# A measured step forward™

An Introduction to Metering Technology

Total | Metering
Fluid | Transfer
Management | Chem Feed

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# Preface

There is almost no industrial branch or plant which does not apply the "dosing" function in some way or other. Dosing technology is used for the production of chemicals and products as well as for their economical and ecologically beneficial application in manufacturing industries. A significant number of users of dosing technology are waterworks and sewage treatment plants as well as swiiming pools for conditioning the pool water.

The spreading of dosing technology to increase the quality and economic efficiency of processes requires more information and training on "dosing technology" so that unsatisfactory results in dealing with it can be avoided. The following "brief introduction to dosing technology" aims at explaining its basic principles and those of the media to be dosed in a deliberately simple way. The purpose is to avoid errors in planning dosing systems and to optimize system not operating satisfactorily. In addition, a number of impulses might well be given to control chemical dosing automatically where it was done manually before. There is no doubt that a mechanically or better automatically controlled dosing system improves the result and reduces or avoids the recurring mistakes and weaknesses of the human factor.

The following article starts with a description of some chemical properties and then continues to explain different principles of dosing. Special attention is paid to the use and right installation of fittings/accessories which only enable dosing in many cases but definitely improve the result.

# 0.1 Properties of Media

### 0.1.1 Solid, liquid and gaseous substances

All pure, elemental substances can occur in gaseous, liquid or solid condition. The state of the substance depends on pressure and temperature. A familiar example is water at atmospheric pressure: below 0°C water is frozen solid, between 0°C and 100°C it is liquid and above 100°C it converts into steam. Liquids which are made up of mixtures of different chemicals have no precise melting or boiling point because the individual components solidify or volatilize at different temperatures. This fact is e.g. made use of to distil the different components (fuel oil, petrol, etc.) from crude oil.

Knowing the boiling behaviour of a liquid is also important since it determines the suction lift of the liquid achievable by pumps. Also because then the consequences of leakage can be evaluated more exactly. The question of whether the liquid will remain in liquid condition or evaporate spontaneously in the case of leakage may be important when selecting the type of dosing pump (e.g decision for a leakproof version).

For application engineers it is important to know whether the liquid is heavier or lighter than water, if it can be mixed easily or only partially with water, if it tends to precipitates, whether it is aggressive, abrasive or combustible, and its viscosity. Most liquids can be regarded as non-compressible with negligible influence up to 100 bar.

In contrast to liquids, gases occupy any available space. Important gas values gases are those for temperature, density and pressure, all dependent of each other. For process technology it is e.g. significant whether the gas is under vacuum or under pressure, if it is heavier or lighter than air at atmospheric pressure, if it is explosive or poisonous or becomes aggressive in combination with moisture.

The answers to these questions give an idea of what will happen in the case of leakage. For the selection of fittings or dimensioning of piping for gases, calculation methods and diagrams must be applied which take the gas laws into account (not to be mixed up the diagrams prepared for liquids).

Special dosing equipment has been developed for the last decades particularly for chlorine gas which is used extensively for treating of potable water, swimming pool water and also waste water. It has been improved to such an extent that it is now included in the German Standard Sheets (e.g. DIN 19606 or 19643).

Solid matters are all those substances occurring in solid condition within the relevant temperature range. Depending on the formation or production process, the particle diameter may differ from dust to several centimeters. The choice of the suitable dosing unit does not only depend on the grain size but also on the shape of the grain, i.e.: the grain geometry.

Dosing of solid matters implies that the substances are in a relatively homogeneous dischargeable state concerning their particle size in relation

to the total quantity of the bulk material. Therefore it is a prerequisite that for most process the dry material is supplied either as powder or as granulates with grain sizes of up 5 mm. But also in the case it is a question of scale. Broken stones with diameters of 50 mm, for example, are still relatively easy to dose if the magnitude of track installations or coal feeding systems in power plants are taken into consideration.
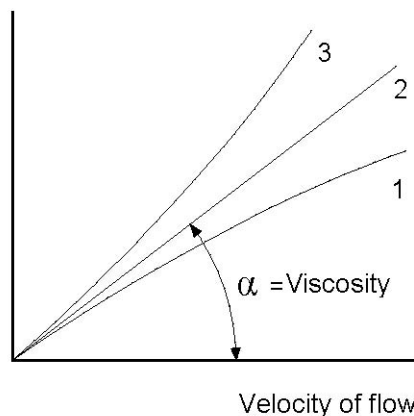
## 0.1.2 Viscosity

Liquids and gases are more or less flowable. This property is specified by their viscosity. The lower the flowability the higher the viscosity. In the case of gases viscosity is of minor importance as far as dosing units and fittings are concerned. It is, however, taken into account for the calibration of measuring glasses (float element flow meter). Viscosity is very important for liquids because the readiness of the liquid to flow strongly effects the dosing capacity of the pump. This is due to the fact that the nominal output of dosing pumps is determined with water at 20°C. With increasing viscosity, i.e.: with lower flowability of the liquid, it becomes more and more difficult for the pump to force the set quantity through the dosing and piping system.

Viscosity has different modes. Some liquids have a certain viscosity at a given temperature which does not change at varying velocities of flow. Most liquids, however, behave differently. There are some which show a high viscosity in idle position and become relatively fluid when flowing (as e.g. non-dripping varnish which clings to the brush as it is applied to a vertical wall and then becomes fluid through the faster movement of the brush. After painting the varnish immediately becomes highly viscous again and does not drip). Other liquids behave the other way round. They are fluid in idle positon and become more viscous at higher velocities (this can be a problem when using e.g. agitators).

1 Intrinsically viscous (viscosity decreases with increasing velocity)

2 Theoretical liquid (viscosity remains constant)



Effect of viscosity

Velocity of flow

$\alpha$ = Viscosity

3 Dilatant liquid (viscosity grows with increasing velocity)

**Viscosities**

| Medium 20 °C | mPa*s |
|---|---|
| Air | 0.02 |
| Water | 1.0 |
| Acetone | 0.3 |
| Organic solvent | 0.5 ... 3 |
| Sulphuric acid 100 % | 27 |
| Cooking oil | 100 |
| Motor oil SAE 20 | 200 |
| Machine oil | 20 ... 500 |
| Warm fuel oil | 7000 |
| Honey | 2000 ... 50000 |

## 0.1.3 Solutions, suspensions, emulsions, colloids, coagulation, peptization

Solutions are liquids in which solid substances are distributed in their finest physical form, i.e. as molecules. Every liquid can dissolve solid particles to a certain level (saturation point). Molecular solutions are not detectable anymore by luminous reflectance (there is no cloudiness).

**Suspensions** are liquids in which finely distributed solid matters are suspended. They tend to settle (sediment) or float in idle position. Thus the particles are not dissolved. A light beam passing through the liquid is visible by reflection. According to the hardness of the particles, fast flowing suspension may cause damage to the pump and piping system due to abrasion. On the other hand, higher velocities of flow are desirable to prevent the particles from settling (see sedimentation) and thus clogging of the lines.

**Emulsions** are mixtures of liquids which will normally not mix with each other (e.g. oil and water). Emulsions are achieved by vigorous mechanical stirring (homogenizing). They tend to split up into the individual liquids as soon as they are motionless for some time and not stirred anymore (e.g. creaming of milk). To keep emulsions unchanged over longer periods, they can be stabilized using special chemical additives (emulsifiers).

**Colloids** are extremely fine particles which are so small that they no longer behave like suspended particles but remain evenly distributed in the liquid. Although the particle size is only about 1 millionth of a mm and less, they are no molecular solutions. This is also proved by the fact that a light beam passing through the liquid is visible by reflection from the particles (cloudiness). The stable condition of even distribution can be explained by the equal electrical charge of all particles and the resulting mutual repulsion. To remove colloids from a liquid, this homogenous mutual repulsion of the particles must be disturbed. Differently charged ions can be used for this purpose which can be added as salts, for example. As a result even the smallest particles can join together electrostatically.

## 0.1.4 Sedimentation, flotation

Larger particles in the range of 0.001 – 1 mm carried in liquids tend to float or settle, according to their specific gravity in comparison to the carrying liquid. The slower the velocity of flow, the faster the particles are able to either rise to the surface or sink to the bottom. The settling of particles is called sedimentation, the rising of particles to the surface is called flotation. The latter can be accelerated by injecting air. Both occurrences are used to separate undesired or desired matter from liquids. Removing the floated particles over the tank edge is also called decantation.
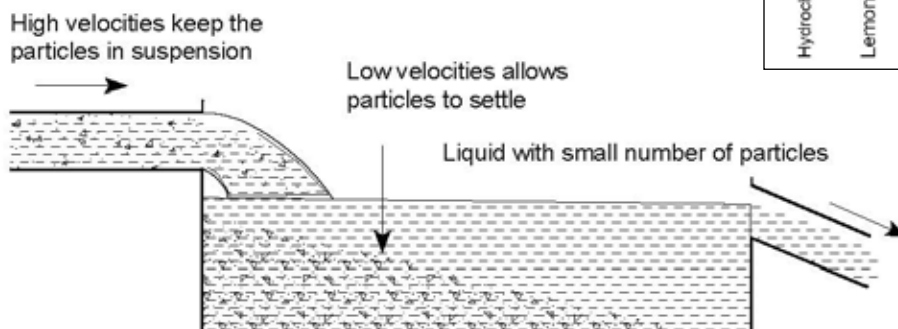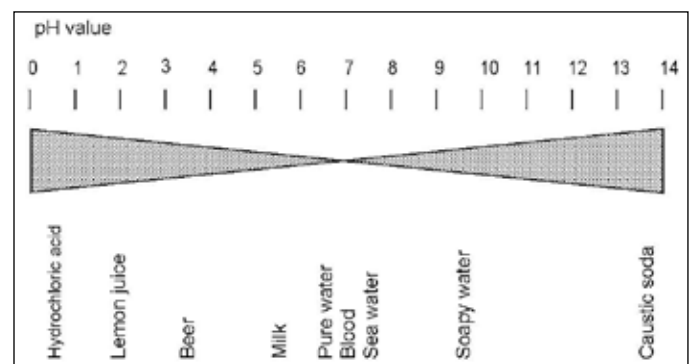
## 0.1.5 Abrasion

Particles suspended in the liquid which – as mentioned before – can sediment or float due to their size have a more or less abrasive effect when in motion. The degree of abrasion depends particularly on the hardness and the surface structure of the small particles. All suspensions are abrasive when in motion.



Due to inertia the particles continue to flow straight on and erode the pipe bend
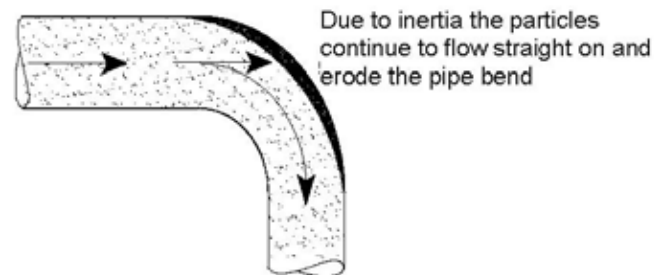
## 0.1.6  Aggressiveness

Aggressiveness of a liquid is its characteristic to corrode other materials. Gases or solid matters can be highly aggressive after being dissolved in water or in contact with air humidity (e.g. the "solid" salt or the "gas" chlorine dissolved in water). The aggressiveness of chemicals is one of the most important factors to be considered when selecting materials for fittings and piping. A measure of aggressiveness is e.g. the pH value of the liquid. Neutral liquids have values around "7" whereas lower values indicate increasing acidity and values up to 14 indicate increasing alkalinity.





High velocities keep the particles in suspension

Low velocities allows particles to settle

Liquid with small number of particles

## 0.1.7 Release of gas

There are chemicals which either contain gases in solution or which decompose in the course of time and thus release gas from the liquid. This process referred to as degassing must be considered from different point of views.

One important aspect is the danger to environment, another point is that degassing affects the function of pumps and piping systems, since many fittings can only handle pure, gas-free liquids. Especially the dosing pumps constructed for liquids have larger or smaller dead spaces which have the effect that gas entering the head cannot be compressed to operating pressure. Thus it cannot leave the head and dosing fails. To solve this problem, various measures have to be taken (for further details, refer to the text below).

## 0.1.8 Flow behaviour of bulk material

Powder, granulates and grained matters of up to several millimeters in diameter are called bulk material. Larger accumulations of solids in the form of powder or small grains almost behave like liquids. In contrast to liquids bulk material has a considerable friction resistance between the particles. As a result, e.g. goods emptied at random do not spread over an unlimited area but form a heap with a material-specific angle of repose. With suitable machines bulk material can be conveyed similarly to liquids (screw spindles are used for water pumping stations as well as for dosing of powder). The internal friction of bulk material depends very much on its nature, such as grain size, shape and surface structure. Besides, it is important how fast the dry material moves. The faster it flows, the more it behaves like a liquid. Of course, strong abrasion of the lines must be taken into account here. In contrast to liquids, blockage among the individual particles may occur in the case of complete standstill which results in so-called "bridging". Thus the operation may considerably
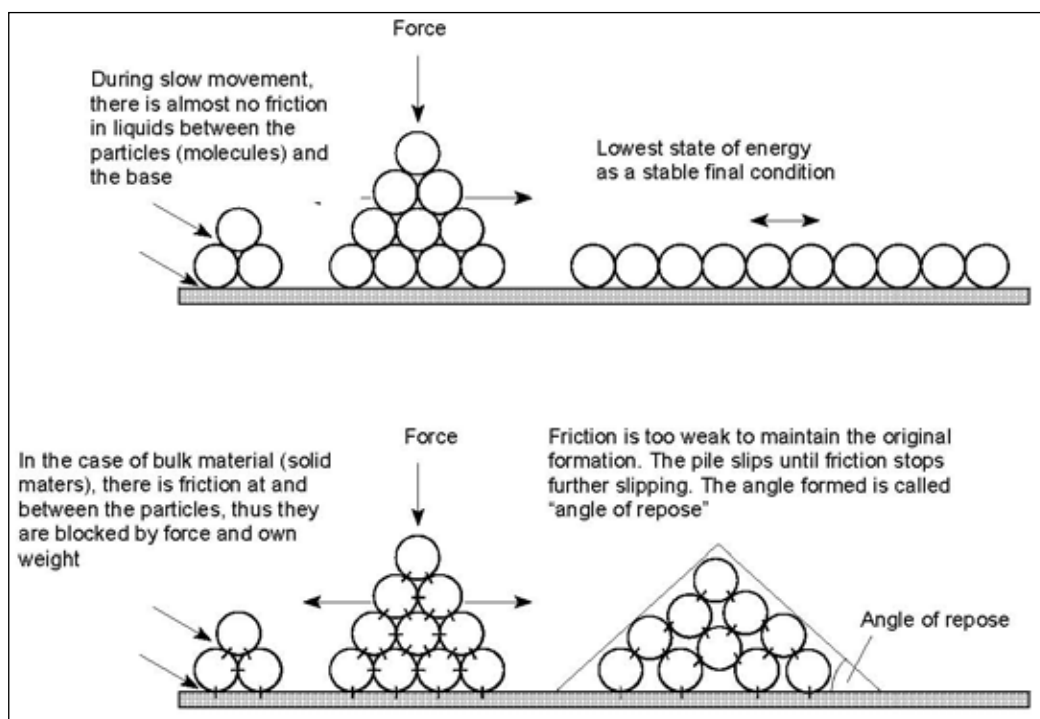
be disturbed. Only by applying energy in the form of shocks or stirring movements or by injecting air or nitrogen can the bulk material be put back to a "flowing" condition.

Dry material may also be hygroscopic, i.e. it absorbs water in the presence of humid air and thus agglomerates. As a result, operational failures and, depending on the medium, corrosion due to the aggressiveness caused by moisture may occur.

## 0.1.9 Burning and explosion behaviour

It is of greatest importance in chemical engineering to know the burning and explosion behaviour of the media to be handled. This topic is too essential to be discussed here shortly. Therefore the relevant literature as well as the rules and regulations for prevention of accidents have to be studied carefully. Inflammable materials are subdivided and clustered according to their burning and explosion danger potential. It is particularly important to consider the explosion classification when using electrical machines because of possible sparking. It must be checked whether the gases, liquids and solids to be dosed might form inflammable mixtures under certain operating conditions. In most cases oxygen which is always present in the atmosphere will be the reaction partner. There are, however, also chemicals already containing reaction partners which cause ignition or explosion due to high temperatures or shocks. These materials are particularly dangerous because they can ignite even in closed tanks under exclusion of air. In general the chemico-physical reaction is stronger the larger the surface of the reaction partners. It makes sense that the surface of a certain mass increases with smaller particles. This also explains that there is the danger of dust explosions. Besides, materials are also distinguished according to their ignition performance and their strength of reaction after having ignited once. There are substances which ignite easily but do not release a large amount of energy, and there are others which are hard to ignite but which cause a violent explosion.



Force

During slow movement, there is almost no friction in liquids between the particles (molecules) and the base

Lowest state of energy as a stable final condition

In the case of bulk material (solid maters), there is friction at and between the particles, thus they are blocked by force and own weight

Force

Friction is too weak to maintain the original formation. The pile slips until friction stops further slipping. The angle formed is called "angle of repose"

Angle of repose

## 0.1.10 Density

The density of a substance indicates how many kilograms are contained
in a cubic meter (kg/m³). It is expressed in relation to the density of water
which is 1.000 kg/m³. While the density of liquids is relatively constant and
alters only slightly with pressure and temperature, the density of gases is
greatly dependent on pressure and temperature. The same mass of gas has
in double the space only half the density, because gas is able to expand
to twice the volume at half the pressure (provided that the temperature is
the same). A liquid on the other hand will only occupy half of the double
volume, and the density will remain constant.  The specific weight of
the particles of a solid is virtually constant. But since the mass of bulk
material in a given space depends on how close together the particles are,
the density is variable in practice and must be determined by experiment
(powder density or tap density). Firmly tapped bulk material will have a
higher density than loosely poured powder.

**Bulk material**
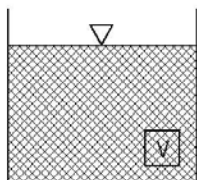**The density of bulk material depends on the „tapping" condition**
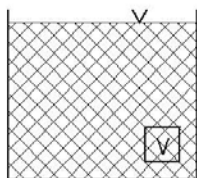
10 kg loosely poured
V=1dm3 weighs 0.8 kg
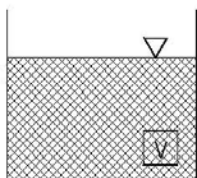
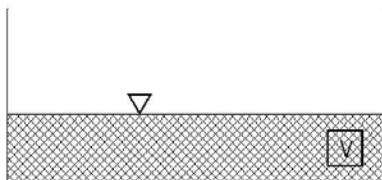10 kg firmly tapped
V=1dm3 weighs 1.1 kg

**Liquids**
**The density of liquids is independent of the volume**

V=1dm3 weighs 1 kg
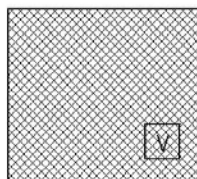
V=1dm3 weighs 1 kg
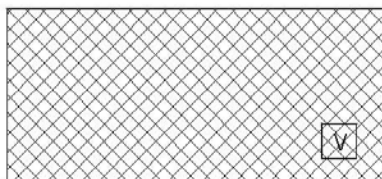
**Gases**
**The density of gas depends on pressure and temperature**

V=1dm3 weighs 1,2 kg at 20°C

V=1dm3 weighs 0.6 kg at 20°C
if the volume is twice as high

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# 0.2 Methods of dosing

## 0.2.1 Continuous and quasi-continuous dosing

Processes which deal with continuous manufacturing or treatment of products mostly require an equally constant addition of chemicals such as acids, lyes, dyes, aromatic substances, flocculants, etc. Strictly speaking the term "constant" refers to a continuous, uniform addition of the aforementioned chemicals (a permanently running water tap would be the best comparison). However, as will be explained later, for certain reasons dosing units have proved to be suitable which show considerable fluctuations in the dosing rate over a period of time of one second but which dose exactly the same amount on a statistical average of longer periods due to the uniformity of these fluctuations. For those processes which have production times of several minutes to hours, fluctuations within a second are not a problem. It is just a question of the actual dosing period whether a dosage process can still be considered as continuous or discontinuous. If the total dosing period is only a few seconds, fluctuations within a second are not admissible. But if the fluctuations are relatively short in comparison to the total dosing period so that the result corresponds to a continuous dosage process, this is referred to as "quasi-continuous" dosing. Thus quasi-continuous dosing can also be regarded as continuous dosing if it is ensured that, at any given moment of verification, the rate dosed in the past corresponds to the actual requirements.

## 0.2.2 Batch dosing

Batch dosing is the process of measuring a limited amount to be dosed. For this purpose, the dosing unit works either for a preset period of time or for a certain number of dosing strokes. Another possibility is to fill a tank to the required level and then add the contents to the process. If the chemical must be dosed into a system under pressure, the use of tanks is not suitable in most cases. Instead a precisely working dosing unit must be chosen which is able to introduce the chemical almost independently of the backpressure.

## 0.2.3 Dosing in proportion to a guide signal

Proportional dosing means that a chemical is dosed into another medium so that the preset percentage rate remains constant all the time. If e.g. 100 ml of a chemcial are to be added to every cubic meter of potable water, a proportionally working dosing system must be designed to continuously adapt its flow rate to the water flow rate. Very simply, this type of dosing can be imagined as follows: „0" water flow corresponds to a closed position of the chemical valve and max. water flow corresponds to a 100% open valve. All water flow rates in between would cause the valve to open by a corresponding percentage. To measure the water flow, e.g. inductive flow meters with a continuous output signal can be used or contact water meters which make a contact per liter, for example. The type or controllability of the dosing unit determines which control signal is used. The aforementioned valve could be controlled perfectly by the continuous signal of an inductive flow meter. It would be just as effective to use the same signal to set the speed of a dosing pump between 0 and 100%. Here it has just to be
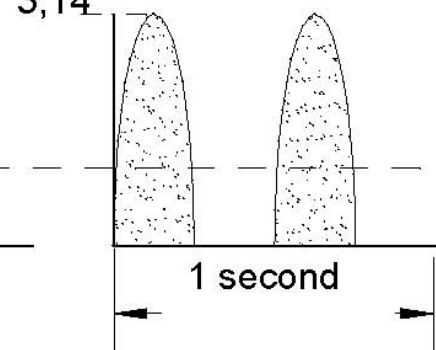


**Continuous dosing** — l/h — 1 — 1 second
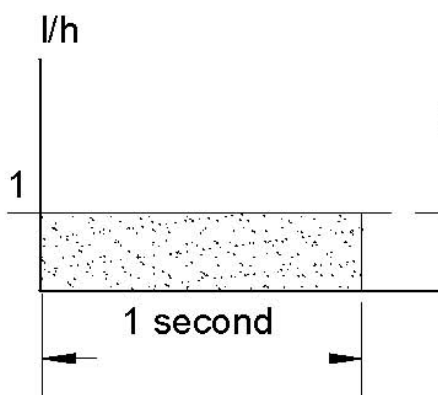
**Oscillating dosing processes of the same flow rate**

rectangular pulses — 2 — 1 second

Sinusoidal pulses — 3,14 — 1 second
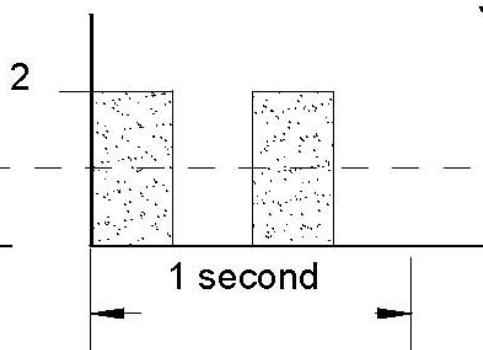
ensured that, at a speed of 100%, the rate dosed corresponds to a 100% water flow. If the water flow is metered by measuring instruments, which make a contact after a preset number of liters (contact water meters), the latter can be used to activate a dosing unit for a determined period of time. The running period must be completed before the next control pulse is received. This type of proportional dosing also allows precise dosing on a statistical average of longer periods. During the time of dosing, the quantity added is, however, larger than required with regard to the water flow, because, after completion of the running period, no dosing takes place for a certain interval. Careful mixing ensures in the piping system that the water is treated correctly. It is, however, the final decision of the process engineer whether this type of dosing is admissible. Only he knows if the water (or other media) treated has reacted satisfactorily with the chemical at the time and location of application. For the treatment of potable water, a special dosing pump concept was developed: Dosing pumps are driven by an electrical stroke solenoid which converts a water meter contact directly, without gear reduction, into a single precise dosing stroke for the addition of the chemical. The immediate and reproducible controllability of the single stroke is the prerequisite for a homogenous and reliable water treatment. Proportional dosing is fully ensured with this method, because every single liter of potable water is treated equally due to a high pulse

frequency (6000 strokes per hour). Thanks to state-of-the-art electronics with a high functionality, today's solenoid-driven pumps are dosing units to be used universally not only in potable water treatment applications but also in general process industries. With proportional dosing the result is only constant if all characteristics of the medium to be treated, the dosing chemical and the process data such as pressures, temperatures, viscosity, etc., which were taken into account for the system design, remain constant as well. Thus the properties of the water to be treated, for example, must not vary as otherwise the defined dosing quantity is either too high or too low. If considerable changes in the water properties are likely, proportional dosing is inadequate and dosage must be realized according to the measuring results of the water analysis. The use of proportional dosing is also advantageous, if the process system is characterized by strong forces of inertia and dead times due to long flow distances through pools or pipings so that there are long periods of time between addition of the dosing chemical and reaction result. Automatic controllers for a direct correction of the reaction result (e.g. pH value) thus lead to slight oscillations caused by overdosing and underdosing. Proportional dosing follows the control signal more or less instantly in dependence of the water flow and does not require any time for analysis or any other feedback from the process.
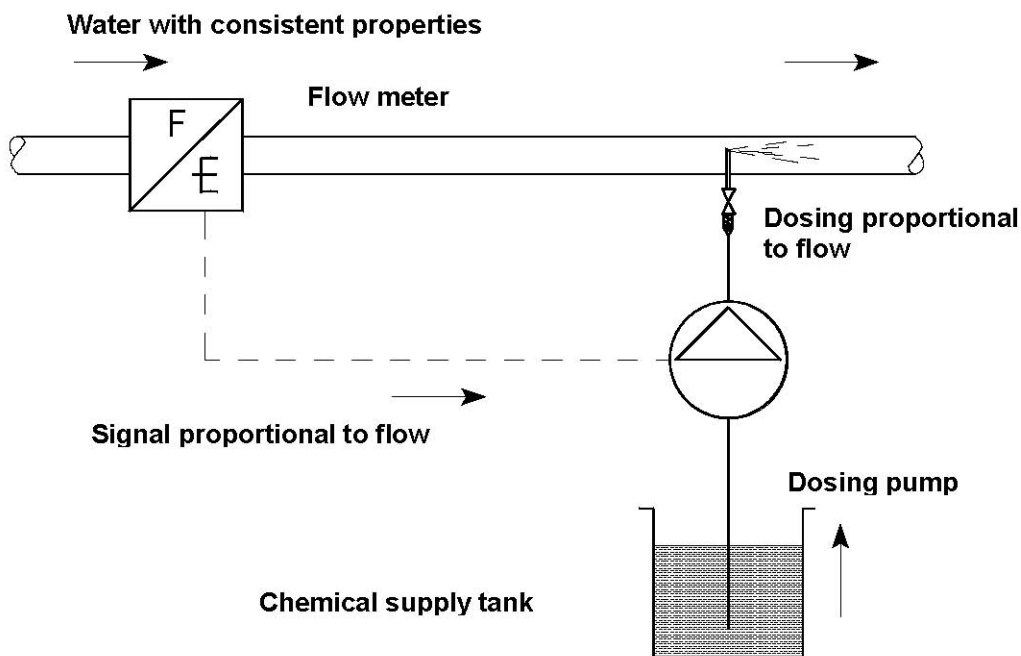


The aforementioned explanations refer to the dosing of liquids as well as to the dosing of gas or solids.

![JESCO Lutz-JESCO America Corp.]

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## 0.2.4 Dosing pumps as correcting elements in automatic control systems

To obtain a certain water quality (or certain properties of other process media) it may be necessary to add differing quantities of components to the same amount of water. Therefore proportionally dosing is not suitable for such an application. Water with extremely varying properties must therefore treated with a dosing system which analyses the actual water quality and determines the amount of chemical to be dosed accordingly. The following example serves to explain the difference between proportional dosing and dosing with feedback:

### Proportional dosing

Water with consistent properties is taken from one spring. A dosing system for adding a disinfectant is therefore controlled proportionally ensuring that the appropriate quantity is dosed at maximum water flow. Due to the linear dosage proportionality, each volume of water is supplied with the corresponding chemical quantity. Because of the constancy of the incoming raw water quality, the right treatment is guaranteed at any time for any volume of water (see section 0.2.3).
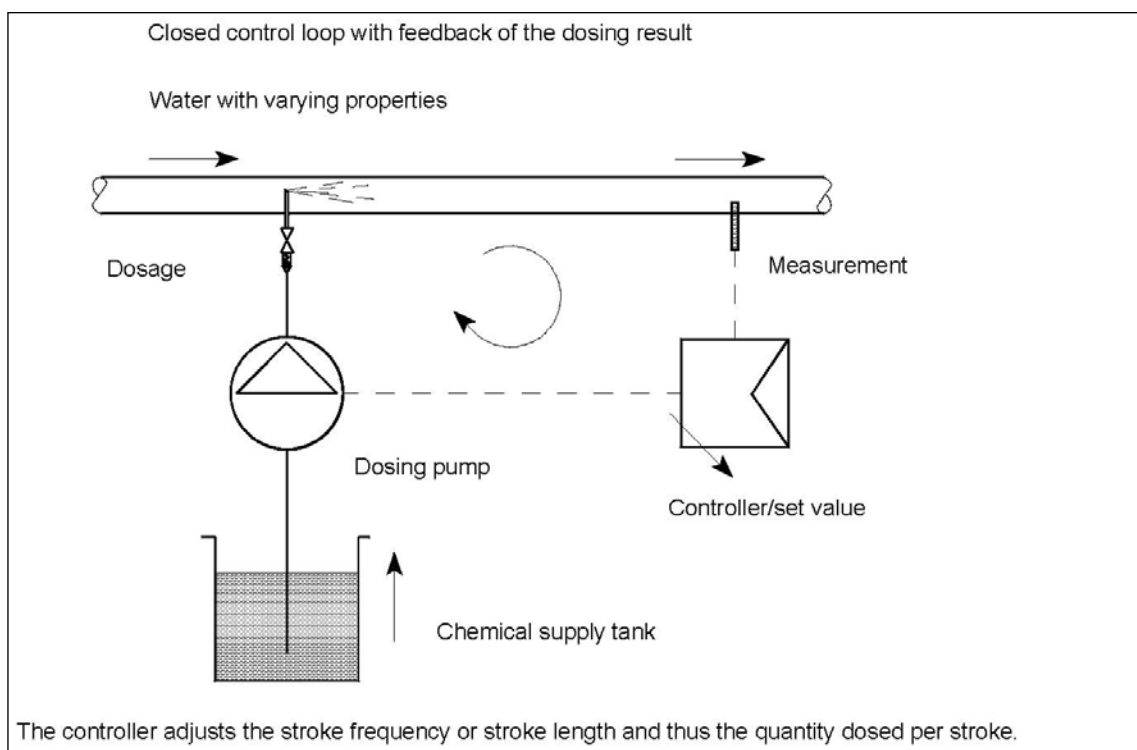
### Controlled dosing

In the second example, the water comes from different springs and, besides, is mixed with varying surface water. In this case, a flow signal cannot indicate the necessary quantity of chemical to be added, because very different amounts of chemical per cubic meter may be required due to the great dispersion of the water quality. To solve the problem a control method is needed which measures the actual water quality and adjusts the dosing rate correspondingly by means of a controller. Thus the dosing process is determined exactly by the quality of water prevailing at any point of time.

## 0.2.5 Volumetric dosing

In chemical and process technology mostly the mass of the materials to be handled or produced is of significance. Volumes are important as far as they concern the dimensioning of the piping systems, tanks and reactors and, of course, the selection of the dosing units. It would be logical if the dosing units supplied the materials according to the required mass. As for liquids the density and thus the mass specific to a certain space are constant in most cases, it is sufficient to determine the dosing rate volumetrically. If a fairly precise reproducibility can be ensured, this method is preferred due to its simplicity. Whereas with liquids the mass is sufficiently constant at a given volume, with gases it is extremely dependent on pressure and temperature. Therefore chlorinators must take the following three parameters into account: pressure, density and temperature. By maintaining a constant pressure normally at room temperature, the density thus defined also ensures a constant mass flow at a constant volume flow (for this reason the calibration pressure and temperature are mostly engraved on float element-type flow meters).

In the case of bulk material, the density of the individual particles is constant but the effective density of the overall mass depends on whether it is loosely poured or firmly tapped. Besides, hygroscopic effects must be taken into account which may change the specific gravity of the bulk material considerably due to a high water concentration. The process engineer has to decide whether the mass of the bulk material to be handled is sufficiently constant or whether gravimetric dosing is more suitable because of the great dispersion.



Closed control loop with feedback of the dosing result

The controller adjusts the stroke frequency or stroke length and thus the quantity dosed per stroke.

## 0.2.6 Gravimetric dosing

As mentioned before, the mass is of decisive importance in almost all process applications and not the volume. On the other hand, it is easier to measure and dose a volume more precisely than a mass. Therefore volume dosing units are used for media which show a consistent relation between volume and mass. This applies with sufficient accuracy to the dosing of liquids. Depending on the process, for bulk material with its varying density, it may        be necessary to determine the dosed mass and not the volume. In this case, the medium dosed per unit of time is weighed. The dosing rate is then corrected by the weighing equipment so that always the desired quantity per unit of time is dosed. To increase the accuracy, of course, this principle can also be used for the dosage of liquids.  Gravimetric dosing is practically not applied for gases. Because of increased requirements regarding accuracy, the three parameters pressure, volume and temperature are measured and considered mathematically.

**Gear pump**
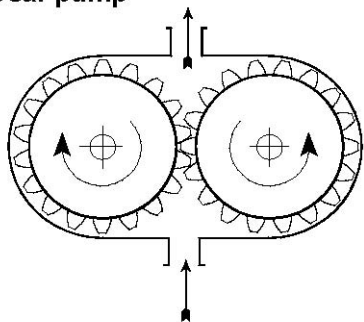


**Peristaltic pump**
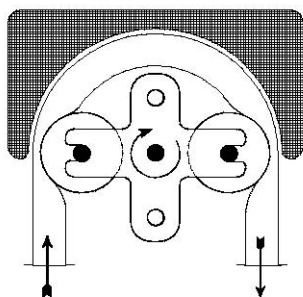


# 1.0 Dosing units for liquids

## 1.1 General principles of liquid dosing pumps

With regard to the economic efficiency when comparing technical expenditure and result, volume dosing units according to the positive displacement method prevail for dosing liquids. For the process the mass dosed is of importance but, with an assumed constant density, it is proportional to the volume. Liquid dosing equipment must therefore be suited to meter constant units of volume. A specific quantity can be considered as one large volume or many small equal volumes. One large volume would e.g. be the filling and emptying of a tank at constant intervals. This method is, however, not suitable for many processes, especially because it is not possible with this system to dose the chemical against higher pressures. Therefore dosing units were developed which divide the large volume into a multitude of small equal volumes and which, due to energy supply, are able to dose the chemical even against highest pressures. The volume is "quantized" by injecting the chemical once or twice per second into the process. Thus dosing is "quasi-continuous". If a process requires daily 60 liters of sulphuric acid per hour, adding spontaneously 60 liters after one hour could already be referred to as dosing. The question is whether the process allows this procedure. Continuous processes mostly require a uniform addition and therefore dosing units which, in this case, supply the 60 liters per hour so that an equal unit of volume is dosed e.g. every second. Note: If the very small volumes per second are still disturbing, it is possible to produce a uniform flow using special fittings (e.g. pulsation dampeners). Different mechanical methods are suitable for quantization. One of them is the use of **gear pumps**. Every tooth space accommodates a defined quantity of liquid which is also dosed against high pressures. The dosing rate is mainly reduced by gap leakage occurring between toothed wheel and housing. The losses decrease with a higher viscosity. For this reason gear pumps are more suitable for more viscous media. For dosing suspensions (abrasive particles, wear!) gear pumps should not be used. At constant speed of the toothed wheels, dosing is constant with regard to time.

A completely different method is the **peristaltic pump** which meters the chemical to be dosed by separating a specific quantity in a tube between two pressure rollers and then displacing it with the turning rollers from the suction to the discharge side. Naturally these pumps are only suitable for low pressures (approx. 5 bar), as the tube would expand considerably at high pressures (reduced flow rate) or could not be pressed easily anymore when using more solid tubes.

It is an advantage that this type of pump does not require any valves and can be used for effervescent media without additional equipment.

![JESCO Lutz-JESCO America Corp. logo]

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**Eccentric spiral pumps** and **screw pumps** also displace defined dosing volumes per unit of time but they are more sensitive to abrasive media (suspensions) and show increased gap leakage at higher pressures. They are very suitable for more viscous, greasy media.

## Eccentric spiral pump



Outlet  Hou-  Rotor  Propeller shaft  Inlet  Drive

Void for displacement of the medium
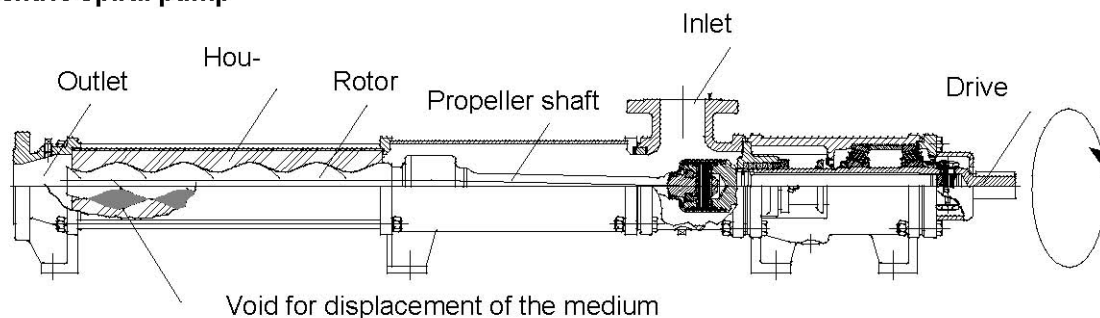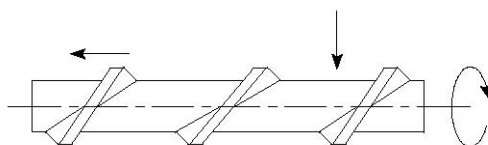
## Screw pump



Liquid dosing can also be realized by using flow meters to continuously measure the medium under pressure or displaced with the help of an auxiliary pump, and by using controllers and control valves to set the required flow (dosing rate). For flow rates of several m³/h, such a method may be more reasonable than dosing pumps.

### Self-regulating orifice plate

A reasonable method to achieve constant dosing is the use of a "self-regulating orifice plate". The flow remains constant since the orifice changes in dependence of pressure differences causing the plate to bend.



Process to be treated

Dosing    Set value of dosing rate

Controller

Auxiliary pump

Chemical supply tank

Total | Metering
Fluid | Transfer
Management | Chem Feed
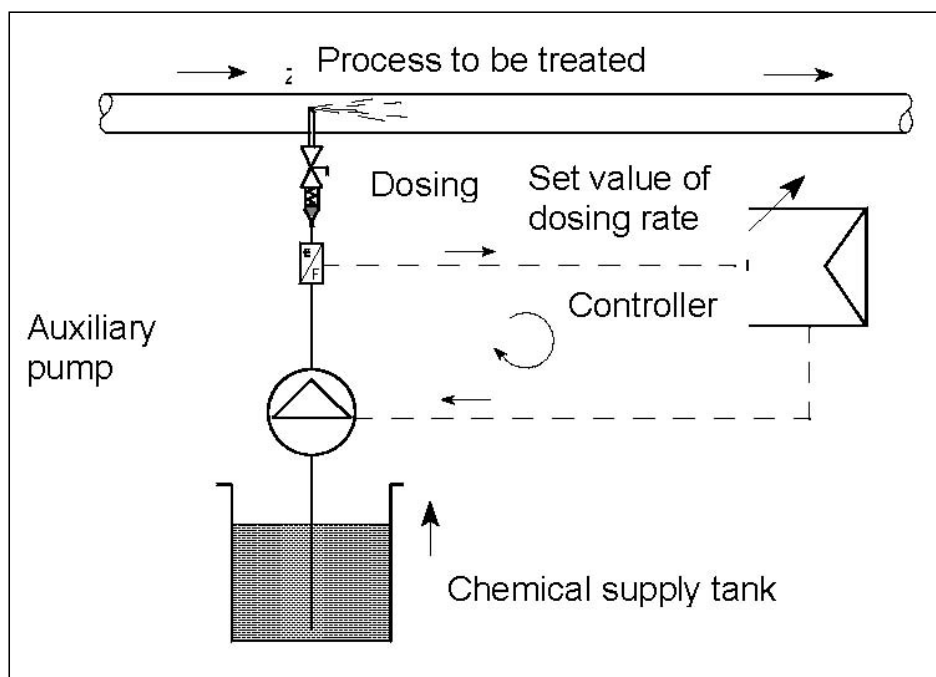
According to previous experience some of the known pump systems are unsuitable or only insufficiently suitable as dosing pumps. E.g. all centrifugal pumps are unsuitable because they are dynamic displacement systems and thus extremely dependent on the pressure conditions on the suction and discharge side. The Q (flow rate) – H (head) curve shows this.

**small difference in pressure**     **big difference in pressure**



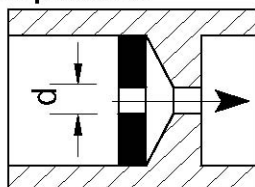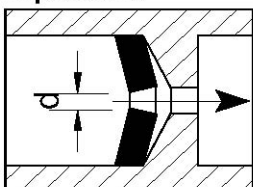The dosing pumps used most frequently all over the world are diaphragm dosing pumps, piston dosing pumps and the combination of both, referred to as piston-diaphragm pumps. These pumps, their applications and accessories will be described in detail in the following chapters.

Dosing pumps consists of the following modules:

1. Drive
2. Gear with mechanical adjustment of the flow rate per stroke
3. Dosing head with suction and discharge valve
4. If required, with remote stroke adjustment for using the pump in automatic control systems
5. Electronic control directly at the pump (selectable)



Comparison of Q-H curves

Backpressure
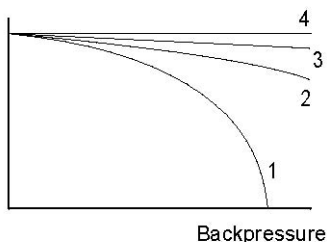
1 Centrifugal pumps
2 Diaphragm dosing pumps
3 Piston dosing pumps
4 Theoretical characteristic curve

## Drive

The drive supplies the energy which is required to displace the dosing medium through the piping system against friction and operating pressure. Three-phase motors are mainly used as drive since they normally rotate at a sufficiently constant speed, even at varying load. If the dosing process requires more accuracy, fittings can be used to make sure that the load of the motor remains the same at any time and thus the average speed is not affected.



Drive (motor)

Discharge valve

Control

Dosing head

Suction    Base    Gear

The aforementioned modules are available in a multitude of versions according to the versatile requirements of the different applications.
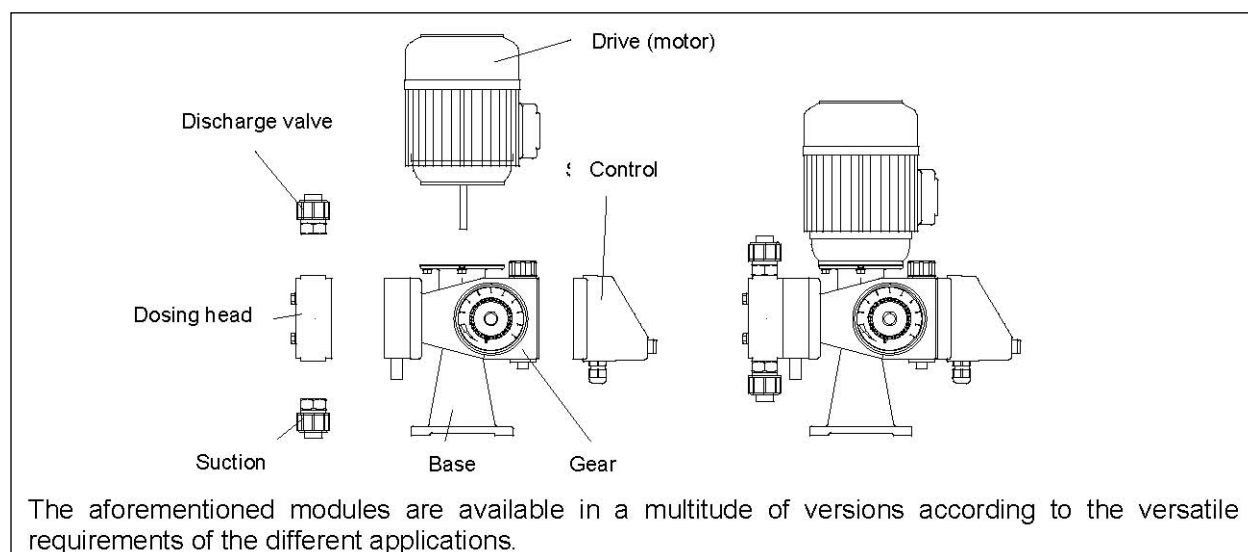
# An Introduction to Metering Technology

## Motor Characterisitc



MAnl = starting torque      Mmax = max. torque
MKipp = breakdown torque      Mmin = min. torque

a = no-load speed
b = operating speed on lower load (e.g. rear dead center of the crank drive)
c = operating speed on higher load (e.g. 90° position of the crank drive)
d = change-over point at which the motor speed decreases considerably and overheating occurs.
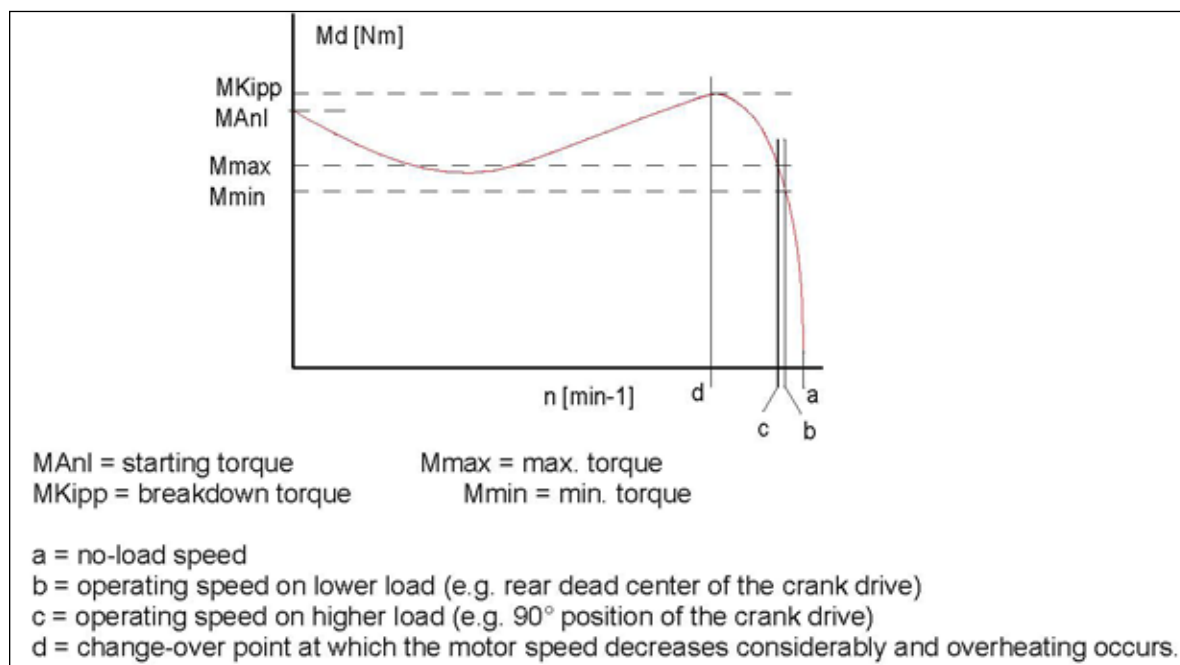
To adjust the flow rate via the pump stroke frequency, i.e. the motor speed, frequency converters are used. Nowadays d.c. motors with thyristor controllers are only applied rarely for speed control, although these offer a much wider control range than three-phase motors, especially in connection with tacho feedback of the motor speed.

**Caution!**

Contrary to centrifugal pumps, dosing pumps need practically the same torque at any speed. The maximum torque is already required when starting from standstill. Besides, in the case of three-phase and d.c. motors, the cooling effect of the fan wheel is missing at low speeds below 50 % due to operational conditions. Therefore an additional motor fan (separate fan) must be installed to ensure sufficient cooling. This becomes necessary when the dosing pump is applied as correcting element in connection with a controller. It can be checked from case to case whether it is possible to do without the separate fan by using an oversized motor the larger surface of which allows enough heat to dissipate.

In the case speed-controlled three-phase motor, a PTC resistor monitoring the coil should be installed for safety reasons.

Due to economical reasons, often three-phase motors are operated with starting capacitor designed as Steinmetz connection in the case of single-phase mains supply. Here it has to be taken into account that the torque is thus reduced to less than 25 % and that the dosing pump might not start at all or restart after a power failure.

For flow rates of up to 100 l/h the so-called solenoid-driven dosing pumps which do not need any gear or rotary parts have been successful worldwide in addition to the motor-driven dosing pumps. A d.c. stroke solenoid allowing to control each individual dosing stroke is used for energy supply and movement of the dosing diaphragm. Thus very precise, proportional dosing is possible which can be controlled by contacts (e.g. of a water meter) or other signals.

The principle of the solenoid drive is limited technically and economically to capacities of approx. 100 l/h against 1.5. bar.

The use of hydraulic and pneumatic drives is restricted. Pneumatic diaphragm pumps are mainly operated as sludge pumps for large volumes. These drives are also found in potentially explosive installations because they can be controlled without current.

## Schematic diagram of MAGDOS
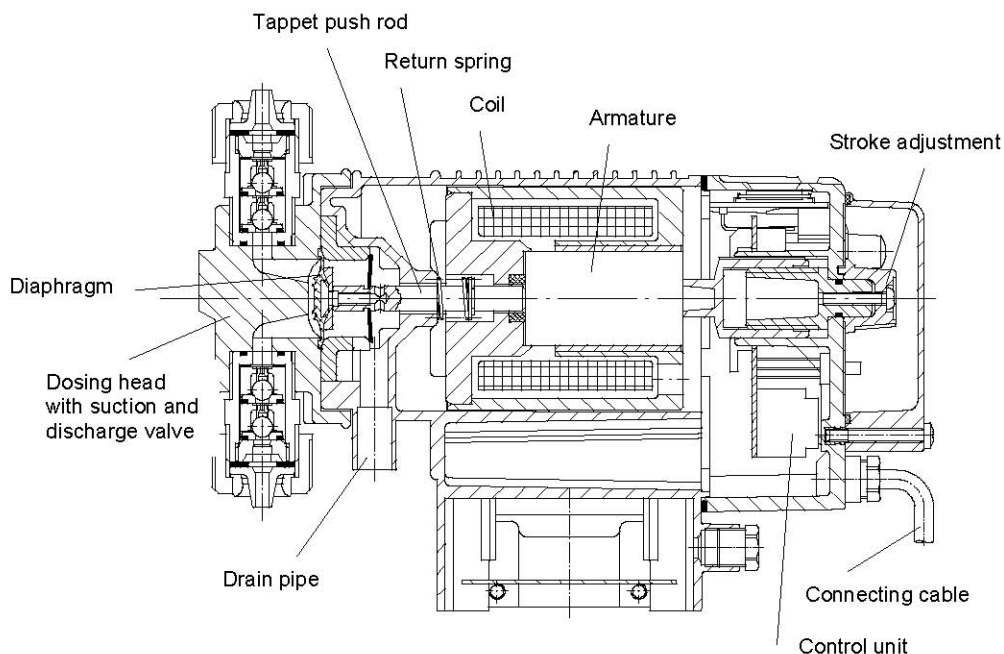


**Gear**

The gears of most commercial dosing pumps are designed to reduce the rotating movement of the drive motor via a single-stage worm wheel set to the speed of the required stroke frequency and to convert it into an oscillating movement. The oscillating or back and forward motion is produced by an eccentric. In the case of simple pumps and those of lower flow rates up to 1,000 l/h, the eccentric is scanned by a spring-loaded tappet moving the piston or diaphragm. For the capacity setting of the dosing pump, an adjustable stop is used which limits the return action of the tappet. Thus a continuous adjustment of the stroke length is possible between 0 and 100%. In practice only a stroke length of more than 10% should be used for capacity adjustment because the flow rate is extremely dependent on the backpressure in the case of lower settings. Spring-loaded tappet gears show produce a sinusoidal curve only at 100% performance. At reduced power they are stopped or accelerated abruptly, thus causing a rather impulsive dosing behaviour. Compared to other methods, the relatively reasonable construction is advantageous. With regard to hydraulic aspects, it is also an advantage that the diaphragm or the piston always reaches the front dead center, even at reduced stroke settings, and thus minimizes the clearance volume.

Gear with amplitude adjustment More complex mechanisms allow a continuous adjustment of the eccentricity and thus of the stroke length during operation. The displacing movement remains sinusoidal without discontinuity. Adjustment is possible between 0 and 100%. Lutz-Jesco KARDOS dosing pumps use the below principle of continuous amplitude adjustment.

1 Diaphragm
2 Diaphragm flange
3 Spring
4 Tappet
5 Adjusting knob
6 Locking knob
7 Stroke limiter
8 Eccentric bearing
9 Worm wheel
10 Eccentric shaft
11 Worm (of motor shaft)
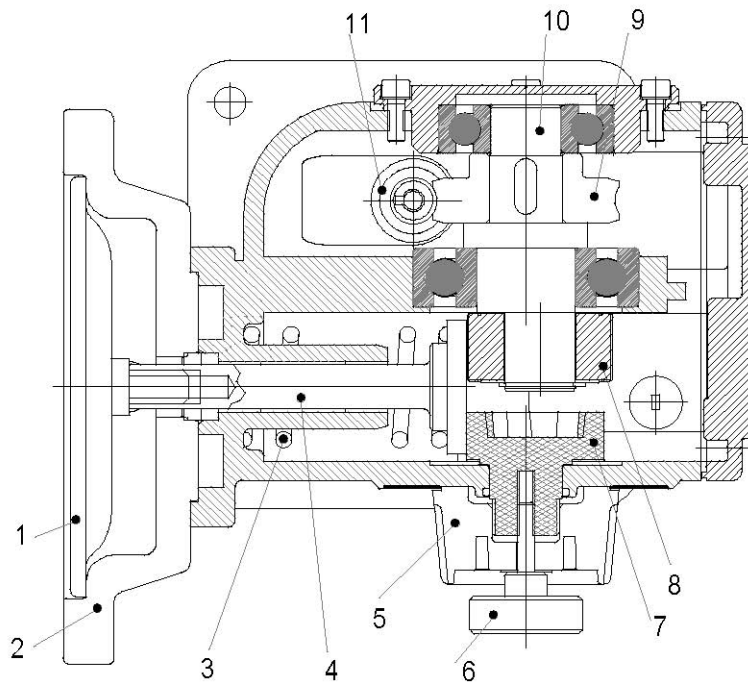


**Tappet gear, set to 43% of flow rate**



Tappet

Return spring

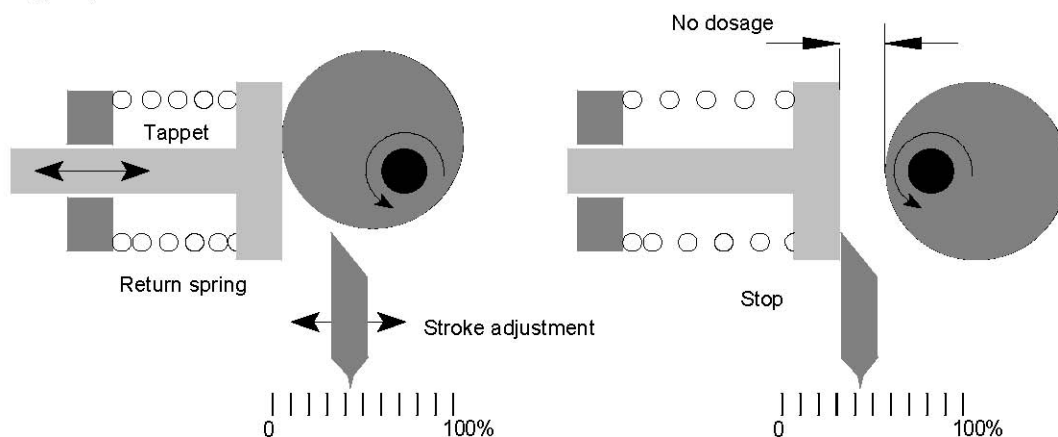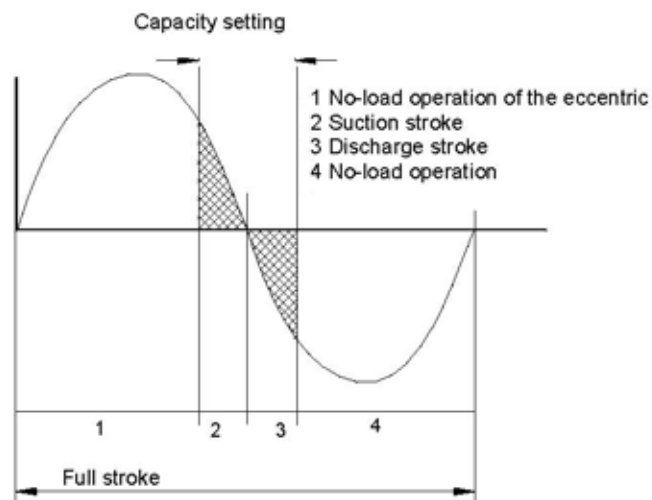Stroke adjustment

0      100%

No dosage

Stop

0      100%

## Gear with amplitude adjustment

More complex mechanisms allow a continuous adjustment of the eccentricity and thus of the stroke length during operation. The displacing movement remains sinusoidal without discontinuity. Adjustment is possible between 0 and 100%. Lutz-Jesco KARDOS dosing pumps use the below principle of continuous amplitude adjustment.

The drive consists of an oil-filled worm gear with single-stage reduction. The main component of the KARDOS gear is the radially movable eccentric. It can be adjusted according to the required flow rate by means of the helical rack. It is an advantage that there is no apparent sliding motion between the parts after completion of the stroke adjustment. The eccentric acts like a fixed crank pin. The stroke length of the tappet or connecting rod gear can be adjusted manually or remotely using a servomotor. Most servomotors are operated electrically but they can also be activated pneumatically (adjusting cylinder). For batch control the pump gears can be equipped with a stroke count mechanism. Thus the pump can be switched off after a preset number of strokes.

## Dosing head

In many respects, the dosing head is the most important part of a dosing pump. It is not only required to meter the volume precisely but must also be resistant to extremely aggressive media. In some cases the dosing head must be suited to withstand very high operating pressures and temperatures exceeding 100°C. If toxic, volatile or abrasive media must be dosed, the dosing head should be leakproof. Highly viscous media affect the valve function so that the valves close with delay. Special measures such as providing spring-loaded balls or valve disks support the valves in closing more quickly and thus ensure perfect dosing. Substances which are not fluid anymore at room temperature (e.g. congealed fat, tallow, molasses or bunker fuel) must be warmed up until flowability by heating dosing head and valves before startup. Of course, heat must also be applied to the suction and discharge lines to ensure that the medium remains fluid.



Output diagram of a tappet gear

Capacity setting

1 No-load operation of the eccentric
2 Suction stroke
3 Discharge stroke
4 No-load operation

Full stroke



Crank gear with adjustable amplitude

Eccentric with continuous rack adjustment

Stroke    Stroke/2    No stroke

Total | Metering
Fluid | Transfer
Management | Chem Feed
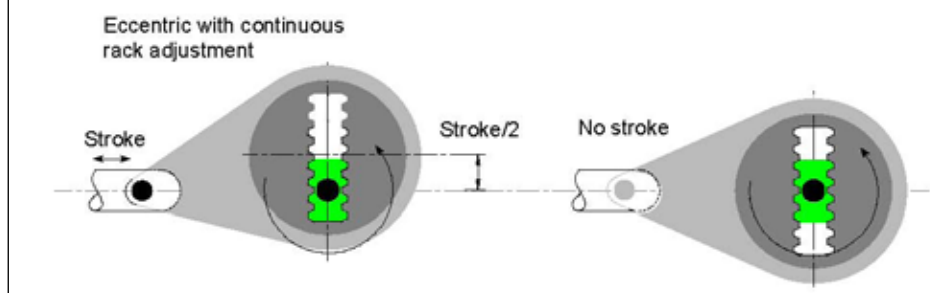
## Diaphragm dosing head

## Piston dosing head

Double-ball discharge valve

Deflector plate

Packing

Piston

Gland

Diaphragm

Drainage

Gland nut

Double-ball suction valve
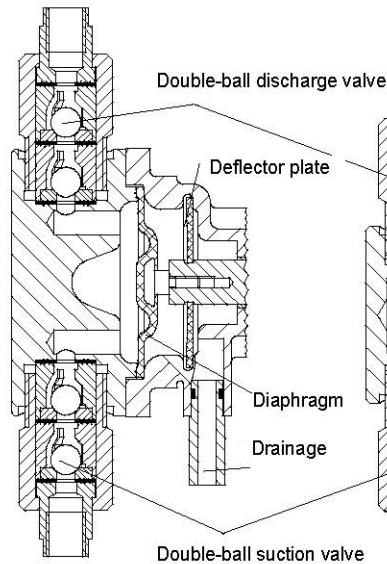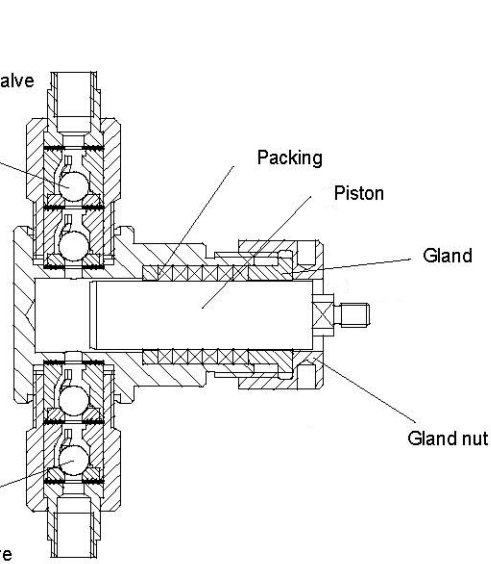
### Suction and discharge valves

Suction and discharge valves have a very important function as they must ensure that the dosing chemical flows only in one direction and that there is no return flow. Balls or valve disks are used as non-return elements. For larger cross-sections valve disks are more suitable than balls because their mass is lower and thus the working noise is reduced. To allow the valves to close quickly and reliably also in the case of more viscous media, it is advisable to use spring power. From experience pumps up to 100 l/h should be fitted with springs at viscosities of 200mPa*s and more and larger pumps at viscosities of 400mPa*s and more. Small pumps up to 100 l/h are equipped with two balls per valve to increase the non-return reliability.

## Heated dosing head
electrical

1  2  3

5

4
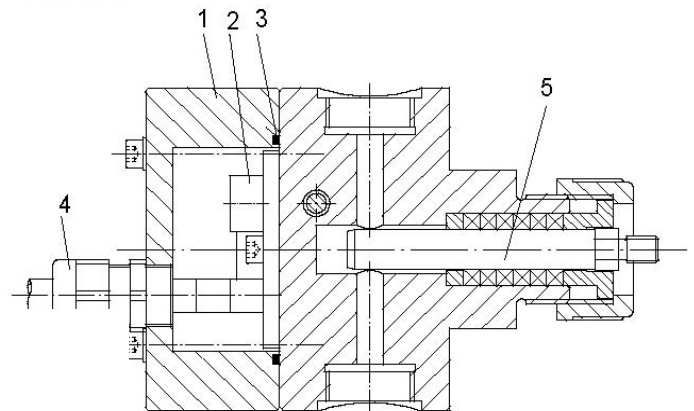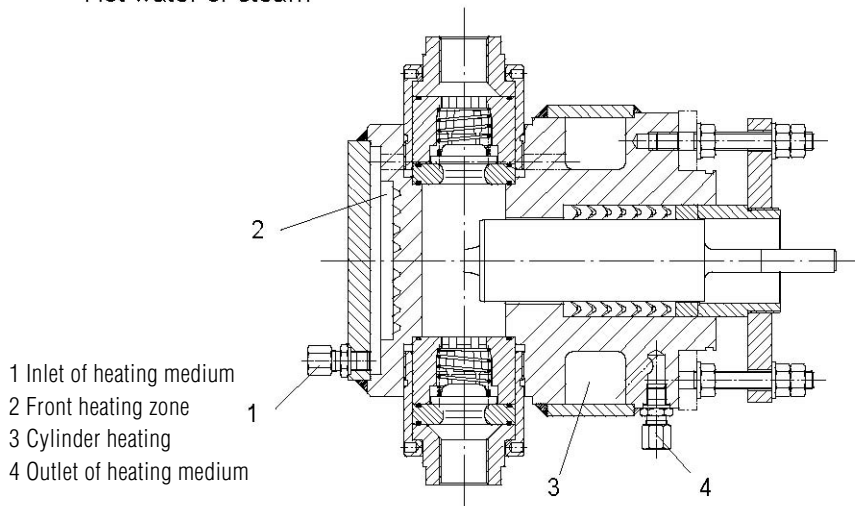
1 Protective housing
2 Electrical heating element
3 Seal
4 Cable inlet
5 Piston

### Hot water or steam

2

1 Inlet of heating medium
2 Front heating zone
3 Cylinder heating
4 Outlet of heating medium

1

3

4

## Spring-loaded single-ball valve
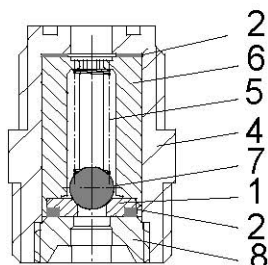


## Spring-loaded disk valve
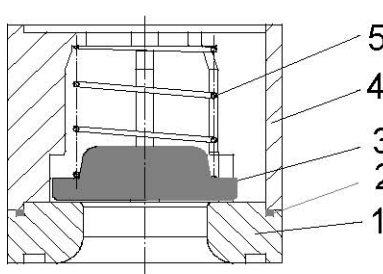


## Double-ball valve
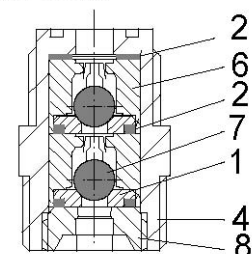


| | |
|---|---|
| 1 Valve seat | 5 Spring |
| 2 Washer | 6 Ball guide |
| 3 Valve disk | 7 Valve ball |
| 4 Valve housing | 8 Plug |

### Displacement elements

The standard displacement elements are dosing diaphragm and piston. Depending on the task, i.e.: the type of medium to be dosed and the operating conditions, both have advantages and disadvantages which will be explained in the following:

### Diaphragm

The main advantage of a diaphragm is that it is absolutely leakproof so that no toxic, aggressive or ecologically harmful media can escape to the environment. Besides, the diaphragm is mostly insensitive to abrasive media. It is also safe to run dry although this advantage becomes effective



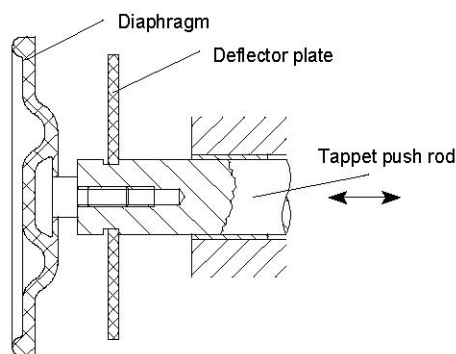only if remainders of the chemical do not tend to crystallize due to air entering the valves (the latter can, however, be avoided by a level control installed in the chemical supply tank). The disadvantages are mainly that the flow rate depends more
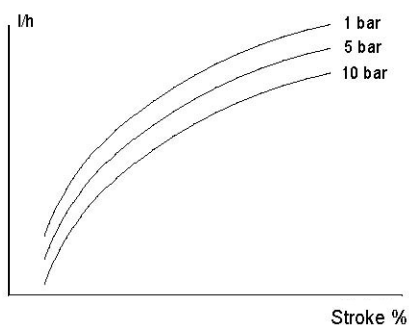
or less on the pressure and that there is no linear relationship between stroke length and flow rate (half the stroke does not necessarily mean half the output). Normally dosing diaphragms can only be used up to 10 bar. Special constructions or operating modes with an accepted service life reduction allow pressures of up to 20 bar. The diaphragms are made from fabric-reinforced rubber such as EPDM, Hypalon or Viton. To increase resistance, the diaphragms are available with a teflon coat. The thickness of the coat represents a compromise with regard to non-porous teflon and rigidness restricting the diaphragm movability. To improve the performance curve (linearization in dependence of the stroke length) and to increase the flow rate, diaphragms can also be reinforced by so-called "support plates". A round metal part is vulcanized with threaded stem to attach the diaphragm to the gear tappet.

### Piston

Piston pumps can operate against several 100 bar and the flow rate is rather independent of the backpressure. Furthermore there is a very linear relationship between stroke length and flow rate. A disadvantage is, however, the leakage which is in fact necessary to lubricate the packing. Dry operation is not allowed. Dry friction between piston and packing would cause local overheating and scoring with increasing leakage. The use of toxic and extremely aggressive media is impossible because of the leakage. There is, however, the possibility of dosing the aforementioned type of chemical by flushing the lantern ring of the packing intensely with water so that the leakage escaping to the environment contains no more than a low concentration of the problematic chemical. Flushing, however, depends considerably on the local conditions and on the type of medium. For abrasive media, it might be useful to build up a pressure higher than the operating pressure at the flushing lantern ring so that possibly entering particles are pushed in the direction of the medium.

## Performance curves of diaphragm pumps

# An Introduction to Metering Technology



Outlet of flushing water
Piston
Extremely diluted leakage
Inlet of flushing water

**Lantern flushing**



Flushing water          Flushing water
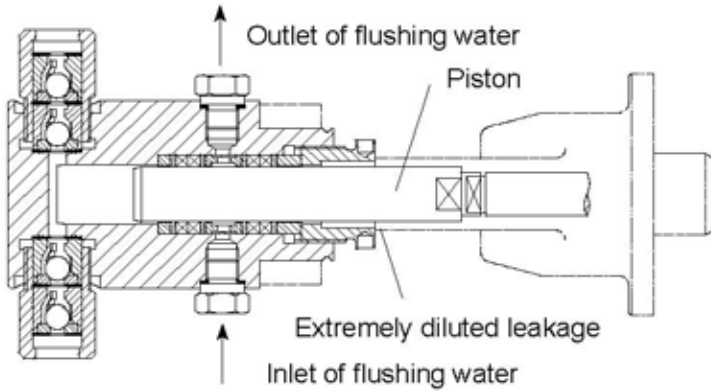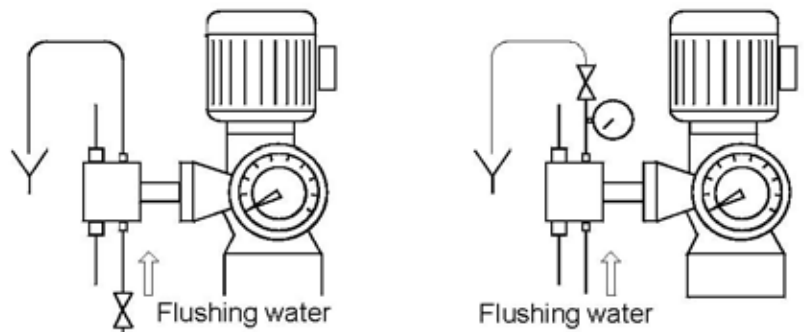
## Performance curve of piston dosing pumps

Piston dosing pumps



l/h

1 bar

200

Hub %
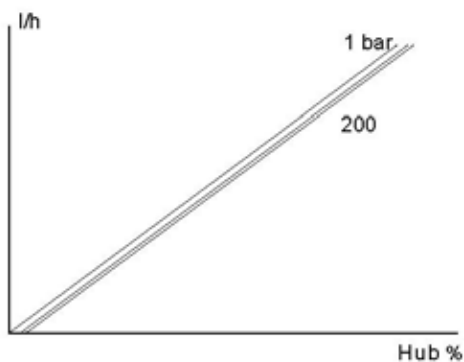
Comparison of the discharge behaviour

l/h

Diaphragm dosing pumps

Piston dosing pumps

Stroke %
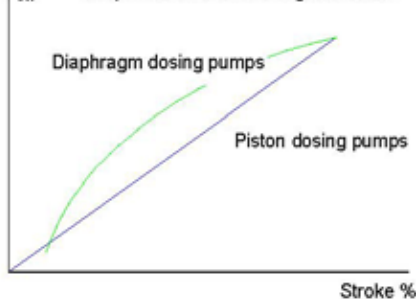
The conflict situation between aggressiveness on the one hand requiring leakproof operation and high operational pressures on the other hand making the use of simple diaphragm pumps impossible is solved by piston-diaphragm dosing pumps. This type of pump combines the precision and high discharge pressures of piston pumps with the leakproof operation of diaphragm pumps.

## Piston-diaphragm system KMS

The "piston-diaphragm" system combines the advantages of diaphragm pumps and piston pumps without including their disadvantages. The function of the piston-diaphragm system is most easily to understand if we imagine the cylinder of the piston pump to be hermetically sealed from the actual dosing head by a diaphragm. To transmit the volumetric displacement of the piston to the medium side, the gap between piston and diaphragm is filled with glycerin or silicon oil (without air). Thus the diaphragm is forced to displace the same volume as the piston, and the medium on the other side of the diaphragm will be moved in the same way. To compensate for the liquid lost at the piston due to leakage, a blow valve ensures that the missing quantity can be reprimed. At the same time a pressure relief valve causes surplus glycerin or silicon oil to flow back to the supply tank in the case of excess pressure.

### Principle of the piston-diaphragm dosing head
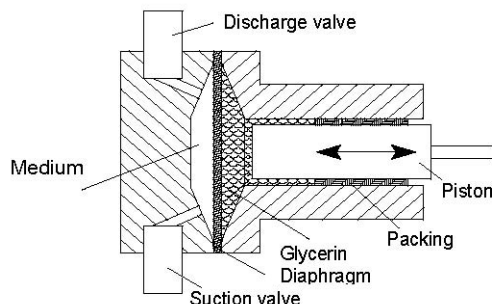


### Actual construction of piston-diaphragm dosing head
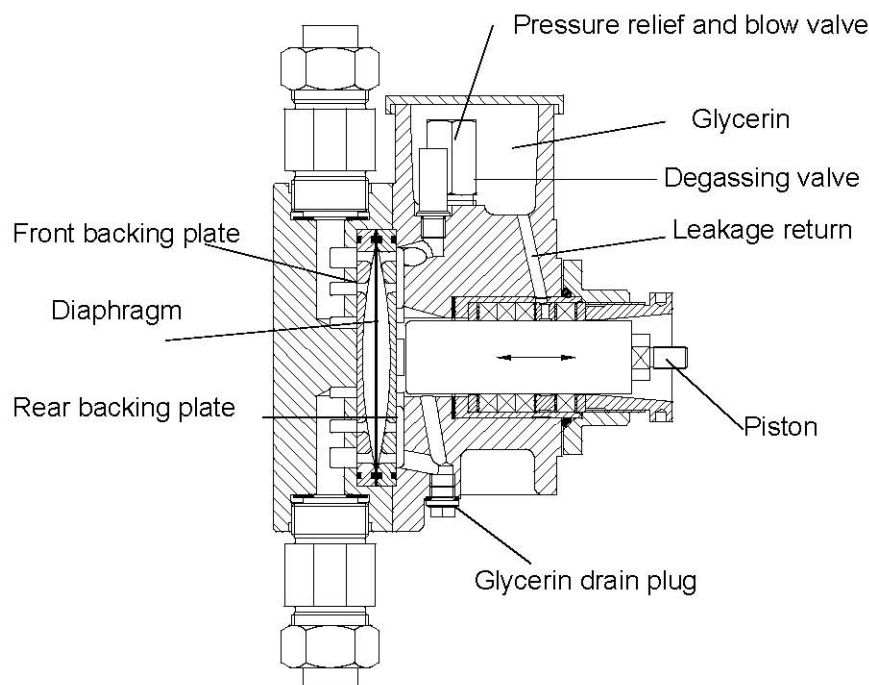


## Bellow pump

Regarding the effect, the bellow pump lies between piston-diaphragm pump and normal diaphragm pump.Instead of the diaphragm, it is fitted with bellows similar to those of a concertina, which are changed in length by the eccentric. Bellows are leakproof and have a rather linear performance curve (similar ot a piston). Unfortunately this principle is only suitable up to 5 bar due to the mechanical strength of PTFE which is used in most cases.
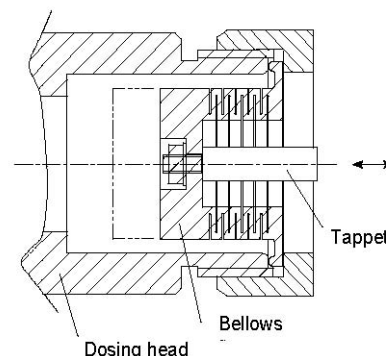


## Materials

Plastic dosing heads are preferred because of the high chemical resistance. Among other materials PVC, PPh, PE, PVDF; PTFE and PMMA (acrylic glass) are used. Plastic materials are, however, only suitable for pressures up to 10 bar unless reinforced by metallic chambers.

For seals and movable rubber parts Hypalon, EPDM, Viton, etc. are used. If required, all elastomers are available with protective PTFE coating.

Pistons are made from different types of stainless steel, also surface-hardened as protection against wear, or from aluminum oxide ceramics. Plastic pistons have not proved to be reliable.

Valve balls are mostly of glass, ceramic or plastic materials (e.g. PVDF or PTFE) as well as stainless steel. Valve disks instead of balls are available in plastic materials (PVC, PVDF and Teflon) and stainless steel. Depending on the viscosity, valve balls can be loaded with locking springs. Valve disks are spring-loaded in most cases.

For sealing the pistons, mainly silk-woven PTFE packings are used with regard to their almost universal resistance. In the case of abrasive media and pressures exceeding 100 bar, aramid packings (on the basis of carbon fibers) or lip seals (grooved junk rings) made of elastomers are more suitable because this type of sealing allows to remove particles from the piston more effectively (usable for suspensions).

The sealing effect of grooved junk rings rises progressively with increasing pressure.

Lutz-JESCO America Corp.

## An Introduction to Metering Technology

### 1.1.1 Different dosing tasks

In industrial and process applications there is a great variety of tasks, which require dosing of a medium in a certain way. These tasks can be, for example:

1. Continuous and uniform dosing as long as the process is in operation.
2. Dosing for a limited period of time to add a specific quantity per batch.
3. Simultaneous dosing of several components which are in a fixed ratio to each other. It is important that the ratio is not changed by external influences on the dosing equipment so that the overall formula remains constant.
4. Proportional dosing ensuring that the dosing rate adjustment instantaneously follows a signal. In the case of a signal coming from the flow meter, this means: If the flow is 0, the dosing rate is 0 as well, and at 100% flow, the dosing rate also increases to 100%.
5. Adjustment of the dosing rate so that the set value defined for the process is achieved. For this purpose the value to be controlled must influence the dosing rate. In the case of a pH value control, the dosing pump is thus adjusted by the pH controller depending on how much the actual pH value deviates from the set value.

**Dosing pump can also be used to**

1. fill media from supply tank to a batch container,
2. to transport high-concentration chemicals to a mixing device for dilution,
3. to circulate a medium in the same tank,
4. to dose a specific quantity defined by a single stroke into a separate vessel, as e.g. aromatic essences into the different tins of a filling machine.
5. to feed a circulation line to supply different consumers from this line,
6. to transfer media measured precisely by means of a balance to a tank or process. In the case of gravimetric dosing, often the complete supply tank is weighed and the quantity taken is measured exactly per time unit.

# 1.2 Lutz-JESCO dosing pump program

In addition to the sales literature folder, a general idea of the dosing pump program will be given in the following. For more detailed technical information, refer to the brochures, data sheets and operating instructions. The below schematic diagram divides the Lutz-Jesco product range for liquids in diaphragm dosing pumps, piston dosing pumps and piston-diaphragm pumps.

**Lutz-JESCO pump program**

All standard versions are driven by three-phase motors. The output is adjusted mechanically via the stroke length. In the case of electrical remote adjustment by hand or controller, the three-phase motors can be regulated with the help of frequency converters, or the pumps are equipped with d.c. motors to be driven via thyristor controllers. As a result of the permanent improvement of frequency converters for three-phase motors, however, d.c. motors are only used very rarely now. The advantage of speed adjustment is that the flow rate directly follows the control signal. As an alternative or in addition, the stroke can be adjusted remotely by means of a servomotor.

**Schematic diagram of frequency converter for speed control**

Variable drive speed, constant stroke

Frequency converter with manual adjustment by poti or
impressed direct current 0(4)…20mA

Mains 230 V A.C. or 400 V D.C.
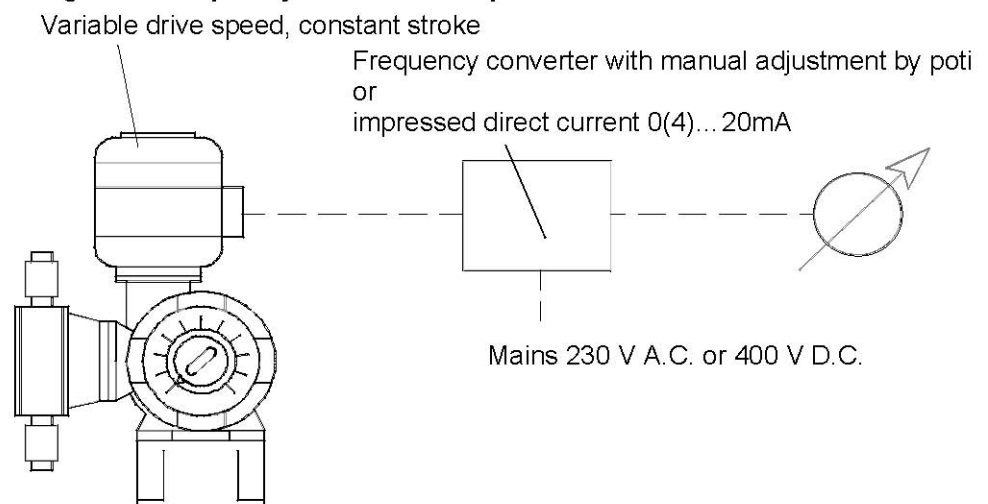
## Schematic diagram of ATE servomotor for stroke adjustment



Constant drive speed, variable stroke

Servomotor for electrical stroke adjustment with manual key button or controller

Control "left-stop-right"

ATE

## Circuit diagram of locking contact

Contact opens if drive motor is not running e.g. 3-point step controller
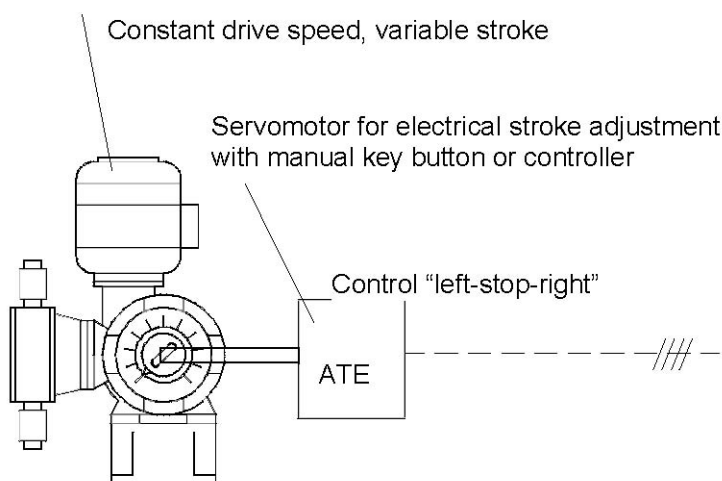


Make sure that the stroke of the servomotor is never adjusted during standstill of the drive motor. For this purpose, an electrical locking contact must be provided. In the case of non-observance the gear of the servomotor may be damaged.

With regard to control-relevant aspects, it must be considered, that the servomotor completes the stroke adjustment much more slowly compared to the effect achieved by changing the speed of the drive motor. It is another advantage of speed adjustment over stroke adjustment via servomotor that a better linearity between signal and flow rate is ensured. Half the speed corresponds to half the flow rate, independent of whether a diaphragm dosing pump or piston dosing pump is used.  As already described in previous chapters, diaphragm metering pumps do not have a linear relationship between stroke length and flow rate. Therefore half the stroke length does not necessarily mean that also half the quantity is dosed. This must be taken into account if the dosing pump is operated without feedback in an open control system, e.g. in the case of proportional dosing according to a flow meter signal.

**Note**: If the dosing pump is used as a correcting element in automatic control systems, it is almost irrelevant whether there is a linear relationship between signal and flow rate, as the controller adjusts the dosing pump until the actual value matches the set value. Most gear versions of motor-driven pumps are tappet gears with single-stage worm wheel reduction. Crank gears with connecting rod are only used for GMR diaphragm pumps and KARDOS piston pumps. While the stroke of the GMR is always constant and the speed is variable, the eccentric of the KARDOS can be adjusted continuously. Thus a uniform sinusoid is constantly repeated, but with variable amplitude. The dosing ranges start at  0 … 0.1 l/h for solenoid pumps and end at 4,200 l/h per head for the largest diaphragm pump as well as for piston pumps. With the exception of the solenoid dosing pumps and MEMDOS E/DX, all dosing pumps are available with single or duplex head.
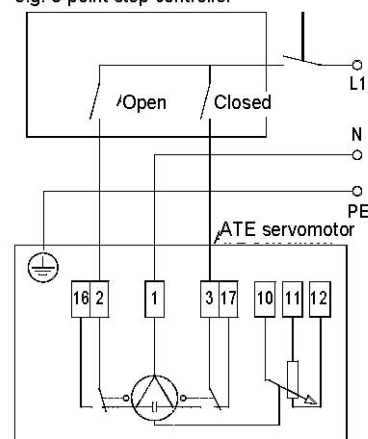
**Multiple head pumps**

The use of multiple head pumps can have various reasons:

1. Increase the flow rate
2. Distribute the required flow rate to several dosing heads, as the permissible pressure for each individual head is higher than for one large head.
3. Reduce the dosing pulsations. For this purpose the required dosing capacity to several shifted dosing heads (e.g. 2 heads by 180°) to obtain a more even flow.
4. Mixing different components is an ideal application for multiple head pumps, since the mixing ratio once set remains constant even in case of speed variations due to the common drive motor. If there is power or motor failure, the pump stops for all media to be dosed at the same time.
5. If different components have to be dosed absolutely in parallel, the gear of the multiple head pump can be prepared so that the dosing strokes take place at exactly the same time, i.e.: they superimpose the sinusoidal dosing strokes without phase shift.

Characteristic curves of different dosing pumps which all have an output of 100 liters over the same period of time.  The hatched areas represent 100 liters.

## Characteristic curves
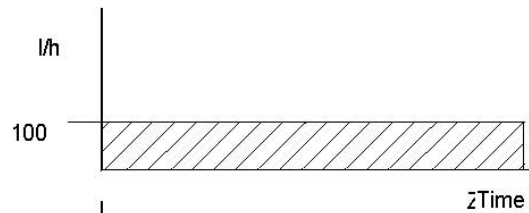


Constant output
(e.g. centrifugal pump)
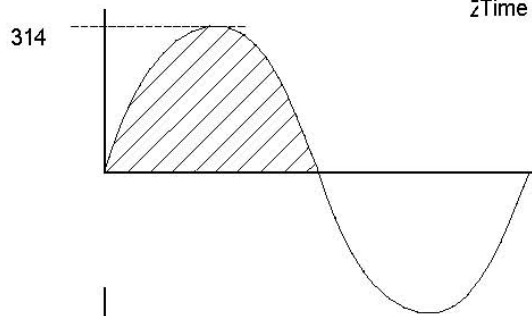
Single-head dosing pump
with a peak output of
3.14*100 = 314 l/h
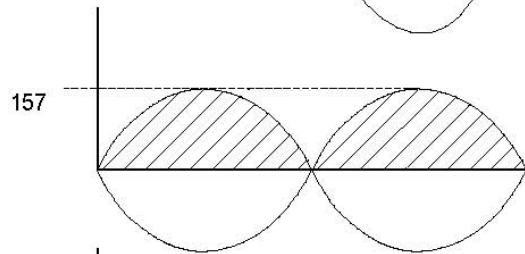
Duplex head dosing pump, with the
total flow rate being halved and
distributed to the two heads.
3.14*50 = 157 l/h
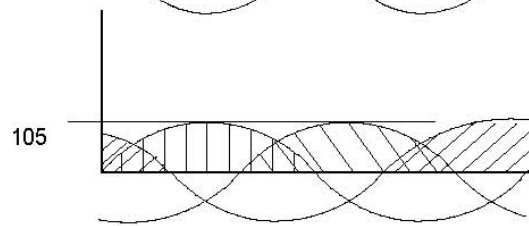
Triple head dosing pumps, with the
total flow rate being divided into thirds
and each head dosing
3.14*33.3 = 105 l/h

# 1.3 Fittings and accessories

In many cases the dosing pump alone cannot perform the set task. Then auxiliary equipment and fittings are required in addition to optimize the hydraulic conditions so that dosing can take place or the pump achieve maximum accuracy. The following situations may require supplementary measures:

| Operating condition of the dosing system to be improved | Recommended fitting or installation |
|---|---|
| 1. Priming is facilitated if the volume primed after a stroke cannot run back in the suction line but remains at the level reached before. | Use suction line with foot valve (ball non-return valve) and additionally protective strainer |
| + | Install priming aid close to suction valve of the dosing pump.<br><br>Provide pressure relief at the pressure joint of the suction pump. For this purpose either the multifunction valve PENTABLOC or a manually or electrically operated dosing head venting, e.g. GAS-EX, can be used.<br><br>Provide siphon with hand vacuum pump or manually or automatically activated injector. |
| 3 Dosing pump often have large dead centers. Therefore included air immediately has a negative effect. Dosing may fail completely. | Install manual or automatic degassing device GAS-EX or/and air bleed traps at the suction valve. |
| 4. Varying heads in the supply tank influence the flow rate. | Provide an intermediate receptacle (siphon-type collector) with constant filling level, e.g. float valve or suction controller SDR. |
| 5. If the dosing line is closed by mistake or blocked up, the resulting excess pressure may cause damage to the dosing pump or system. | Install pressure relief valve as safety valve. |
| 6. Varying backpressures affect the flow rate, especially in the case of diaphragm pumps. | Install backpressure valve for constant backpressure. |
| 7. More chemical is dosed than defined according to the flow rate setting, caused by the following conditions:<br>a) pressure too high on the suction side<br>b) vacuum at the point of injection<br>c) point of injection geodetically below the dosing pumps<br>d) Mass inertia of the liquid head due to a long dosing line | Referring to a), b) and c):<br>Install backpressure valve at the end of the dosing line.<br><br>Referring to d):<br>Install pulsation dampener PDS just before the suction valve and backpressure valve at the end of the line. |
| 8. The dosing chemical should be introduced into the injection nozzle through a non-return valve so that no medium can escape in the case of a dosing line rupture. | Mount injection fittings ready for installation, consisting of shutoff valve, non-return valve and injection pipe (down to the middle of the process pipe).<br><br>Before longer shutdown periods of the dosing pump the shutoff valve of the injection fitting should be closed. Do not only rely on the function of the non-return valve! |
| 9. Pressure and flow fluctuations of the oscillating dosing pump are unwanted. The high pressure peaks resulting from the accelerations may affect the dosing output and the service life. Float element flow meters require a uniform flow. | Install pulsation dampener at the outlet of the dosing head.<br><br>In the case of critical priming conditions (long suction lines, high suction heads), pulsation dampeners mounted on the suction side will also have a positive effect. |
| 10. The dosing chemical tends to deposit or precipitate (sedimentation). Thus dosing lines and, in the case of standstill, also valves or displacement elements may be affected. | Fit dosing head with a flushing facility which flushes head and valves e.g. with water before shutdown periods. |
| 11. The dosing chemical has congealed at room temperature and is no longer fluid. | Fit dosing head and valves with heating. Current, steam or hot water heating is possible. Possibly also provide external heating for lines to and from the pump. |
| 12. Aggressive or toxic media might leak due to a diaphragm failure. | Install leakage sensor LECKCHECK at the dosing head. |
| 13. No control if dosing takes actually place. | Install visual flow control or electrical flow sensor FLOWCON at the pump outlet. |

# An Introduction to Metering Technology

**In the following the fittings are described in more detail:**

## 1.3.1 Suction lines

Perfect filling of the dosing head at the suction stroke depends on whether enough liquid flows through the suction line during the short time of stroke movement. Mass inertia of the liquid and pipe friction work against the flow. In this connection attention is drawn to the fact that the suction process is no "priming" in its proper sense but that the displacement element (diaphragm or piston) "makes room" so that hopefully the air pressure is able in the available short time to push forward enough liquid from the supply tank. The liquid in the suction line must be displaced by the air pressure very fast so that it always remains in contact with the diaphragm or the piston and does not "break off". This process of breaking off is also called cavitation and has two disadvantages:

    a) The dosing head is not filled sufficiently which causes reduced flow rates.

    b) The steam bubbles occurring during cavitation strike together again afterwards and lead to mechanical destruction of the internal parts of the dosing head.

If the liquid must be primed upwards (e.g. from buried tanks or with pumps mounted above the tank) the required suction pressure also affects filling of the head. In the case free supply, i.e.: if the pump is installed below the tank level, the static pressure helps to fill the head. The negative effects are reduced with shorter suction lines and larger line diameters. The length of the suction line should not exceed 2m for water-like media and the diameter should allow velocities of not more than 0.8 m/second. For oscillating dosing pumps without pulsation dampening, the flow is not uniform. The top speed of single-head pumps with eccentric drive is approximately three times as high as would be expected according to the nominal pump capacity (hence at uniform flow). Therefore three times the max. flow rate must be taken into account when dimensioning the suction line of oscillating dosing pumps with motor drive. For safety reasons, five times the rate must be considered in the case of solenoid pumps, since the stroke is not sinusoidal but more pulsed.

**Note**: For suction lines longer than 2 meters and media with high steam pressures as e.g. methanol, the suction line and, for media of a higher viscosity than water, also the discharge line should be checked mathematically and dimensioned accordingly. In addition to the generally available literature about hydraulics, chapters 1.3.1.1 and 1.3.1.2 can be helpful.

### 1.3.1.1 Calculating the diameter of the suction line with due regard to the stroke frequency

To constantly ensure perfect fillling of the dosing head despite a pulsating operation of the dosing pump, the pressure existing at the inlet of the suction valve must be high enough to allow the dosing chemical to flow into the dosing head at the speed required by the piston (diaphragm) during the suction stroke. If the dosing chemical cannot follow at the same speed, the flow "breaks off" and cavitation occurs. The pressure existing at the suction valve is generally referred to as the available NPSHa value (abbreviation of

(I) $\quad NPSHa = p_{tank} - p_{steam} \pm H_{suction} \times \varsigma / 10^4$ [bar abs]

$p_{tank}$ = **absolute pressure** in the dosing chemical tank (bar abs) (for open tanks, $p_{tank} \approx 1$ bar abs at height above sea level)

$p_{steam}$ = **steam pressure** of the dosing chemical (bar abs) at the temperature existing at valve entry. (Water at 20 °C has a steam pressure of 0.023 bar)

$H_{suction}$ = **suction head** [m]      (+) for free supply      (-) for upward suction

$\varsigma$ = **density** [kg/m³]

With a given NPSHa value and known stroke frequency of the dosing pump, the minimum diameter of the suction line can be calculated using the following formula:

(II) $\quad d \geq \sqrt{\dfrac{Q * F * L * \varsigma}{8.6 * 10^5 * (NPSH_a - 0.15)}}$

This formula does not take any flow losses into account.

| | | |
|---|---|---|
| Q | = | flow rate [l/h] |
| F | = | stroke frequency [strokes/min] |
| $d$ | = | suction line diameter [mm] |
| $L$ | = | suction line length [m] |
| $\varsigma$ | = | density [kg/m³] |
| $NPSH_a.$ | = | see formula (I) |

"Net Positive Suction Head, available"). The system-related accelerations and decelerations of the liquid head in the case of oscillating dosing pumps have to be taken into account in particular when dimensioning the suction line. As the distance between dosing pump and tank is often fixed, the diameter must be chosen with due regard to the length of the suction line so that caviation is avoided. The available NPSH value can be calculated according the following formula:

**Note:** factor 8.6*105 compensates for measuring units, constant 0.15 represents a safety factor in [bar]

## 1.3.1.2 Calculation of the pressure peak in the dosing head caused by acceleration during discharge stroke

(III)

$$p_{accel.} = \frac{Q*F*L*\varsigma}{8.6*10^5*d^2} \text{ [bar] (units see above)}$$

The pressure peak calculated with the help of this formula must be added to the operating pressure against which dosing is to take place. The total must be below the admissible pump pressure.

The acceleration relevant for line calculation reaches its maximum values at the rear or front dead center. As exactly at these two dead centers no dosing takes place, because the displacement element (piston or diaphragm) is not working, at this moment there is no pressure loss due to friction in the pipe. On the other hand the friction in the pipe is the strongest when the flow speed reaches its highest level at a crank angle of approx. 90°. During this moment there is uniform flow, i.e.: no acceleration or deceleration.

For the calculation of the lines, it is thus sufficient in most cases to check the critical situations, i.e.: maximum acceleration and the pressure stroke to be expected or pressure reduction until cavitation, and on the other hand pressure loss occurring at maximum flow due to friction in pipes and fittings.

Also for the discharge line, it is recommended to calculate the pipe diameter for an acceptable pressure stroke.

(IV)

$$d \geq \sqrt{\frac{Q*F*L*\varsigma}{8.6*10^5*p_{accel.}}} \text{ [bar] (units see above)}$$

**Note:** To calculate the frictional loss in pipes for oscillating pumps such as diaphragm and piston dosing pumps, often only the nominal capacity is used by mistake. It is neglected to consider the actually occurring maximum flow which is approximately three times as high for motor-driven dosing pumps and approximately five times as high for solenoid pumps (see 1.5.3.4). When using a pulsation dampener, this increased flow rate only applies for the section between pump and dampener. For the rest of the piping, the nominal capacity can be taken into account.

Especially the calculation of pressure losses by friction in pipes is rather complicated, since it also depends on the viscosity of the liquid. Apart from the fact that the viscosity is strongly related to temperature (a low temperature causes the viscosity of liquids to increase), the viscosity of different liquids also shows other varying characteristics. Liquids with the same viscosity at the same temperature, for example, may have a completely different behaviour when moving at high speed. There are liquids which, at higher speeds, show progressively increasing viscosity properties in pipings or tanks, and there are others with an apparently decreasing viscosity. As far as dosing pumps and fittings are concerned, it is recommended to calculate the frictional losses in pipes carefully according to the formulas and values available by technical literature. To estimate the dimensioning of the piping roughly with due regard to acceleration, the formulas in chapter 1.3.1.1 can be used.

Dimensioning of the piping according to the frictional losses can be estimated roughly using the following formulas:

## 1.3.1.3 Calculation of the pressure loss with due regard to friction in pipes

For a rough estimate of the pressure losses due to pipings and inline components such as elbows, reducers, valves, etc., the following calculation model can be used:

### 1. Flow speed
Coming from the quantity Q to be dosed (l/h) and the assumed flow speed w (m/s), the pipe diameter d (mm) is determined.

Diagram 1.5.3.4 can be used for this purpose.

## 2. Pressure loss △p_A due to fittings

From the table, the drag coefficient of the individual fittings, elbows, etc. integrated in the course of piping have to be determined and added.

For inline components not listed in the table, use comparable values.

$$(V) \qquad \Delta p_A = \frac{\Sigma \xi * w^2}{2 * 10^5} * \varsigma = \left( \frac{\Sigma \xi * Q}{1{,}264 * d^2} \right)^2 * \varsigma \quad \text{[bar]}$$

w = flow speed [m/s]
$\varsigma$ = density [kg/m3]
d = pipe diameter [mm]
Q = flow rate [l/h]

Pipe bend

| r/d | 1 | 2 | 4 | 6 | 10 |
|-----|-----|-----|------|------|-----|
| $\zeta$ | 0,5 | 0,3 | 0,23 | 0,18 | 0,2 |

Sockets, bushings, reductions

| d/d1 | 0,1 | 0,3 | 0,5 | 0,6 | 0,8 | 0,9 |
|------|------|------|------|-----|------|------|
| $\zeta$ | 0,45 | 0,42 | 0,38 | 0,3 | 0,17 | 0,09 |

Elbows, sharp-edged

| $\alpha$ | 10 | 15 | 30 | 45 | 60 | 90 |
|------|------|------|------|-----|-----|-----|
| $\zeta$ | 0,04 | 0,06 | 0,15 | 0,3 | 0,6 | 1,2 |

T-piece

$\zeta$ = 1,3
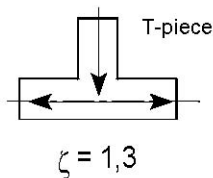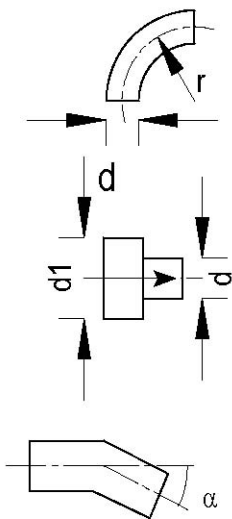
Inlet or outlet connection piece

$\zeta$ = 0,06

$\zeta$ = 0,56

$\zeta$ = 2,8
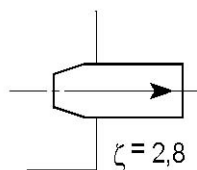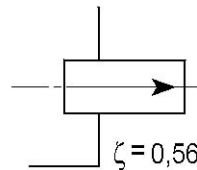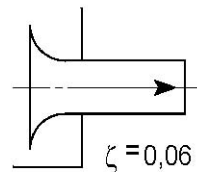
| Type of fitting | $\zeta$ |
|-----------------|-----|
| Ball valve | 0,6 |
| Y-valve | 0,6 |
| DIN shutoff valve | 3,9 |
| Corner valve | 3,0 |
| Solenoid valve | 6,0 |
| Non-return valve | 6,0 |
| Clack or needle flow detector | 5,8 |
| Float element flow meter | 6,5 |

## 3. Pressure losses $\triangle p_R$ in the piping

For a rough estimate of the pressure loss in the line, it must be determined first whether the flow is laminar or turbulent. For this purpose Reynolds' number is calculated according to the following formula:

## 4. Overall pressure loss ptotal

The total pressure loss to be expected is the sum of losses caused by piping and fittings.

$$(X) \qquad \Delta P_{total} = \Delta P_R + \Delta P_A$$

## 5. Example

400 l/h saline solution is to displaced against 1bar system pressure using a dosing pump MR 400. The oscillating pump is operated with a tappet gear at 50 strokes/min and produces a sinusoidal output.

The max. flow rate of the pump is 456 l/h against max. 5 bar. The pipe diameter and pressure losses have to be determined.

$$\rho = 1180 \text{ kg/m}^3$$
$$\nu = 2*10^{-5} \text{ [m}^2\text{/s]} \longrightarrow \eta = 23.6 \text{ [mPa*]}$$

## System design:

Dosing pump; 0.5m PVC pipe; shutoff valve (DIN valve); 30m PVC pipe, solenoid valve; flow detector; elbow; flow meter, elbow, T-piece, 4m PVC pipe. Roughness of the piping: 0.01 mm.

System pressure: 1 bar

---

$$(VI) \qquad Re = \frac{w*d/1000}{\nu}$$

$w$ [m/s] = flow speed     $\nu$ [m²/s] = kinematic viscosity
$d$ [mm] = pipe diameter     $\eta$ [mPa*s] = dynamic viscosity
$\rho$ [kg/m³] = density

$\nu$ = viscosity [m²/s] $\longrightarrow$ conversion: $\nu = \dfrac{\eta}{\rho*1000}$

If **Re<=2320,** the flow is **laminar** and the below formula must be used for the pressure loss factor:

$$(VII) \qquad \lambda = 64/Re$$

If **Re>2320** and thus the flow is **turbulent,** a good approximate calculation is possible for smooth pipes and tubes using the following formula:

$$(VIII) \qquad \lambda = 0.3164/Re^{0.25}$$

$$(IX) \qquad \Delta p_R = \frac{L*\lambda*w^2}{d*2*10^2}*\varsigma \quad \text{[bar]}$$

---

**Solution:**

Because of the oscillating operation, the nominal flow capacity must be multiplied by 3.456 * 3 = 1368 l/h

According to diagram 1.5.3.4, the pipe diameter is 16 mm at a velocity of 1.89 m/s.

Line length = 0.5 + 30 + 4 = 34.5m

The total of the $\xi$-values amounts to:

| | |
|---|---|
| DIN valve | 3.9 |
| Solenoid valve | 6.0 |
| Flow detector | 5.8 |
| Elbow | 0.5 |
| Flow meter | 6.5 |
| Elbow | 0,5 |
| T-piece | 1.3 |
| $\Sigma\xi$ = | 24.5 |

$$Re = \frac{w*d/1000}{\nu} = \frac{1,89*16/1000}{2*10^{-5}} = 1512$$

$$\lambda = 64/Re = 64/1512 = 0.0423$$

$$\Delta p_R = \frac{L*\lambda*w^2}{d*2*10^2}*\varsigma = \frac{34,5*,0423*1,89^2}{16*2*10^2}*1180 = 1.92 \text{ bar}$$

$$\Delta p_A = \frac{\Sigma\xi*w^2}{2*10^5}*\varsigma = \frac{24.5*1,89^2}{2*10^5}*1180 = 0.52 \text{ bar}$$

$$\Delta P_{total} = \Delta P_R + \Delta P_A = 1.92 + 0.52 = 2.44 \text{ bar pressure loss}$$

**Note:** 2.44 bar are admissible for the pump, as the pressure is still below 5 bar (max. allowed backpressure) despite the system pressure of 1 bar. But how about acceleration? According to formula (III), chapter 1.3.1.2, the acceleration pressure amounts to

$$p_{accel} = \frac{Q * F * L * \varsigma}{8.6 * 10^5 * d^2} \ [bar] = \frac{456 * 50 * 34,5 * 1180}{8.6 * 10^5 * 16^2} = 4.22 \ [bar]$$

The acceleration pressure is added to 1bar system pressure: **1 + 4.22 = 5.22 > 5bar !!!**

Thus the allowed pressure is exceeded and the diameter must be recalculated taking this aspect into account:

According to formula (IV) , chapter 1.3.1.2: $d \geq \sqrt{\dfrac{Q * F * L * \varsigma}{8.6 * 10^5 * p_{accel}}}$

$$d \geq \sqrt{\frac{456 * 50 * 34,5 * 1180}{8.6 * 10^5 * 1}} = 32.85 \rightarrow \quad \text{DN32 would produce pressure peaks of max. 1bar.}$$

If a pulsation dampener was used, the flow would be rather uniform and the average flow rate would correspond to the nominal pump capacity of 456 l/h. Pressure peaks due to acceleration do not occur and the friction of the 16 mm pipe is determined as follows:

According to the diagram 1.5.3.4, the velocity is 0.63 m/s for a 16 mm pipe.

The pressure loss in the piping amounts to:

$$\text{Re} = \frac{w * d / 1000}{v} = \frac{0,63 * 16 / 1000}{2 * 10^{-5}} = 504$$

$$\lambda = 64/\text{Re} = 64/504 = 0.127$$

$$\Delta p_R = \frac{L * \lambda * w^2}{d * 2 * 10^2} * \varsigma = \frac{34,5 * ,127 * 0,63^2}{16 * 2 * 10^2} * 1180 = 0.64 \ \text{bar} << 5 \ \text{bar}$$

Due to the use of the pulsation dampener, the nominal width can be DN16 in this case. Refer to chapter 1.3 "Fittings".

## 1.3.2 Suction line assemblies

For the most common dosing systems, suction lines are ready-made according to the application needs. They are fitted with a foot valve protected by a filter. There are flexible or rigid suction lines available. Rigid suction lines must always be used if an agitator is installed in the supply tank. A flexible tube would wind itself around agitator shaft.

Flexible suction lines are fitted with a counterweight to ensure that the foot valve is always in vertical position and does not float with a still empty suction line.

### Foot Valve



1 Ball guide
2 Ball
3 Seat
4 Filter
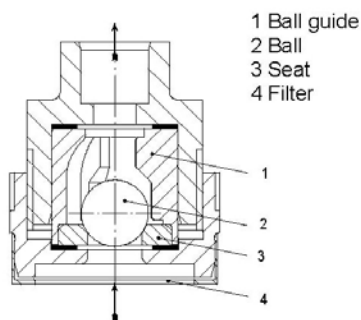
If the pump is located at or below the level of the tank bottom and if a connection at the bottom of the tank is admissible, no foot valve is required. In this case, however, a shutoff valve and a filter should be provided to keep away impurities from the pump valves. It must also be ensured that the liquid pressure of the tank is not transmitted to the pump and thus affects the dosing accuracy or causes excessive dosing and siphoning of the tank. Required fittings such as backpressure valves are described in chapter 1.3.4.

## 1.3.2.1 Protection against dry operation

Air or gas in the pump system disturbs the dosing process and mostly requires complete venting of the dosing head and repriming with the supply line relieved from pressure. In the case of aggressive or toxic media, this procedure should be avoided by all means. To prevent air from entering the system after emptying the supply tank, it is generally recommended to equip the tank with a level control as protection against dry operation. An agitator possibly installed as well must also be protected against dry operation. Suitable control equipment can be float switches with electrical contact as well as rod electrodes (using the conductivity of the medium), the switching relays of which stop the pump before the tank is emptied completely. For the most frequent applications, again standard versions have been defined which combine level control with suction line.

Other methods of level control, as e.g. echo, electrical capacity, radioactivity or light refraction, are not described here.

Suction lines with foot valve and float switch for low level indication are available as useful units, e.g. for standard non-returnable chemical containers.

## 1.3.2.2 Suction lines for non-returnable containers

Many chemicals and products are sold in easy-to-handle containers between 30 and 60 liters. Also the covers are standardized in most cases (e.g. size K 60). For direct chemical supply from these non-returnable containers, a specific suction line was developed. It has the following advantages:

1. Suitable for pumps up to approximately 25 l/h.
2. Slidable cover and thus adjustable to various container sizes.
3. All functional parts protected against impact and obstruction.
4. Suction line equipped with non-return valve.
5. Design of inlet nozzle does not allow air to enter while the container is exchanged. This would disturb small dosing pumps in particular.
6. 2 connecting pieces for chemical return lines which are used to recirculate e.g. liquid from a safety valve or a degassing device.
7. Two-stage level control giving an alarm in time so that a new container can be provided and the pump is switched off to avoid entry of air after emptying of the container.

The suction lines with integrated level control can be connected directly to Lutz-Jesco solenoid dosing pumps to switch these without an additional level relay.



1 Protective pipe
2 Sealing cap
3 Tubing connection
4 Connecting piece for medium from non-return valve
5 Connecting piece for medium from automatic degassing valve
6 Low level control plug
7 Suction nozzle
8 Non-return valve
9 Cable for low level indication
10 Float (alarm signal)
11 Reed switch contact
12 Float (tank-empty signal)

![JESCO Lutz-JESCO America Corp.]
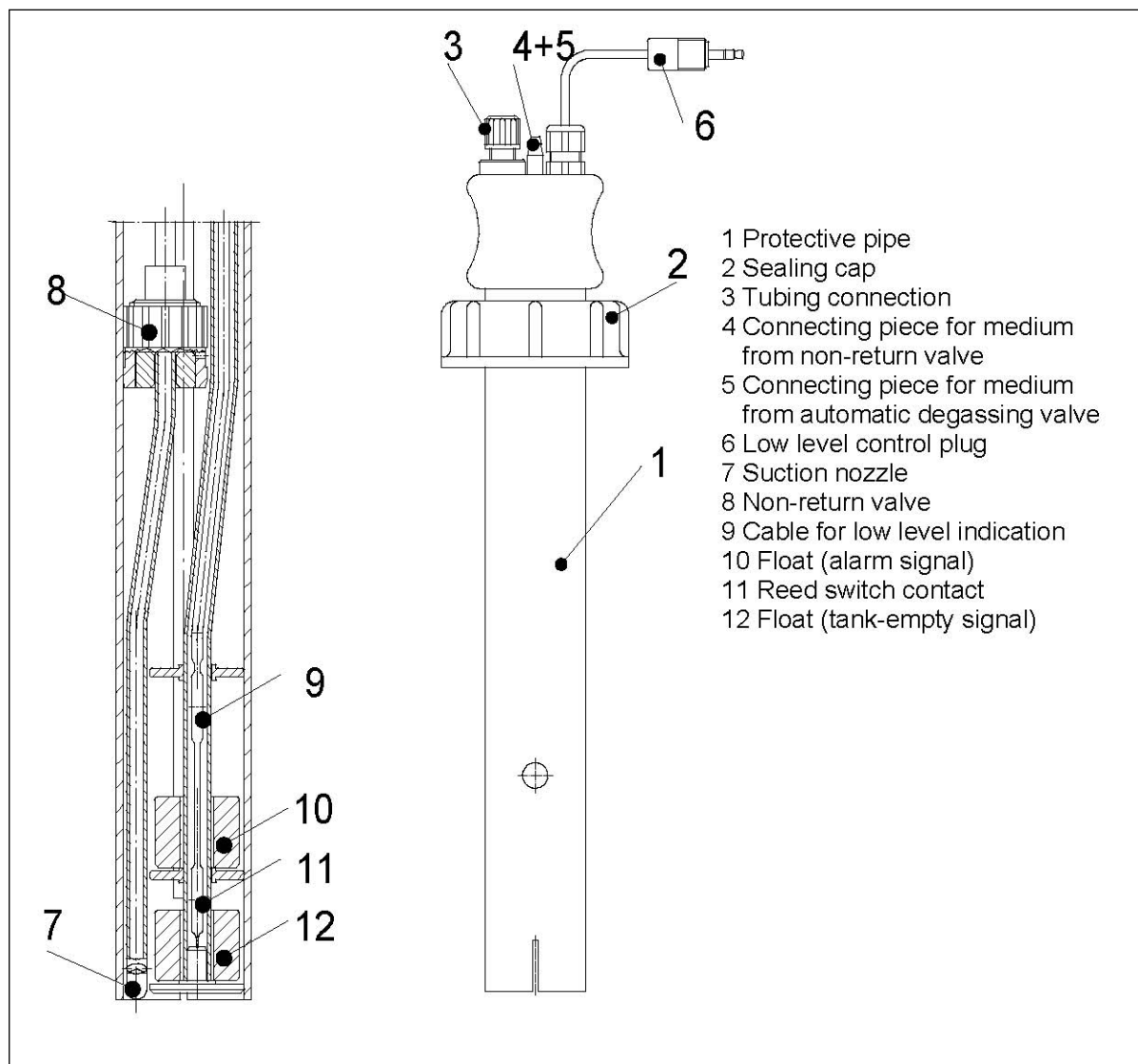
# An Introduction to Metering Technology

## 1.3.3.1 Siphon-type collector and priming aid

There are mainly two reasons for installing priming aid before the suction valve:

### a) Easier priming

On startup, dosing pumps with lower flow rates are not able – due to the low suction volume - to produce a vacuum allowing the liquid head in the suction line to reach the dosing head. In this case the first filling of the siphon-type collector enables the pump to prime directly and is used to wet the valves and to improve the efficiency.

As a result of the reduced level in the collector, a vacuum is produced which makes a permanent supply from the chemcial tank possible. If there is no degassing (see b), the collector does not need maintenance for a long time.

### b) Gas separator

Collection of gas or air which is released by the medium or enters the suction line during the replacement of a non-returnable container and which may interrupt dosing due to the clearance volume effect. If the liquid in the collector is displaced by the gas, it must be refilled.



Siphon-type collector and priming aid
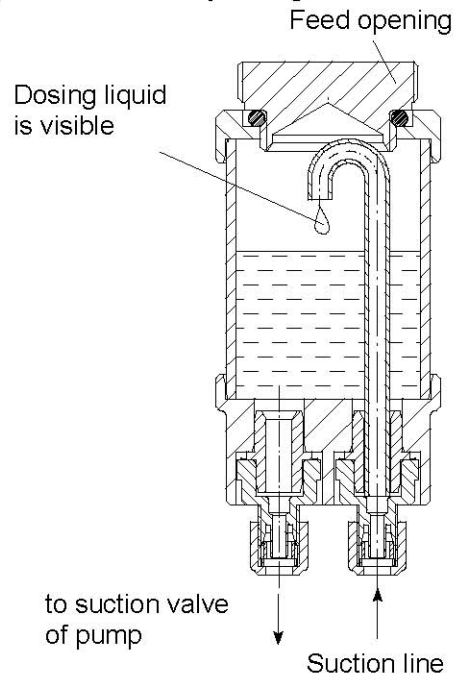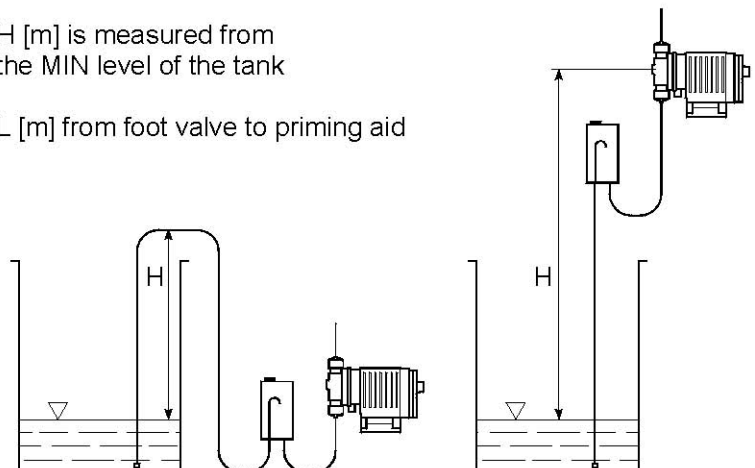
The following table applies 1bar abs. air pressure and constant nominal width for the complete piping. The required collector volume for any pipe diameter is calculated by V=Bx(DN)². The volume thus determined includes approx. 20% allowance and enables the pump to prime medium up to height H.

## Table for dimensioning priming aids

| Suction head H{m} at almost empty tank | Overall line length L{m} starting at valve | Density {kg/m3} | Min. volume B{dm3} for DN1 | Min. volume of the collector at line diameter DN [dm3] | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 4 | 6 | 10 | 16 | 25 | 40 |
| 1 | 2 | 1000 | 0.00115 | 0.02 | 0.04 | 0.11 | 0.3 | 0.7 | 1.8 |
| 1 | 2 | 1500 | 0.00127 | 0.02 | 0.05 | 0.13 | 0.3 | 0.8 | 2.0 |
| 1 | 2 | 2000 | 0.00140 | 0.02 | 0.05 | 0.14 | 0.4 | 0.9 | 2.2 |
| 1 | 5 | 1000 | 0.00146 | 0.02 | 0.05 | 0.15 | 0.4 | 0.9 | 2.3 |
| 1 | 5 | 1500 | 0.00176 | 0.03 | 0.06 | 0.18 | 0.4 | 1.1 | 2.8 |
| 1 | 5 | 2000 | 0.00209 | 0.03 | 0.08 | 0.21 | 0.5 | 1.3 | 3.3 |
| 2 | 3 | 1000 | 0.00258 | 0.04 | 0.09 | 0.26 | 0.7 | 1.6 | 4.1 |
| 2 | 3 | 1500 | 0.00306 | 0.05 | 0.11 | 0.31 | 0.8 | 1.9 | 4.9 |
| 2 | 3 | 2000 | 0.00371 | 0.06 | 0.13 | 0.37 | 1.0 | 2.3 | 5.9 |
| 2 | 6 | 1000 | 0.00327 | 0.05 | 0.12 | 0.33 | 0.8 | 2.0 | 5.2 |
| 2 | 6 | 1500 | 0.00424 | 0.07 | 0.15 | 0.42 | 1.1 | 2.7 | 6.8 |
| 2 | 6 | 2000 | 0.00554 | 0.09 | 0.20 | 0.55 | 1.4 | 3.5 | 8.9 |
| 3 | 4 | 1000 | 0.00440 | 0.07 | 0.16 | 0.44 | 1.1 | 2.7 | 7.0 |
| 3 | 4 | 1500 | 0.00581 | 0.09 | 0.21 | 0.58 | 1.5 | 3.6 | 9.3 |
| 3 | 4 | 2000 | 0.00822 | 0.13 | 0.30 | 0.82 | 2.1 | 5.1 | 13.2 |
| 3 | 6 | 1000 | 0.00519 | 0.08 | 0.19 | 0.52 | 1.3 | 3.2 | 8.3 |
| 3 | 6 | 1500 | 0.00730 | 0.12 | 0.26 | 0.73 | 1.9 | 4.6 | 11.7 |
| 3 | 6 | 2000 | 0.01092 | 0.17 | 0.39 | 1.09 | 2.8 | 6.8 | 17.5 |
| 4 | 5 | 1000 | 0.00681 | 0.11 | 0.25 | 0.68 | 1.7 | 4.3 | 10.9 |
| 4 | 5 | 1500 | 0.01051 | 0.17 | 0.38 | 1.05 | 2.7 | 6.6 | 16.8 |
| 4 | 5 | 2000 | 0.02096 | 0.34 | 0.75 | 2.10 | 5.4 | 13.1 | 33.5 |
| 4 | 8 | 1000 | 0.00864 | 0.14 | 0.31 | 0.86 | 2.2 | 5.4 | 13.8 |
| 4 | 8 | 1500 | 0.01456 | 0.23 | 0.52 | 1.46 | 3.7 | 9.1 | 23.3 |
| 4 | 8 | 2000 | 0.03127 | 0.50 | 1.13 | 3.13 | 8.0 | 19.5 | 50.0 |
| 5 | 6 | 1000 | 0.01016 | 0.16 | 0.37 | 1.02 | 2.6 | 6.3 | 16.3 |
| 5 | 6 | 1500 | 0.02046 | 0.33 | 0.74 | 2.05 | 5.2 | 12.8 | 32.7 |
| 5 | 6 | 1750 | 0.03899 | 0.62 | 1.40 | 3.90 | 10.0 | 24.4 | 62.4 |
| 5 | 10 | 1000 | 0.01379 | 0.22 | 0.50 | 1.38 | 3.5 | 8.6 | 22.1 |
| 5 | 10 | 1500 | 0.03095 | 0.50 | 1.11 | 3.10 | 7.9 | 19.3 | 49.5 |
| 5 | 10 | 1750 | 0.06184 | 0.99 | 2.23 | 6.18 | 15.8 | 38.6 | 98.9 |
| 6 | 7 | 1000 | 0.01509 | 0.24 | 0.54 | 1.51 | 3.9 | 9.4 | 24.2 |
| 6 | 7 | 1500 | 0.05540 | 0.89 | 1.99 | 5.54 | 14.2 | 34.6 | 88.6 |
| 6 | 12 | 1000 | 0.02284 | 0.35 | 0.79 | 2.18 | 5.6 | 13.6 | 34.9 |
| 6 | 12 | 1500 | 0.09093 | 1.45 | 3.27 | 9.09 | 23.3 | 56.8 | 145.5 |

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## 1.3.3.2 Siphon

To overcome high suction heads may become difficult even for larger pumps if effervescent media have to be dosed. This applies especially if the medium is not supplied freely to the pump via a suction line connected at the bottom of the tank but must be primed over the edge of the tank. The system is balanced hydraulically if no air is enclosed in the filled line. The pump is subject to the supply pressure depending on the tank filling level. As soon as the upper part of the suction line is filled with gas, the hydraulic balance is not ensured anymore. The pump must then prime more and more in dependence of the tank height. This may lead to the failure of the pump. Thus a system has been successful which, from time to time, primes liquid manually or by means of a vacuum pump (manually operated pump or injector) from the supply tank into a controllable intermediate collector (siphon). As a result gas can only accumulate outside the suction line, and the communicating effect of the suction line is ensured continuously.

**Schematic Diagram of a Siphon**
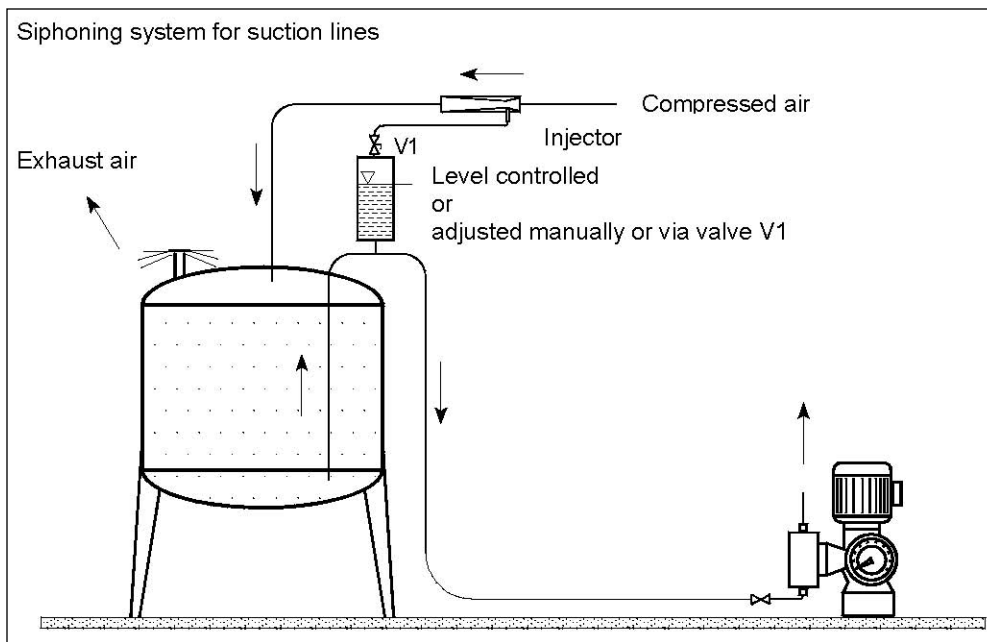


## 1.3.4 Avoiding changeable suction pressure

From the chapter about diaphragm dosing pumps we know that the flow rate depends on pressure, also on the supply pressure. If the leakproof operation of the diaphragm pump is preferred because of the medium to be dosed, it has to be defined how to avoid the fluctuating supply pressures, e.g. due to a considerably varying filling level of the supply tank.

## 1.3.4.1 Intermediate tank to keep the suction pressure constant

There are two possible solutions:

**1. Overflow tank**

By means of a separate refill pump, an overflow tank mounted at the highest point can be filled so that medium is returned permanently into the supply tank, even if the dosing pump primes max. quantity from this overflow tank. Now the dosing pump is only subject to the always constant supply pressure, which results from the geodetic height.

**2. Intermediate tank**

It is, however, also possible to use an intermediate tank controlled via float valve. This intermediate tank must be positioned at the bottom level or lower than the supply tank. The dosing pump then primes liquid from the intermediate tank with an always constant level.

**See flow diagram under 1.4.1.**

## 1.3.4.2 Suction controller SDR 50

Constant suction pressure and leakage stop Dosing pump which are mounted above the tank (e.g. buried tanks) or also below the tank deliver less the more the tank gets empty, because either the suction lift increases or the positive suction head decreases.

Dosing pumps with large diaphragms can develop a remarkable force on the stroke adjusting mechanism, if tanks and density (e.g. sulphuric acid) are particularly high.

As a result of the mass moment of inertia of the liquid in motion, in long suction lines overfeeding can occur if the diaphragm or also the piston suddenly stops at the stroke limiting stop. Even if backpressure valves avoid overfeeding on the discharge side, a force which increases wear is produced at the stroke adjusting mechanism of the pump and on the suction side of the system.

In installations with a free supply to the pump, the danger of leakage from the tank is given in the case of a diaphragm or line rupture.

Under normal conditions dosing pumps must not be fed directly from pressure lines, because a pressure of e.g. 2bar multiplied by the effective diaphragm area might exert destructive forces on the pump gear. On the other hand overfeeding would take place if a backpressure valve was not installed on the discharge side or wrongly adjusted.

In the case of long suction lines, cavitation can result in reduced flow rates or the destruction of fittings due to the oscillating operation of dosing pumps.

The aforementioned problems can be solved by one single fitting: **suction controller SDR50**.

The suction controller is a spring-loaded diaphragm valve which can only be opened by the suction pressure of the dosing pump. Thus it is ensured that no medium can flow if the pump is not working or cannot create a vacuum due to a leaking suction line.

An undesired suction effect at the pump outlet must be avoided by means of backpressure valve.

Depending on the individual operating conditions, the required maximum vacuum can be set up to 300mbar using an adjustable spring. For pumps with a positive suction head, it is sufficient to set a very low vacuum of approx. 50mbar. This vacuum must be created by the pump in any case, even with a pressureless supply.

At a supply pressure of e.g. 1bar, corresponding to a tank height of 10m and a liquid density of 1,000 kg/m³, the vacuum for the pump is increased by only approx. 100mbar.

For emptying buried tanks or in the case of installations where the pump is located above the tank, the vacuum required for dosing is set to the highest occurring vacuum by means of the adjusting spring. This value corresponds to an almost empty tank. Thus the pump has to prime all the time as if the tank was empty and is hardly affected by actual filling level or suction head.

The flow in the suction line due to the mass moment of inertia is stopped will be stopped in the suction controller, if the pump does not carry out a suction stroke. In this case the suction controller must be installed directly in front of the pump inlet in order to avoid pressure impacts.

If the suction controller is to be used as a leakage stop for the tank, it must be installed at the tank, if possible, or close to it in a mechanically protected position. In the case of a suction line rupture, the suction controller closes immediately by spring force, since the pump cannot open the suction controller anymore due to the broken line. Supply pressure exerted on the closing element supports the closing function.

If the suction controller is installed before the pump, priming by the pump becomes easier because the liquid volume below the controller diaphragm is directly available at the pump when priming is started.

### Caution!

If the dosing line between the pump and the process is under vacuum or tends to siphon because of the geodetic conditions, a backpressure valve must be installed at the end of the line.

### Cross sectional view of the suction controller
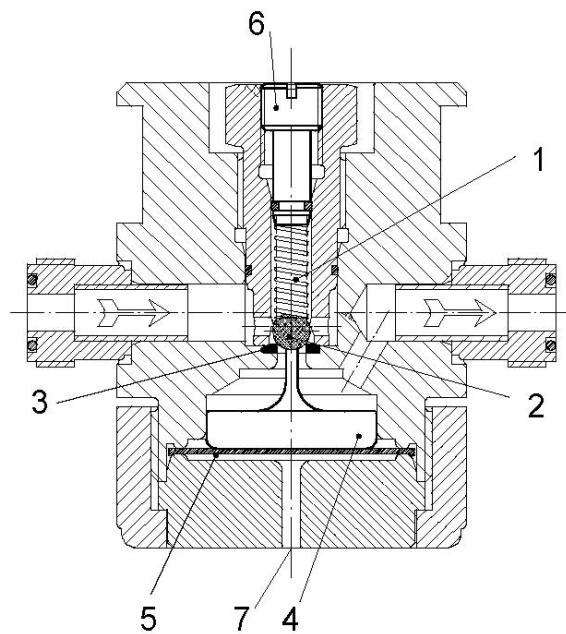


The liquid coming from left first faces a shut valve (ball/seat 2+3), which is closed by the spring (1) and sealed additionally by the liquid pressure. Thus liquid can only flow if the ball (2) is pushed down by the plunger (4). This happens only if liquid is drawn off to the right, because then the reduced volume between diaphragm (5) and ball (2) causes the atmospheric pressure entering through the drilled compensating hole (7) to push the diaphragm (5) with the plunger (4) against the ball (2).

### Positive suction head

If the level of the supply tank is always higher than the pump (up to 20m water head or 2bar), the spring force can be set to a low value which allows the ball to just touch the seat. The supply pressure seals additionally via the ball. Therefore atmospheric pressure is practically found on the outlet side.

Consequently, the pump must only create a vacuum which is strong enough to lift the ball from the seat. Due to the large diaphragm diameter compared to the seat diameter, a very low vacuum is required. Thus the static pressure of the tank does almost not become effective in the pump head.

### Negative suction head

If the level of the supply tank is always below the pump, the suction controller would permanently be opened with a pressureless spring because the atmospheric pressure would keep the ball open over the effective diaphragm area. To ensure a constant suction head for the pump also in this case, the spring can be pressurized so that it always simulates the highest suction lift (up to max. 4m water head). The pump must then prime the maximum vacuum all the time no matter if the tank is full or almost empty. (Of course, the pump must be able at all to overcome the highest suction lift; see technical data of the pump.)

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## Installation

The installation location of the suction controller SDR50 depends on the application. Due to its low weight, the controller can be mounted freely in the case of rigid lines or fixed to the wall using a pipe clamp. The operating position is arbitrary but entry of dirt or water into the drilled pressure compensating hole (7) should be avoided.

## Possible applications:

a) Protection of the metering pump against excessive supply pressure due to high tanks or supply from pressure lines

b) Avoiding siphoning

c) Avoiding varying positive and negative suction heads which affect the dosing accuracy

d) Protection of the dosing pump against pressure peaks due to acceleration in the case of long suction lines

e) Use as leakage stop for tanks in the case of diaphragm or line rupture

## Installation diagram for cases a) to d)

1 Tank or pressure line for medium to be dosed
2 Suction controller SDR50
3 Dosing pump
4 Backpressure valve if there is the danger of siphoning
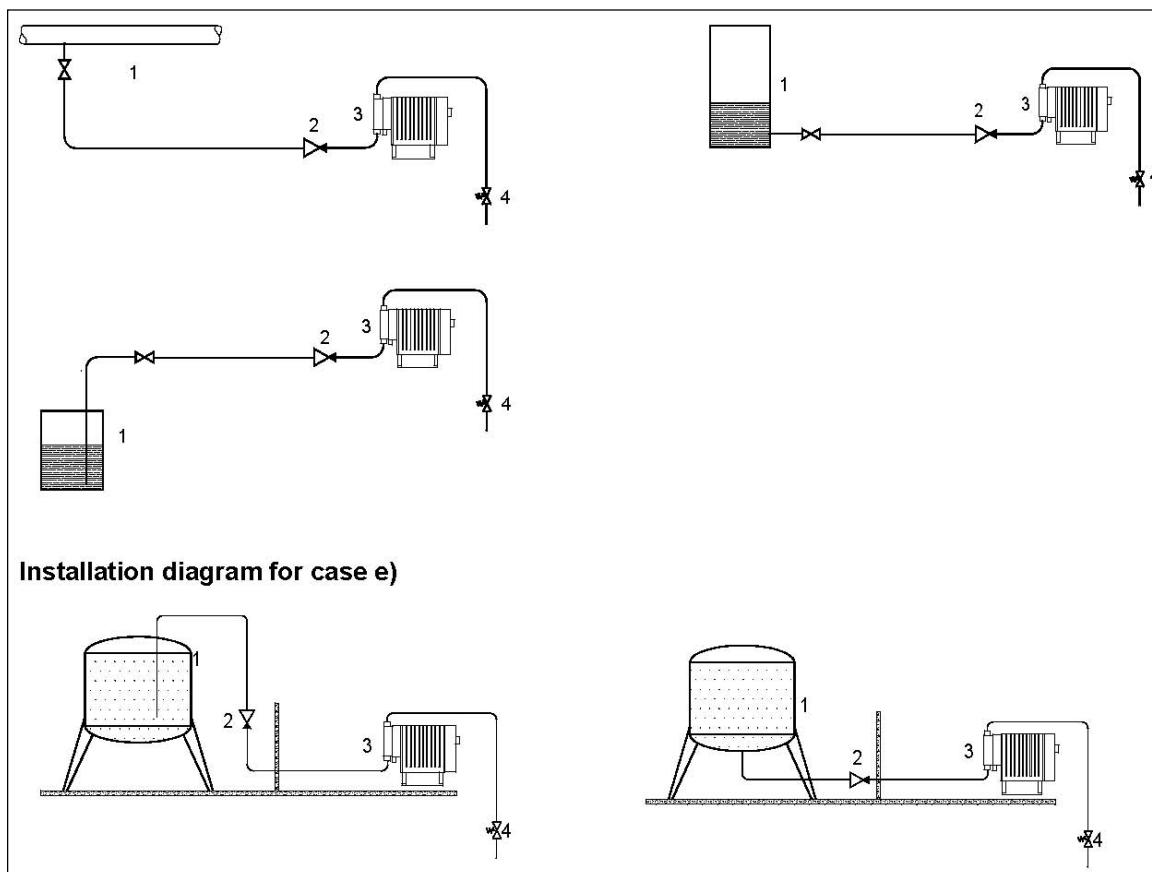
## 1.3.5 Dosing head venting

With small pumps, dosing might fail in the case of effervescent media or gas entering the head if no appropriate measures are taken. Therefore equipment for manual or automatic venting of the dosing head should be provided in advance when handling critical media. Venting systems which can also be mounted subsequently as separate fittings on any type of pump are advantageous. Venting fittings are bypass valves which allow to prime or vent the pump without pressure. If the medium tends to release gas permanently, continuous automatic venting is to be preferred. Most automatic venting systems which are integrated in the dosing head and must therefore be ordered together with the pump use the difference in viscosity between dosing chemical and gas to control the venting valve. The disadvantage of these solutions are, however, that for small flow rates, a situation occurs in which the small dosing quantity just achieved escapes through the drain sleeve and thus no operating pressure can be produced anymore. In the following dosing will not take place. Therefore venting equipment with forced control is to be preferred which works at certain times settable to fixed intervals or controlled by the program and is sealed hermetically in between. As a result, 100% dosing is ensured.



**Installation diagram for case e)**

## Integrated dosing head venting
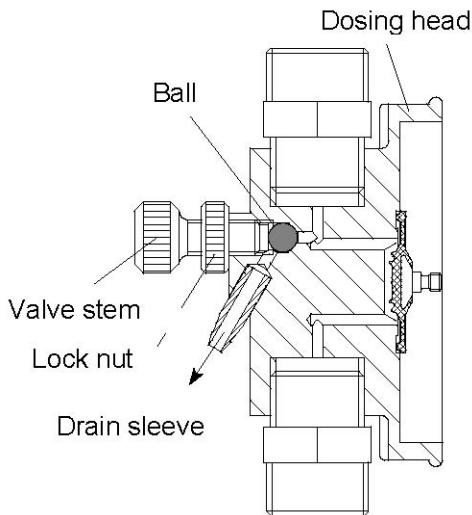


In the case of integrated dosing head venting, the valve is turned to the left by half a revolution for starting or venting. Thus the ball is lifted from the seat and the pump can discharge the gas without pressure against atmosphere until liquid appears. Then the valve is closed tightly again.

## Retrofittable manual dosing head venting

The dosing head venting equipment is mounted directly on the discharge connection of the dosing pump and also allows easing starting and venting of the pump. With this version, continuous venting can be set as well by closing the venting valve after successful startup to such an extent that just a few drops escape per minute. The output is reduced by this permanent leakage. No medium will escape from the process side, since a non-return valve prevents backflow.
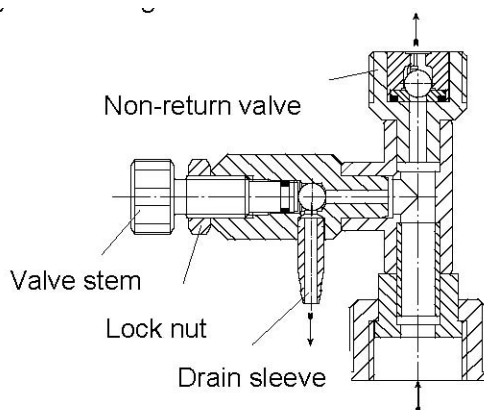


## Electrical degassing device GAS-EX

In the case of the degassing device GAS-EX, a solenoid valve is opened e.g. every 30 seconds for 2 seconds. Thus the pump is allowed to release any existing gas continuously after fixed time intervals. If there is no gas, liquid will escape. Depending on the pump capacity and amount of released gas, the time interval can be increased or reduced. This system also uses a non-return valve to ensure that the dosing line under pressure is not depressurized during the degassing phase. The design has an optimized clearance volume so that even small pumps re-attain full operating pressure right after venting and thus continue to discharge without losses.
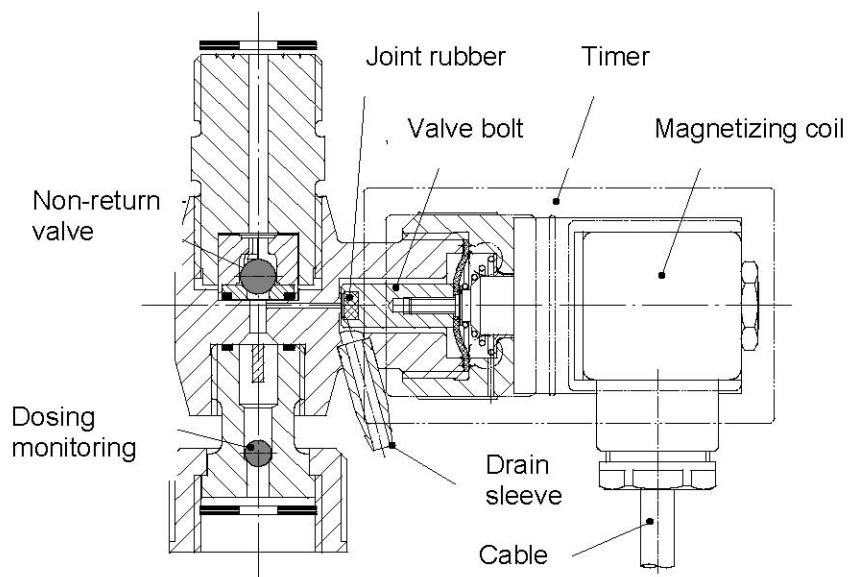


If the pump only carries out dosing strokes after long time intervals and automatic venting takes place in between at fixed times, the system is depressurized so that possibly existing gas can expand. But if no gas was present, there will be hardly any leakage despite the open valve because liquid cannot expand. After the next dosing stroke, the operating pressure is re-attained almost immediately and dosing is continued. It is an advantage of this degassing device operated by auxiliary energy that it can be controlled by an SPC (PLC). After longer standstill periods on weekends, for example, a venting phase of several minutes can be set, during which the pump only recirculates the medium into the chemical supply tank. The actual dosing process can then be carried out without disturbing venting phases.

## 1.3.6 Pressure relief valves

Pressure relief valves are spring-loaded diaphragm valves which, in the case of excessive pressure, allow medium to flow back into the supply tank through a branch line. Relief valve have the function of safety valves to protect dosing pumps and systems.

**Sectional view of a backpressure and pressure relief valve (same fitting for both functions)**

Pressure adjusting spindle

Counternut

Spring disk

Spring

Spring hou-

Clamping ring

Support

Diaphragm

Valve housing

## 1.3.7 Backpressure valve

Backpressure valve are mainly used for four reasons:

### a) Artificial backpressure

As mentioned before, the dosing capacity of diaphragm pumps depends on the backpressure. If it can be anticipated that the backpressure will fluctuate extremely (e.g. from 2 - 6 bar in a potable water line), an artificial backpressure which is always higher than the maximum system pressure to be expected can be simulated for th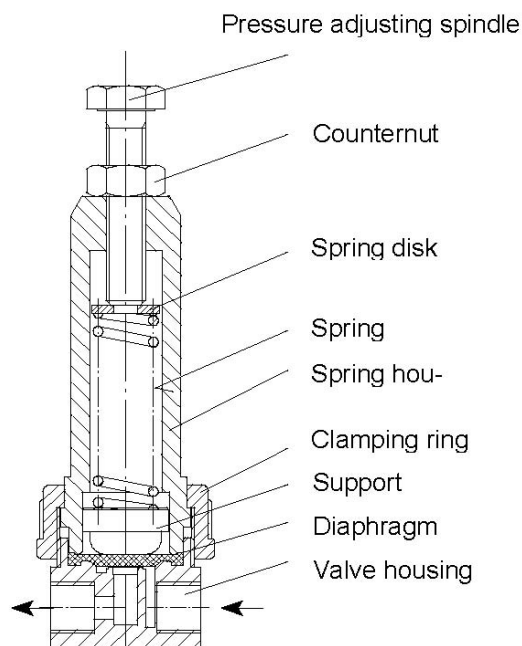e dosing pump by means of a backpressure valve. In this particular case the valve should be set to 7bar. Backpressure valves work like an overflow control and therefore do not allow pressures exceeding the aforementioned 7bar. The pump must also attain this pressure if the flow rate is reduced in order to push the medium through the backpressure valve. In every case, the pump always has a constant backpressure of 7bar and is not affected by the fluctuating pressures between 2 and 6bar.

The following diagram shows the conditions once again:

Required flow rate..........100 l/h
Backpressure fluctuating between 2 and 6bar

The flow rate is set without back pressure valve to 6bar and 100l/h as required via stroke length "a". If the pressure goes down to 2bar, the dosing pump will dose 110l/h and thus too much. After installing the backpressure valve and setting the opening pressure to 7bar, stroke length "b" must be adjusted to achieve 100l/h. Otherwise the flow rate would only be about 90l/h. With this constellation, the pump will now continuously discharge 100l/h against 7bar without noticing that the pressure is actually fluctuating.
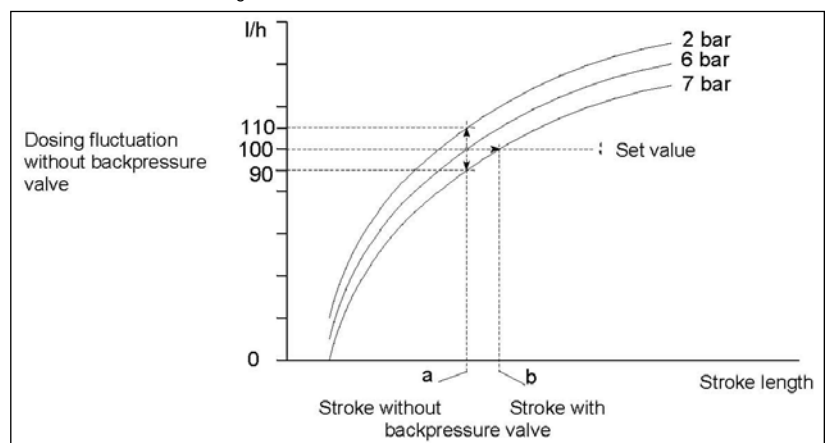


### b) Avoiding siphoning (anti-siphon function)

In the case of dosing pumps which discharge against atmosphere, e.g. into open basins, a supply tank level above the injection nozzle may cause uncontrolled flow of the dosing chemical (siphoning). This problem can be solved perfectly by installing a backpressure at the end of the dosing line and setting it to a pressure which is slightly higher than the corresponding hydrostatic height between maximally filled tank and outlet point.

### c) Dosing into vacuum lines

For dosing pumps which have to discharge the dosing chemical into a vacuum line or also e.g. into the suction connection of a centrifugal pump, there is the danger of priming more medium than required through the pump due to the vacuum. Also in this case a backpressure valve is useful which is not opened by the vacuum but only allows dosing chemical to flow if the dosing pump opens the valve due to its higher pressure.

### d) Constant pressure in circulation lines

In process engineering often a closed circular line is used, in which medium to be provided to different consumers at a constant pressure is circulating. In this case the medium displaced in the closed circular line by a dosing pump is set to the required pressure by means of a backpressure valve installed at the end of the line. It only has to be ensured that the reserve of the dosing pump is sufficient to maintain the pressure if all consumers are supplied with max. output. If the output is low, the remaining medium is returned to the supply tank via the backpressure valve. This method is used, for example, if suspensions must be moved permanently to avoid deposits.

### e) Backpressure valves are no non-return valves

With regard to safety aspects, the principle of the backpressure valve generally interdicts the use of this device as non-return valve, since the backflow pressure to be stopped acts in opening direction on the diaphragm. It is just a question of the pump head until the backpressure valve opens in the opposite

direction. Only with knowledge of this principle and the general function may the backpressure valve may be used as return stop.

## 1.3.8 Multifunction valve PENTABLOC

PENTABLOC is a valve which combines several functions of the fittings described above and can be mounted easily on the discharge valve of the dosing pump. Each individual dosing stroke is indicated by a jumping ball (flow indicator). The individual functions can be explained as follows:

Fig 1: Direction **A - B** : keeping the pressure to approx. 3bar
Fig. 2: Direction **B - C** : pressure relief of the feed line for service purposes
Fig. 3: Direction **B** priming: anti-siphon effect = no siphoning
Fig. 4: Direction **A - C** : overflow = safety valve at approx. 11bar
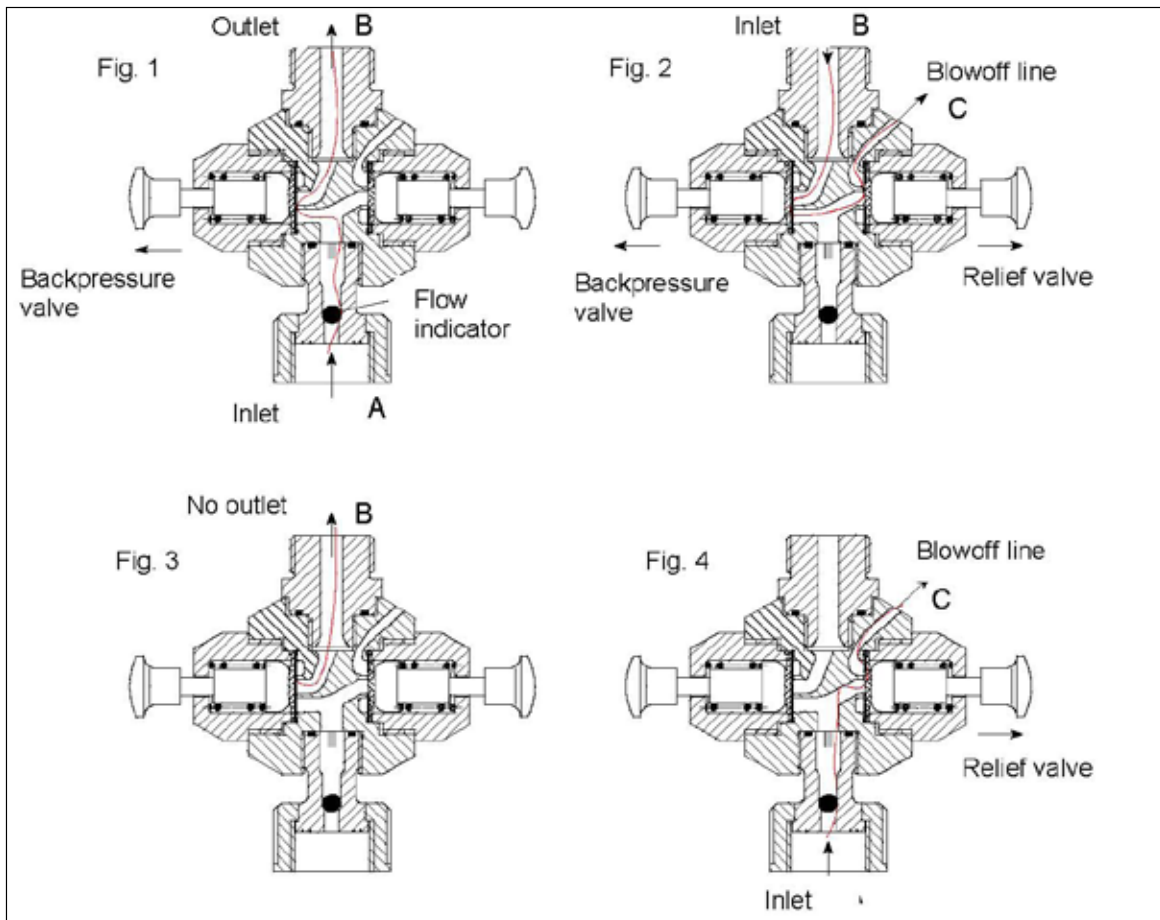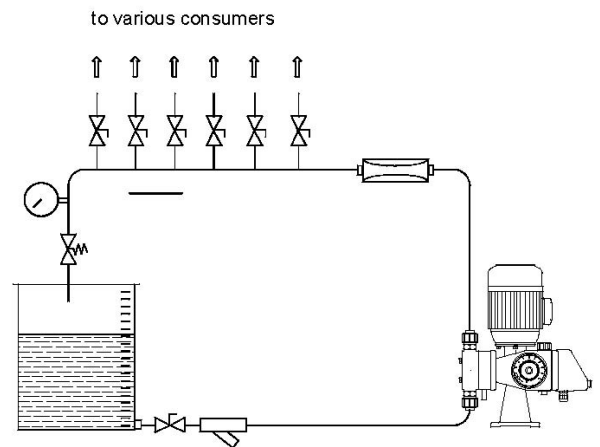
## 1.3.9 Injection nozzles

Mainly injection nozzles are fittings used to introduce the dosing chemical into a system under pressure. A non-return valve with spring-loaded ball or valve tubing makes sure that no process medium can flow back to the dosing pump under normal operating conditions and during process-related standstill periods.

Injection nozzles should be equipped with a shutoff valve to ensure reliable locking before longer standstill times. It is not admissible to rely just on non-return valves over longer periods.

Dosing chemicals which cannot be mixed easily due to their high viscosity or aggressive media which tend to corrode if close to the wall of the process line should be injected into the center of the piping for optimum mixing. Therefore the injection nozzles can be fitted with so-called solution introduction aids which must be shortened before installation so that the dosing chemical is injected more or less into the center of the process line.

For the selection of the injection nozzle material, it must be taken into account by all means, whether the dosing chemical causes exothermal reactions or increases its aggressiveness (sulphuric acid in water) when being injected into the process. Conflict situations between thermal and chemical resistance may result. PVC is chemically resistant in many applications, for example, but would soften up in the case of exothermal reactions. Then PTFE (Teflon) or PVDF can be used instead.

## 1.3.10 Pulsation dampeners

The typical acceleration and deceleration of media displaced by dosing pumps may cause considerable trouble if this characteristic is not taken into account. On the suction side, cavitation and thus interruption of the suction flow may occur as a result of high acceleration. On the discharge side, strong forces produced in long lines may damage the dosing pump. Furthermore damaging pulsations occurring in piping systems may also lead to destruction of the equipment.

Flow meters require a rather uniform flow for perfect function. Float element flow meters cannot be installed at all on the discharge side of dosing pumps without special precautions, because the float element would move extremely up and down.

Both problems can be minimized successfully by using pulsation dampeners:

a) Avoiding high pressure peaks
b) Smoothing the discharge flow

The principle of pulsation dampeners is that a defined amount of gas is made available to the dosing system filled with incompressible liquid. The gas can be expanded or compressed close to the dosing pump by converting energy. It has the function of a gas spring. There are two types of pulsation dampeners: those where the gas (air) is in direct contact with the medium and those where the gas cushion is separated from the medium by a flexible elastomer wall (bubble, rolling diaphragm, tubing, etc.) The last version is to be preferred because the dampening air does not get lost in the medium by absorption. Depending on the installation and task, pulsation dampeners can be used and are necessary on the suction or discharge side or on both sides at the same time.



**Ball non-return valve** — Seat, Ball, Spring

**Tubing non-return valve** — Valve tubing

**Installation of injection nozzle**

Dosing chemical
Ball non-return valve
Spring
Shut-off valve
Water or process medium to be treated

**Uniform distribution of the dosing chemical**
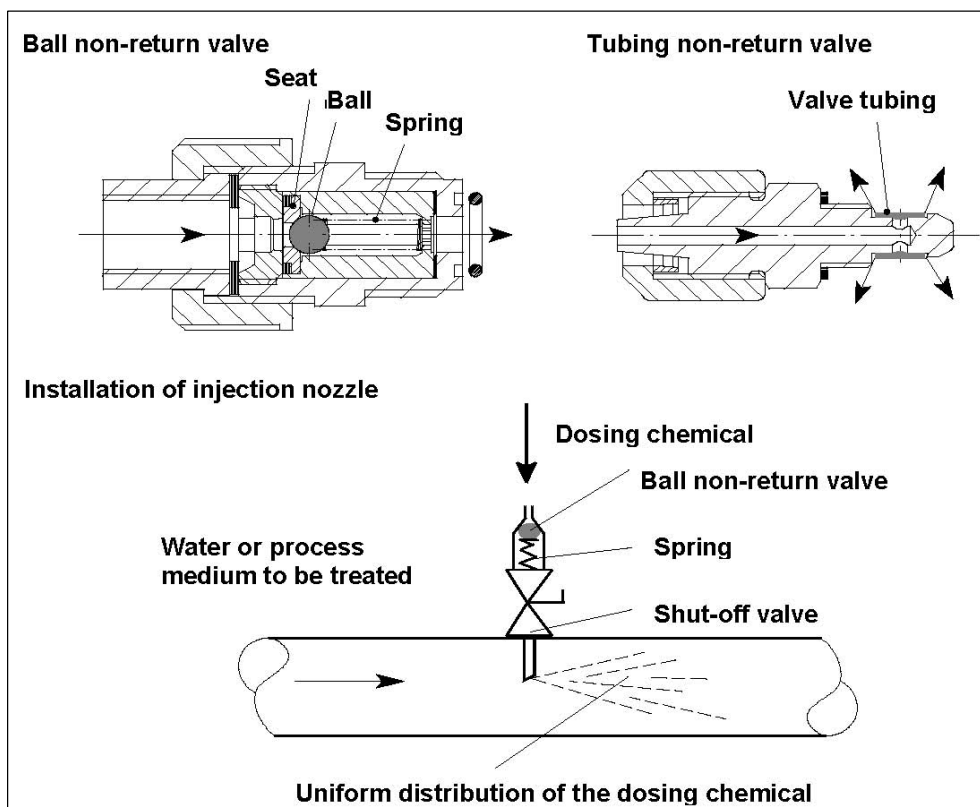
## 1.3.10.1 Pulsation dampeners on the discharge side

The pressure pulsations caused by dosing pumps increase with longer dosing lines and smaller diameters and can result in inadmissible pressure peaks. Apart from nonuniform dosing undesired anyway, pressure fluctuations are disadvantageous for the pump as well as for the piping. The velocity in the piping should not exceed 1.5m/second on the discharge side, if the medium is similar to water. As for a simple oscillating pump the maximum output is three times higher than the nominal capacity, three times the nominal capacity must be taken into account when calculating the dosing line. Even if the dosing line diameter is designed reasonably, it must be checked for lengths exceeding 10m whether a pulsation dampener might be required. Then three times the quantity between dosing head and pulsation dampener must still be considered. Only after the pulsation dampener must the line be calculated with the single nominal value of the dosing pump. For viscosities exceeding 300mPa*s, no more than 1m/second has to be taken into account with reference to uniform flow. The aforementioned values are recommendations to avoid gross errors. For line lengths of 20 meters and more or viscosities exceeding 1,000 mPa*s, the pressure conditions for suction and discharge line as well as the perfect dosing behaviour of the dosing pump must be verified using the standard calculation methods (see also chapters as of 1.3.1.1).

During the discharge stroke, pulsation dampeners store a portion of the media dosed and release it again during the suction stroke.Thus the gap between the two dosing strokes is filled. The following diagram for determining the design of the pulsation dampener refers to a desired residual fluctuation around the average discharge flow.

Pulsation dampener **without** separation of medium and gas
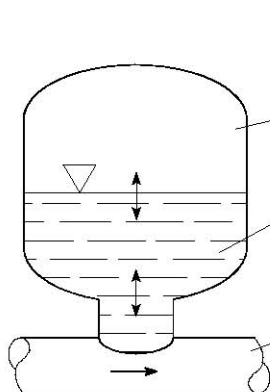
Pulsation dampener **with** separation of medium and gas

Filling sleeve for air or nitrogen

Compressed air

Separating diaphragm

Medium (fluctuating entry)

Dosing line to injection point
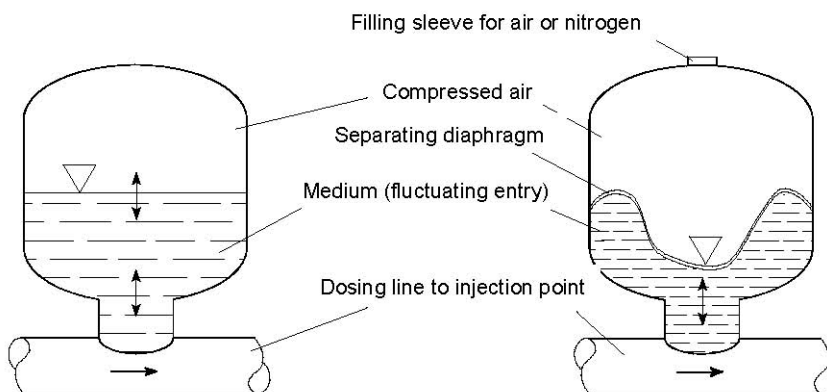
**Tube pulsation dampener PDS (also suitable for inline installation)**

7

1 Tension cone
2 Union nut
3 Tubing
4 Charging valve
5 Housing
6 Support pipe
7 Pressure gauge connection

⇕ Tubing contractions

1　2　3　4　5　6
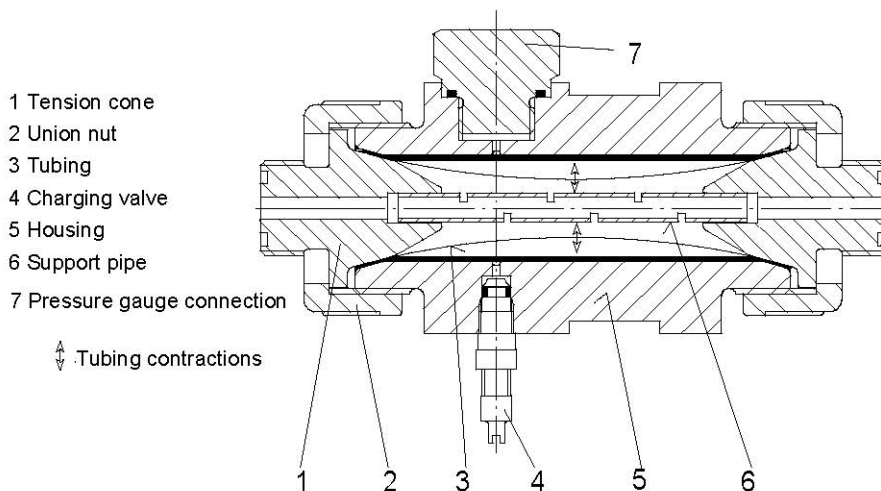
# An Introduction to Metering Technology

For perfect operation of the pulsation dampener, it must be made sure that it is prepressurized to 60 – 70% of the operating pressure to be expected later on using compressed air or nitrogen.

**IMPORTANT!**

During the filling process, there must be no pressure on the diaphragm side facing the medium so that the gas can fill the pulsation dampener optimally. Therefore it has to be ensured before startup or in the case of later recharging that there is no system pressure on the medium side during the gas filling process. Therefore planning should include a pressure relief valve. If this is not considered, the right gas pressure is reached but no or only insufficient gas volume which is required to allow the pulsation dampener to store a portion of the dosing stroke. Refer to flow diagrams 1.5.3.1.3.

**Visualization of the dampening effect**

The following diagram refers to single-head dosing pumps with pulsation dampener, the total nominal volume V0 of which is prepressurized with air or nitrogen to 60...70% of the later operating pressure, before the pressure of the dosing chemical is applied to the pulsation dampener.

**Caution for automatic control systems:**

According to the functional prinicple of pulsation dampeners, a portion of the medium transported during the dosing stroke is stored in the pulsation dampener and released again during the suction stroke. Thus it may happen that, after the controller causes a dosing stop, a small amount of medium continues to flow and affects the controlled variable. If the controller requires medium again, it flows with a certain delay because a portion is first stored in the pulsation dampener. The control behaviour of sensitive pH controls may thus be affected.

For dosing pumps which are used as correcting elements in automatic control systems, this aspect should be taken into account.



Residual fluctuation
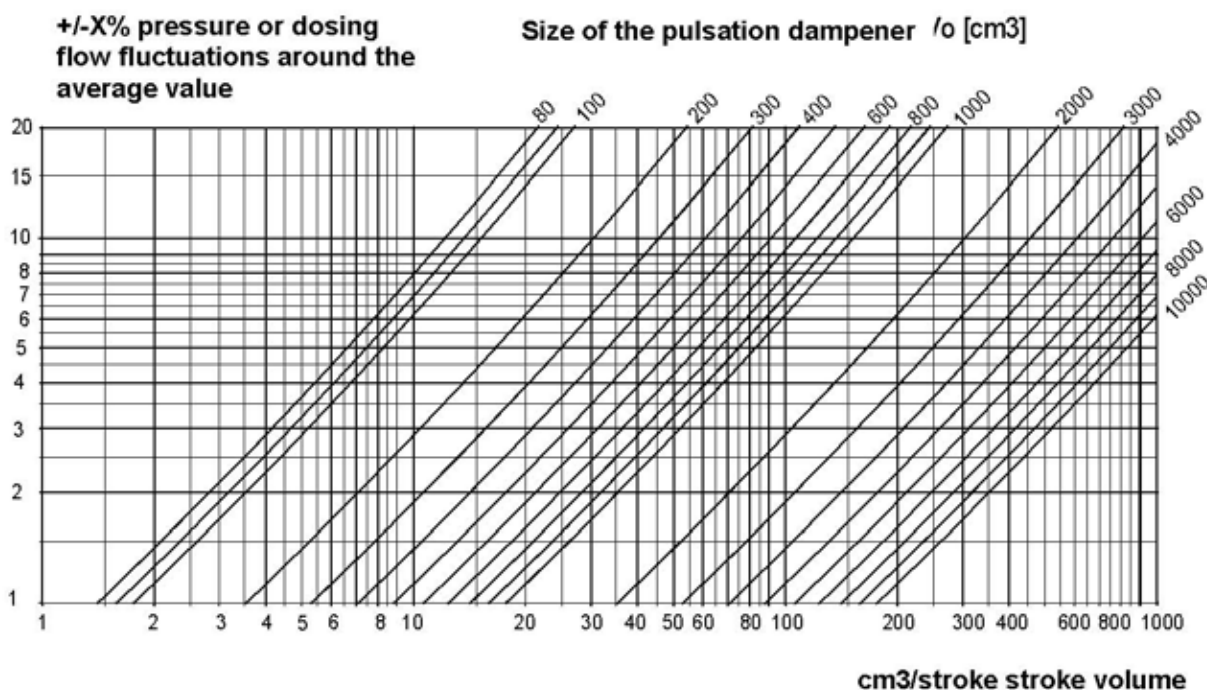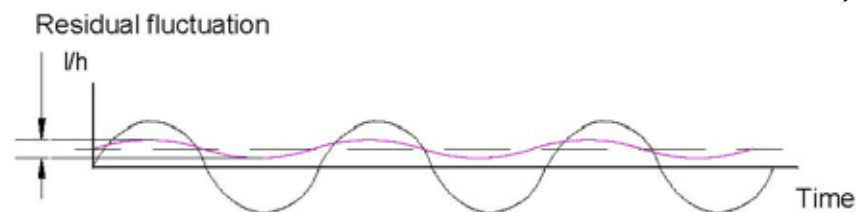
## 1.3.10.2 Pulsation dampeners on the suction side

If, for system-related reasons, a long suction line cannot be avoided or the suction heads are relatively high, suction problems or reduced outputs of the pump may be the result. In the worst case, cavitation occurs, i.e.: the liquid head is interrupted and vapour bubbles are produced in the dosing head. This situation must be prevented by all means.

The suction process is no "priming" in its proper sense but the displacement element "makes room" so that hopefully the atmospheric pressure is able in the available short time to push forward the liquid head following the displacement element (piston or diaphragm). However, as the atmospheric pressure is only about 1bar absolute, the chance of accelerating the liquid head quickly enough to fill the dosing head during the short suction stroke decreases with longer lines.

The problem can be solved perfectly by installing a pulsation dampener directly near the suction valve. The dosing head is then fed from the liquid supply of the pulsation dampener, which quickly releases sufficient liquid due to the expansion capability of the gas. During the discharge stroke, the gas pressure under vacuum is able to prime new liquid from the supply tank.

## 1.3.10.3 Pulsation dampener for flow meters

To smooth the dosing flow, a flow control valve to be installed after the pulsation dampener is required for short lines or dosing without pressure. This applies especially if the flow is to be measured and the flow meters cannot handle extremely pulsating flow (see following diagram).

The flow control valve must be set so that a uniform flow can be achieved at maximum output. If the flow rate is reduced, slight fluctuation of the measurement may occur again.

The larger the pulsation dampener, the better is the dampening effect. According to the above diagram a residual fluctuation between 2 and 5% should be aimed at.

For measuring the flow of high-pressure pumps, the flow meter can be installed on the suction side to keep the pressure away from the measuring unit. Also in this case a pulsation dampener and a flow control valve are needed.

## 1.3.11 Flow monitoring

There are many flow metering and monitoring devices on the market working according to the most different principles:

1 Orifice flow meters
2 Baffle plates
3 Impeller wheel meters
4 Oval wheel meters
5 Toothed wheel meters
6 Float element flow meters
7 Inductive flow meters
8 Thermal effects
9 Evaluation of flow turbulences

The aforementioned and some other systems are only insufficiently suitable for pulsating flow. Besides they cannot be used with a flow rate below 50l/h at a reasonable price compared to the other dosing units. Therefore the FLOWCON system was developed especially for dosing pumps with their pulsating output. It cannot directly measure but monitor the volume of each individual dosing stroke. Failures or reduced flow rates per dosing stroke are evaluated.

With the flow sensor FLOWCON, it is possible to monitor an accuracy of approx. 10% for dosing pumps with flow rates between 0.1l/h and 50l/h. The sensor is designed so that the pump capacity is set using a bypass flow control valve and the set value is adjusted by means of a tangent screw. With each dosing stroke, a float element must jump up to reach the switch contact located at the set value adjusting screw. An electronic unit compares the command to initiate the dosing stroke with the switch contact of the flow sensor. As long as perfect dosing follows each trigger contact, the dosing process continues without interruption. The number of pulses accepted to fail can be set at the electronic unit. If this number is reached, it releases an alarm and the pump can be switched off.



Flow meter

Flow control valve

Pulsation dampener

![JESCO Lutz-JESCO America Corp.]
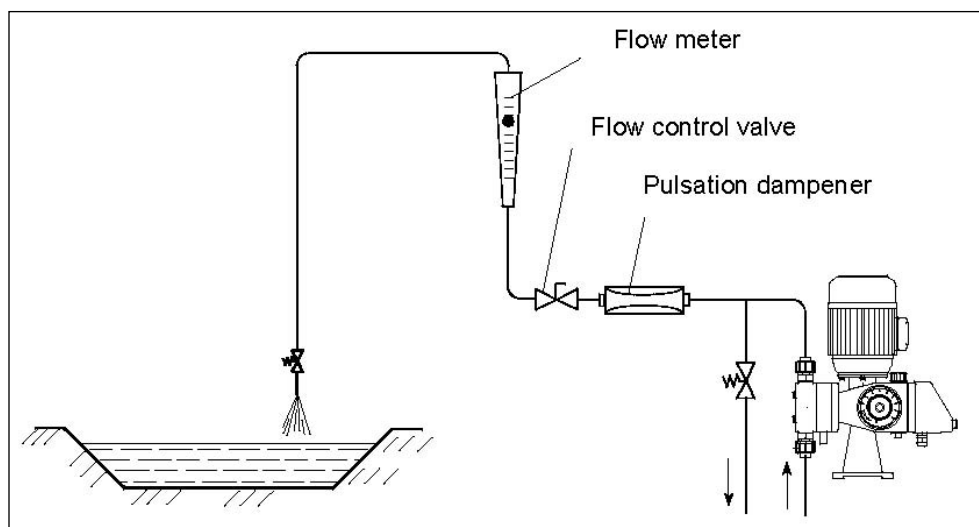
# An Introduction to Metering Technology

**FLOWCON**

1 Bypass valve
2 Contact adjusting screw
3 Float element with solenoid
4 Reed contact

Entry of dosing chemical

### Simple visual flow monitor

The flow monitor is mounted on the discharge valve of the dosing pump and indicates by a jumping ball whether a dosing stroke was carried out.

Ball
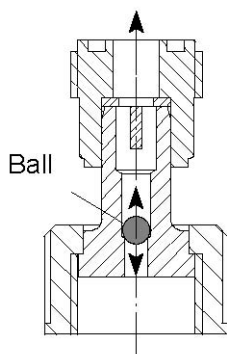
## 1.3.12 Stroke counters

Stroke counters allow to count the number of strokes carried out by the dosing pumps. In the case of batch operation, it is thus possible to complete a preset number of

strokes or tune the ratio of the number of strokes between different pumps. Stroke counters use e.g. an inductive approximation initiator to scan the pump tappet or eccentric, or reed contacts which scan a solenoid moved with the gear.

In the case of solenoid-driven pumps, the stray field of the drive solenoid can be used. For this purpose, a stroke sensor with reed contact can be fitted – also subsequently – outside the pump. In this case, the contact can be used control an additional pump. A water meter contact, for example, controls a solenoid pump which activates the second pump by means of the stroke sensor.

## 1.3.13 Leakage probe for diaphragm dosing pumps

Diaphragm dosing pumps are leakproof. If the diaphragm is destroyed due to wear or overload, larger amounts of dosing chemical may escape. To be able to react in time, a leakage probe which uses the conductivity of the leaking medium immediately releases an alarm and causes the pump to stop. In the case of non-conductive media, e.g. float switches in the collecting basin can be used for monitoring.

Drain inlet

Metal pipe 1

Gap

Cable

Metal pipe 2

Drain outlet

Inductive approximation sensor

Stray field is influenced by the eccentric

Switchbox

Tappet

Return spring

# 1.4 Selection of dosing pumps and fittings

In the following directions are given for the correct selection of a dosing pump. Apart from pressure and flow rate, the chemical and physical properties of the dosing chemical must be taken into account. For the purpose of this article it is only referred to pure diaphragm pumps, piston pumps and hydraulically coupled piston/diaphragm pumps.

**The following main factors are essential for the selection of the pump:**

**Nature and properties of the medium**

1. Concentration
2. Density
3. Temperature
4. Viscosity
5. Solidification temperature
6. Aggressiveness
7. Abrasiveness
8. Tendency to crystallize
9. Tendency to release gas
10. Toxicity (admissible threshold value)
11. Odor intensity
12. Steam pressure
13. Explosiveness (observe ex classification)

**System-related characteristics and requirements**

1. Is it allowed to connect the suction line at the side of or below the tank? (Environmental protection!)
2. Position of the dosing pump **above** the suction level with an **empty** tank. (Suction head!)
3. Position of the dosing pump **below** the suction level with a **full** tank. (Positive suction head!)
4. Maximum flow rate (provide an appropriate reserve!)
5. Lowest pressure in the system at the injection point (possibly vacuum, siphoning!)
6. Highest pressure in the system at the injection point (consider pressure losses due to piping and fittings!)
7. Dosing at atmospheric pressure (free discharge)
8. Injection point above the dosing pump (observe geodetic height for pressure!)
9. Injection point below the dosing pump (siphoning effect!)
10. Length of the suction line (friction, cavitation, reduced output!)
11. Length of the discharge line (observe friction, acceleration pressure for backpressure)
12. Admissible flow rate fluctuations (e.g. with reference to flow meters)
13. Is pump to be installed in an ex area? (Motors, etc.!)
14. Indoor or outdoor installation (protective roof!)

**In addition to the aforementioned characteristics of the system, it must also be considered how the pump is to be operated:**

1. Flow rate adjustable manually at the pump
2. Flow rate adjustable remotely electrically or pneumatically by hand
3. Remote control by a command signal (proportional follow-up from a process variable or water flow))
4. The pump is used as correcting element in an automatic control system.
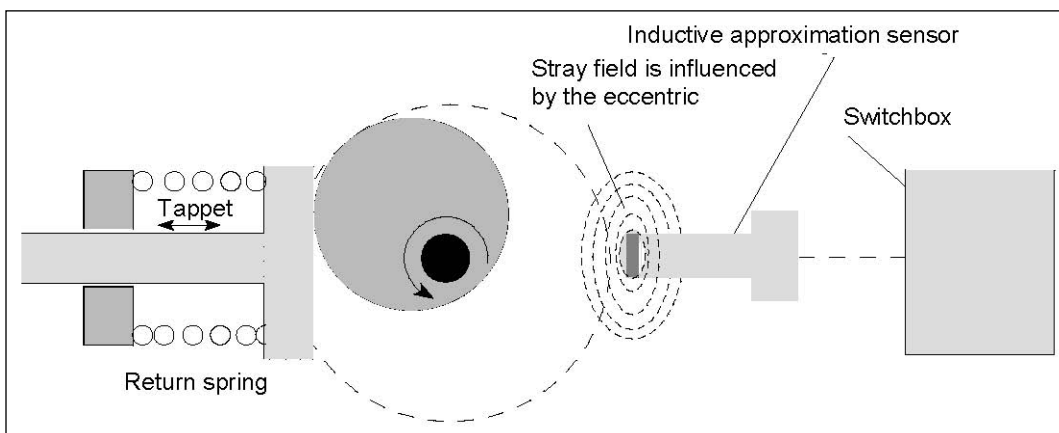5. The pump must be able to consider tow process variables (disturbance variable compensation by acting on speed and stroke length simultaneously)

For the versatile applications in process engineering, a large number of optimally adapted dosing pumps was developed. The following diagram is meant to be a guide to select the right and most economical dosing pump and to avoid design errors. With the diagram, preliminary decisions considering the properties of the dosing chemical are taken, which must be taken into account when finally determining the pump (e.g. that spring-loaded valves or wearproof packings are used).

**Design aids**

Before finally determining the dosing pump, the following questions must be answered:

**1. Chemical**

Which chemical is to be dosed and which are its properties?

Is leakage admissable regarding toxicity, odor or aggressiveness? If not, the leakproof diaphragm dosing pump should be preferred as far as it is possible with regard to pressure, linearity, etc.

**a) Viscosity**

The higher the viscosity, the lower should be\ the stroke frequency or the larger should be the line diameters. The use of spring-loaded suction and discharge valves is recommended for viscosities of 300mPa*s and more.

**b) Abrasiveness**

Suspensions (e.g. kieselguhr) or chemicals which tend to christallyze (phosphate solution) may cause premature packing leakage in the case of piston pumps. Therefore piston pumps with Aramid-Kevlar packings must be used preferably if diaphragm pumps are not suitable because of high pressure requirements. Highly acid or alkaline chemicals, however, make the application of this type of packing impossible.
Then piston-diaphragm pumps must be used.

**c) Aggressiveness**

The materials of the parts in contact with the chemical should be preselected according to practical experience and standard resistance lists and then be determined depending on the materials available for the pump.

Total | Metering
Fluid | Transfer
Management | Chem Feed

## 2. Flow rate

The dosing pump must be designed so that it achieves the maximally required flow rate at a setting of 80 – 90%. Thus there is still a reserve and the accuracy of the pump is used perfectly. Diaphragm pumps are not suitable satisfactorily at stroke lengths below 20% against max. pressure. With lower pressures, the pump can still be used in this range.

## 3. Backpressure

Backpressure is important directly at the ump. If the line from the pump to injection point is too long (e.g. more than 10m), pressure fluctuations may reach a considerable intensity and superimpose the pressure at the injection point. With increasing length, also the frictional losses are added to the operating pressure at the injection point. If these conditions are not observed, the hydraulic system may be damaged or the output may be reduced. Use pulsation dampeners to solve the problem.

Fluctuating backpressure may affect the accuracy of diaphragm dosing pumps. A constant backpressure can be attained by using backpressure valves.

## 4. Suction pressure

The suction pressure of the running pump must not exceed the suction pressure admissible for the pump. In the case of diaphragm dosing pumps, the suction pressure must be kept as constant as possible, since fluctuating suction pressure also affects the flow rate.

A level varying by a head of 4 meters, for example, would be extremely disadvantageous, especially if in addition the\ density was 1,900 kg/m³. The suction pressure fluctuations of 0.76bar in this case would cause dosing errors of much more than 10%. If the dosing pump is operated as correcting element in an automatic control system, this effect would be of minor importance because a controller would adjust the pump until therequired flow rate is achieved.

In the case of simple proportional dosing, however, this error might have a negative effect. For piston and piston-diaphragm dosing pumps, a fluctuating suction pressure is only of minor influence. If extreme level fluctuations are to be expected because of high supply tanks, a level-controlled intermediate container with float valve or a suction controller SDR can be used for the dosing pump.

Suction lines must be as short as possible or, for lengths of more than 8 meters, equipped possibly with a pulsation dampener just before the suction valve of the pump. In the case of closely dimensioned suction lines, a pulsation dampener may already be necessary at a length of 3 meters.

## 5. Dependence on pressure

Diaphragm dosing pumps are also dependent on the backpressure due to the flexible dosing diaphragm. The pump can be simulated a constant backpressure using a backpressure valve. It is set to a pressure which is approx. 1bar higher than the result of system pressure and line losses.

## 6. Nominal line width

When dimensioning the lines of installations **without** pulsation dampener, three times the value of the nominal dosing capacity must be taken into account to calculate the nominal width for a flow velocity of 1m/s on the discharge side and 0.5m/s on the suction side.

## 7. Dosing pump control

It must be checked whether the dosing pump will work according to a fixed value set manually or will be adjusted by a remote signal. In this connection, it is of decisive importance if the control signal is to change the pump speed (stroke frequency) or the stroke length (diaphragm or piston path).

If the **stroke frequency** is **changed**, the output for all types of dosing pumps is **linear**.

If the **stroke length** is **changed**, the output of:

| | |
|---|---|
| piston dosing pumps is | **linear**. |
| piston-diaphragm pumps is | **linear**. |
| diaphragm dosing pumps is | **non-linear** |

according to the characteristic curves of the corresponding documentation.

In the case of automatic control systems (pH control), the non-linearity of a diaphragm is hardly of any importance and would be compensated for by the controller.

### Diagram for the selection of dosing pumps

## 8. Dosing in dependence of water meter contacts

An ideal possibility to dose chemicals proportionally to the water flow is the control of solenoid dosing pumps by contact water meters. As the stroke once set and thus quantity dosed per stroke remain constant, the non-linearity of the diaphragm is not effective anymore. The output now only depends on the stroke frequency.

If the required flow rate cannot be achieved anymore by available solenoid dosing pumps, those motor pumps must be selected which can be run using a time relay in on-off operation in dependence of the water meter contact. Each contact is followed by a settable fixed running period.

**Nomogram to detrmine the pump size and running time per pulse**

```
┌──────────────┐      ┌──────────────────────┐      ┌──────────────┐      ┌──────────────┐
│ What is to be│ ───▶ │ Determine resistant  │      │ Contact      │      │ For viscosities│
│ dosed?       │      │ materials and        │      │ headquarters │      │ exceeding    │
│              │      │ compare with         │      │              │      │ 1000mPa*s,   │
└──────────────┘      │ available pumps at   │      └──────────────┘      │ only use     │
                      │ the end of the       │           ▲ yes           │ pumps with   │
                      │ diaphragm            │           │               │ stroke       │
                      └──────────────────────┘                           │ frequency    │
                                 │                                        │ below 80     │
      no                         ▼          yes                   no      │ strokes/min. │
┌──────────────┐      ┌──────────────┐     ┌──────────────┐     ┌──────────────┐│ Choose       │
│ Use standard │ ◀─── │ Viscosity    │ ──▶ │ Use spring-  │ ──▶ │ Viscosity    ││ shortest     │
│ valves       │      │ exceeding    │     │ loaded valves│     │ exceeding    ││ possible line│
│              │      │ 300mPa*s?    │     │              │     │ 3000mPa*s?   ││ lengths and  │
└──────────────┘      └──────────────┘     └──────────────┘     └──────────────┘│ longest      │
                                                                                │ possible line│
                                                                                │ diameters.   │
┌──────────────┐ yes  ┌──────────────┐ yes ┌──────────────┐ yes ┌──────────────┐└──────────────┘
│ Pressure     │ ──▶  │ Pressure     │ ──▶ │ Pressure     │ ──▶ │ Contact      │
│ higher than  │      │ higher than  │     │ higher than  │     │ headquarters │
│ 10bar?       │      │ 40bar?       │     │ 400bar?      │     │              │
└──────────────┘      └──────────────┘     └──────────────┘     └──────────────┘

   │ no                  │ no                │ no
   ▼                     ▼                   ▼
┌──────────────┐      ┌──────────┐ no ┌──────────────┐    no   ┌──────────────┐
│ Chemical     │      │ Chemical │ ──▶│ Chemical     │ ──────▶ │ Pressure higher│
│ abrasive?    │      │ abrasive?│    │ abrasive?    │         │ than 100bar? │
└──────────────┘      └──────────┘    └──────────────┘         └──────────────┘
   │ no        yes                       │ yes                   yes │    │ no
   ▼        ┌──────────┐                 ▼                           ▼
         │ Diapragm │            ┌──────────────┐
         │ dosing   │            │ Is Aramid    │ ◀──────
         │ pumps    │            │ Kevlar       │
         └──────────┘            │ resistant to │
              or                 │ the medium?  │ ─── no ──▶
                                 └──────────────┘
                                     │ yes
┌──────────────┐  ┌──────────────┐  ┌──────────────┐        ┌──────────────┐
│ Then generally│ │ Piston-      │  │ Piston pump  │        │ Piston pump  │
│ all types of │  │ diaphragm    │  │ with Aramid  │        │ with PTFE silk│
│ dosing pumps │  │ dosing pumps │  │ packing      │        │ packing      │
│ can be used  │  │ KMS          │  │              │        │              │
└──────────────┘  └──────────────┘  └──────────────┘        └──────────────┘
```

**Example:**

0.1 l chemical is to be used to treat each of 20m³/h water, i.e. 2l/h have to be dosed.
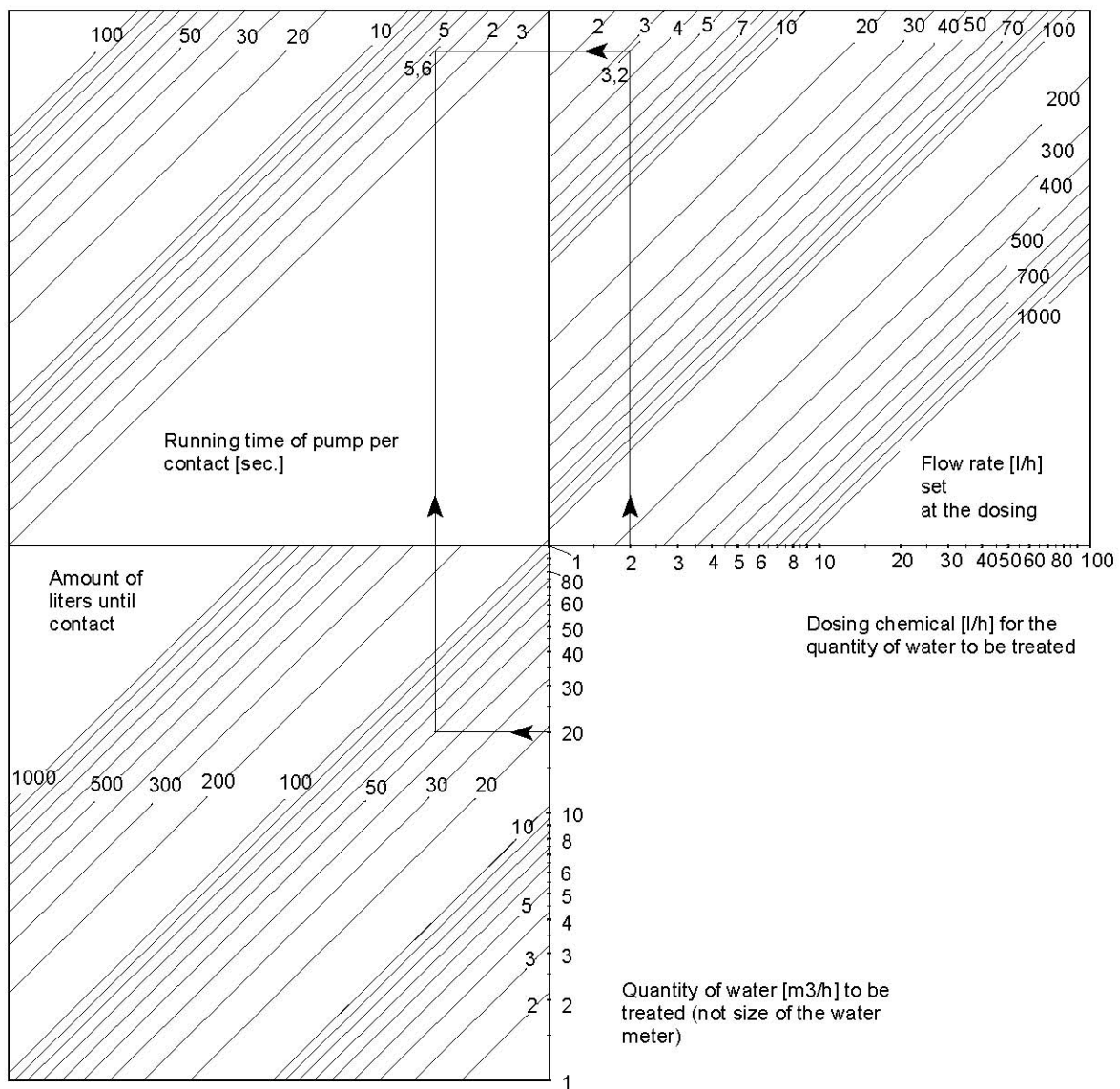
**Question:**

Which must be the minimum size of the pump and how long must it run per water meter contact which takes place every 50 l?
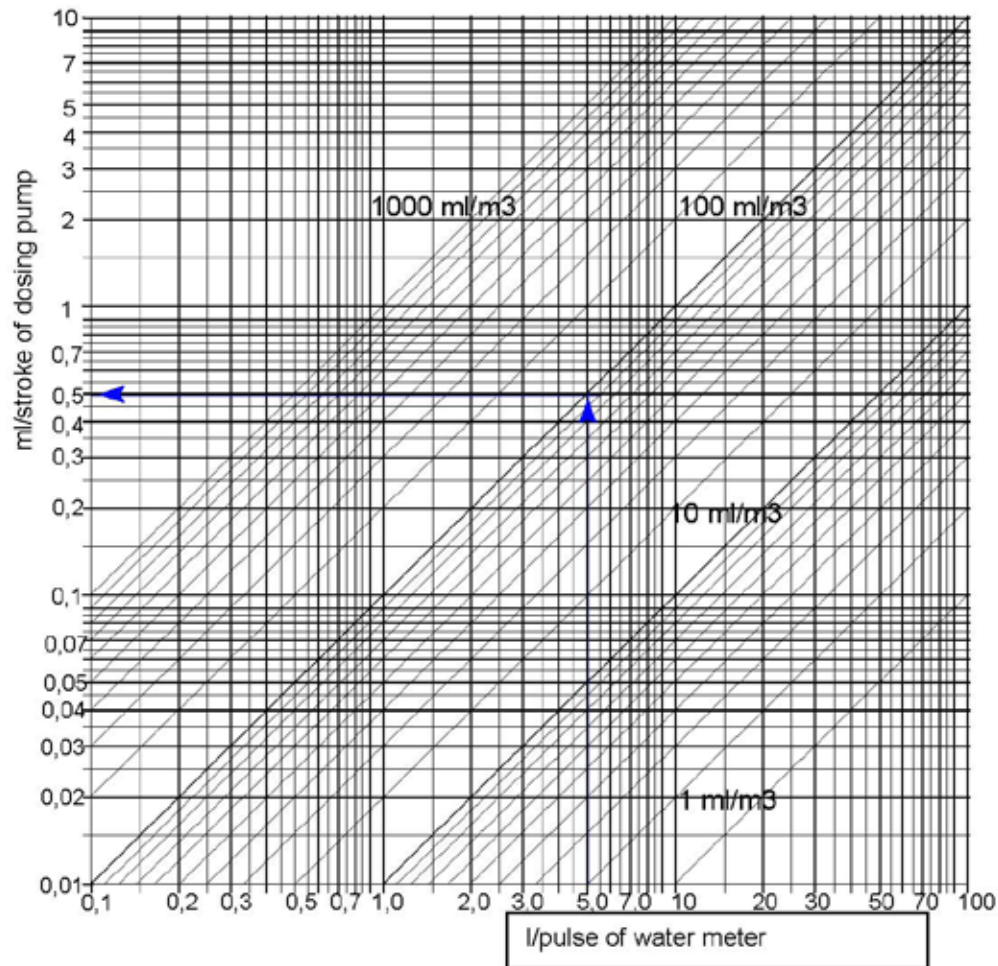
**Solution:**

In the above nomogram, e.g. a pump is found which must run 5.6 seconds at a flow rate of .2l/h.

**Nomogram to coordinate flow rate per cubic meter, water meter pulse sequence and solenoid pump**



Running time of pump per contact [sec.]

Amount of liters until contact

Flow rate [l/h] set at the dosing

Dosing chemical [l/h] for the quantity of water to be treated

Quantity of water [m3/h] to be treated (not size of the water meter)

## 1.5 Installations

For selection of the dosing pump during lanning and all the more for installation and operation, the local rules regarding electrical installation and handling of the chemicals must be observed.

It is recommended to plan and install all additional fittings required to increase accuracy and operational reliability. These include relief valves used in the safety valve function, backpressure valves to avoid undesired siphoning and to improve dosing accuracy, leakage probes for ruptured diaphragms and low level indicators in the storage tank to prevent air from entering the dosing head.

Disconnect the power supply and check that there is actually is no voltage anymore before working on the electrical wiring of the pump. The power supply must be secured against unintended reconnection.

The dosing pumps must not be installed in rooms exposed to the danger of explosion unless they are marked with an appropriate type approval label.

When working on suction and discharge lines of the pump or unscrewing connections or venting screws (e.g. on startup of the pump), wear safety glasses and protective gloves, if the dosing chemical is harmful to health. In the case of chemicals releasing gas which is toxic or caustic for the respiratory tracts, a breathing mask prescribed or recommended for the process must be used.

Keep the operating instructions of the dosing pump and the relevant fittings readily accessible.

Always use appropriate tools for the installation of plastic connecting parts. To avoid damage, never apply excessive force.

Plastic parts, especially PVC parts, can be screwed and unscrewed more easily if the thread is lubricated with vaseline or silicon grease before.

**Caution!**

Check the compatibility with the chemical to be dosed! For paint treatment applications (e.g. spray booths), silicon must **not** be used!

Never connect the pump to power supply, if no dosing lines are connected, since chemical possibly existing in the head will spurt out to\ the top.

If connections at the dosing head must unscrewed for the purpose of venting or other reasons, remove any leaking chemical,\ especially if it is caustic, aggressive or toxic, by all means and rinse it off with water, if necessary.

Dosing pumps are produced according to highest quality standards and have a long service life. Nevertheless some parts are subject to wear because of principle (diaphragms, dosing valves, valve seats). To ensure long operating life, visual checks are required from time to time. Particularly in the case of diaphragm pumps, attention must be paid to leakage at the fixing flange (drain sleeve) to identify a diaphragm rupture in time and prevent larger amounts of chemicals from escaping. Leakage due to diaphragm rupture can be monitored automatically using a special fitting (leak check).

Both, the designer and the user are responsible to make sure that the whole plant including the dosing pump is designed so that neither plant equipment nor buildings can be severely damaged in the case of chemical leakage caused inevitably by piston pumps or by diaphragm rupture as well as burst tubing. Dosing pumps are not responsible for unnecessary consequential damage. If there is a high danger potential, the plant must be designed so that, even in the case of a pump failure, no consequential damage appears which is unreasonably high compared to the value of the pump. Leakage probes and containment tanks are therefore recommended.

The manufacturer of the dosing equipment is not responsible for damages due to excessive or low flow rates resulting from wrong dimensioning, faulty pump settings or incorrect or insufficient installation of peripheral fittings. The following system flow diagrams are meant to be a planning aid for applications often found in dosing technology.

## 1.5.1 Installation of the dosing pump above the chemical tank

### 1.5.1.1 Standard installation

For the startup of small dosing pumps in particular which are still dry, the stroke should be set 100% so that liquid enters the dosing head after a short time. Priming can be facilitated using a siphon-type collector.

The geodetic difference in height between the suction valve of the dosing pump and the (lowest) level of the chemical tank must be kept as small as possible. The maximum suction heads normally stated for water change in the ratio of the densities of medium/water.

$$H_{Chem} = H_{Water} / \varsigma_{Chem} \text{ [possible suction head]}$$

$$H_{Water} = \text{maximum suction head for water}$$

$$\varsigma_{Chem} = \text{density of the dosing chemical [kg/dm}^3\text{]}$$

Protection against dry operation applies analogously for all following examples.



max. head

Float for supply control

Foot valve with ball check and filter
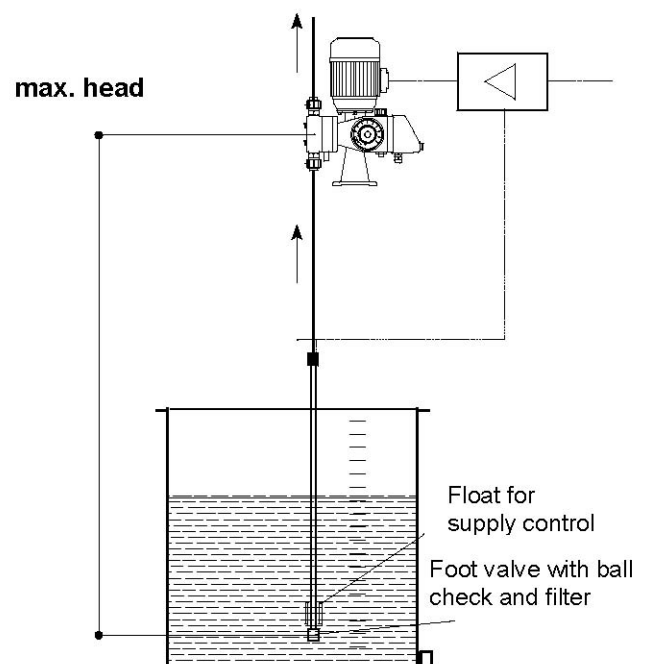
## 1.5.1.2 Suction line with priming aid

The siphon-type collector is filled with medium or with water, if admissible, and closed **tightly**. The pump primes medium into the dosing head without having to draw high vacuum initially. The dosing head works perfectly almost at once. A reduced level in the siphontype collector creates a vacuum in the upper section thus causing liquid to rise from the supply tank.

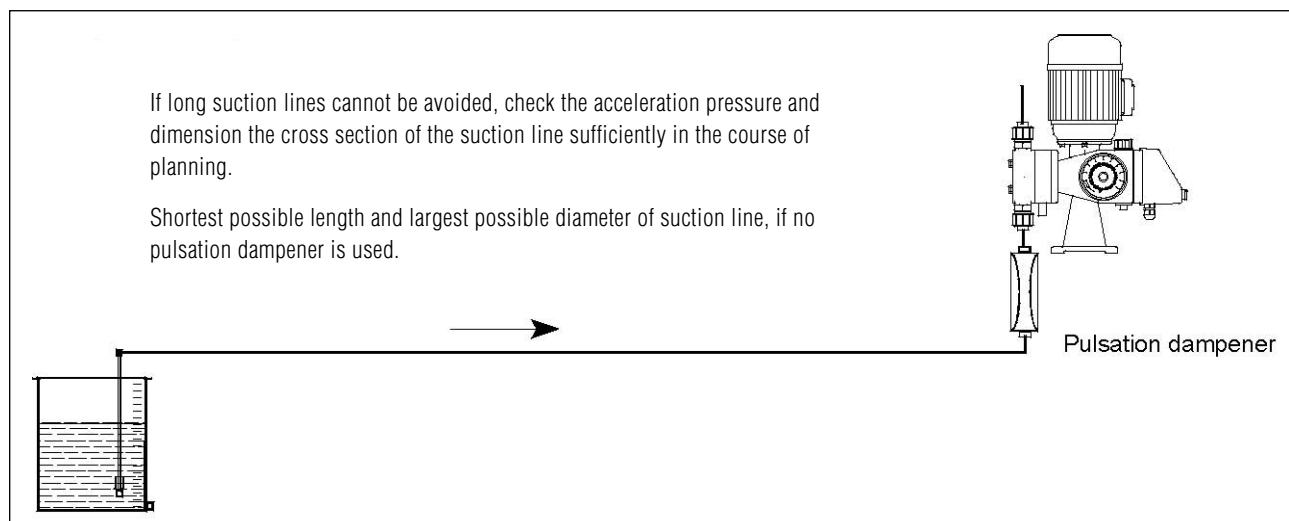Practically the pump must only overcome the smaller suction head 2 until the dosing head is\ filled.
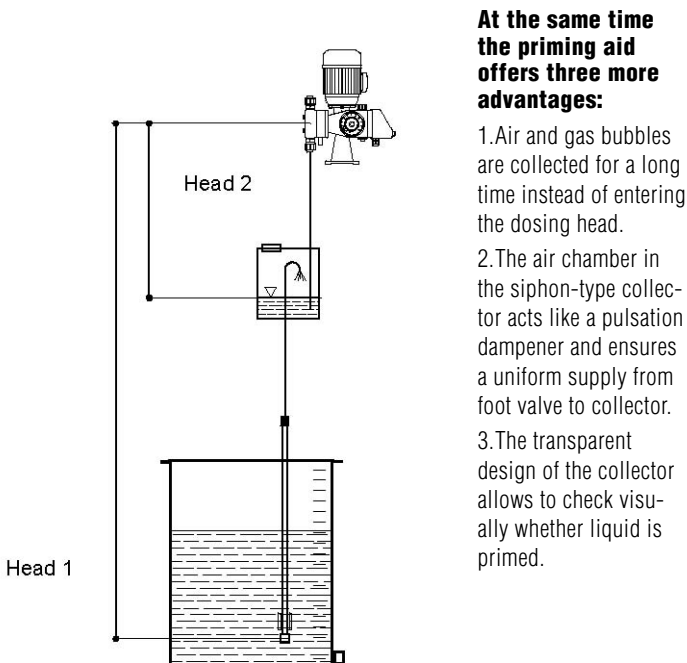
## 1.5.1.3 Suction line with pulsation dampener

If the dosing pump is positioned in the geodetically admissible range above the level but at a lateral distance of e.g. more than 5m, the pressure may fall below the steam pressure of the liquid (cavitation) due to the acceleration pressures. A reduced output or dosing failure may be the result. In this case a pulsation dampener is useful which is installed right before the suction valve.

If long suction lines cannot be avoided, check the acceleration pressure and dimension the cross section of the suction line sufficiently in the course of planning.

## 1.5.2 Installation of the dosing pump on the side of or below the chemical tank
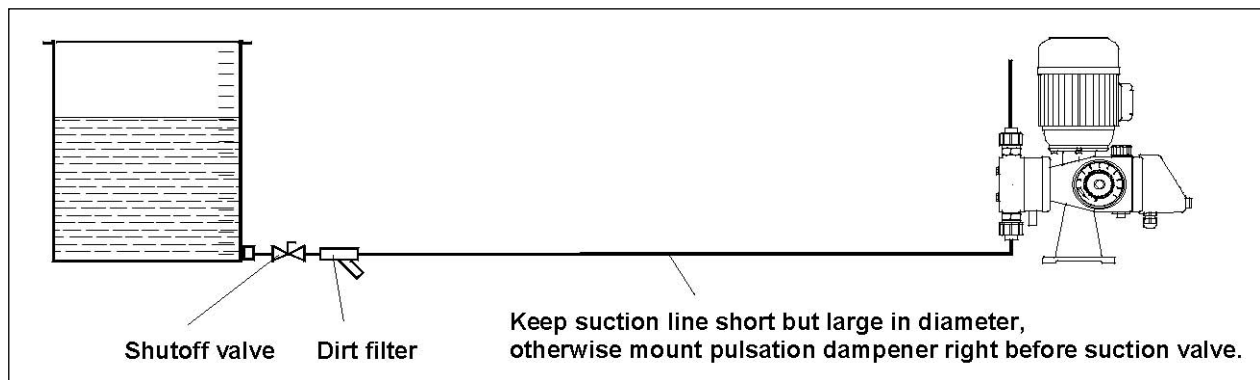
## 1.5.2.1 Connection at the bottom of the tank

**At the same time the priming aid offers three more advantages:**

1. Air and gas bubbles are collected for a long time instead of entering the dosing head.

2. The air chamber in the siphon-type collector acts like a pulsation dampener and ensures a uniform supply from foot valve to collector.

3. The transparent design of the collector allows to check visually whether liquid is primed.



Head 2

Head 1



If long suction lines cannot be avoided, check the acceleration pressure and dimension the cross section of the suction line sufficiently in the course of planning.

Shortest possible length and largest possible diameter of suction line, if no pulsation dampener is used.

Pulsation dampener

## 1.5.2.1.1 Standard installation

If the level has changed by more than 1m, it must be checked, whether the varying supply pressure affects the accuracy of the diaphragm dosing pump, taking the density into account. If this is the case, piston pumps or piston-diaphragm pumps can possibly be used as an alternative. The negative influence of the varying supply pressure can also be eliminated by installing a suction controller SDR or an intermediate container with constant filling level.

If long suction lines cannot be avoided, check the acceleration pressure and dimension the cross section of the suction line sufficiently in the course of planning.

Shortest possible length and largest possible diameter of suction line, if no pulsation dampener is used.



Shutoff valve     Dirt filter

Keep suction line short but large in diameter, otherwise mount pulsation dampener right before suction valve.

## 1.5.2.1.2 Suction line installation for effervescent media

To avoid that more gas than inevitable reaches the dosing head, the suction line should be connected to the suction valve with a positive suction head so that the gas flows back to the tank. This also requires an overdimensioned suction line to keep the flow velocity low. If the problem of released gas cannot be solved differently, the gas collector described under 1.5.2.1.2.1 or the head venting equipment treated under 1.3.5 must be used.



Gas

Dosing chemical
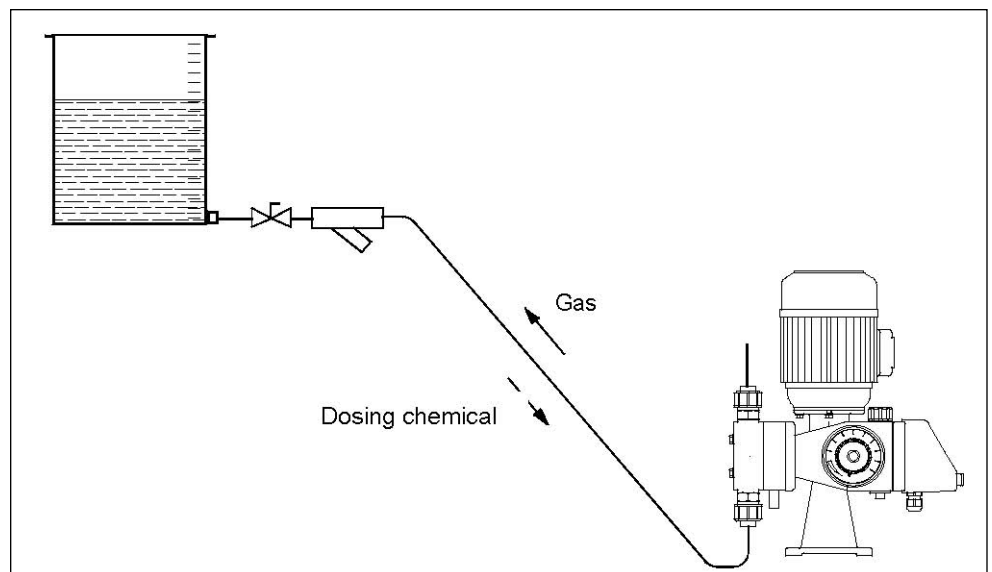
## 1.5.2.1.2.1 Gas collector

Also a gas collector, which besides has the positive effect of a pulsation dampener on the suction side, can be installed in addition to or instead of the inclined suction line right before the suction valve. It must, however, be vented from time to time, i.e.: be refilled with medium.
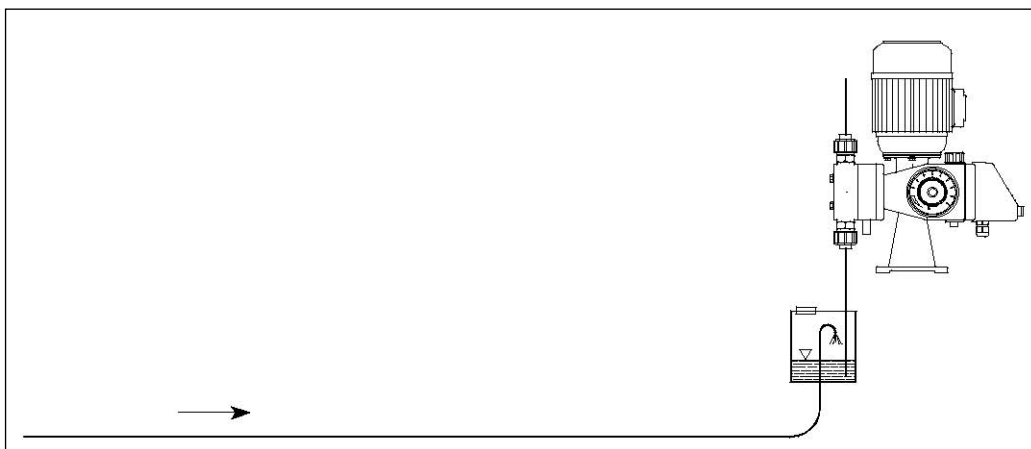


## 1.5.2.1.2 Intermediate container for constant supply pressure to dosing head

Especially the flow rate of diaphragm dosing pumps depends on the suction and supply pressure. This influence can be eliminated by means of an intermediate container permanently filled to the same level. This solution is only usable with a positive head to enable free supply to the intermediate container.
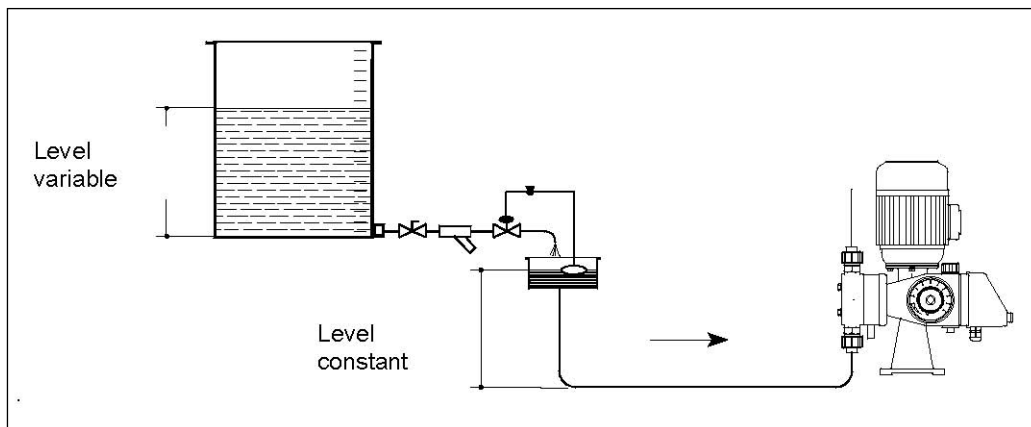


**1.5.2.2 Installation of the dosing pump** for those applications which, for safety reasons, do **not** allow to connect the **tank laterally** or **at the bottom** (prevention of water pollution).

Supply is only permitted from the top.
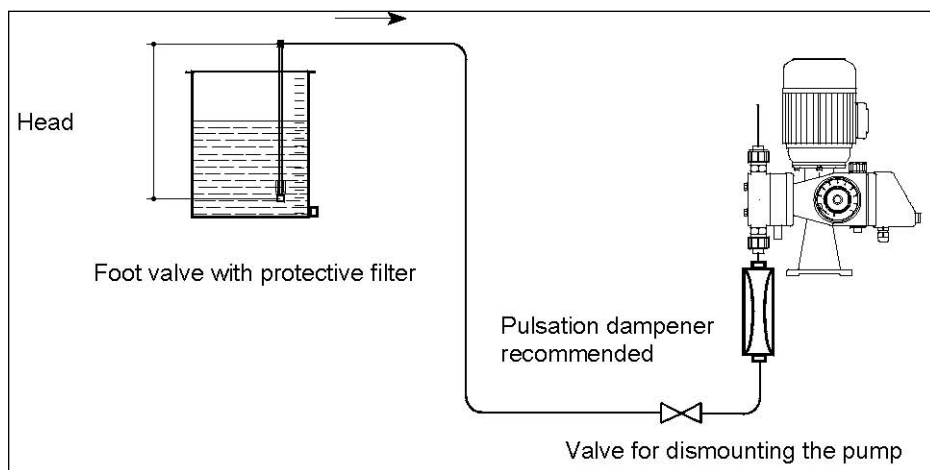
## 1.5.2.2.1 Standard installation

This installation is only functioning if the head H to be overcome at minimum level can also be achieved by the still dry pump, taking the density into account. If the lines are filled, the hydrostatic pressures in the lines inside and outside the tank neutralize each other so that this system behaves statically like the system according to fig. 1.5.2.1.1. An **important** difference, however, has to be considered: The suction line length is counted from the foot valve for the liquid head to be accelerated and can cause priming problems due to the long line. A pulsation dampener as described under 1.5.1.3 is helpful, because the pressure peaks produced by acceleration are reduced.

For effervescent media a siphoning system as described under 1.3.3.2 can be used.

## 1.5.2.2.2 Suction line with filling funnel

By filling the suction line before startup, priming is possible without any problem because of the hydrostatic balance thus created (provided that a pulsation dampener is installed on the suction side, if the distancebetween foot valve and pump is too long, as mentioned under 1.5.2.2.1). Close valve tightly after filling.



Filling funnel for suction line

Close valve tightly after filling

Head
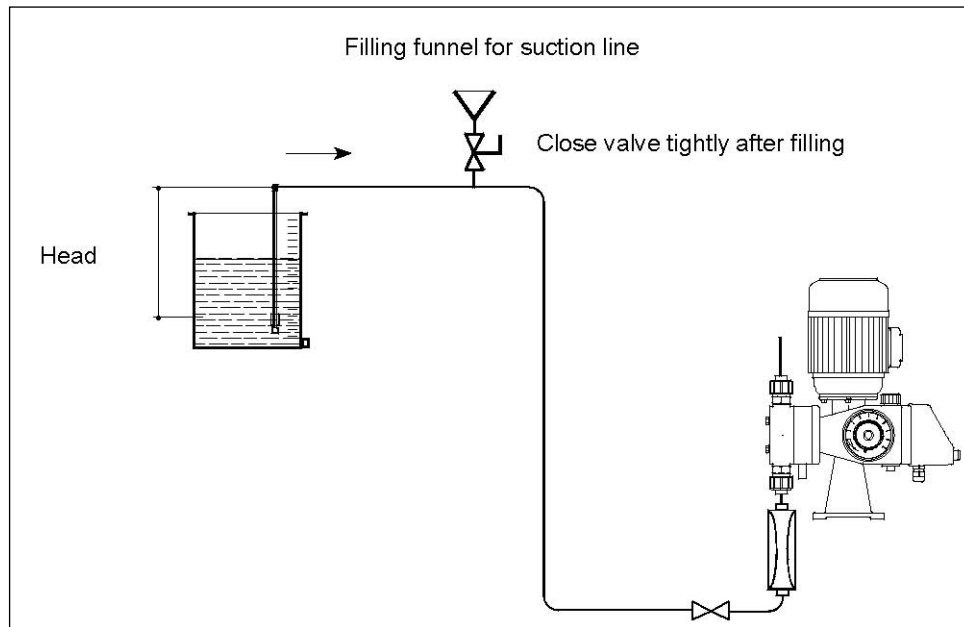
## 1.5.2.2.3 Suction line with siphon-type collector

A siphon-type collector can also be installed close to the dosing pump because of the positive secondary effect of pulsation dampening. The collector acts in the same way as described under 1.5.1.2. The volume V to be filled in before startup can be calculated from volume Vs of the suction line filled with air from the foot valve to the level of the filled siphon-type collector. The vertical head H between foot valve and highest point as well as the density of the medium and the air pressure are included in the calculation. See table 1.3.3.1.



Volume Vs of the suction line
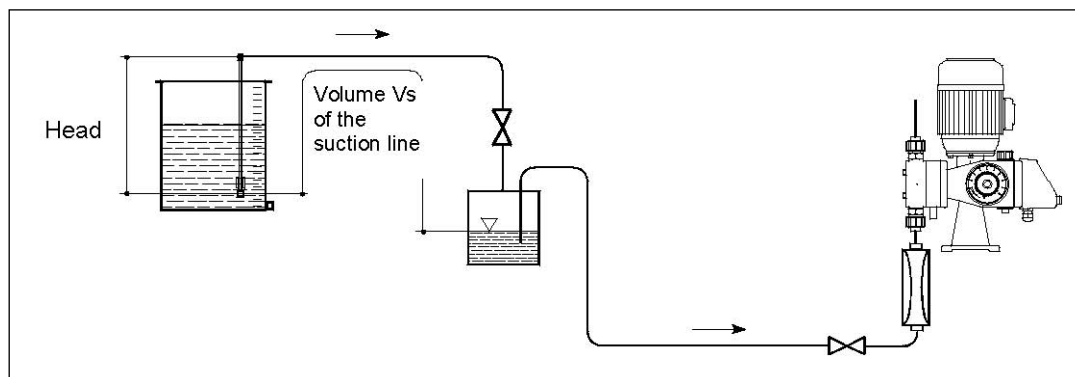
Head

## 1.5.2.2.4 Suction line with overflow container to keep the supply head constant

The flow rate of diaphragm dosing pumps depends on the suction or supply pressure. This influence can be eliminated by means of an overflow container constantly filled to the same level. Just a separate filling pump might be necessary which permanently delivers more than maximally primed by the dosing pump. The quantity not required by the dosing pump is returned to the supply tank.

The filling pump does not have to be a dosing pump.
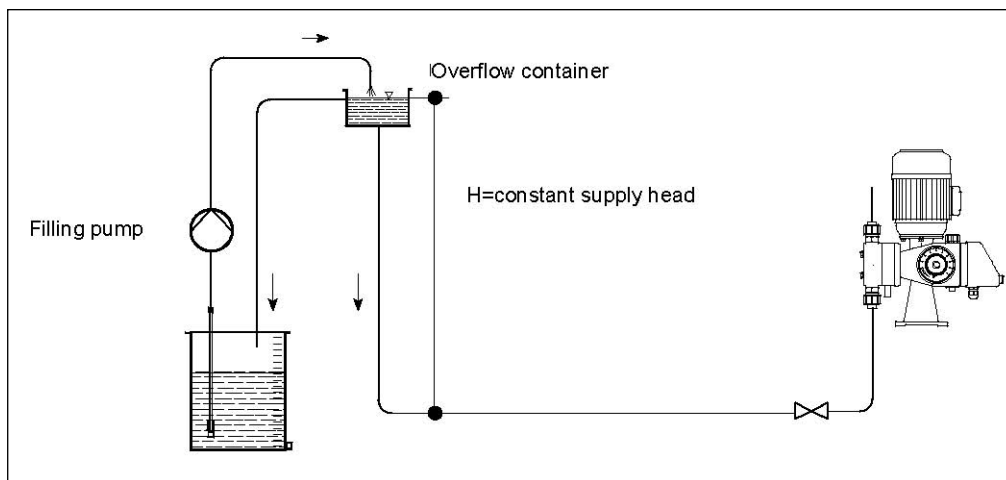


## 1.5.3 Discharge line from dosing pump to injection point
## General notes which apply to all following installations

## 1.5.3.1 Tubing line

## 1.5.3.1.1 A tubing used for the discharge line instead of a rigid piping has a dampening effect on pressure fluctuations of an oscillating dosing pump.

## 1.5.3.1.2 The discharge line consisting of a flexible tubing is self-cleaning as far as deposits are concerned and is therefore recommended for suspensions as e.g. milk of lime.
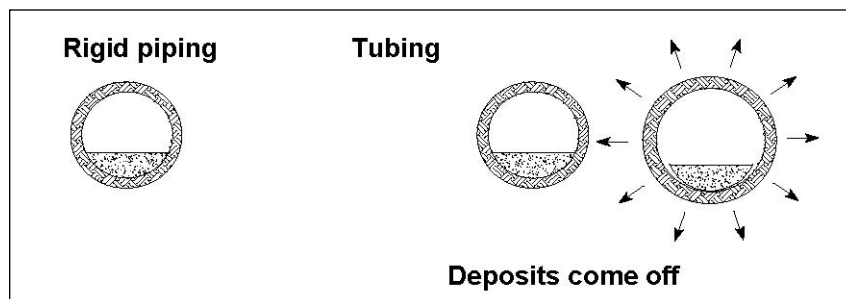


## 1.5.3.1.3 For line lengths of more than 10 m, the extent of the pressure peaks caused by the oscillating operating mode of the dosing pumps must be checked.

To reduce the pressure peaks, either the line diameter must be increased or a pulsation dampener used. If a ppulsation dampener is installed, it must be ensured that the dampener can be locked and relieved by means of valves from operating pressure for later maintenance and refilling of gas.
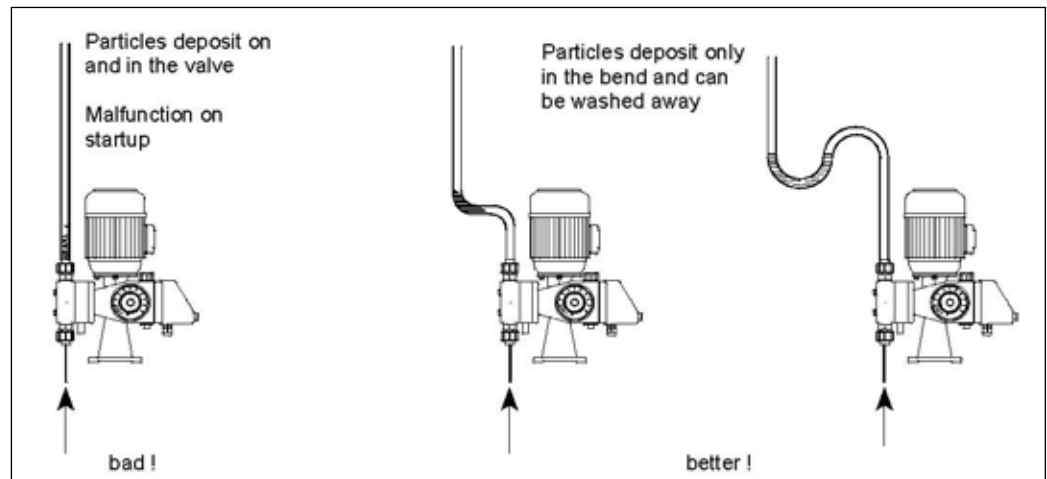
Before each check or refilling of air, the pulsation dampener must be separated from the system under pressure by shutoff valve $V_1$ and relieved by valve $V_2$.



**Connection via T-piece**      **Connection inline with flow**
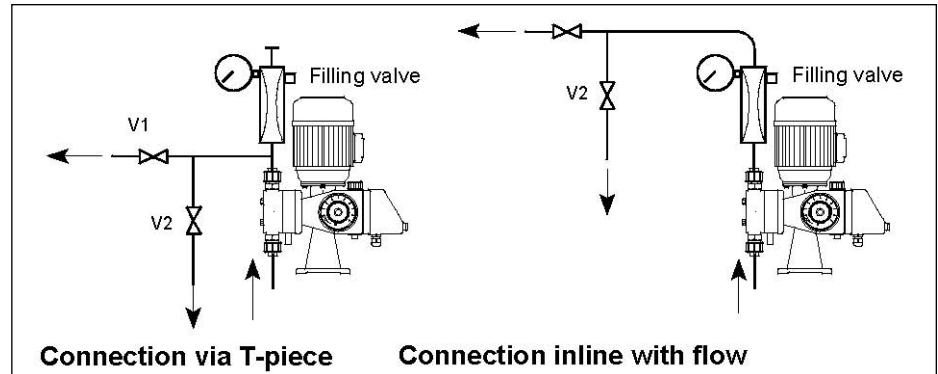
## 1.5.3.1.4 Suspensions

Suspensions tend to deposit also in functional parts of the pump such as valves. During standstill periods the particles would "cement" the discharge valve and affect the restart. Therefore it is recommended to shift the line laterally directly above the valve.

For suspensions, the highest admissible flow velocity should be chosen to avoid deposits in the line.



Particles deposit on and in the valve

Malfunction on startup

Particles deposit only in the bend and can be washed away

bad !      better !

## 1.5.3.1.5 Flushing

In addition to the previous chapter, flushing of the complete dosing head is recommended at certain time intervals and/or standstill periods. This task can be controlled by the process flow using a a time relay. If the flushing water (e.g. in the case of settling basins) can also be routed to the dosing point, 2 valves (and D) can be saved.



D zu      zu = closed
auf = open
A auf
B auf      B auf
C zu      C zu
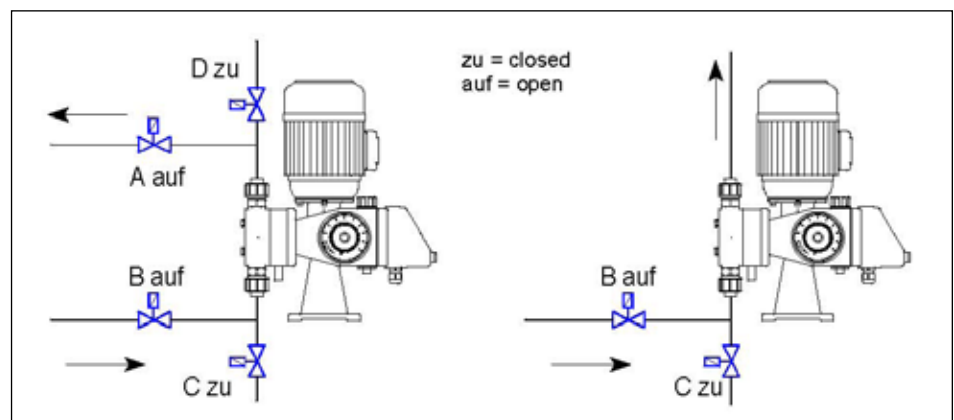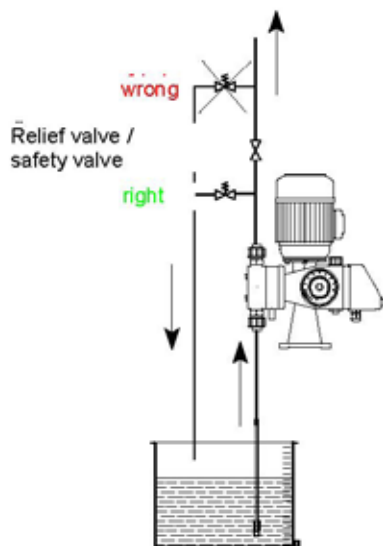
### 1.5.3.1.6 Relief valve (safety valve)

If there is the possibility in the suction line between dosing pump and injection point to close the line without having to switch off the pump before, a relief valve must be installed to protect pump and line. The relief valve should be provided anyway if a powerful pump might cause destructions in the case of a blocked line. The installation must ensure that the relief valve can never be shut off. A relief valve is not required for solenoid dosing pumps which cannot build up a destructive pressure (e.g MAGDOS 12l/h with 4bar, MAGDOS 40 with 4bar and MAGDOS 100 with 1.5bar).

### 1.5.3.2 Dosing at free discharge

When dosing into an open tank or into a (settling) basin, it must be taken into a account, if the injection point is geodetically above or below the level of the dosing chemical tank.
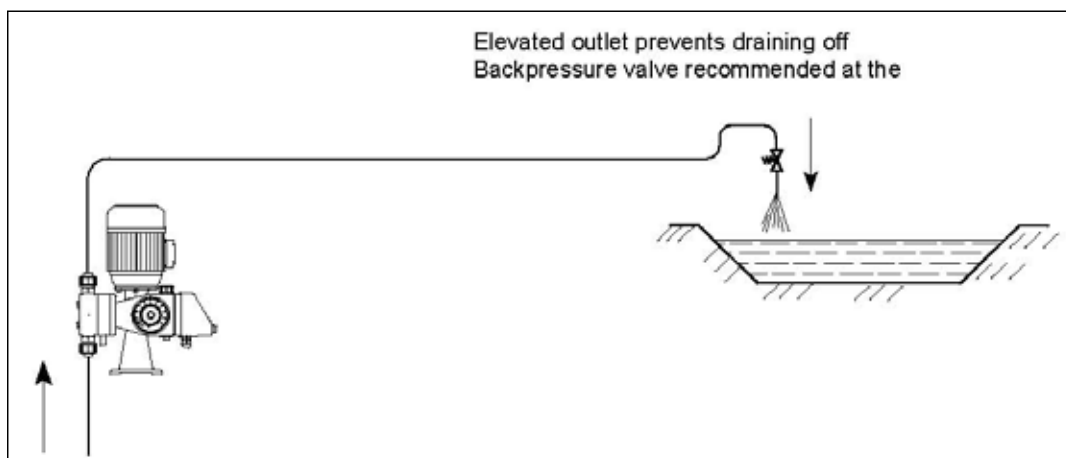
### 1.5.3.2.1 Injection point geodetically above the tank

If the injection point is positioned above the tank, a simple line from the dosing pump to the injection nozzle is sufficient without further fittings. If the line is, however, long (more than 10m), an integrated pulsation dampener may have a smoothing effect. A backpressure valve prevents excessive dosing in the case of long lines, which occurs as a result of the mass moment of inertia of the flowing dosing volume.

In any case the installation of the line should nsure that it is always filled and does not drain off accidentally (which would have a negative effect on the control).

An elevated bend which prevents emptying after dismounting the backpressure valve must be installed shortly before the outlet.

### 1.5.3.2.2 Injection point geodetically below the tank

If the injection point is positioned below the level of the tank, chemical would flow back from the tank to the injection nozzle also with the pump switched off. With a running pump, the flow rate would be higher than adjusted.

The effect is called "siphoning". In such cases, a backpressure valve must always be installed **at the end** of the line. The pressure to be maintained should be approx. 0.5bar higher than the hydrostatic siphoning pressure.

$$\text{Siphoning pressure} = \frac{Gradient(m) \bullet Density(kg/dm^3)}{10} \text{ bar}$$

Total | Metering
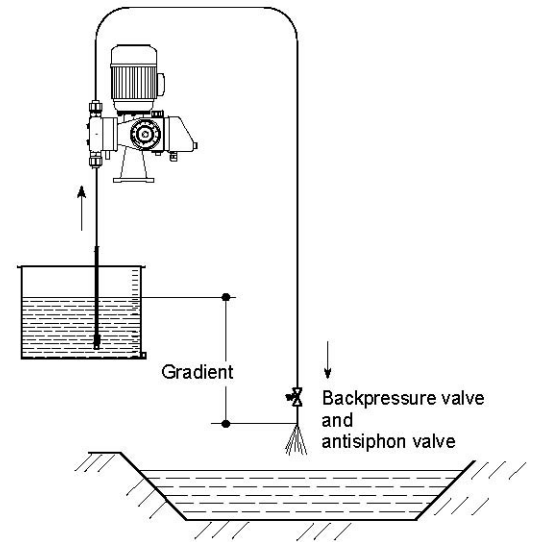Fluid | Transfer
Management | Chem Feed
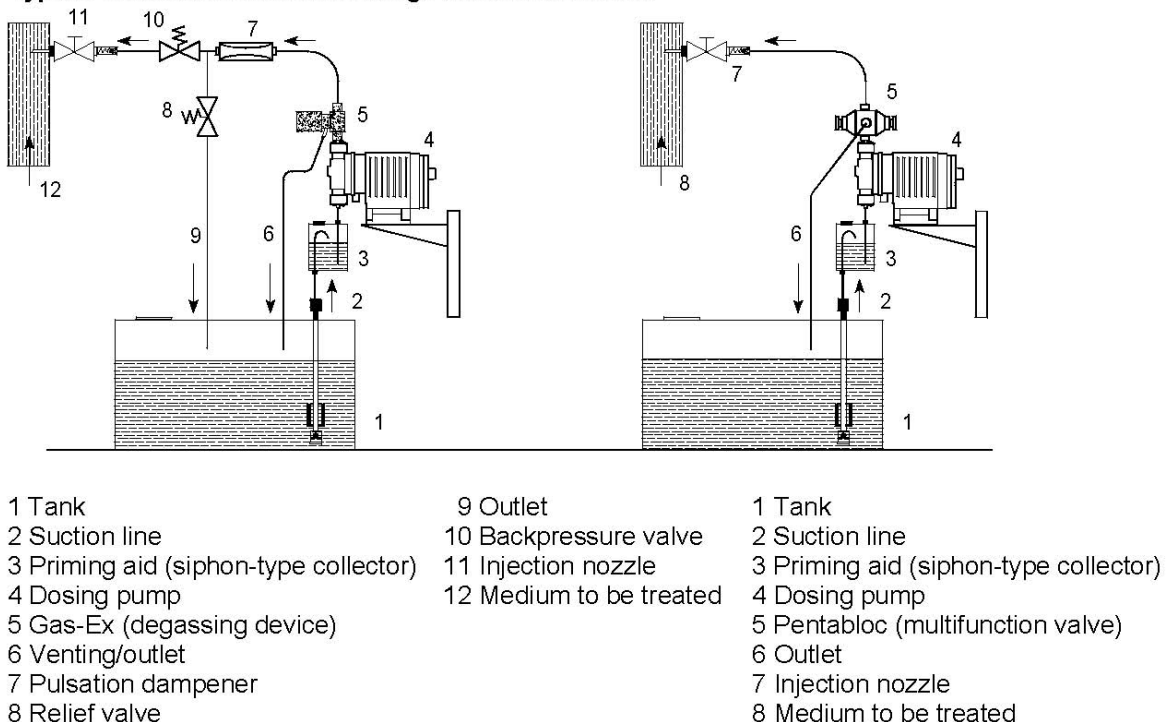
## 1.5.3.3. Dosing into pressure systems

Always use a lockable injection nozzle with non-return valve to discharge into systems with excess pressure. Thus no process medium can flow backwards into the dosing system. It would be dangerous, for example, if water could flow from the process into a sulphuric acid dosing system. Plastic lines would be exposed to danger by the exothermal reaction, PVC lines would even melt.

All aforementioned directions before apply, such as the use of a pulsation dampener for longer lines or backpressure valves in the case of fluctuating backpressures or "siphoning". A relief valve protects dosing pump and line against inadmissibly high pressure.
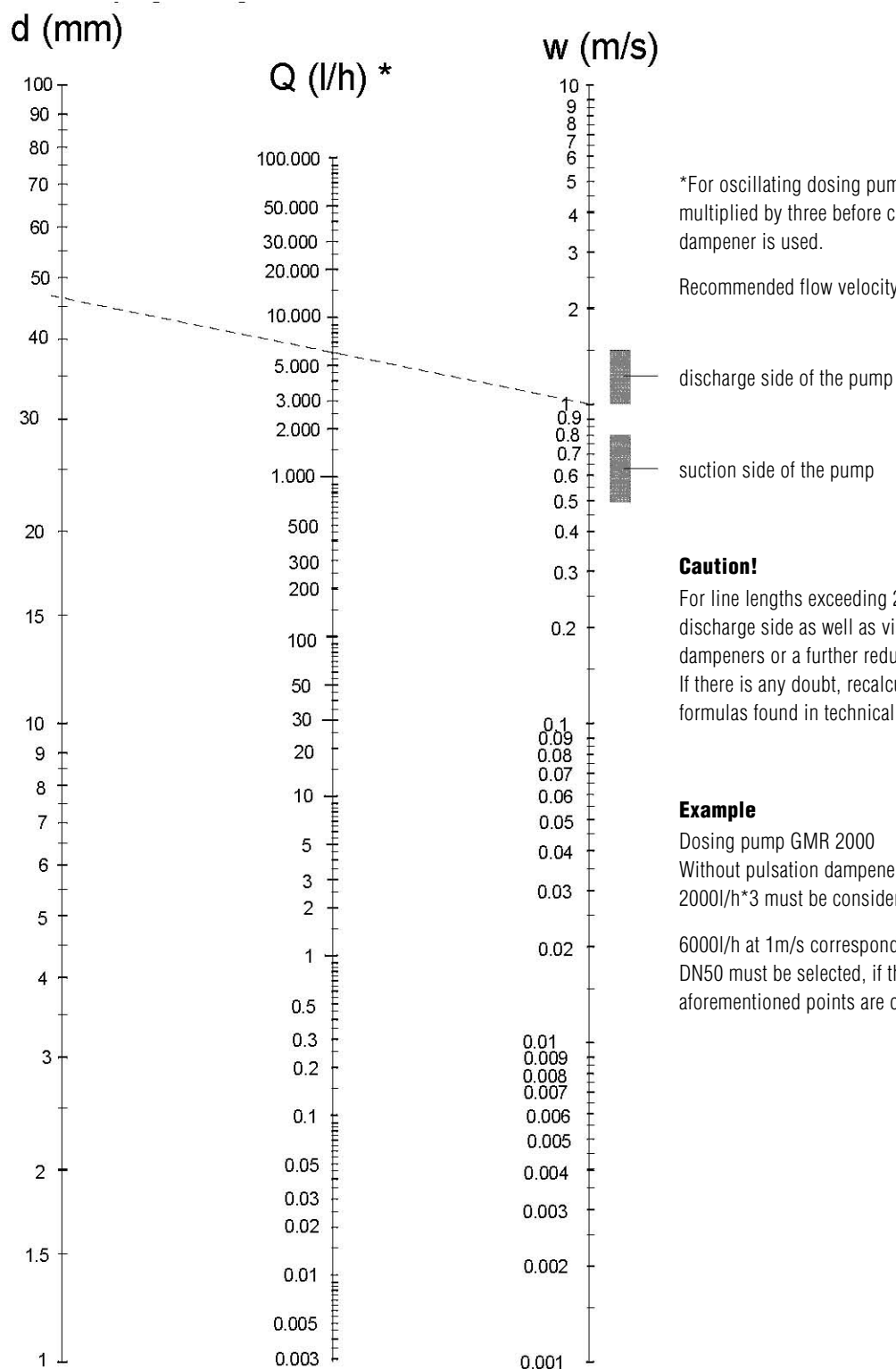
The injection nozzle must be shut off before longer standstill periods, because the nonreturn function integrated in the injection nozzle does not ensure safe locking. Only ball valves, stop valves etc. are suitable for this purpose.



Gradient

Backpressure valve and antisiphon valve

### Typical installation with the fittings described before



| | |
|---|---|
| 1 Tank | 9 Outlet |
| 2 Suction line | 10 Backpressure valve |
| 3 Priming aid (siphon-type collector) | 11 Injection nozzle |
| 4 Dosing pump | 12 Medium to be treated |
| 5 Gas-Ex (degassing device) | |
| 6 Venting/outlet | |
| 7 Pulsation dampener | |
| 8 Relief valve | |

1 Tank
2 Suction line
3 Priming aid (siphon-type collector)
4 Dosing pump
5 Pentabloc (multifunction valve)
6 Outlet
7 Injection nozzle
8 Medium to be treated

## 1.5.3.4 Piping nomogram

**d (mm)**

**Q (l/h) ***

**w (m/s)**

*For oscillating dosing pumps, the nominal pump capacity must be multiplied by three before calculating the nominal width, if no pulsation dampener is used.

Recommended flow velocity liquids similar to water on the:

discharge side of the pump

suction side of the pump

**Caution!**

For line lengths exceeding 2m on the suction side and 10m on the discharge side as well as viscosities of more than 20mPa*s pulsation dampeners or a further reduction of the flow velocity are recommended. If there is any doubt, recalculate the pressure loss of the piping using the formulas found in technical literature or chapter 1.3.1.1.

**Example**

Dosing pump GMR 2000
Without pulsation dampener,
2000l/h*3 must be considered

6000l/h at 1m/s correspond to 45 mm.
DN50 must be selected, if the
aforementioned points are observed.

# 1.6 Accuracy of dosing pumps

Dosing pumps do not principally have a specific accuracy. Their precision also depends on adherence to the operating mode of the pump. Therefore it is very important that the operating data given during setting of the required flow rate are kept to all the time. Only then can a sufficiently constant dosing be ensured. The operating conditions include the characteristic of the medium, its temperature and viscosity, supply pressure or suction pressure as well as backpressure. Of course, such parameters as voltage and mains frequency which have an effect on the drive motor are also important. In the case of diaphragm pumps, it must be additionally considered that rigidness decreases in the course of service time. If the constancy of the aforementioned data is not provided by the system already, appropriate precautions must be taken to produce stability or at least minimize variation.

For the pump itself, the achievable accuracy is already defined during construction. Design and dimensional stability of the machine parts against application of force and compressive stress as well as backlash-free concurrence of the moving elements are the preconditions.

Constant backpressure can be produced by using backpressure valves, constant suction pressure conditions are achieved by means of a suction controller or level-controlled intermediate containers.

If all aforementioned parameters are constant, the output can be evaluated according to the following criteria:

## 1.6.1 Dosing error

The dosing error indicates the deviation of the output from the average value which is calculated from a certain number of individual measurements at constant stroke length setting.

## 1.6.2 Adjusting accuracy

The adjusting accuracy indicates the deviation of the output from the average value which is calculated from a certain number of individual measurements, the stroke being changed considerably after each individual measurement and reset to the previous value after the following measurement. In a simplified way the output can be described by the following equation:

$$m = A \bullet H \bullet n \bullet \rho \bullet \varepsilon$$

m = Output mass/time
A = Effective area of the piston or diaphragm
H = Stroke length of the piston or diaphragm
n = Stroke frequency
$\rho$ = Density of the dosing chemical
$\varepsilon$ = Efficiency

As the parameters contained in the equation are not constant in practice but are subject to production faults, pressure and temperature influences as well as fluctuations of the mains frequency and voltage in the case of threephase motors, the output achieved is not 100% but just a certain portion of it. This is expressed by efficiency $\varepsilon$ which itself is not constant either but depends on the pressure especially if strain or gas enclosures occur   can be determined by trials.

There are errors which are constant in absolute values for all stroke settings and therefore affect the output more strongly in the case of low stroke settings. An error of ± 1 % corresponds to ± 1 l/h for a 100 l/h pump. This error also occurs, if the pump is set to an output of 25%. Then ± 1 l/h already corresponds to ± 4 % related to 25 l/h.

Such errors relative to the maximum value are e.g. leakage at the piston or slip of leaking valves.

Other errors refer to the individually set output. Then an error of ± 1 % corresponds to only 0.25 l/h, if the 100 l/h pump is set to 25%. A fluctuating mains frequency is such an error, for example. A change in speed of ± 1 % influences the 100l/h setting and the 25l/h setting by the same percentage, i.e.: ± 1l/h at 100 l/h and ± 0.25 l/h at 25 l/h output.

Errors caused by strained diaphragms and by compression or expansion of air and gas enclosures in the pump head are most difficult to control.
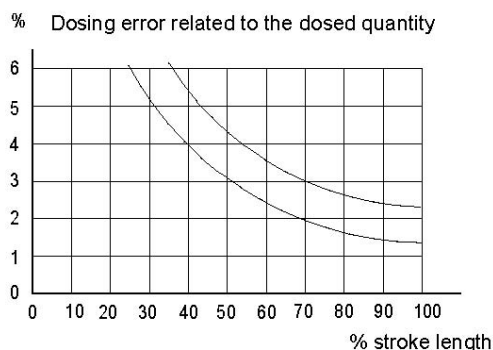
Therefore the design engineer should minimize clearance volumes and elastically compressible parts and the planner should design the installation so that no gas enters the dosing head.

The dosing accuracy can be increased right from the beginning if the user does not only refer to the adjustment scale of the dosing pump and characteristic curves of the data sheets but calibrates the dosing pump under operating conditions (see chapter 1.7).
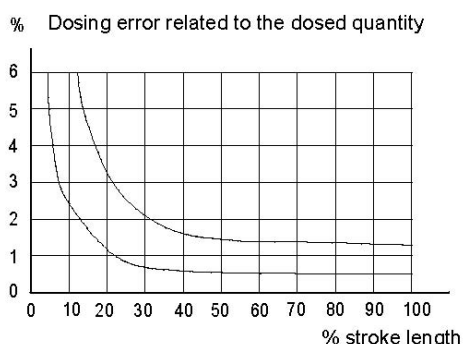
For piston dosing pumps, a dosing accuracy of 0.5…1.0% at constant operating conditions can be stated. This accuracy is achievable by an adjusting range of 10…100%. At a stroke length below 10%, the error increases superproportionally. Diaphragm dosing pumps reach an accuracy of approx. 3% related to a stroke length of 100% at constant operating conditions. Contrary to piston dosing pumps, however, the influence of the share of error caused by the strain of the diaphragm is strong and grows superproportionally at low stroke lengths. Therefore diaphragm dosing pumps should not be operated at stroke lengths below 20%. At a stroke length of 20%, the dosing error may already be higher than 10% of the values stated according to the characteristic curve. The accuracy of the dosing pumps is almost unimportant if they are just used as conveying (feed) pumps or as correcting elements in automatic control systems. In the latter case, the controller adjusts the pump until the set process value is reached.

## Diaphragm dosing pump

**% Dosing error related to the dosed quantity**



% stroke length

## Piston dosing pump

**% Dosing error related to the dosed quantity**



% stroke length

# 1.7 Testing the output

The output can be determined by various methods. During measurement (also called calibration), suction pressure and backpressure must remain constant. In most cases the dosing pump is calibrated for different backpressures in turn and the suction pressure is maintained at e.g. 100mbar all the time (approx. 1m water head). To record a characteristic curve, the output can be measured at stroke lengths of e.g. 0-20-40-50-80-100%. The dosed quantity can be collected on the discharge side which is mostly only possible with pump test benches (see chapter 1.7.1). For operating installations, the method which measures the quantity primed by the pump per time unit (e.g. minute) has proved successful. If a system requires this measurement frequently for control purposes, an appropriate measuring vessel should be installed at the suction line (see chapter 1.7.2).

## 1.7.1 Test bench for dosing pumps

The functional construction of the test bench should provide for the possibility to easily change the pumps (2) to be tested. The testing procedure is explained with the help of the following schematic diagram:

Clean water to be used as test medium is contained in the container (12). It must be exchanged regularly to avoid impurities by algae or bacteria. The suction line (1) should be flexible for easier handling. Besides, a foot valve should be available so that the suction lines must not refilled again to test the next pump. Also the connection of the discharge line (3) should be flexible. Before testing, the required test pressure must be applied to the dosing pump. If a pulsation dampener (4) is to be used to ensure a uniform dosing flow, it must be prepessurized to 60 − 70% of the test pressure. The valve (5) must be opened before filling the pressure reduction unit with air so that the air pressure is able to push out the water present in the system. If the valve (5) is open, the pump is switched on to make priming easier. After the pump has primed, the

Dosing error related to the dosed quantity Dosing error related to the dosed quantity % stroke length % stroke length valve (5) must be closed. Then the pump discharges through the backpressure valve (7) and builds up the required pressure. The test pressure is to be read at the pressure gauge (6), not at the pulsation dampener (4).  According to its setting, the pump discharges the quantity to be tested against the pressure read at the pressure gauge (6) via the solenoid valve (8) to outlet (A) and back into the supply tank (12). From this uniform operation, the dosing output is now measured for e.g. 1 minute. This is possible by activating a time relay (9) with the help of a key button (10) which switches the solenoid valve (9) for exactly one minute to route the dosing quantity from the connection piece (B) into the measuring vessel (11). After one minute has passed, the relay

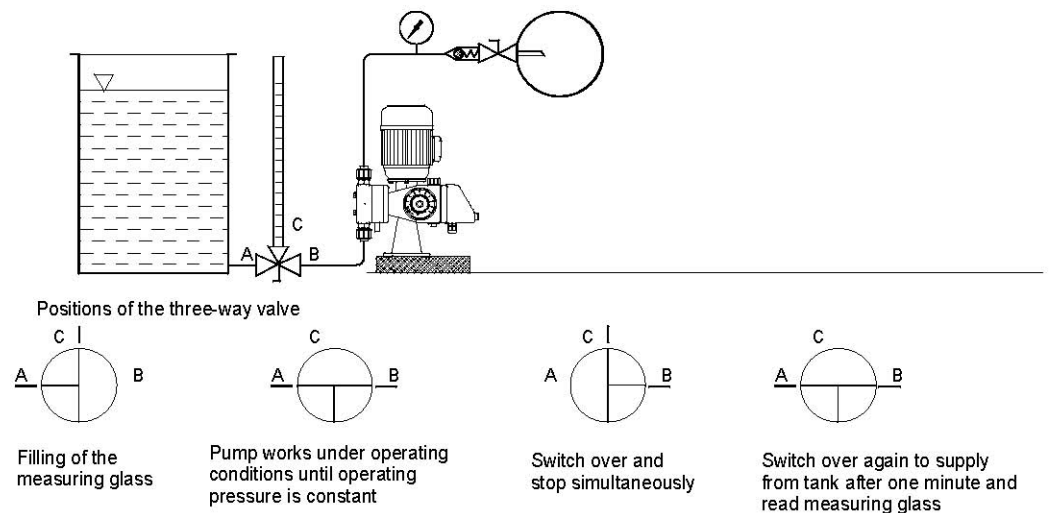**Schematic diagram of the test bench**
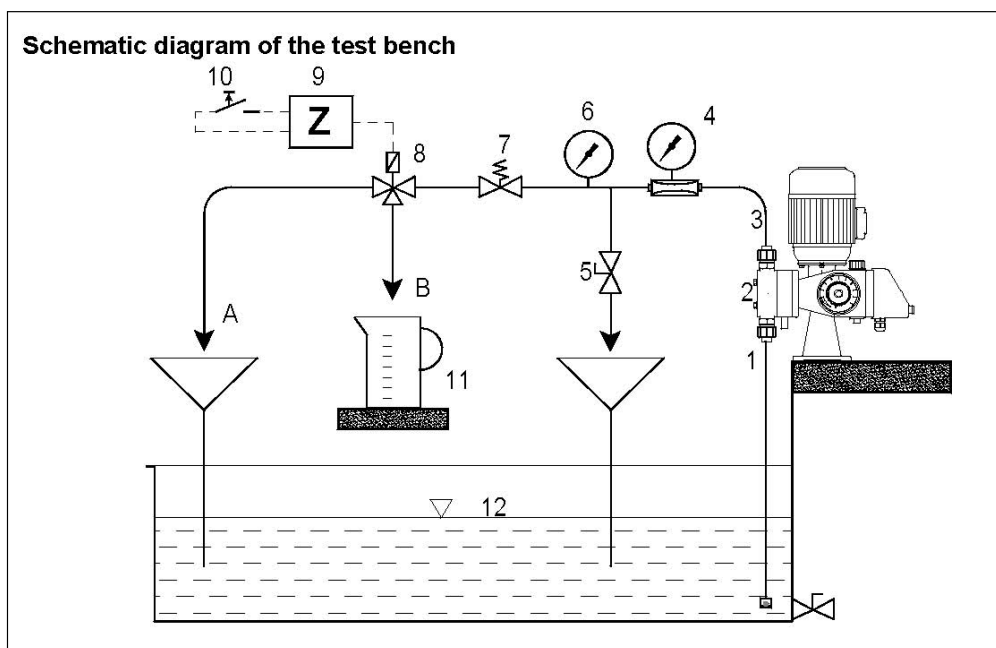
switches the solenoid valve (9) back to outlet (A). The dosed quantity (11) is recorded and compared with the calibration curves of the pump.

For solenoid dosing pumps, it is more important to know the quantity dosed per stroke. Therefore the time relay (9) is replaced by a counter. After activating the counter, the pump then discharges for the duration of e.g. 100 strokes into the tank (11). In this connection, the time needed to carry out the 100 strokes is less significant. Nevertheless it is recommended to complete calibration at approx. 80% of the maximum stroke frequency.



**Installation diagram and calibration during operation**

Positions of the three-way valve

| Filling of the measuring glass | Pump works under operating conditions until operating pressure is constant | Switch over and stop simultaneously | Switch over again to supply from tank after one minute and read measuring glass |

## 1.7.2 Calibration during practical operation

To make sure that calibration takes place under the same conditions as during practical operation, the discharge side should not be influenced by the test equipment. Therefore the installation of a measuring glass (as stand pipe) is recommended which can be filled from the tank by means of a three-way valve or correspondingly switched single valves. During measurement the right switching of the valve ensures that the liquid is supplied to the pump exclusively from the measuring glass.

# 1.8 Maintenance of dosing systems

The importance of the system and its danger potential for human being and equipment in the case of malfunction determines the frequency of maintenance or precautionary inspection of dosing systems. As pumps and their fittings for dosing more or less aggressive chemicals are also potential sources of danger, these must be planned and installed appropriately. It is not possible to clearly define possible failures to be expected, since dosing pumps – just like other technical devices – are also subject to wear, which mainly depends on whether the system is working 24 hours per day or just sporadically and whether the devices operate at their nominal capacity limit or are only utilized partly. Especially diaphragms of dosing pumps are not only affected by the service life but also by chemical corrosion and furthermore by weakening due to ageing unavoidable in the case of elastomers. From experience, the life of diaphragms is therefore between 1,000 and 20,000 hours, depending on the aforementioned influences. A general rule for important industrial processes could be that the diaphragm is replaced preventively once a year. The pump system should be checked for leakage at least once every week. To avoid damages occurring between the inspection times, the installation of containment tanks around the pump and/or leakage probes is recommended as mentioned before.

For many applications, local rules or regulations for prevention of accidents apply. Some applications allow the installation of the chemical tank only in containment tanks anyway. The pump should also be mounted at this area. It is recommended, in some system areas prescribed, to route the lines through jacket tubes to be able to collect any leakage caused by bursting pipes.

If the standard process-related and legal rules as well as the maintenance instructions for dosing systems are observed, the risk of damage is extremely low.

Accessories

Chemical Feed Systems

Measuring and Control Technology

Transfer Pumps

Metering Pumps

April 2008

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