000119254 (\text{Pressure})$

3.3 Net Positive Suction Head Concept

Net Pressure Suction Head is the total inlet pressure, stated in meters head minus the vapour pressure of the liquid in meters.

NPSH can be calculated by determining the difference between Positive Heads and Negative Heads.

$$\text{NPSHA} = H + H_{st} - H_{vp} - \sum H_{fr} - H_{ma}$$



Graph 4: Main Effect plot for efficiency (1750 Model)

3.2 Regression Analysis Equation By use of MINITAB 16 software

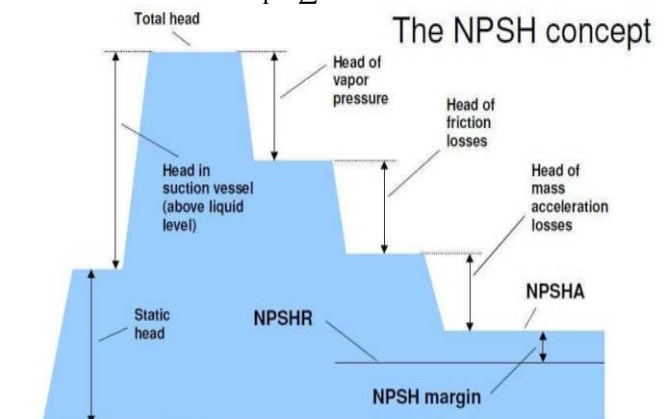


Figure 2: The NPSH Concept

4. Metering Pump Working Problems and Possible Solution

4.1 Different Problems Encountered during Working of Metering Pump

- Cavitations
- Over-Delivery

- Pump does not build pressure just by starting it.
- Pumps deliver higher capacity than specified on the nameplate
- Vortexing
- Syphoning effect

4.2 Cavitations

The basic definition of Cavitations is the formation of an empty space within a solid object or body, the formation of bubbles in a liquid, typically by the movement of a propeller through space. Cavitations occur when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapour at the inlet of the pump. This vapour is carried over to the discharge side of the pump where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure. This imploding action occurs violently and attacks the pump rotors, gears etc. Rotors, screws, gears, etc. that have been operating under a suction cavitation condition have large chunks of material removed from their faces causing premature failure of the pump. In this case the suction pressure required is quite high, which causes the problem of cavitation due to vacuum pressure created for suction. This reduced suction pressure causes the vapourization temperature also to be reduced. Hence the fluid converts into vapour bubbles in the suction side pipe at the room temperature itself. These vapour bubbles burst when passing through high pressure delivery line. This problem of cavitation causes the fluctuation of delivery and also pitting of the pipes.

To eliminate the problem of cavitations, the suction lift has to be reduced. To reduce the suction lift, the pump has to be located on a lower level and near to the base of the tank to get advantage of pressure head. (Increase in NPSH) If the suction pipe is drawn out from above the tank then it creates air traps in the vertical loop, hence it is only required to take the suction line out from the base of the tank only.

4.3 Over delivery

Discharge side piping (Eliminating Over delivery and overflow) the delivery side piping should be designed such that over-delivery should be avoided. When over-delivery happens the delivery side pressure increases due to increased delivery level. This causes an increase in the requirement of the pump work due to high pressure requirement. Along with the increased back pressure, this causes severe pressure rise in the delivery line. This can cause the bursting of the pipes and damage to the equipment.

To avoid this pressure relief valves should be provided, so that the increased back pressure can be released and the pump can continue working within permissible pressure limits. In the last case, to avoid the overflowing of the fluid, syphoning effect is used. In this case the fluid from the reservoir tank is sucked up to a level above the delivery tank, therefore creating a steady fluid flow in the downside suction line and the delivery line.

a) Pump is not developing pressure

Pump does not build pressure just by starting it. Pump discharge line must be connected to elevated pressure

point to build pressure of discharge side. If still pump does not generate pressure or deliver desired flow, check pump discharge and suction valve for dirt and foreign particles.

b) Pump delivers Higher Capacity than Specified on name plate

Ensure that discharge pressure is always greater than suction pressure, if these conditions do not fulfill then pump will deliver higher flow than specified on nameplate. There should be some amount of pressure difference between suction and discharge.

c) Vortexing

“Something is wrong with the pump! It’s sucking in slugs of air”. This remark is frequently made when vortices form in flow patterns, causing loud rumbling noises. A vortex is a whirlpool caused by a combination of factors such as sump design, inlet velocity, direction and flow, submergence, and the position of the bowl assembly in the sump. Air entering the pump through these vortices causes noise and vibration, but not cavitation. Various methods can be used to prevent vortices. These include using suction umbrellas, lowering the inlet velocities in the sump, increasing submergence and relocating pumps.

d) Syphoning Effect

The effect is exactly the same if a Pump is connected to a long discharge pipe which falls below the level of stored water i.e. the sensor reservoir. Once the pump has begun the process of pumping the water and the column of water has past the point where gravity takes over the water will continue its journey to the end of the discharge tube even when the pump is switched off so draining all the remaining water. The next time the pump is signaled by the sensor to energize it has to pump air out to bring water to the internal pumping mechanism. This can be noisy for a few seconds until water completely fills the pump, this repeated many times in a few hours can be both very irritating and very wearing to the pump literally. The pump starts to wear out its internal parts, the result is it takes even longer to prime, more wear takes place the pump then gets even louder, very soon it fails completely.

It is possible to stop this effect in several simple ways and keep the pump from being noisy and failing prematurely.

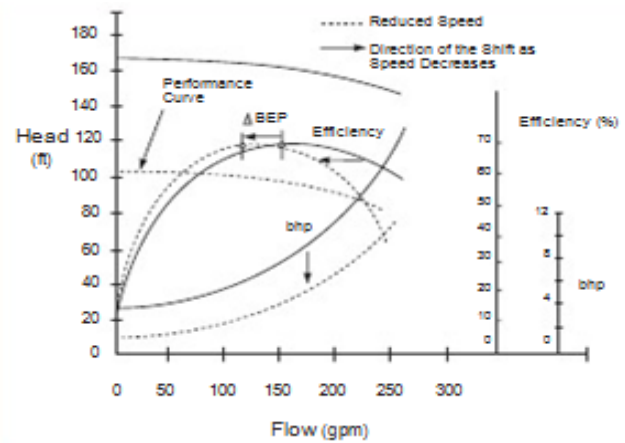
- 1) Install the metering pump so no syphoning can occur by routing the discharge line to a drain point level with the pump reservoir or even above the pump.
- 2) Install the discharge line into a fixed drain line such as 20mm PVC overflow pipe to create an air break level with the pump reservoir, where the drain is at ground level.
- 3) An Anti Syphon Device is a special device which can allow a small amount of air into the discharge line in a controlled way, this effect is only present when syphoning is actually occurring, at all other times it remains inactive, this device then is a passive device within the system sensing when the effect of syphoning is starting and passively preventing this unwanted effect.

This little device will take away the problem of syphoning and complaints about noisy metering pumps once and for all.

5. Result and Conclusion

Efficiency of metering Pumps is greater than Centrifugal Pumps and Rotary Pumps. In this dissertation work volumetric efficiency for different models of pump was calculated which are available at Swelore Engg. Pvt. Ltd.

- Problem of Cavitations can be solved by reducing the suction lift. To reduce the suction lift, the pump has to be located on a lower level and near to the base of the tank to get advantage of pressure head (Increase in NPSH).
- The problem of Over- Delivery can be solved by the use of the relief valve and by the making the arrangement of pipe in such a way that it creates a syphoning effect. In this effect the fluid from the reservoir tank is sucked up to a level above the delivery tank with creating a steady fluid flow in the downside suction line and the delivery line.
- Best Efficiency Point (BEP) for 1125 Model can be achieved at 93.23% with Plunger Diameter of 10mm, SPM of 100mm/min, and capacity of 8 Pressure of 38 kg/cm².
- Best Efficiency Point (BEP) for 1750 Model can be achieved at 94.20% with Plunger Diameter of 10mm SPM of 100mm/min Capacity of 10 Pressure of 290 kg/cm².
- Pump efficiency can decrease significantly when the pump is operating away from the designed Best Efficiency Point.
- Metering pump speed adjustments are the most efficient means of controlling flow. Reducing the speed means less energy is imparted to the fluid and less energy needs to be throttled or by- passed.
- There are two primary ways of reducing the speed: Multiple-speed pump motors and using Adjustable speed drives (ASDs).
- Multiple-speed motors contain a different set of windings for each motor speed; consequently, they are more expensive and less efficient than single- speed motors. Multiple-speed motors also lack subtle speed-changing capabilities within discrete speeds.
- In contrast, ASDs allow speed adjustments to be made over a continuous range, avoiding the need to jump from speed to speed. ASDs control pump speeds using several different types of mechanical and electrical systems. Mechanical ASDs include hydraulic clutches, fluid couplings, and adjustable belts and pulleys. Electrical ASDs include eddy current clutches, wound-rotor motor controllers, and variable frequency drives (VFDs). VFDs adjust the electrical frequency of the power supplied to a motor to change the motor's rotational speed. VFDs are by far the most popular type of ASD.
- In applications with high static head, slowing a metering pump could induce vibrations and create performance problems that are similar to those found when a pump operates against its shutoff head. For systems in which the static head represents a large portion of the total head, however, user should use caution in deciding whether to use ASDs. User should review the performance of ASDs in similar applications and consult ASD manufacturers to avoid the damage that can result when a metering pump operates too slowly against high-static-head conditions.



Graph 5: Speed Variation and Efficiency Change

For many systems, VFDs can help to improve metering pump operating efficiency despite changes in operating conditions. The effect of slowing metering pump speed on operation is illustrated by the three curves in Graph 5. When a VFD slows a metering pump, its head/flow and brake horsepower (bhp) curves drop down and to the left, and its efficiency curve shifts to the left. This efficiency response provides an essential cost advantage, keeping the operating efficiency as high as possible across variations in the system's flow demand can reduce the energy and maintenance costs of the metering pump significantly. VFDs can also be used with positive displacement pumps.

- One major benefit of VFDs is that they can reduce energy losses by lowering the overall system flow or head. By slowing down the pump and reducing the amount of fluid energy imparted to the system when it is not needed, VFDs offer substantial savings with respect to the cost per gallon of liquid pumped. Another system-related benefit is that VFDs provide a soft-start capability. During start-up, most motors experience in-rush currents that are 5 to 6 times higher than normal operating currents. This high current fades when the motor achieves normal speed.
- VFDs allow the motor to be started with a lower start-up current—usually only about 1.5 times the normal operating current. This reduces wear on the motor and its controller.
- By reducing a pump's operating speed, a VFD often shifts the BEP to the left of the BEP corresponding to the pump's normal operating speed. In these cases, since the bearing loads on a pump are lowest when the pump is operating at its BEP, this shift of the BEP during periods of low flow allows the pump to operate with lower bearing loads and less shaft deflection. Consequently, using a VFD can extend the interval between bearing maintenance tasks.

6. Future Scope

As is known, there is always some future scope of any Research work. For the present work, the futuristic proposal of work to be included is summarized as under.

- Here in this Present work, specified metering pumps were analyzed for efficiency, for future scope different capacity and different pumps can be analyzed for different output factors.

- Different approaches and procedures can be used to solve the working problems of metering pump.
- Different methods can be used to improve the efficiency of metering pump.

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