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THE PROCESS CONTROLLER's GUIDE TO

PUMPS, BLOWERS and their OPERATION

This is number 6 in the Process Controller Guide series of documents

Number 1	Pollution Control.
Number 2	Water Sources and Water Treatment.
Number 3	Wastewater Treatment
Number 4	Phosphorus Removal from Wastewater.
Number 5	Electricity and Electric Motors.
Number 6	**Pumps, Blowers and their Operation.**

This guide is NOT intended to be a comprehensive manual on pumps, blowers and their operation.

This guide is intended to give Process Controllers an overview of the different types of pumps and blowers to be found on the water or wastewater treatment works and to give them a better understanding of these items of equipment.

It is intended that this document be a useful reference and training manual guide to all persons involved in the Water and Wastewater Industry.

These documents are dedicated to the thousands of men and women (both present and past) who are involved in the life critical profession of Water and Wastewater Treatment.

NOTE:

Credits: some information was obtained via Google. Where original authors could be determined, this is indicated.

August 2020

THE PROCESS CONTROLLER's GUIDE TO

PUMPS, BLOWERS AND THEIR OPERATION

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PART 1.

BACKGROUND.

1.1 INTRODUCTION.

What is a fluid?

A definition is - A fluid is a substance that has no fixed shape and yields easily to external pressure. In this guide, the fluids that will be discussed are liquids (including sludges) and gas – in this case air.

1.2 USE OF PUMPS.

Pumps are used to move liquids (including sludges) from one point to another. They require an energy input in order to do the work of moving this liquid or sludge.

There are various types of pumps for various duties. These will be covered in part 2.

1.3 USE OF BLOWERS.

Blowers are used to pressurise air so that it can perform a number of duties such as aeration in an activated sludge treatment. They can also be used in a lift pump to pump a mixture of water and solids.

There are various types of blowers for various duties. These will be covered in part 3.

1.4 THE OPERATION OF PUMPS AND BLOWERS.

Pumps and blowers require energy to do the necessary work. In the *Process Controllers Guide 5 no. - Electricity and Electric Motors*; it was seen how electric motors work.

Process Controller Guide no. 7 - Gearboxes and Drive Systems will cover what equipment fits in between the electric motor and the pump or blower.

PUMPS, BLOWERS AND THEIR OPERATION

PART 2.

PUMPS, HYDRAULICS, VALVES and PIPELINES.

2.1 INTRODUCTION.

2.1.1 The Concept of "Head".

The term "head" is used to describe the pressure that a pump can produce. As we are dealing with water (and wastewater), it is more convenient to think of the discharge pressure in terms of the height of a column of water that a pump can could create from the kinetic energy the pump gives to the liquid. In this case, kinetic energy will be converted into potential energy.

For example, if a pump pumping into a tall pipe can pump the water to a height of 30 metres; then the pump is said to create a head of 30 metres. If the pipe is 30 metres in height, then the water will just reach the top of the pipe, but no water will flow out of the top of the pipe. If the pipe is shortened to say 28 metres, then some water will flow out of the top of the pipe. If the pipe is shortened further to say 15 metres, then the water will flow out at a higher rate than from the 28 metre high pipe.

It would be useful if a chart was available where one could see how the flow rate increases as the head is reduced. There is such a chart (or diagram) where such information can be shown. It is called the Q/H diagram = Quantity versus Head diagram.

2.1.2 The Quantity/Head Diagram.

As shown above, a pump will produce a certain head. At the maximum head, there will be no flow, but as the head reduces, the flow rate will increase. This may be seen when the flow rate (indicated as "Q") is plotted against the head (indicated as "H").An example is shown in figure 1:

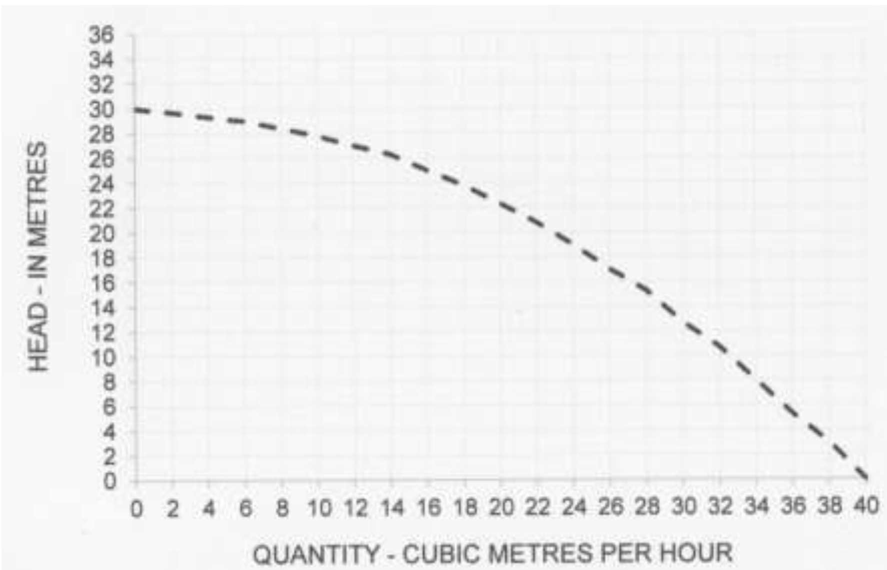

Figure 1 – A TYPICAL QUANTITY / HEAD DIAGRAM FOR A CENTRIFUGAL PUMP.

From figure 1, it may be seen that this pump can produce 30 metres head. If the **TOTAL** head was 20 metres, then the flow rate would be 22.3 cubic metres per hour. The reason why the word **TOTAL** is used here will be explained below.

2.2 AN INTRODUCTION TO HYDRAULICS.

Hydraulics is that branch of science that deals with (amongst others), the flow of liquids in a conduit. The latter may be a pipe or an open channel.

In *Process Controller Guide no. 5*, it was shown that in order for electrons to move along a conductor a force must be applied at the one end of the conductor. In a similar fashion, in order to move water along a pipe; a force must be applied to the end from which the water must move. This force is called pressure. The unit of pressure is known as a Pascal (Pa). It is a very small unit being 1 Newton per square metre. The more commonly used unit is the kilopascal (kPa). The pressure of the atmosphere at sea level is 101.3 kPa. This is also known as 1 Bar.

The term Bar is usually used when referring to the pressure of the air in a vehicle tyre.

If a pump produces say 300 kPa, it is difficult to imagine what this is like. As this guide deals with water (and wastewater); it would be useful if one could imagine this pressure as being equal to a column of water so many metres tall. Due to the force of gravity, a column of water 9.82 metres tall would exert a pressure of 101.3 kPa. In the pumping of water, it is not necessary to be quite so accurate and therefore it is easier to say that 10 metres of water produces a pressure of 1 Bar. For the above pump, it is much easier to imagine that this pump produces enough pressure to pump water up a pipe 30 metres tall. Once the pipe was full to its height, there would be no more flow of the water. That is why this is known as the Static Head and is measured in metres.

2.2.1 Suction Head, Static Discharge Head and Dynamic Head.

It was mentioned earlier that the pressure produced by a pump was called the head and the water industry is usually measured in metres (of water). The total head required is often called the DYNAMIC head. There are FOUR components to this head:

1. static suction head;
2. static discharge head
3. friction head;
4. velocity head.

At the velocities used in the water and wastewater industry, the velocity head is low and can be ignored. These components are illustrated in figure 2 below:

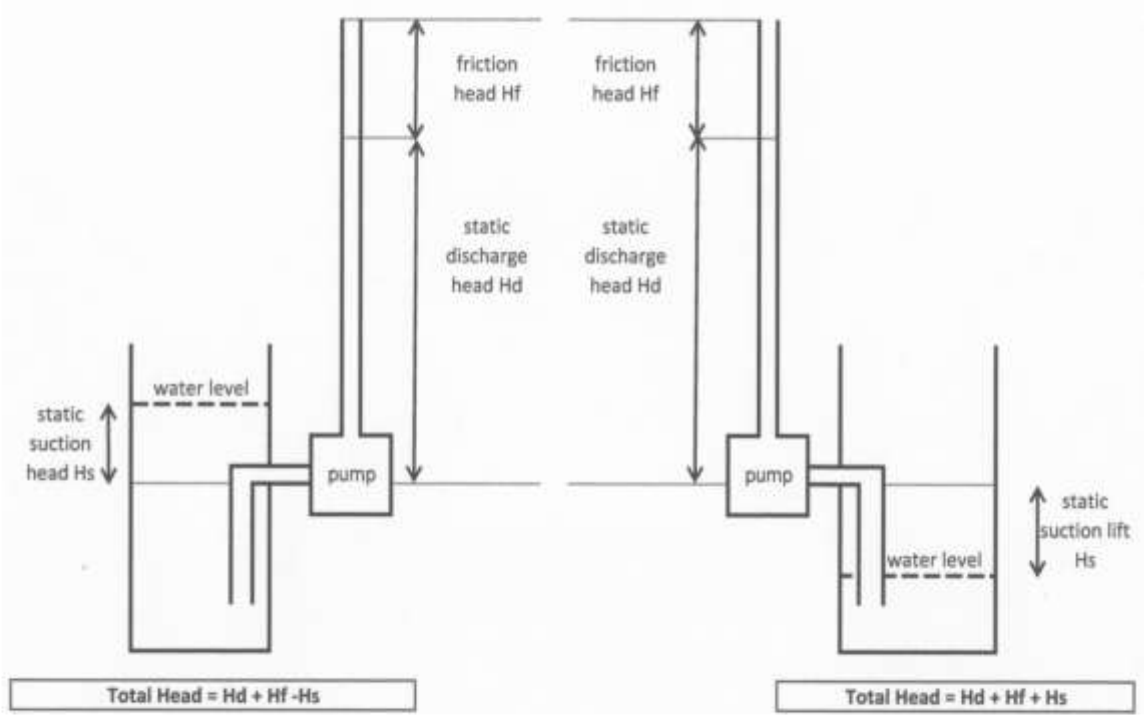

Figure 2 – SHOWING THE MAKE UP OF TOTAL HEAD.

It may be seen in the left hand layout that the water level being ABOVE the level of the pump has the effect of REDUCING the total head required from the pump.

In the right hand layout with the water level being BELOW the level of the pump, this has the effect of INCREASING the total head required from the pump. In both cases the mean water level is shown. The pumps(s) will switch on when the water level is higher than the mean and switch off when the level is below the mean.

In *Process Controller Guide no. 5* in section 3.1, the concept of the resistance to the flow of electricity was covered. This concept of resistance to flow also applies to the flow of water in a pipe. Even though materials such as copper, silver, gold etc., are very good conductors of electricity they nevertheless do have some resistance to the flow of electricity. In electricity, it is only the electrons that are moving along the conductor whereas in the movement of water, it is the whole water column that is moving. There will be resistance to the flow of the water caused by the friction of the water moving along the inside wall of the pipe. There will be other sources of friction such as bends in the pipe and valves in the pipe line.

In the flow of electricity, it was indicated that the loss of energy in the form of heat was proportional to the square of the electrical current. In the same way, the friction of the pipe on the flow of water is proportional to the square of the velocity of the water. If the velocity is doubled, then the friction is 4 times as great.

It is very useful to be able to express the friction effect as equal an equivalent head of water. For example if the static head is say 30 metres and the friction is equal to 5 metres, then the pump needs to produce a head of 30 + 5 = 35 metres.

There are several formulas in use to calculate the friction in a straight length of pipe. Fittings on pipes such as bends also create friction. Tables have been produced that give an equivalent length of pipe that would have the same friction as that fitting. An example is given in table 1 below:

TABLE 1 – EXAMPLE OF PIPELINE EQUIVALENT FOR A BEND.

Equivalent Length of Straight Pipe for Valves and Fittings in Metres								
Flanged Fittings		Pipe Size (mm)						
		50	100	150	200	250	300	450
Elbows	Regular 90 deg	0.9	1.8	2.7	3.7	4.3	5.0	6.7
	Long Radius 90 deg	0.8	1.3	1.7	2.1	2.4	2.6	3.4

The calculation of the total head required is best shown by an example using the layout shown in figure 3. The various properties are:

1. the total length of the pipeline is 50 metres;

2. the static suction lift is 3 metres;

3. static discharge head (the static head) is 10 metres;

4. the pipeline diameter is 250 mm (0.25m)

5. the flow rate is 94 litres per second.

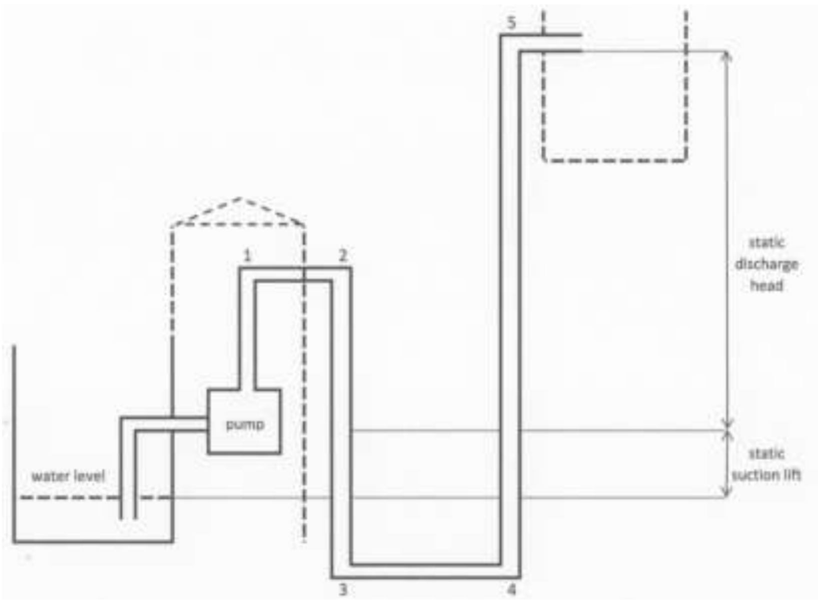

Figure 3 – PIPELINE LAYOUT FOR TOTAL HEAD CALCULATION.

From table 1, each 90 degree bend of a 250mm pipe is the equivalent of 4.3 metres of straight pipe. The equivalent length of the pipe plus fittings is calculated in table 2 below:

TABLE 2 – CALCULATION OF EQUIVALENT LENGTH OF PIPELINE.

ITEM	CONVERSION FACTOR	EQUIVALENT PIPE LENGTH
Pipeline	1	50.0 m
5 x 90 deg bends	5 x 4.3	21.5 m
Suction pipe	Estimated to be 5.0 m	5.0 m
EQUIVALENT LENGTH		**76.5 m**

The friction head will be calculated using the Darcy-Weisbach formula.

$$H_f = \frac{f\ L\ V^2}{2\ D\ g}$$

Hf = friction head - m
F = Darcy friction factor (it should be noted that this is just a number)
L = length of pipe - m
V = velocity – m/s
D = diameter of the pipe – m
G = gravity - 9.82 m/s^2

The flow rate is stated to be 94 litres per second – in terms of the above formula, the velocity must be calculated.

The cross sectional area of the pipe is $\frac{\pi D^2}{4} = \frac{3.142 \times 0.25 \times 0.25}{4} = 0.03142\ m^2$.
94 litres per second = 0.094 m^3 per s.

The velocity = flow rate / cross section area = $\frac{0.094}{0.03142}$ = 2.99 m/s – call it 3 m/s

The Darcy friction factor will be assumed to be 0.05. This will be higher for a pipe with a rougher internal wall.

Inserting all the known values into the Darcy-Weisbach equation:

$$H_f = \frac{0.05 \times 76.5 \times 3.0 \times 3.0}{2 \times 0.25 \times 9.82} = \frac{34.42}{4.91} = 7.0\ m$$

The total head that the pump must produce is:

static suction lift of 5 m plus static discharge lift of10 m plus friction head of 7.0 m = **22 m.**

From the Darcy-Weisbach formula, it is noted that the friction head rises in proportion to the square of the velocity. This is why the system curve (in blue in figure 4) shows the curve steepening as the flow rate increases. Where the system curve crosses the pump curve, the intersection is known as the DUTY POINT. This is sometimes known as the OPERATING POINT.

If the friction in the pipe line increased as a result of the inner surface becoming rougher due to corrosion of the pope material, the system curve would become steeper and would then cross the pump curve more to the left. This means that the pumping rate would drop – this exactly what one would expect. HIGHER FRICTION = LOWER PUMPING RATE.

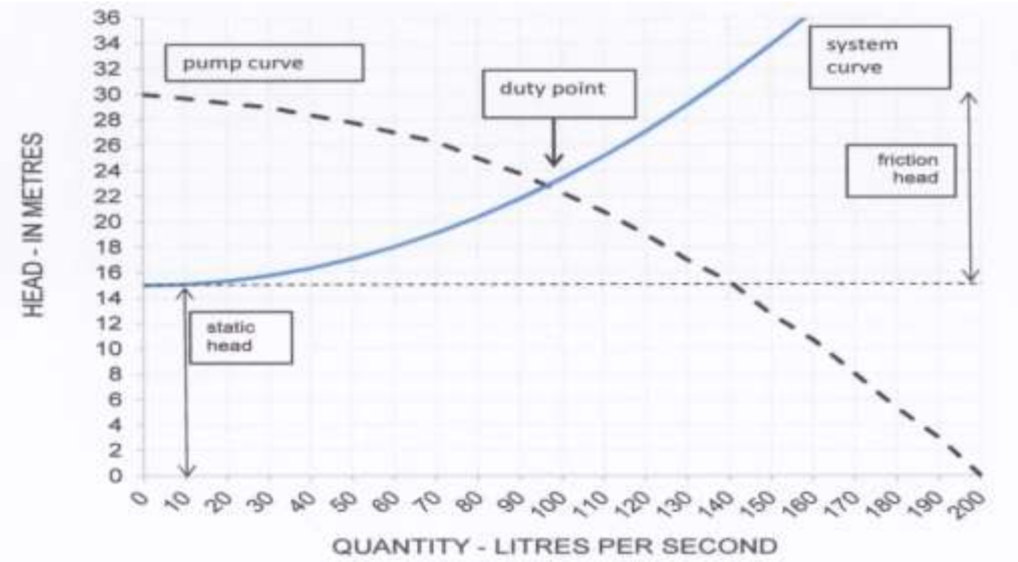

Figure 4 – SHOWING DUTY POINT WHERE PUMP CURVE CROSSES SYSTEM CURVE.

2.3 TYPES OF PUMPS.

Pumps may split into different types of pumps in several ways. This guide uses just one of those ways. The initial split into types is as follows:

1. roto-dynamic pumps. Here Roto means turning and dynamic means moving. This type of pump uses a spinning impeller to move the liquid being pumped. These are covered in sections 2.4, 2.5 and 2.6;

2. positive displacement pumps. Here the pump discharges a fixed volume on reach stroke or rotation of the internal component. These are covered in section 2.7;

3. other types of pumps. These are covered in section 2.8.

2.4 ROTO-DYNAMIC PUMPS.

These may also be further split into different types as shown in figure 5:

1. centrifugal – single stage and multistage

2. axial flow;

3. mixed flow.

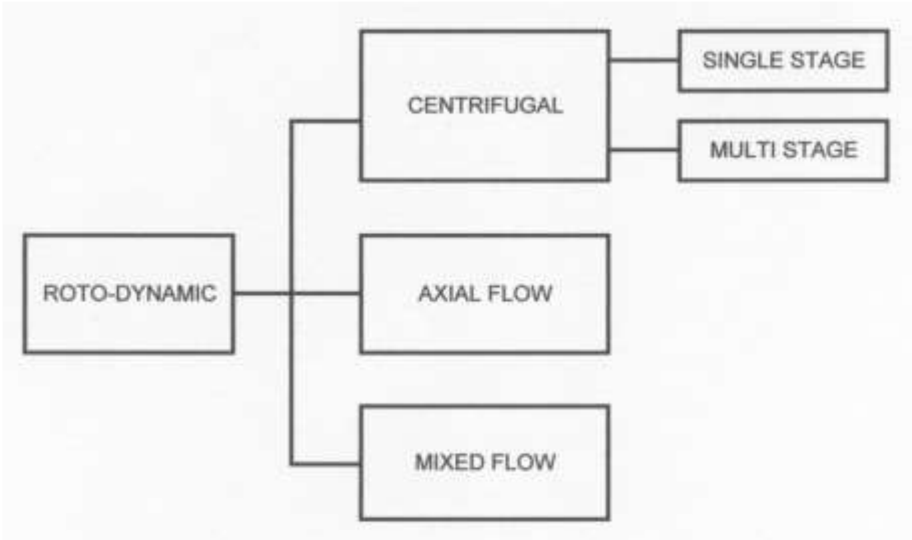

Figure 5 – EXAMPLES OF ROTO-DYNAMIC PUMPS.

2.4.1 Centrifugal Pumps.

This type of pump uses centrifugal force to pump liquid such as water or sludge. The rotating part is called the impeller. These have vanes that extend from a point near the centre towards the outer edge of the impeller. As the impeller rotates, the spinning vanes create the centrifugal force that pushes the liquid to the outside of the case and ultimately out of the discharge. This creates a low pressure area in the centre of the impeller and the outside atmospheric pressure forces the liquid into the suction pipe.

Traditionally, one talks about the pump "sucking" the liquid into the pump, but in reality it is the outside pressure pushing the liquid into the low pressure part of the pump. Figure 6 gives an idea of the internal part of a centrifugal pump.

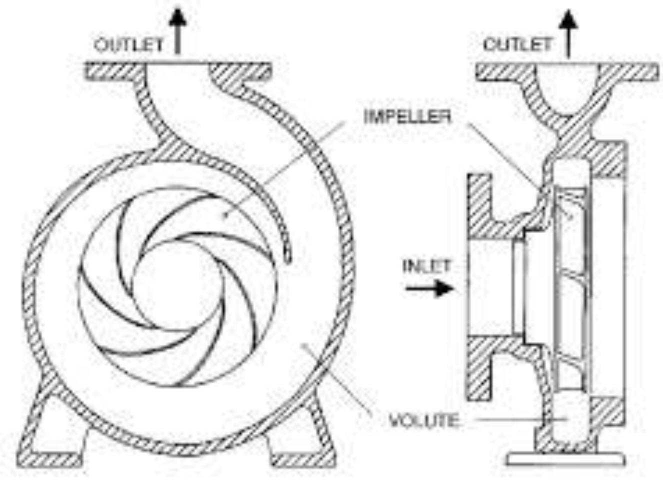

Figure 6 - INTERNAL PARTS OF A TYPICAL CENTRFIGAL PUMP.

Depending on the liquid to be pumped, the design of the impeller varies widely. There are 4 basic designs of impellers.

1. enclosed impeller;

2. semi-open impeller;

3. open impeller;

4. vortex or torque flow impeller.

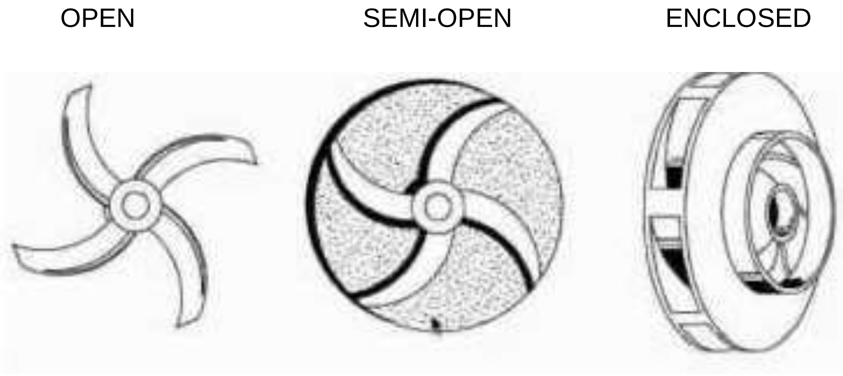

Figure 7 – TYPES OF IMPELLERS.

2.4 2 Enclosed Impeller Centrifugal Pumps.

These are the most efficient in that they need the least amount of power to perform a certain pumping duty. As may be seen in figure 7, the vanes have a disc on either side. This means that are small spaces inside the impeller. This is what gives it the higher efficiency. The problem is that the smaller spaces mean more chances of a blockage occurring inside the impeller. This is why this type of impeller is used only for water or wastewater with a very small amount of suspended solids.

This type of impeller will produce the highest discharge pressure of the three types. If the pump cannot produce the head required, it is possible to have two stages (or even more), so that the discharge from the first stage is the feed to the second stage. The discharge pressure is then about twice that of the single stage. A cross section of a two stage centrifugal pump is shown in figure 8.

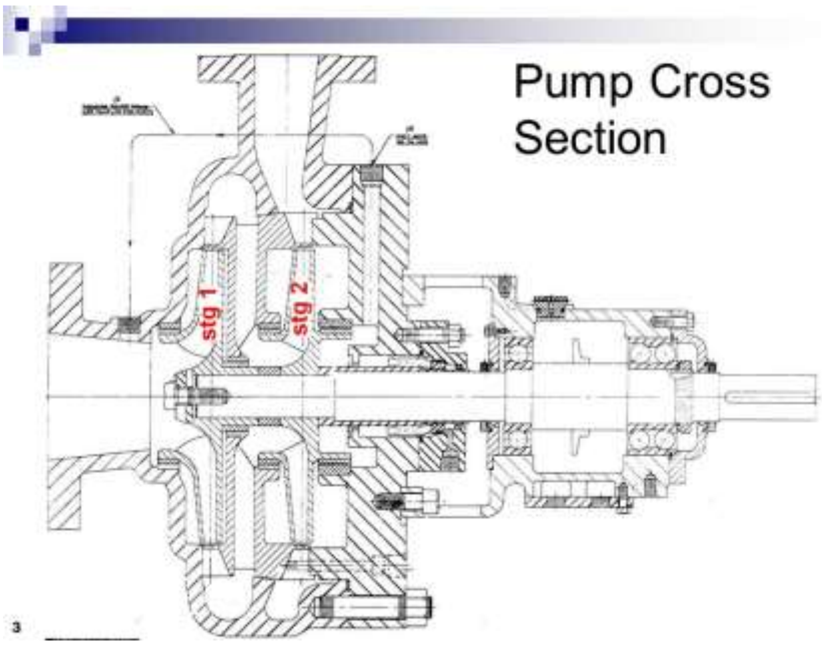

Figure 8 – CROSS SECTION OF A TYPICAL TWO STAGE CENTRIFUGAL PUMP.

2.4.3 Series and parallel operation of centrifugal pumps.

There are two ways that two (or more) pumps may be connected to run together. This depends what one wants to achieve. Figure 9 below shoes the two layouts – series and parallel. For series operation, it would be more useful to combine the two pumps into one, such as the two stage pump shown in figure 8.

As water is not compressible, the impeller and casing of the second stage of the two stage pump would be the same size as the first stage.

The two layouts will be seen to be the same as when two batteries are connected together. Connected in series, they would give twice the voltage but the same current. If they were connected in parallel, they would give twice the current, but at the same voltage.

In both cases, the discharge flow rate is constant with no variation. This is in contrast to the positive displacement pumps covered in section 2.6.

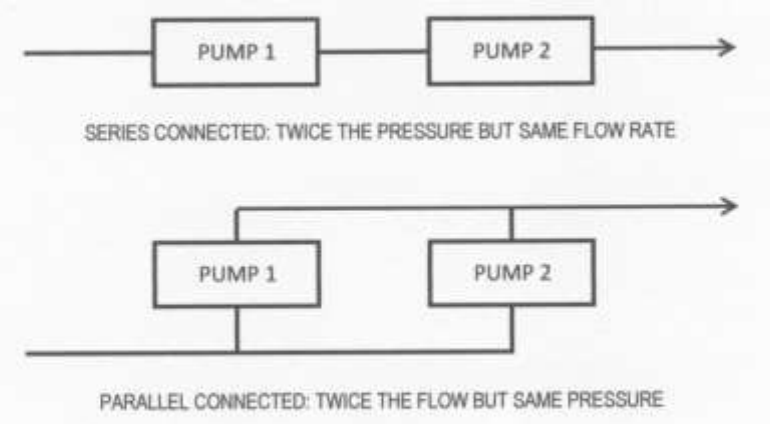

Figure 9 – SHOWING SERIES AND PARALLEL LAYOUTS OF PUMPS.

2.4.4 Semi-Open Impeller Centrifugal Pumps.

There are many cases where the liquid to be pumped is contains some settleable and suspended solids. Here, the enclosed impeller type pump cannot be used. For these liquids, a semi-open type of impeller would be suitable.

These pumps cannot produce the same head as the enclosed impeller type. They are probably limited to a total head of about 30 metres depending on the shape of the impeller. As they are less efficient than an enclosed impeller pump, they will use more electricity than an enclosed impeller pump for the same volume pumped against the same head.

2.4.5 Open Impeller Centrifugal Pumps.

These would be used where the liquid to be pumped contains a lot of suspended and settleable solids and also stringy material. They would be capable of producing only about 25 metres head.

2.4.6 Vortex or torque flow impellers.

These would be used where relative large solids would be present in the liquid to be pumped – such as raw wastewater. Here the impeller is out of the flow stream. The impeller generates a whirlpool in the casing and the whirlpool now acts as the pumping element (impeller) in the casing.

They are up to 50% less efficient than the other types of centrifugal pumps. They would be capable of producing only about 20 metres head. An example is shown in figure 10.

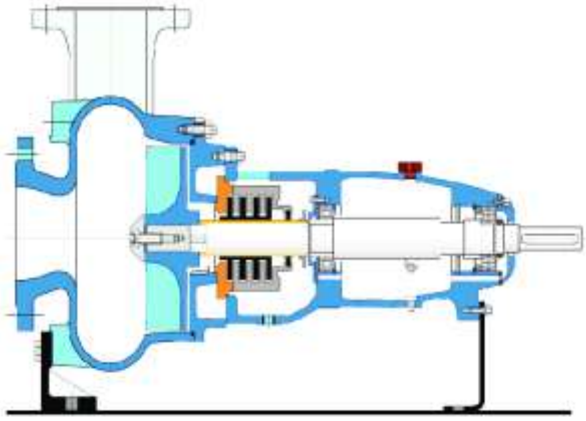

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Figure 10 – A TYPICAL VORTEX OR TORQUE FLOW CENTRIFUGAL PUMP.

2.5 AXIAL FLOW PUMPS.

In the centrifugal pumps described above, the flow leaves the pump at 90 degrees to the inlet. There will often be 90 degree bends on the suction side and on the discharge side, but the outflow of the pump is at 90 degrees to the inflow.

In contrast, the outward flow from an axial flow pump is parallel to the inflow direction. The flow pattern is shown in figure 11 below. It may be thought of as a propeller in a pipe or tube.

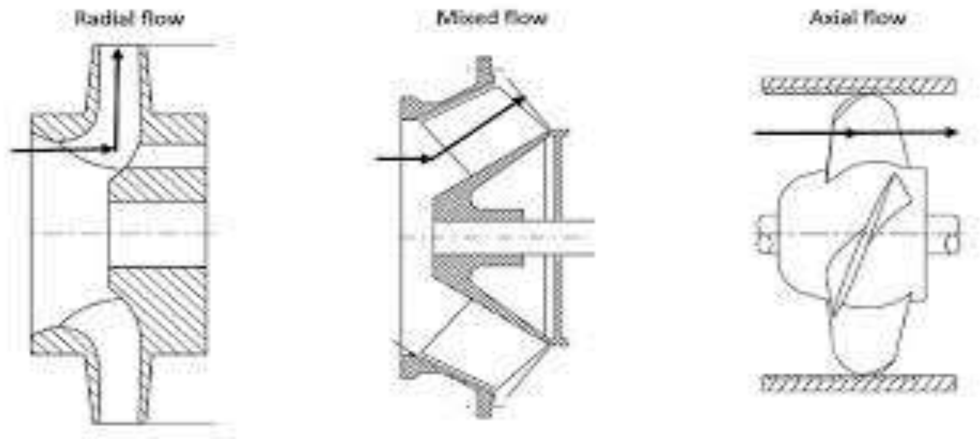

Figure 11 – SHOWING RADIAL FLOW, MIXED FLOW and AXIAL FLOW PATTERNS.

The axial flow pump can produce only about 10 metres of head. They can be thought of as: Low Head, High flow pumps. They can be made be large enough to pump more than 1 megalitre per hour. There could be used in wastewater treatment works for mixed liquor return etc.

The discharge flow rate is constant with no cyclical variation.

2.6 MIXED FLOW PUMPS.

As seen in figure 11, these pumps may be seen to be an intermediate between the radial flow and the axial flow. They will produce a higher head than an axial flow pump but a higher flow than a radial flow pump at low discharge pressure (low head). A typical maximum head is about 20 metres. Again the flow rate is constant with no cyclical variation.

2.7 POSITIVE DISPLACEMENT PUMPS.

These may also be split into different types as shown in figure 12:

1. progressive cavity;
2. reciprocating or piston;
3. diaphragm;
4. peristaltic.

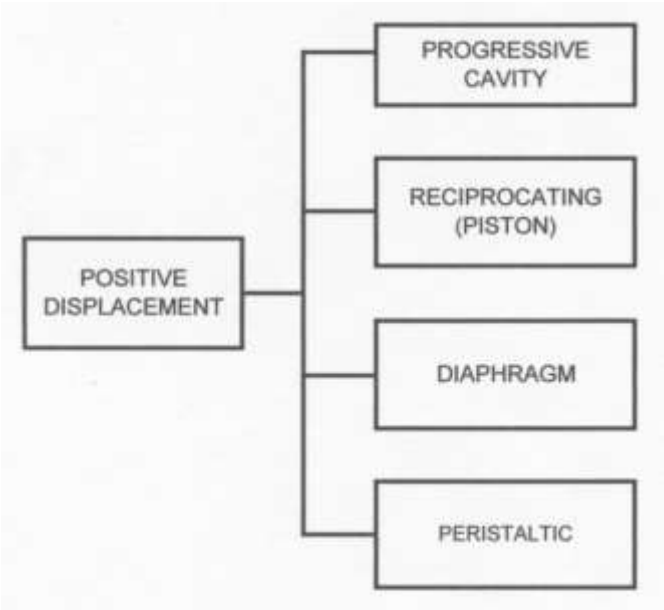

Figure 12 – EXAMPLES OF POSITIVE DISPLACEMENT PUMPS.

It was seen earlier in figure 1, that the quantity discharged varied according the total head against which the pump was pumping. By contrast, the quantity discharged by a positive displacement pump is independent on the head against which the pump is pumping. What will vary is the power input required. The higher the head against which the pump is pumping; the higher the power requirement.

In many cases, it will be necessary to have a pressure relief valve on the discharge side that will open when the pressure gets too high. Also the electrical overload for the motor must be set low enough so that the contactor trips before the electric motor stalls and burns out.

2.7.1 The Progressive Cavity Pump.

The progressive cavity pump normally consists of a helical rotor and a twin helix hole in a stator. The rotor seals tightly against the stator as it rotates. This forms a set of fixed-size cavities in between. The cavities move forward towards the outlet end when the rotor is rotated but their shape or volume does not change. The pumped material is moved inside the cavities. A typical pump cross section is shown in figure 13 below:

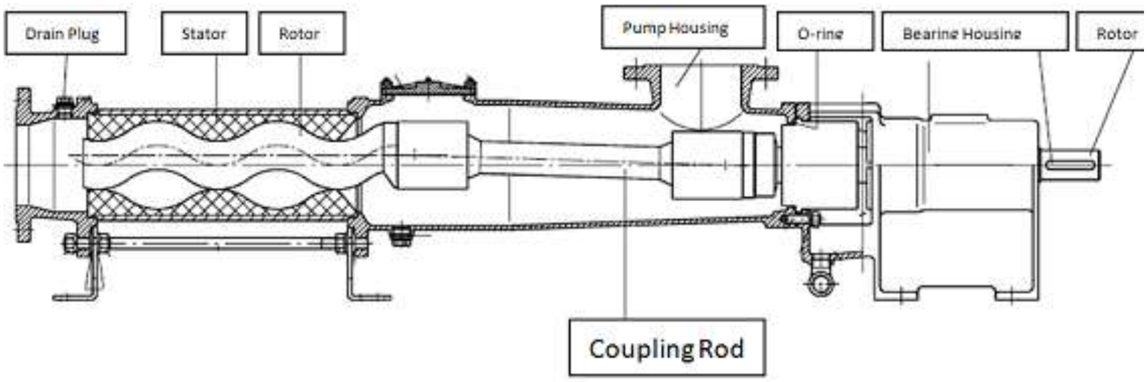

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Figure 13 - CROSS SECTION OF A TYPICAL PROGRESSIVE CAVITY PUMP.

The important factor in this pump is that it is very gentle on the liquid (often a sludge) being pumped and will not harm the floc structure. The rotor is usually chromium plated steel. The stator is usually a type of hard rubber.

As the rotor is in contact with stator at all times it is very IMPORTANT that the pump NEVER be operated when dry. The rubber of the stator will very quickly be damaged and this will allow the liquid to leak back towards the inlet of the pump.

The discharge from the pump does vary as the rotor turns, but the variation in flow is small.

If the pump is used to pump sludge, it may be necessary to ensure that the level of the sludge in the tank from which the pump is drawing, is above the level of the pump. This is to help the sludge flow into the suction side of the pump.

A well-known make of progressive cavity pump is the “MONO” pump.

This pump is not the same as an Archimedes screw in a tube. This will be described later in section 2.8.1.

2.7.2 Reciprocating (piston) Pump.

Reciprocating pumps work on the principle of pushing of liquid by a piston that executes a reciprocating motion in a cylinder of closed fitting. The reciprocating motion is done by a crankshaft driven by an electric motor or engine.

The first stroke of the piston creates a vacuum, opens an inlet valve, closes the outlet valve and draws fluid into the piston chamber (the suction phase). As the motion of the piston reverses, the inlet valve, now under pressure, closes and the outlet valve opens allowing the fluid contained in the piston chamber to be discharged. This is shown in figure 14.

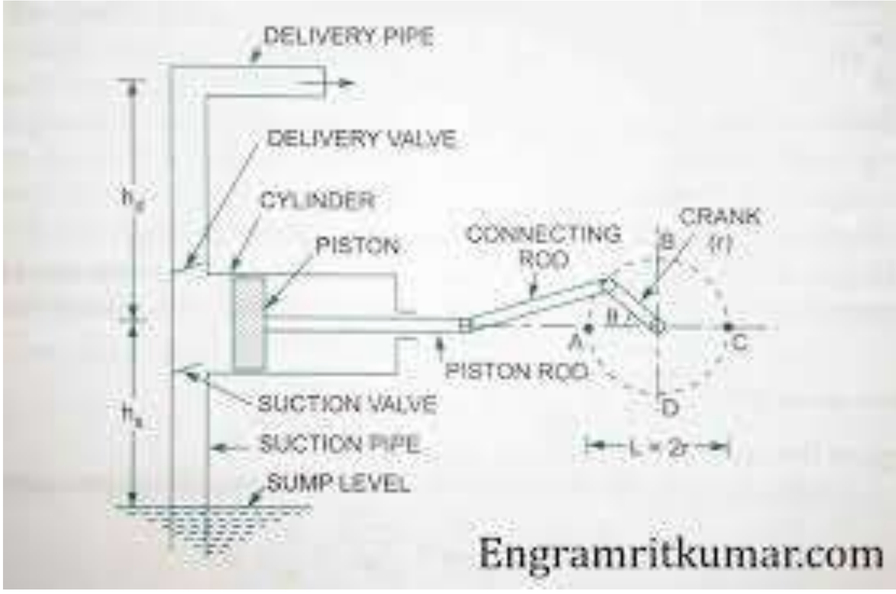


Figure 14– SCHEMATIC OF A RECIPROCATING (PISTON) PUMP.

The flow rate will vary cyclically as discharge takes place only on the discharge stroke. This is 50% of the time. If a double acting pump is used then there will be two discharge cycle for one revolution of the crank. These are seen in figure 15 below. 360 degrees equals one revolution of the crank.

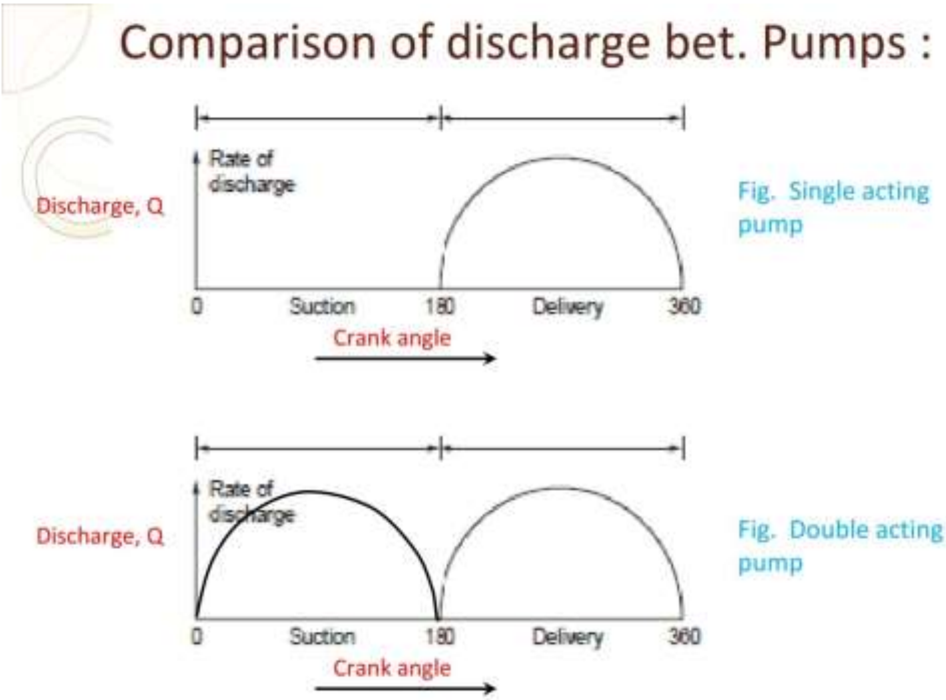


Figure 15 – SHOWING DISCHARGE VARIATION OF SINGLE ACTING AND DOUBLE ACTING PUMPS.

This type of pump can handle medium sized solids depending on the size of the inlet and discharge valves. Large solids and stringy material could cause the valve to not close properly leading to feedback and poor discharge performance.

If the pulsating discharge was a problem, it would be possible to include an air balancing tank on the discharge line. Two types are shown in figure 16 below. The problem with type A is the with time the air above the liquid is dissolved into the liquid and the mean liquid level rises making the unit less effective in balancing the discharge flow rate. It must be remembered that liquids cannot be compressed, whereas the air can be compressed.

The liquid level will rise with each discharge cycle and fall again in between the discharge cycle, this smooths out the discharge flow. A modified unit is shown as type B. Here a membrane separates the air from the liquid so that there is no loss of air. The membrane will move upwards on each discharge stroke and move downwards in between each stroke. Again this smooths out the discharge flow.

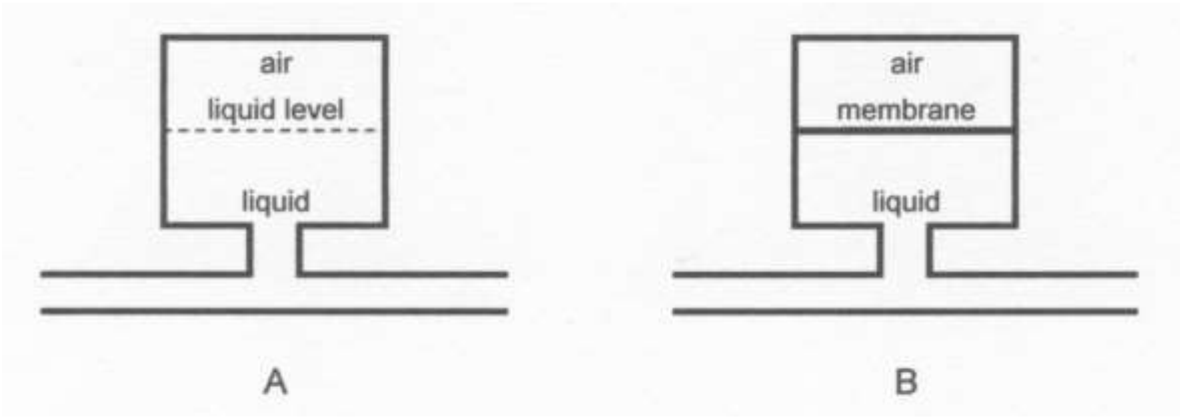


Figure 16 – USE OF AN AIR BALANCING TANK TO SMOOTH OUT DISCHARGE FLOW.

2.7.3 <u>Diaphragm Pumps.</u>

Diaphragm pumps also work on the principle of pushing of liquid by a piston that executes a reciprocating motion. In this case, the piston is a diaphragm. Details of the internal parts are shown in figure 17 below. As with the reciprocating pump, there are valves on the suction side and the discharge side.

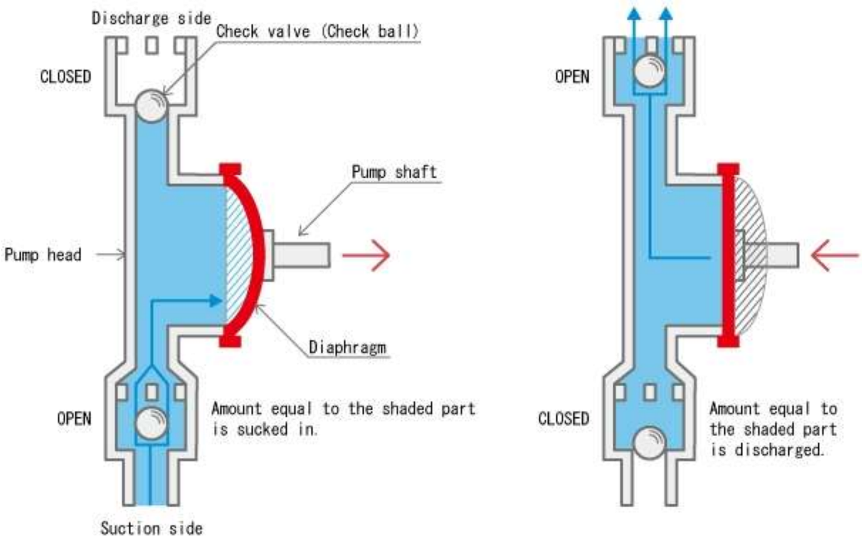


Figure 17 – THE INTERNAL COMPONENTS OF A DIAPHRAGM PUMP.

Diaphragm pumps can vary in size from very small that are used to dose chemicals up to those use for dewatering of construction sites. The latter could have a suction of 100mm diameter and be able to pump a mixture of water, sand and mud. With the right material of construction, the chemical dosing pump can handle sodium hydroxide, ferric chloride, sodium hypochlorite and other such corrosive solutions.

The chemical dosing pump can often be driven by a variable speed motor so that the chemical dosing rate may be varied. The small chemical dosing pump will accurately deliver the same volume for each stroke of the diaphragm. An example of a chemical dosing diaphragm pump is shown in figure 18 below:

Figure 18 – EXAMPLE OF A CHEMICAL DOSING DISPHRAGM PUMP.

As indicated above, there are large diaphragm pumps that are used to dewater construction sites. Here the water being pumped can contain sand, mud and small stones. To protect the pump, a filter with 10mm holes should be fitted to the end of the suction pipe. A typical example is shown in figure 19 below:

Mwi pumps

Figure 19 – A TYPICAL CONSTRUCTION SITE DEWATERING DIAPHRAGM PUMP.

2.7.4 <u>Peristaltic Pumps.</u>

Definition of peristaltic movement: The ongoing series of compressions along a tube that results in the movement of the contents along the tube.

In the peristaltic pump, the fluid is pumped through a flexible tube in a peristaltic motion. Rollers are attached to a rotor that is controlled by a motor. As the rotor turns, the rollers pinch the tubing to force the fluid through. When the tube is not compressed, the fluid flow is sucked into the tube. Peristaltic metering pumps can pump dirty liquids containing particulate matter because they have no check valves to clog. The gentle forces created during the peristaltic pumping action do not damage delicate fluids within the tube.

In contrast, diaphragm metering pumps include check valves in the suction and discharge side of the pump head. If either set of check valves becomes fouled, the pump will not meter accurately, and loss of prime may occur. Diaphragm pumps may create shear stress on fluids, particularly if the pump employs a high velocity stroke action. The internal components of a peristaltic pump may be seen in figure 20.

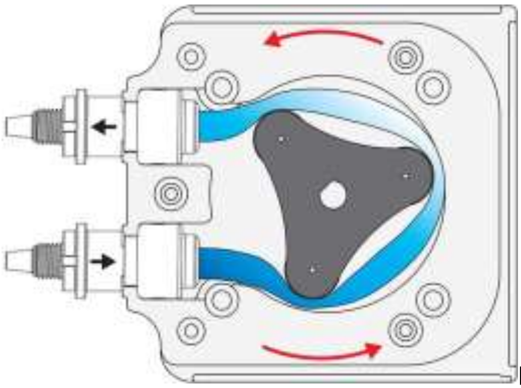
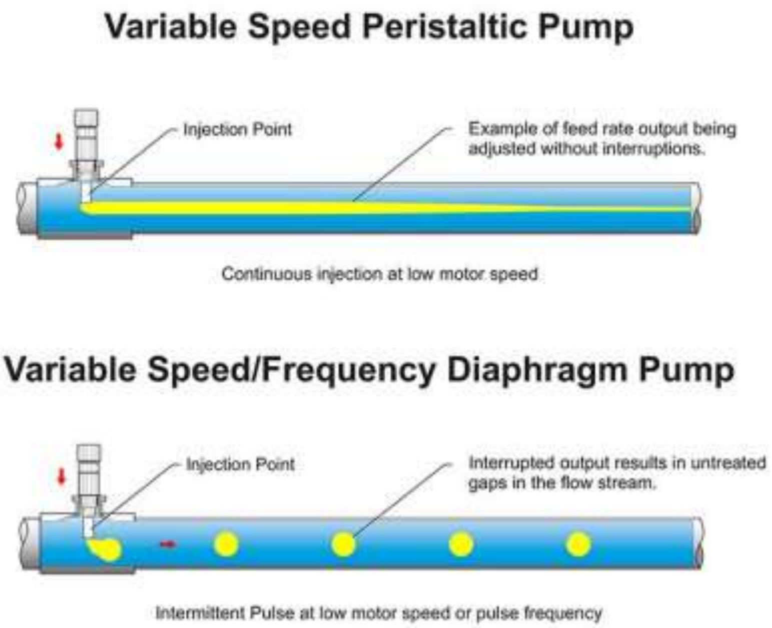

Pumps and systems ®

Figure 20 – THE INTERNAL COMPONENTS OF A PERISTALTIC PUMP.

2.7.5 Comparison of Diaphragm and Peristaltic Pumps for Chemical Dosing.

It was noted earlier that the diaphragm pump has an intermittent pulse discharge as seen in figure 15. The peristaltic pump has a continuous uniform discharge rate. The effect of a continuous discharge compared with a intermittent discharge is clearly shown in figure 21 below.



Pumps and systems ®

Figure 21 – SHOWING THE DIFFERENCE BETWEEN CONTINUOUS FLOW AND INTERMITTENT FLOW DURING CHEMICAL DOSING.

It can be seen that there is a major difference between the two dosing methods.

2.8 OTHER TYPES OF PUMPS.

Two other types of pumps will be covered here:

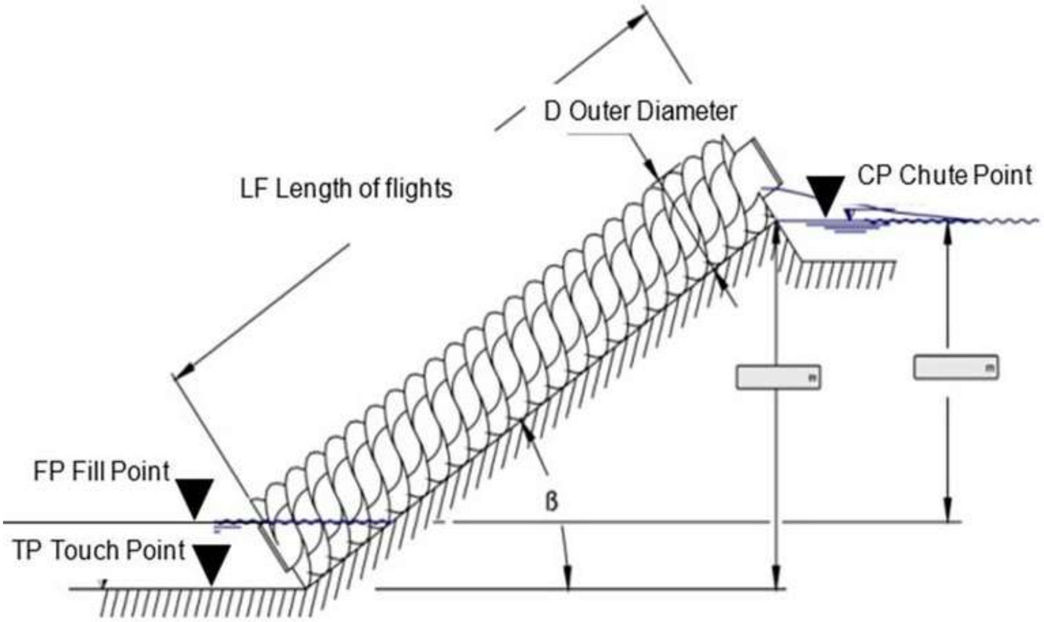
1. archimedes screw pump;

2. airlift pump.

2.8.1 Archimedes Screw Pump.

The Archimedes screw pump consists of a nunber (usually two) of continuous fights wrapped around a centre tube. The unit is laid in a trough with a small (usually 6mm) space beteween the outer edge of the flight and the trough. The trough may be a steel half tube usually supplied with the screw pump or it may be formed with concrete during installation. In the later case, the usual method is to temporarily fix a 6mm steel cable along the outside of the flights, pour concrete under the screw and turn the whole unit slowly for about 24 to 36 hours until the concrete had set. Excess concretet is removed to make a neat finish. The cable is them removed and the assembly is ready for use.

The 6mm gap is to allow for expansion of the tube and the flights when not in use and when the sun is shining on the screw. It may be necesasary to cover the unit with a light weight cover to prevent the problem of heat expansion. A cross-section on an archimedes screw pump is shown in figure 22 below:



Lantec Environmental

Figure 22 – CROSS SECTION OF A TYPICAL ARCHIMEDES SCREW PUMP.

A close up view showing the splash plate on the right hand side of the trough is shown in figure 23.

Roncuzzi S r l

Figure 23 – CLOSE UP VIEW OF AN ARCHIMEDES SCREW PUMP.

The Archimedes screw pump has many operational advantages:

1. it can be operated dry;

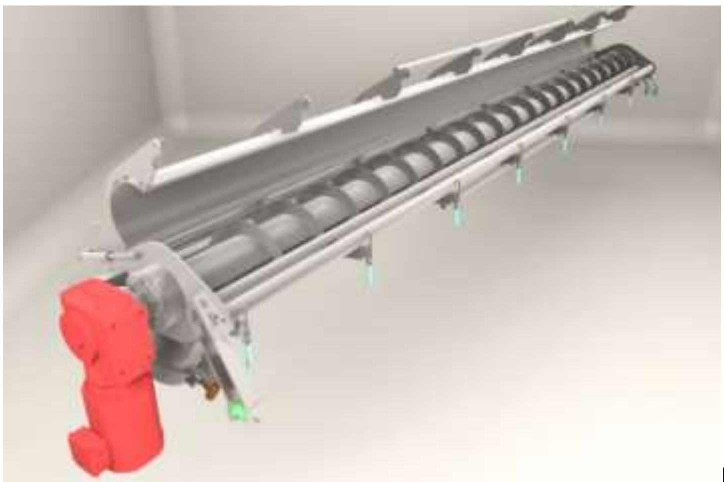
2. the pumping rate automatically matches the inflow rate until the liquid level reaches the fill point as shown in figure 22;

3. It can pump very dirty wastewater containing relatively large solids including sand, stones etc.;

4. it can be used as part of a grit classifier at the inlet of a wastewater treatment works where the heavier sand is carried up the screw while the lighter organics are returned to the liquid at the bottom of the screw.

An Archimedes screw may be made very large – up to 4 metre diameter.

The Archimedes screw pump can be fitted with an outside tube. This is then known as a screw conveyor. It can be used to transport many kinds of material such as thick sludges, grains such as corn etc. A typical example is shown in figure 24 below:



Dodman Ltd

Figure 24– AN EXAMPLE OF A SCREW CONVEYOR.

It is possible when conveying materials such as thick sludge to make one without the centre shaft. An example is given below in figure 25:

Carolina Material Technologies

Figure 25 – AN EXAMPLE OF A SHAFTLESS SCREW CONVEYOY.

2.8.2 Airlift Pump.

This pump works on the principle that a mixture of air and water is less dense that the water alone and will, therefore, rise up a pipe. This principle is often used in grit removal units at a wastewater treatment works. The main advantage is that the air/water mixture can contain quite a lot of sand. A disadvantage is the limited lift. The lift above the water level cannot exceed the immersion length as shown in figure 26 below.

Another advantage when this system is used in a grit removal system at a wastewater treatment works is that a valve may be inserted into the discharge line just before the discharge point. When the valve is closed, the air moves downwards and stirs up the solids at the bottom of the grit removal unit. This allows the flushing out of some of the organics that are returned to the main flow. This has the effect of partially cleaning the grit. When the discharge valve is opened, the airlift action starts and the partially cleaned grit is then removed from the grit removal unit.

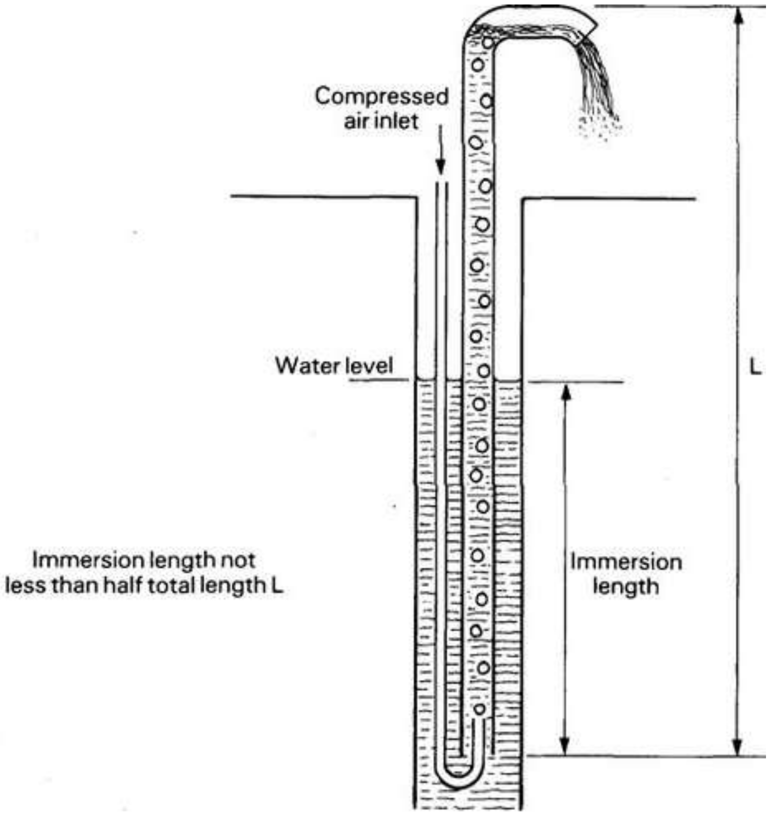
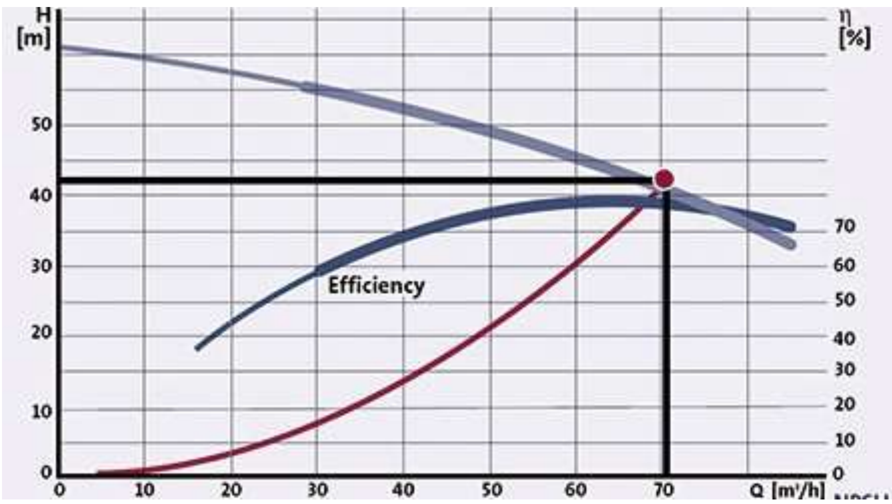


Figure 26 – ILLUSTRATING THE PRINCIPLE OF AN AIRLIFT PUMP.

2.9 PUMP EFFICIENCY CURVE AND PUMP SELECTION.

All pumps have a point where they are the most efficient in terms of their power usage per unit of water pumped. As seen in figure 27 below, the pumping system as a duty point of 70 m^3 / h against a head of 42 metres. At this point, the efficiency is about 78%. At both higher and lower flows, the pump will use more electricity per cubic metre of water pumped. Ideally all pumping systems should have their duty point at the point of highest efficiency of the pump. This is not always possible.

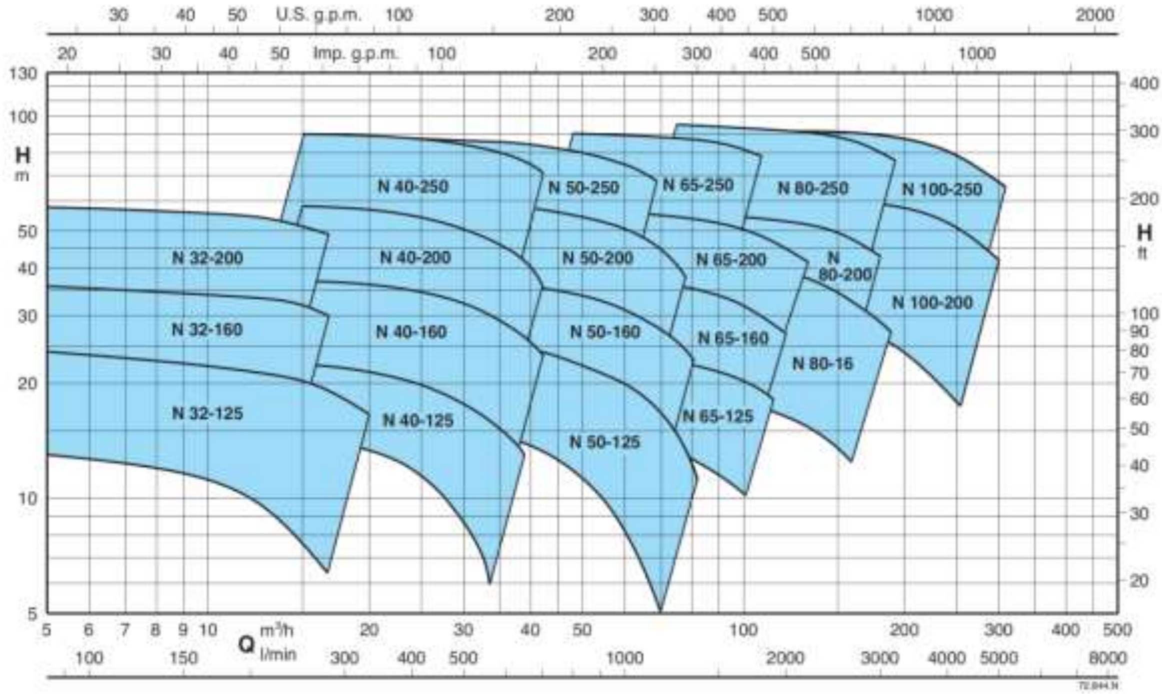


grundfos

Figure 27 – SHOWING CENTRIFUGAL PUMP EFFICIENCY CURVE

As seen in figure 27, it is possible to operate within a band of about 15% on either side of the best efficiency point without too much loss in efficiency. It is usual for pump manufacturers to offer a number of pump capacity and head production to cover a wide range of uses.

A typical example of a selection of pumps is shown in figure 28. It is seen that each pump model has a range of heads and a range of flow rate in which it will operate satisfactorily.



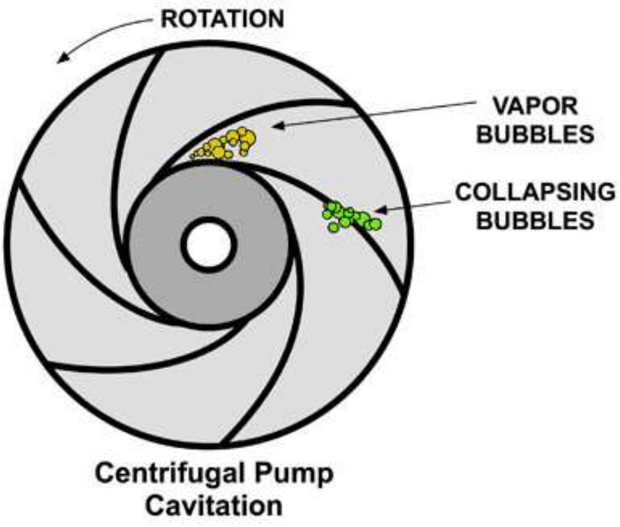
Sopelia

Figure 28 – AN EXAMPLE OF A NUMBER OF PUMP SIZES OFFERED BY A PUMP MANUFACTURER.

Once a pump has been selected and installed, there is nothing that a Process Controller can do to improve the efficiency of a pump other than to ensure that the pump is kept clean and free of blockages and that all valves are fully open.

2.10 CAVITATION.

It was noted earlier that in a centrifugal pump as the impeller spins and forces water out of the discharge pipe; it creates areas of lower pressure inside the pump housing. The outside air pressure then forces water into the pump. If the suction lift is too high or there is a partial blockage on the suction side of the pump; then the pressure in certain parts of the pump can drop so low that some of the liquid water is turned into vapour and forms bubbles. This vapour is carried over to the discharge side of the pump, where the pressure is higher and the water vapour is compressed back into a liquid. The imploding or collapsing of these bubbles triggers intense shockwaves inside the pump, causing significant damage to the impeller and pump housing. This collapsing of the vapour bubbles is called CAVITATION. This is shown in figure 29 below:



thermal engineering

Figure 29 – SHOWING CENTRIFUGAL PUMP CAVITATION.

This cavitation makes a rumbling sound and can be very noisy. It can also cause severe damage to the impeller as seen in figure 30 below:

rodelta.com

Figure 30 – SHOWING DAMAGE TO AN IMPELLER CAUSED BY CAVITATION.

It is important that Process Controllers and other staff listen for cavitation and immediately take steps to find the cause and take corrective action. The most likely causes are a sump being pumped down too low or a partial blockage somewhere on the suction pipeline.

2.11 PIPELINE VALVES.

Pipelines will have valves installed on them for shut down purposes. Valves come in a variety of types. Each has its own advantages and disadvantages. There are several ways to classify valves – one is Rising Spindle (or stem) and Non-rising Spindle (or stem). The major advantage of the rising spindle valve is that it is easy to see if the valve is open or closed. This may be seen clearly in figure 31 below. Here a gate valve is shown but other types of valves can have rising or non-rising spindles.

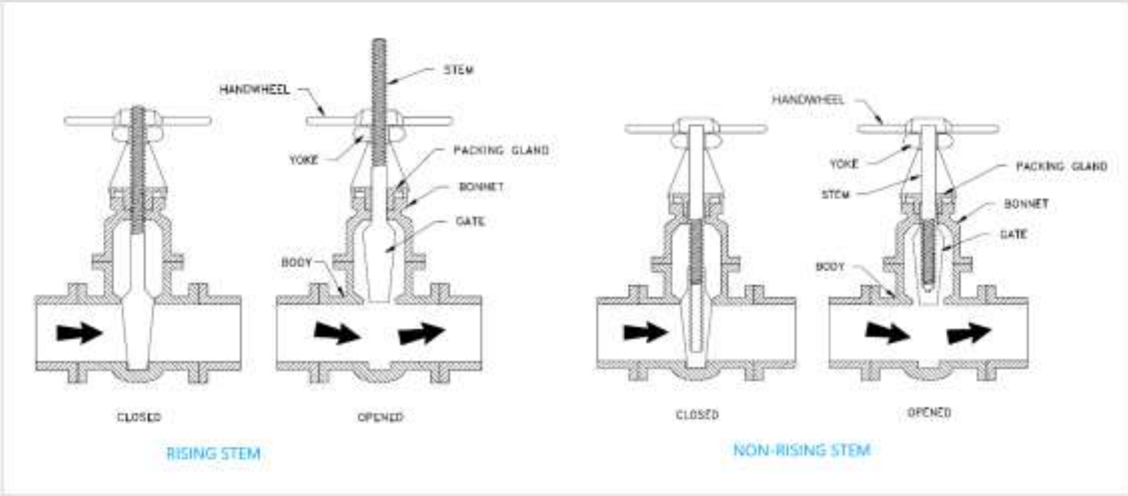


Figure 31 – SHOWING DIFFERENCE BETWEEN RISING SPINDLE AND NON-RISING SPINDLE VALVES.

A disadvantage of the rising spindle is that if the spindle is greased to make it easy to turn then when in the open position, sand may stick on the grease and damage the thread over time. This may be prevented by fitting a clear plastic tube over the spindle. The advantage of the non-rising spindle valve does not have this problem. A disadvantage of the non-rising spindle valve is that one cannot easily see if the valve is open or closed.

A VERY USEFUL OPERATING TIP.

WHEN A VALVE IS OPENED, THE HAND WHEEL SHOULD BE TURNED BACK A ONE HALF TURN.

1. **IF THE HAND WHEEL TURNS EASILY FOR A QUARTER TURN BOTH WAYS, THEN THE VALVE IS KNOWN TO BE OPEN.**
2. **IF THE HAND WHEEL CAN ONLY BE TURNED EASILY IN ONE DIRECTION THEN THE VALVE IS KNOWN TO BE CLOSED.**

ANOTHER VERY USEFUL OPERATING TIP.

NEVER SPIN THE VALVE TO CLOSE IT QUICKLY – THIS DAMAGES THE VALVE AND CAN MAKE IT VERY DIFFICULT TO OPEN OR CLOSE IN FUTURE.

2.11.1 Different Types of Valves - 1,

Most the valves used on pipelines in a water or wastewater treatment works are used to open or shut off a flow. They are not often used to control (i.e. reduce) the flow. This is because the flow control property is poor. For example – half open does not mean half the flow.

The most commonly used type of valve is the gate valve. This has a conical wedge design and angular sealing devices of a metal seated wedge require a depression in the valve bottom to ensure a tight closure. A disadvantage of this design is that material may become jammed in the depression at the bottom of the valve making it difficult to close the valve to ensure no flow when fully closed.

A variation of this type of valve is the resilient seated gate valve has a plain valve bottom allowing free passage for sand and pebbles in the valve.

This type of valve is of the “full bore” type in that when the valve is in the open position, the opening is the same size as the pipe itself. It therefore offers very little resistance to the flow of the liquid in the pipe.

The knife gate valve is similar in design but has a thin flat plate that moves downwards to shut off the flow. It would better than a gate valve in a pipeline handling thick sludge.

Another type of valve that has a full bore when open is the ball valve. A ball valve utilizes a sphere with a hole in it to control flow. When the handle is turned parallel with the valve, the hole is open to flow.

A comparison of the resilient seat and metal seated gate vale in shown in figure 32. An example of the knife gate and ball valves is shown in figures 33 and 34.

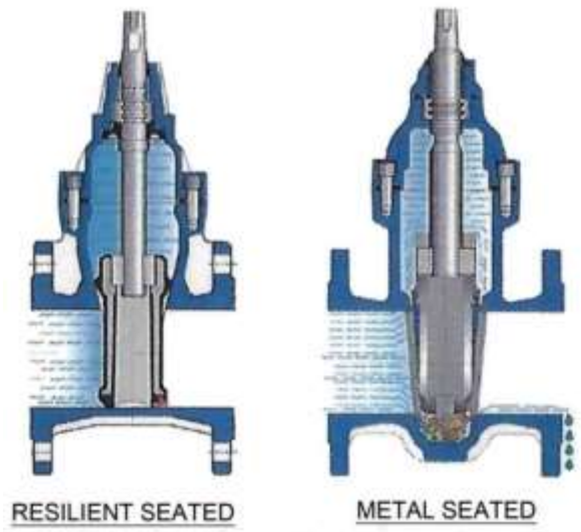


Figure 32 – SHOWING A RESILIENT SEAT AND METAL SEATED GATE VALVE.

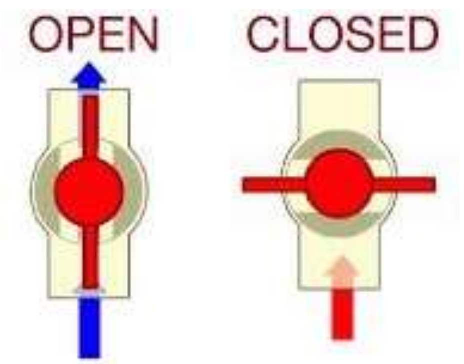


Figure 33 – SHOWING A KNIFE GATE VALVE

Figure 34 SHOWING A BALL VALVE.

Another type of valve that is full-bore BUT has a part remaining in the pipe flow at all times is the butterfly valve. A butterfly valve is from a family of valves called quarter-turn valves. In operation, the valve is fully open or closed when the disc is rotated a quarter turn. The "butterfly" is a metal disc mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passageway. This is seen in figure 35 below:

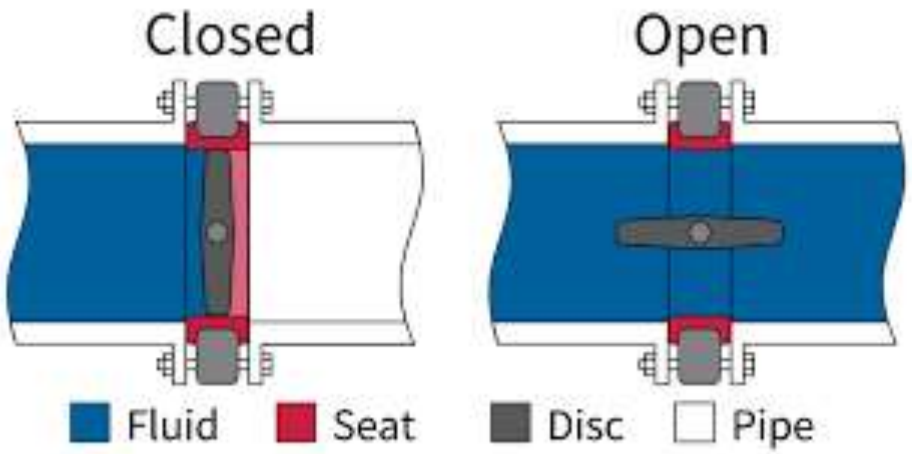


Figure 35 – SHOWING A BUTTERFLY VALVE IN THE CLOSED POSITION AND THE OPEN POSITION.

A small butterfly valve can generally be operated by a lever mounted on the top. This has the advantage that it is easy to see if the valve is open (lever lies parallel to the pipe) or closed (the lever is at right angles to the pipe). A larger butterfly valve will usually be operated by a hand wheel driving through a right angle reduction gearbox. The two methods of operation are seen in figure 36:

Figure 36 – SHOWING LEVER OPERATION AND HAND WHEEL OPERATION OF A BUTTERFLY VALVE.

The main disadvantage of the butterfly valve is the disc that remains in the path of the fluid. This type of valve can only be used with clean water where there are no stringy materials that can be caught on the disc.

2.11.2 Different Types of Valves - 2,

In section 2.11.1 all the valves when open offer very little restriction to the flow as the liquid passes through the valve in a straight line. A valve that offers better control of the flow is the globe valve. These were called globe valves because of the shape of the bowl at the bottom of the valve.

A Globe valve is a linear motion valve and is primarily designed to stop, start and regulate flow. The disk of a Globe valve can be totally removed from the flow path or it can completely close the flow path. Globe valves may be used for isolation and throttling services. Although these valves exhibit slightly higher pressure drops than straight through valves (e.g., gate, ball, etc.), they may be used where the pressure drop through the valve is not a controlling factor.

Because the entire system pressure exerted on the disc is transferred to the valve stem, the practical upper size limit for these valves is 300mm. The layout of a typical globe valve is shown in figure 37 below:

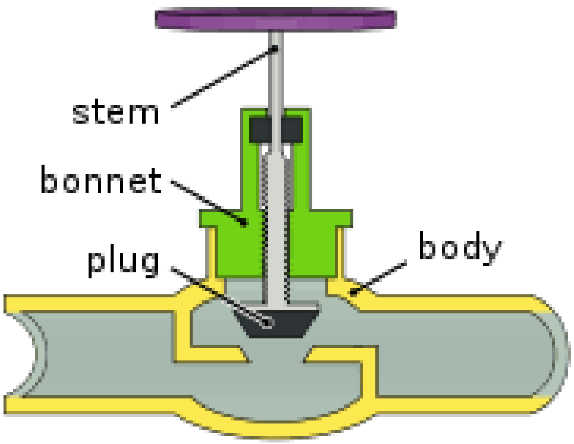


Figure 37 – SHOWING A TYPICAL GLOBE VALVE.

2.11.3 Gland Packing.

Where the spindle extends outside the valve body, there will be what is known as gland packing. This is to stop the liquid inside the pipe from leaking out. As the valve is operated this packing generally wears and after time, it will begin to leak. Depending on the construction of the valve, the nuts on top of the packing assembly may be tightened slightly to stop any leaks. The packing may have to be replaced after many years. It is important not to over-tightening the packing as this make it more difficult to operate the valve.

2.11.4 Different Types of Valves - 3,

In all the types of valves mentioned above, there is a part of the valve that moves in the liquid in the pipeline. This always has the potential of corrosion of those parts in contact with the liquid. A diaphragm valve has no moving parts within the liquid.

Diaphragm valves (or membrane valves) consists of a valve body an elastomeric diaphragm, and a "weir or saddle" or seat upon which the diaphragm closes the valve. This is seen in figure 38 below:

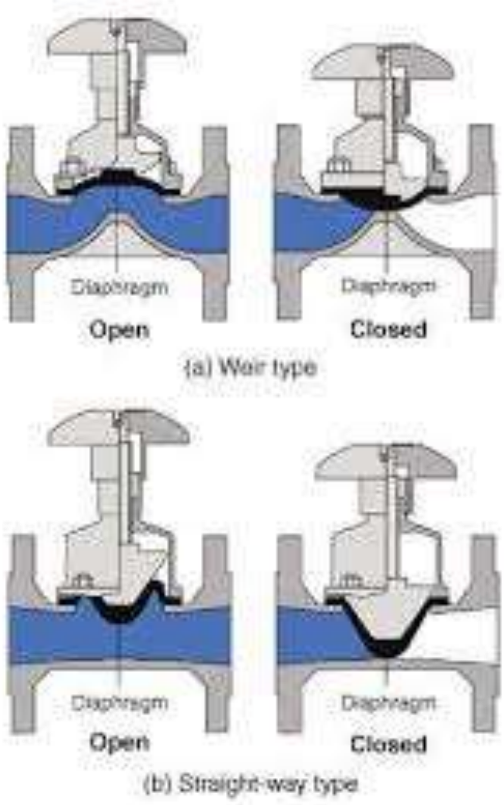


Figure 38 – SHOWING 2 TYPES OF DIAPHRAGM VALVES.

One of the major advantages of using diaphragm valves is that the valve components are isolated from the liquid in the pipe (except the diaphragm itself).

Another major advantage is that this construction helps prevent leakage of the liquid without the use of a gland seal (packing) as seen in other types of valves.

2.12 NON-RETURN VALVES.

When a pump that pumps into a pipeline switches off, the liquid in that pipeline would want to flow back. This needs to be prevented for two reasons:

1. the liquid would need to be pumped into the pipeline again. This would be a waste of energy and a waste of electricity;

2. the back-flowing water would turn the pump and its electric motor in the wrong direction. Starting an electric motor that is turning in the wrong direction would result in an enormous electrical current in the motor windings that would damage the motor.

To prevent the back flow, a non-return valve would be fitted to the pipeline near the pump. A non-return valve is also called a check valve. The most common type is the swing non-return valve. An example is shown in figure 39 below. The valve is shown with the swing gate open. When the flow stops then the gate swings closed. Often on large pipelines, the swing gate is connected to an arm situated outside the pipe that contains weights to ensure that the valve closes fully.

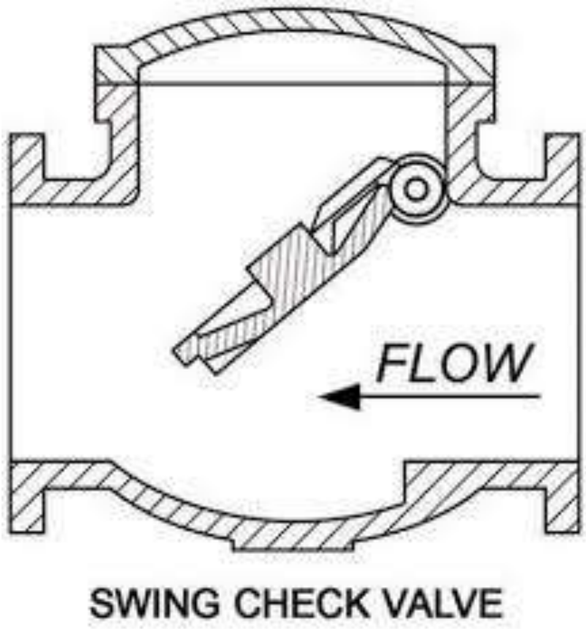


Figure 39 – AN EXAMPLE OF A SWING NON-RETURN (CHECK) VALVE.

2.13 MECHANICAL OPERATION OF VALVES.

Where there is not a high degree of automation on a water or wastewater treatment works, then most of the valves will be hand operated. Where the valve is large then the number of turns of the hand wheel could be more than 50 revolutions. It would then be preferable that the valve closing be mechanised.

There are 3 ways that this may be done:

1. with an electric motor;
2. using air pressure;
3. using hydraulic pressure.

2.13.1 Using an Electric Motor to Operate a Valve.

These are often referred to an electric valve actuator or motorised valve actuator. The electric motor drives the spindle of the valve through a reduction gearbox. There are several makes available today but all perform the same function. The internal control system senses the torque of the motor to know when the valve is fully closed or fully open. The concept of torque was covered in section 4.4 in *Process Controller's Guide no. 5 (Electricity and Electric Motors*).

The valve actuator will have a manual mode, so that if the unit fails or there is an electricity outage, then the valve can still be operated. An example of an electric valve actuator is shown in figure 40 below:

Rotork

Figure 40 – EXAMPLE OF AN ELECTRIC VAVE ACTUATOR.

2.13.2 Using Compressed Air to Operate a Valve.

The air of compressed air to perform a function is called pneumatics. The principle of operation is that air at a high pressure pushes the diaphragm down and this operates the valve in a straight line motion. When the air pressure is released then the internal spring opens the valve. A modification of this system would be to use compressed air to open the valve. By careful regulation of the air pressure, it would be possible to partially close the valve. An external indicator would show whether the valve was fully open partially open or closed. An example is shown in figure 41 below:

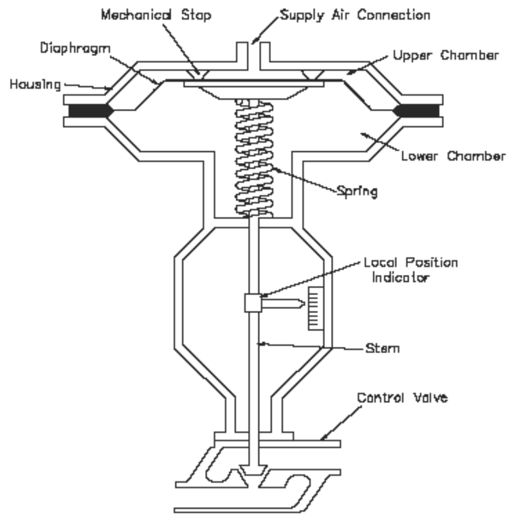


Figure 41 – AN EXAMPLE OF A PNEUMATICALLY ACTUATED VALVE.

2.13.3 Hydraulically Actuated Valve.

This would work on the same principle as a pneumatically actuated valve but would use hydraulic fluid instead of air. The hydraulic fluid would drain bank into a storage tank instead of the discharged into the atmosphere.

2.14 WATER HAMMER.

Water hammer or hydraulic shock is a pressure surge or wave caused when a fluid in motion is forced to stop suddenly. This usually occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave moves up and down in the pipe.

This pressure wave can cause major problems, from noise and vibration to pipe rupture or collapse. It is possible to reduce the effects of the water hammer pulses with accumulators, expansion tanks, surge tanks, blow off valves, and other features. The effects can be avoided by ensuring that no valves will close too quickly. An indication of a typical shock wave is shown in figure 42.

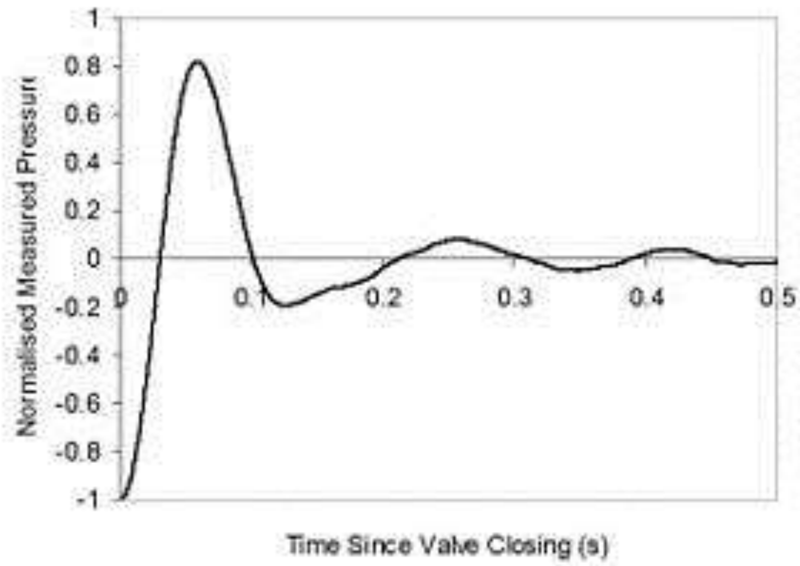


Figure 42 – SHOWING THE AMPLITUDE OF A TYPICAL SHACK WAVE,

This is nothing a Process Controller can do about water hammer as its occurrence is related to the design of the pump and pipeline. The Process Controller can look out for leaks at flange in the pipeline or signs of movement of the pipe and report this to their Manager.

2.15 COLOUR CODING OF VALVES.

It is useful that valves be colour coded as this gives information about the operation of the valve. The body of the valve should be coloured coded as indicated in section 2.16 below.

It is useful to indicate who may operate a valve. One possible system is as follows:

1. GREEN hand wheel – the valve may be operated by the Process Controller as a part of their normal duties;

2. ORANGE hand wheel – the valve may be operated by the Process Controller under special conditions;

3. RED hand wheel – the valve should be operated only under major maintenance conditions.

Concerning the direction of closing of valves, there are unfortunately both clockwise (right hand) closing and left hand closing valves. These can cause confusion especially under emergency conditions.

One possible colour coding that will eliminate confusion is as follows:

1. the whole hand wheel is one of colours indicated above = CLOCKWISE CLOSING;

2. the rim of the hand wheel is one of the colours indicated above BUT THE SPOKES OF THE HAND WHEEL ARE SILVER = LEFT HAND (ANTI-CLOCKWISE) CLOSING.

2.16 COLOUR CODING OF PIPELINES.

It is useful that pipelines be colour coded according to an agreed colour coding schedule. Such a colour coding schedule is given in SANS 10140-43: 2003 Part 3 edition 3.1. This is available from the South African Bureau of Standards.

Email: sales@sabs.co.za

On-line: www.store.sabs.co.za

The standard colours used in identifying the contents of pipelines are given below in figure 43.

Pipe Content	Basic Colour	SANS Colour Reference	Example
Acids	Jacaranda	F18	
Air	Artic blue	F28	
Gasses (other than air)	Light Stone	C37	
Oil	Golden brown	B13	
Refrigerants and air conditioning	White		
Steam	Aluminium/Silver		
Water drinkable	Brilliant green	H10	
Drainage water (sewage)	Black		
Fire fighting water	Signal red	A11	
Hydrocarbons	Aluminium/Silver		

Additional Colour	SANS Colour Reference	Example
Salmon Pink	A40	
Primrose	C67	
Maroon	A01	
Peacock blue	F08	
Crimson	A03	
Light brunswick green	H07	
Canary yellow	C61	
Light grey	G29	
Middle brown	B07	
Poppy red	A14	
Verdigris green	E22	
Cornflower	F29	
Biscuit	B64	
Golden yellow	B49	
Pinotage	A08	
Middle buff	B33	
Emerald green	E14	
Lime green	H41	

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Figure 43 – STANDARD COLOURS USED TO IDENTIFY THE CONTENT OF PIPELINES.

The SANS 10140-43: 2003 Part 3 edition 3.1 specifies the follow colour or colour combinations to identify the content of pipelines in Table 3 below.

TABLE 3 – SANS 10140 COLOUR CODING FOR PIPELINES.
(ONLY CERTAIN TYPES GIVEN)

CONTENTS OF PIPE	MAIN PIPE COLOUR	BAND COLOUR	MAIN PIPE COLOUR
Water (drinkable)	Brilliant Green H10	Cornflower Blue F20	Brilliant Green H10
Drainage Water	Black	NO BAND	Black
Industrial Water	Brilliant Green H10	Golden Yellow B49	Brilliant Green H10
Chlorine	Light Stone C37	Canary Yellow C61	Light Stone C37
Fire Fighting Water	Signal Red A11	NO BAND	Signal Red A11

IMPORTANT NOTES.

1. in terms of SANS 10140, all pipelines carrying wastewater liquids should be black**. It is felt that it would be more useful if treated effluent used for irrigation, process water etc. should be classified as INDUSTRIAL WATER in order to distinguish it from sludge;**

2. in terms of SANS 10140, all pipelines carrying chlorine gas should be Light stone with a Canary Yellow band**. Traditionally, the chlorine pipelines were painted only in Canary Yellow. There is no need to change thus but subject to note 3 below;**

3. in buildings were colour coded pipelines are located, there must be a colour coding chart readily visible for persons to see the colour coding details;

4. the width of the band is not indicated in SANS 10140. It must be clearly visible and obvious to any person in the building.

2.17 AUTOMATIC PRESSURE CONTROL IN PROCESS and IRRIGATION WATER SYSTEMS.

It is very useful to have a treated effluent pipe system where the feed pump starts up automatically when a valve or tap is opened and stops when the valve or tap is closed. A typical system is shown in figure 44.

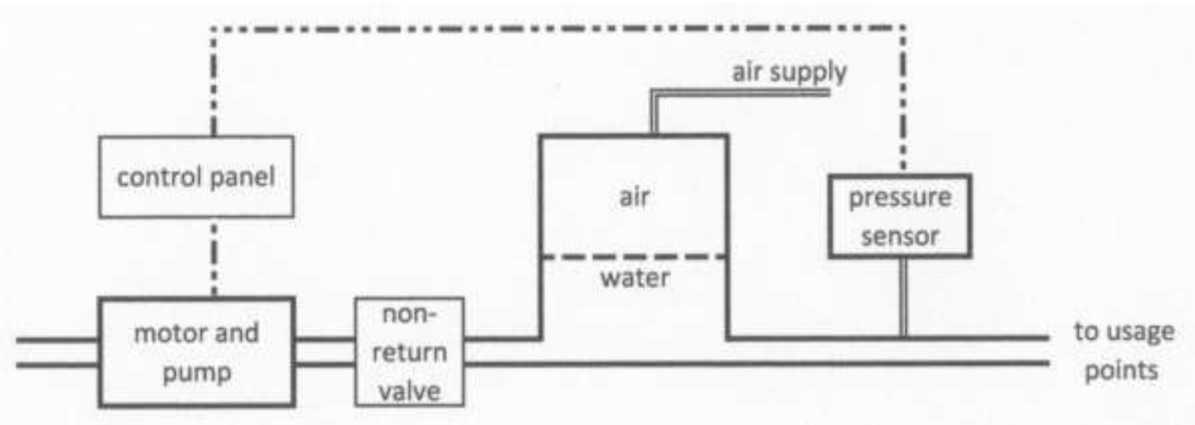

Fig 44 – LAYOUT OF A TYPICAL AUTOMATED WATER FEED SYSTEM.

When any valve or tap in the system is opened, the pressure will drop. The pressure sensor will note this drop in pressure and send a signal to the control panel that will start the pump. When the pressure reaches the pre-set shut off point the pump will switch off. The balancing tank will generally contain about 50% by volume of air and 50% of water. As the pressure rises, the air will compress and the water level will rise. When the pump stops, the non-return valve will ensure that the system remains pressurized. As soon as a valve or tap is opened the pressure will drop and the cycle will begin again.

As the pressure in the balancing tank rises, some of the air in the top part of the tank will dissolve in the water and will move out with the water leaving the tank.

The system will not work properly with no air space above the water. The feed pump will switch on for a short time and then switch off again. The repeated switching on and off of the system will damage the electric motor.

It will be the Process Controllers duty to add air the tank every few days depending of the usage of the system.

2.18 LONG PIPELINES.

Pipelines may be grouped into two classes:

1. gravity pipes (mains) - where the liquid flows under the force of gravity from the high point to a low point. These will not have valves fitted to them except at the discharge point there may be handstops or penstocks to shut off the feed to one unit and to divert the flow to another unit.

.2. pressure pipes (rising mains) – where the liquid is pumped to a higher elevation, by one of the types of pumps covered earlier. The long rising main can often not be built so that the flow in the pipe is always going uphill. This is due to the elevation of the land through which the pipeline is laid. There is often "downhill" section(s) that are followed by an "uphill" section.

   The result of this is that air may become trapped at the high points and silt may be deposited at the low points. It is necessary to have a system to remove the air and the silt. It is usual to include a shut off valve in long pipelines to stop all water draining out in the event of a pipe break or for maintenance to valves etc.

   An example of the placement of air valves and scour valves in shown in figure 45 below:

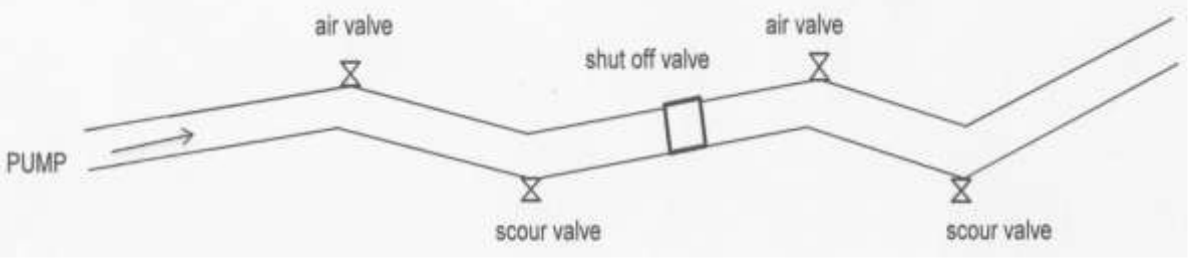

Figure 45 – SHOWING THE POSITIONS OF AIR VALVES AND SCOUR VALVES ON A RISING MAIN.

The scour valve will usually be a gate valve.

2.18.1 Air Release Valves.

As shown in figure 45, these are fitted at high points in the rising main to release any air that may be released from the water or wastewater being pumped. Air release valves use a float that in the lower position allows air to escape through the top of the fitting. When the water level rises (due to the air having been discharged); the float rises and shuts off the discharge hole. As water rising mains often operate at a higher pressure than wastewater rising mains, the air release valve needs to have a tight fitting closure when all the air has been discharged. An example of an air release valve is shown in figure 46 below:

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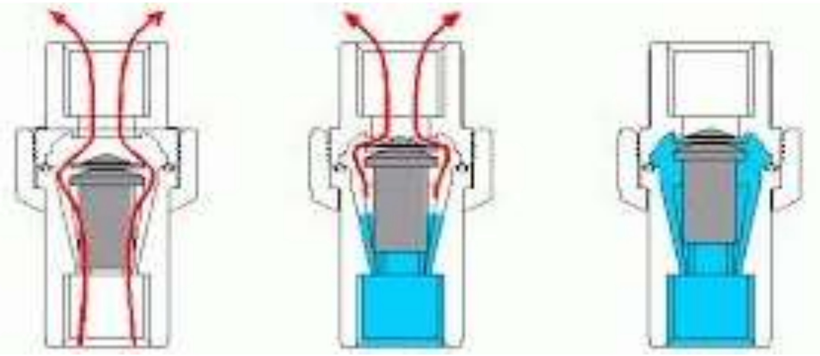

pinterest

Figure 46 – AN EXAMPLE OF AN AIR RELEASE VALVE USED ON A WATER RISING MAIN.

As wastewater contains suspended solids that will block the small spaces in an air release valve used for water, a special type of air release valve should be used.

Unfortunately designers of wastewater rising mains fail to specify that a wastewater air release valve must be used. The air release valve will either not release air OR will fail to close when all the air is out and this results in wastewater leaking out of the valve.

It may be seen below in figure 47 that in the wastewater air release valve the float is connected to the shut off part by a rod or shaft. This will prevent the wastewater from reaching the shut off valve. This will mean that there is always a little bit of air above the float – this does not matter.

empoweringvalves.com

Figure 47 – AN EXAMPLE OF AN AIR RELEASE VALVE USED FOR WASTEWATER

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PUMPS, BLOWERS AND THEIR OPERATION

PART 3.

BLOWERS AND COMPRESSORS.

3.1 INTRODUCTION.

In this guide, a blower is defines as a unit that produces a large flow of air at a low pressure, while a compressor is defined to be a unit that produces a small flow of air but at a high pressure.

The air flow produced from a blower will be used immediately whereas the air flow produced by a compressor will be stored in an air receiver until required.

Blowers may be classified into two main groups:

1. centrifugal;

2. positive displacement.

Each of these may be split into a number of types.

Compressors will be of the positive displacement type due to the higher pressures produced.

3.2 CENTRIFUGAL BLOWERS.

Blowers in the water and wastewater industry will usually not be required to produce an output pressure of more than 65 kPa or 6.5 metres water head. A single stage centrifugal blower will need to operate at about 10 000 rpm to produce this pressure. A two stage blower will need to operate at about 5 000 rpm to produce this pressure.

A typical flow sheet for a centrifugal blower system is shown is shown in figure 48 below. A typical layout is shown in figure 49. The air filtration step will be covered in section 3.4

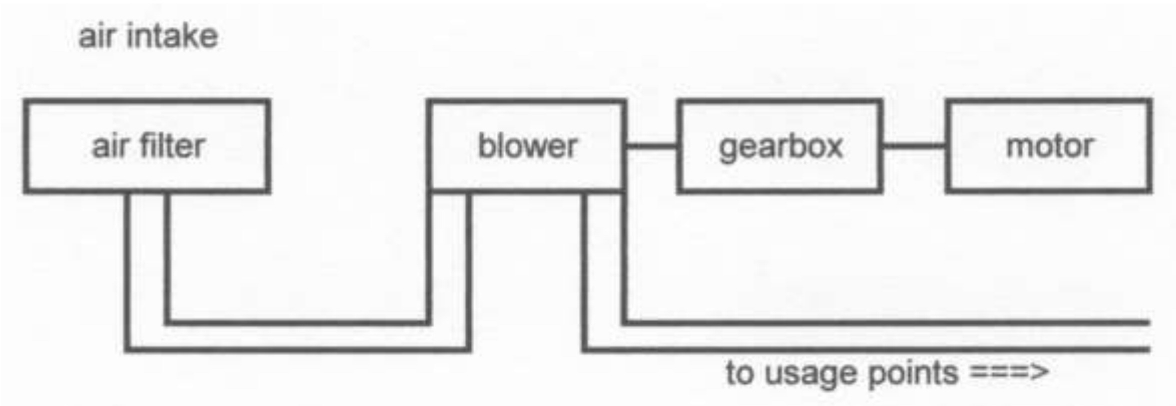


Figure 48 – SHOWING A FLOW SHEET FOR A CENTRIFUGAL BLOWER.

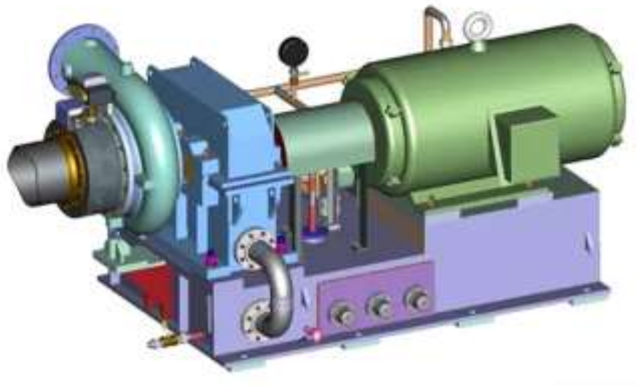


Figure 49 – SHOWING A TYPICAL MOTOR / GEARBOX / BLOWER LAYOUT.

A centrifugal blower works on the same principal as a centrifugal pump where the impeller spins and by centrifugal force pushes the air out of the casing. The low pressure in the centre of the impeller draws in more air to replace the air discharged. The internal components of a centrifugal blower are shown in figure 50 below:

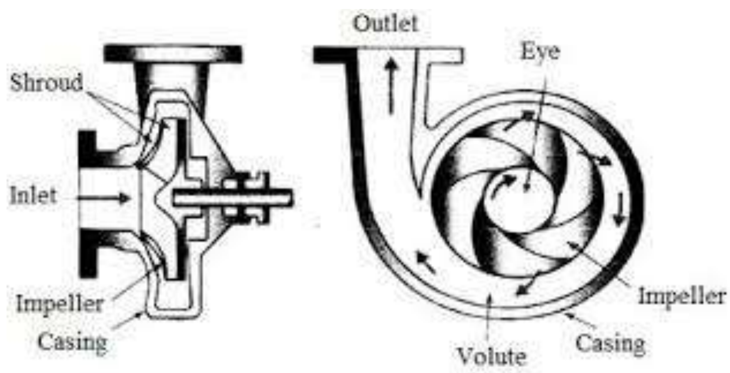


Figure 50 - SHOWING THE INTERNAL COMPONENTS OF A CENTRIFUGAL BLOWER.

As with centrifugal water pumps where two stages may be combined to produce a higher pressure; two centrifugal air blowers may also be fitted into one unit. As the air is compressed in the first stage, the second stage casing and impeller will be slightly smaller.

An example is shown in figure 51 below:

Figure 51 – SHOWING A TYPICAL TWO-STAGE CENTRIFUGAL BLOWER.

Centrifugal blowers have a major advantage that the air output can be varied by means of the inlet vane guide control. At full air output , these are in the fully open position. In order to reduce the air flow (and reduce energy input), the vanes are adjusted to give pre-rotation to the air entering the blower assembly. This means that the air entering the blower is already turning in the direction of the impeller and so that each vane moves less air and so the output reduces. At the same power the electric motor is doing less work and so the eletricity ussage decreases. The discharge pressure also reduces.

The inlet vane guide cotroller is usually set so that the vanes cannot to less than 35% open. Below this point, the discharge pressure would be about the same at the system pressure. This would mean that the air in the blower becomes trapped within the blower. This results in surging, vibration and heat build up. The impeller is turning fast and so the friction with the air heats up both the air and the vanes. This can result in the vanes touching the blower casing. This would result in major damage to the blower. This situation is known as "stalling".

Under normal operating conditions, the air is heated during the passage through the blower but this heat is discharged with the air. The fact that the air is heated is put forward as one of the postive features by suppliers of blowers as to why blowers are better than surface aerators for wastewater treatment. Surface aerators do have a slight cooling effect due to evaporation of water from the mixed liquour.

The traditional centrifugal blower assemblies are very noisy. Noise levels can exceed 110 dBa. This means that the blowers must be installed in a sound proof building. This noise level makes it compulsory for persons entering the building to wear hearing protection.

A more modern type of centrifugal blower is one where the motor and the blower both turn at very high speed. This can be up to 60 000 rpm. Both units use magnetic bearings where there is no contact between the stationary body and the rapidly rotating parts. This results in a much quieter installation. Due to their compact size, the unit may be placed in a sound proof cubicle as shown in figure 52 below:

Figure 52 – A SULZER HST® BLOWER INSTALLATION.

3.3 POSITIVE DISPLACEMENT BLOWERS.

The best known positive displacement blower is the "Roots" blower. The original basic design can be traced by to a patent in 1860. The most common design has two lobes as shown in figure 53 below:

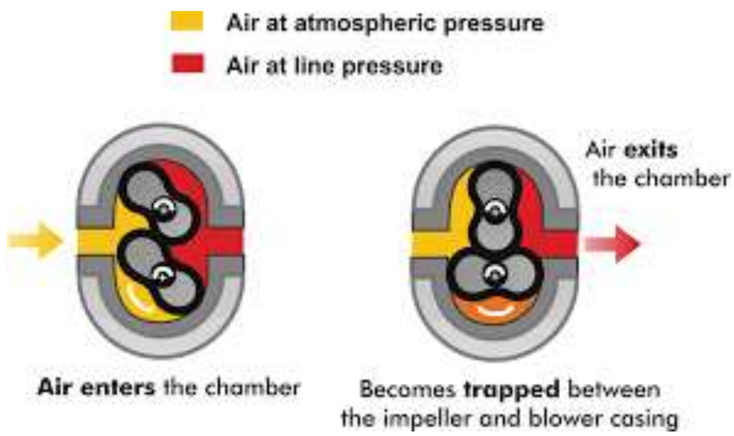


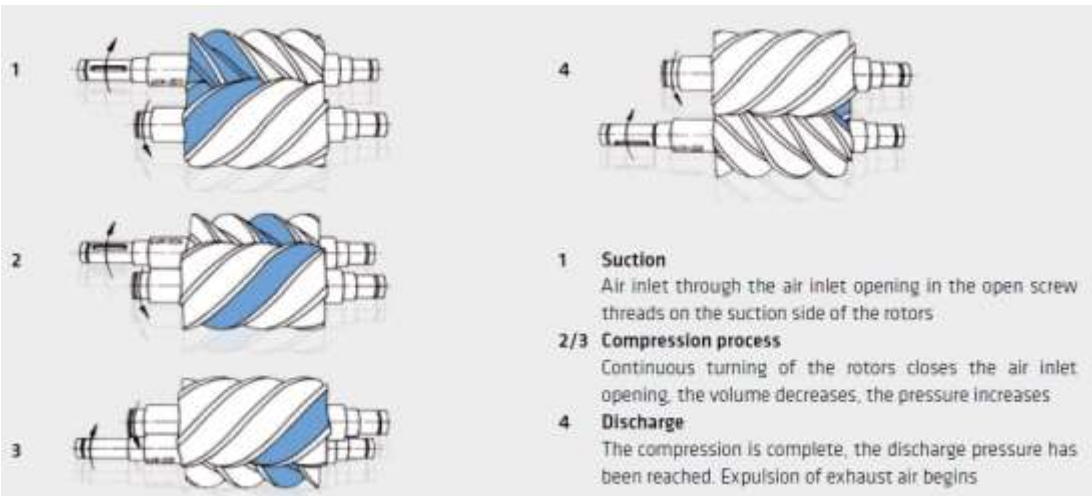
Figure 53 – SHOWING THE PRINCIPLE OF A ROOTS-TYPE BLOWER.

As these produce a pulsing effect in the discharge air, some designs have 3 or 4 lobes. The pulsing action can be further reduced by the lobes have a slight twist to them. The centrifugal blower in contrast produces a smooth air flow.

One disadvantage of this type of blower is that the air output is fixed and depends only on blower size and speed of rotation. For this reason, these blowers are using driven by belts either V-belt or poly-vee. Belt drives will be covered in the *Process Controllers Guide no. 7.*

A common speed of rotation is between 1 000 and 2 000 rpm. These blowers are also very noisy. In order to reduce the noise output and to some extent reduce the pulsating effect of the discharged air, one can install a suitable silencer on the output pipe. The units should also be installed in a sound proofed building.

An improvement on the Roots type blower is the Screw Compressor (blower). It is also a positive displacement blower but has the advantage of a uniform airflow. The principle of operation is shown in figure 514below:



Azom.com

Figure 54 – SHOWING THE OPERATION OF A SCREW COMPRESSOR (BLOWER).

As with the Roots type blower, this unit has a fixed output that is speed dependent.

Both types of positive displacement blowers could be driven by a variable speed motor if a variation of output is required.

A very important consideration for the positive displacement blowers is that they must NEVER be operated with the discharge valve CLOSED. Enormous pressure will be produced that would lead to damage to the blower and pipework and the risk of an explosion.

Positive displacement blowers are used as an air supply for air lift pumps such as those used to remove grit from a grit separation unit.

3.4 AIR FILTRATION.

In the wastewater treatment industry where fine bubble air diffusers are used in the aerated portion of the reactor; it is vitally important that the air be filtered through a very fine filter before entering the blower. If this is not done, then the fine particles will become trapped under the diffuser disk. This will result in an increased pressure drop across the diffuser. This will in turn result in reduced air flow. After a time, the diffusers will have to be replaced at great cost. Various attempts at trying to clean diffusers with detergent or acid or heating in a furnace in the case of carborundum diffusers have not proved worthwhile.

It is usually taken as a rule that the filtration system must remove more than 95% of the 10 micron or larger, particles.

3.5 PRESSURE LOSS IN SYSTEM.

In section 2.2.1, it was seen that the total head against which a pump needed to pump was the sum of the static head and the friction head – the latter was the sum of the pipeline friction and friction due to valves, bends etc. in the system.

Exactly the same scenario applies when dealing with the conveyance of air in a pipe when used in a fine bubble diffuser system in the activated sludge process.

1. The **static head** for water is replaced with **Submersion Head –** this is the depth of water above the air discharge point. In figure 39 below, this may be seen to be about 4.42 metres;

2. the **friction head** for water is replaced with **piping losses** – this is the friction due to the air being conveyed inside the pipe and will include some friction due to bends and valves. In this example it is about 0.8 metres at 90% of maximum airflow;

3. As the air must pass through small holes in the diffuser in order to get a bubble size of about 2mm, there is friction through the diffuser – this is called the **Diffuser Head.** In this example it is about 0.47 metres (when the diffuser is new);

4. The diffuser will become slightly blocked with time even if very fine filters are used to clean the air before it enters the blower. If the air flow stops for any reason, then water will flow back through the diffuser into the air pipework laid across the bottom of the reactor. When the blower is started again, the air is the pipe work must be blown out through the condensation removal pipes. These are placed along the walls at several points on the opposite side of the reactor from which the air enters the underwater pipework. As these condensate removal pipes extend about 0.5 metres above the water level, the blower must be capable of producing enough pressure to blow this water out. Also when the air flow

stops for any reason, some sludge will get into the top few millimetres of the diffuser. This adds to the friction head across the diffuser. In this example, an allowance of 0.66 metres is made.

It may be seen that piping losses, the diffuser head and the aging/fouling head all increase as the air flow increases. This is to be expected as it was seen that exactly the same happens when considering water flow in pipes. This is seen in figure 55 below:

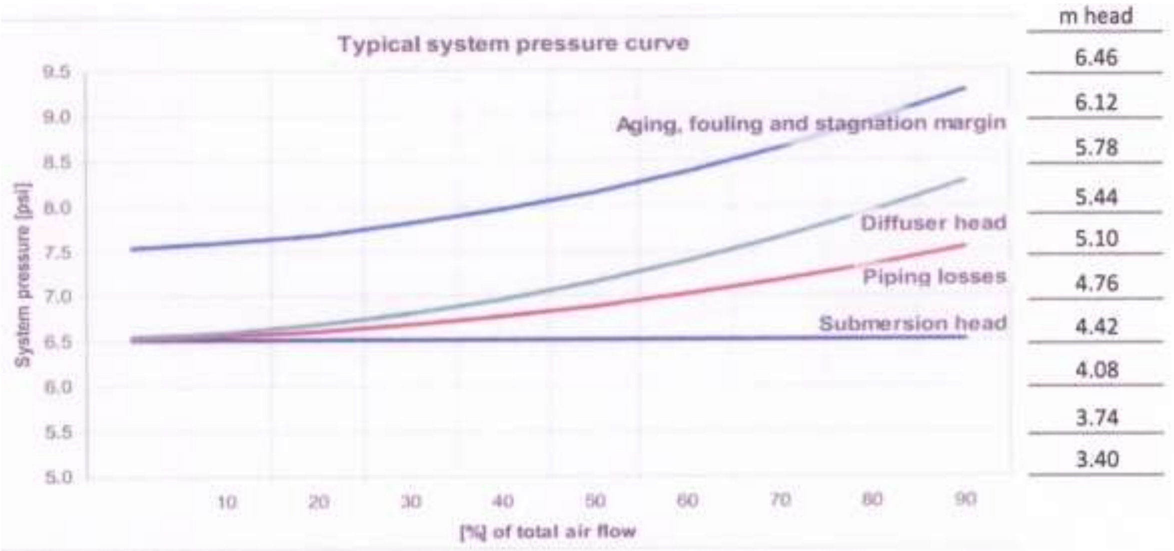


Figure 55 – SHOWING THE VARIOUS FRICION COMPONENTS IN AIR FLLOW TO DIFFUSERS IN AN ACTIVATED SLUDGE WORKS.

The summary of the various head losses at 90% maximum flow is shown in table 4.

TABLE 4 – MAKE=UP OF THE VARIOUS HEAD LOSS IN THE EXAMPLE.

DESCRIPTION	**TYPICAL HEAD LOSS - m**
Submersion Head	4.42
Piping Losses	0.80
Diffuser head loss	0.47
Aging / Fouling head loss	0.66
TOTAL HEAD REQUIRED	**6.35**

It was earlier indicated that the typical blower maximum pressure requirement was about 6.5 metres head.

3.6 COMPRESSORS.

Due to the higher pressures involved (typically 7 bars (700 kPa and above), a positive displacement type of pump would be used. There are a number of types. These include:

1. reciprocating (piston) type;

2. intermeshing screws.

3.6.1 Reciprocating (piston type) compressor.

The suction and compression cycles of the unit are shown in figure 56 below:

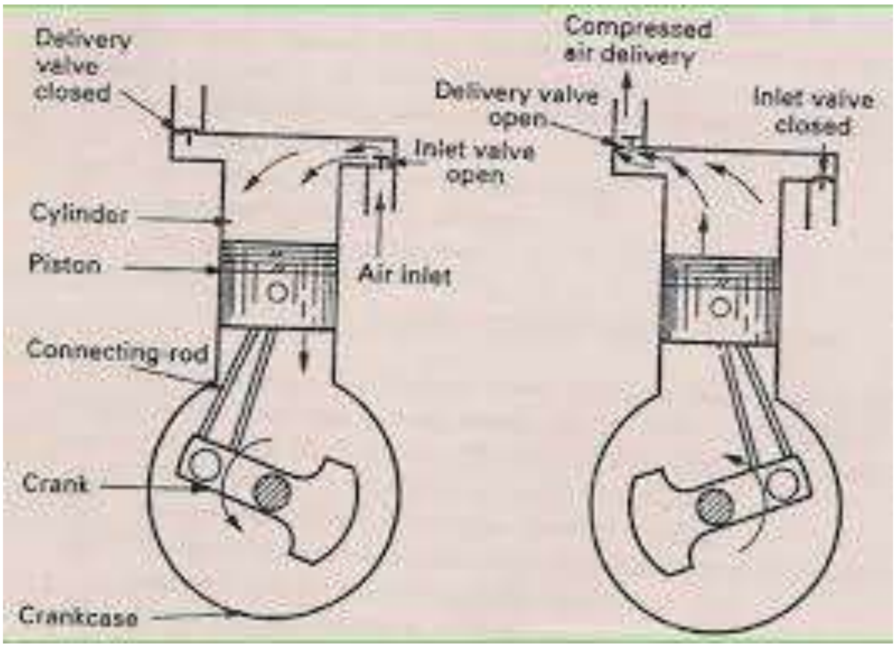


Figure 56 – SHOWING THE SUCTION AND COMPRESSION CYCLES OF A RECEIPROCATING COMPRESSOR.

With blowers, the air flow produced is used immediately and there is no storage of the air. In those cases where the higher pressure air compressors are used, the air usage may be continuous or intermittent. With intermittent usage, there will be storage of the high pressure air in a container usually known as the **air receiver**. These units are generally small and usually have a volume of about 100 litres. The compressor unit is often mounted on top of the air receiver. A typical example is shown in figure 57 below:

Figure 57 – SHOWING A TYPICAL AIR COMPRESSOR MOUNTED ON AN AIR RECEIVER.

3.6.2 <u>Intermeshing screw type compressor</u>.

The internal components of an intermeshing screw type compressor are shown below in figure 58

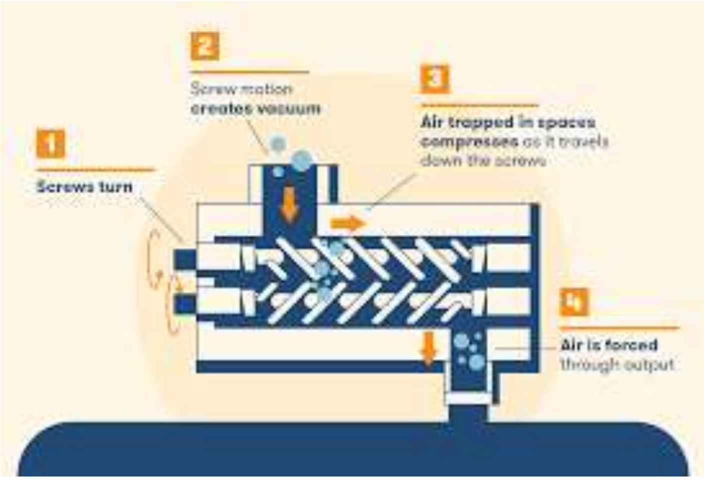


Figure 58 – SHOWING THE INTERNAL COMPONENTS OF A SCREW COMPRESSOR.

3.6.3 <u>Uses of Compressed Air.</u>

Compressed air is used for amongst other, the following uses:

1. actuating pneumatic valves;

2. adjusting rollers on a belt press;

3. pressurising a saturator used for Dissolved Air Flotation units.

3.7 <u>AIR RECEIVERS.</u>

These are used to store compressed air and usually operate at 700kPa or higher. They must have a plate affixed to the receiver containing important information. An example is given below in figure 59:

MANUFACTURED BY:	PRESSUREWELD (PTY) LTD.
MAKERS NO.	11235
INSPECTION NO.	EQ 10735
YEAR OF MANUFACTURE	1981
DESIGN PRESSURE	700 kPa
INITIAL TEST PRESSURE	1050 kPa
ROUTINE TEST PRESSURE	875 kPa
MAX. PERMISSIBLE OPERATING PRESSURE	700 kPa
DESIGN TEMP. MAX. °C	35
CAPACITY M^3	0,594
CODE OF MANUFACTURE	B.S.5169,CLII,GRD E,1975
COUNTRY OF ORIGIN	SOUTH AFRICA
INSPECTED BY SGS ENGINEERING INSPECTION COMPANY (PTY) LTD. GOVERNMENT APPROVED INSPECTION AUTHORITY	

Figure 59 – INFORMATION PLATE ATTACHED TO AN AIR RECEIVER.

There are several safety precautions that must be observed in connection with air receivers. These include:

1. a hydraulic pressure test at intervals as prescribed in the Pressure Vessel Regulations in terms of the Occupational Health and Safety Act – Act 85 of 1993;

2. external and internal inspections in terms of above regulations;

3. testing of the pressure relief valve;

4. daily draining of condensate from the receiver.

Items 1, 2 and 3 would also be applicable to the saturator vessel as used in a dissolved air floatation unit.

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