

**Metalliferous Mining - Processing**

**PUMPS**

**Resource Book**



# Table of Contents

<b>TABLE OF CONTENTS</b> .....	<b>2</b>
INTRODUCTION TO PUMPS .....	4
<i>What is this module about?</i> .....	4
<i>What will you learn in this module?</i> .....	4
<i>What do you have to do to complete this unit?</i> .....	4
<i>What resources can you use to help?</i> .....	4
INTRODUCTION .....	5
<i>Definitions</i> .....	6
What is a Pump? .....	6
What is a Slurry Pump? .....	6
Slurry Pump - Name by Duty.....	6
Slurry Pump - Name by Application.....	6
<i>Installation of Slurry Pumps</i> .....	7
Dry Installations.....	7
Semi Dry Installations.....	7
Wet Installations .....	7
MECHANICS .....	9
<i>Basic Components</i> .....	9
COMPONENTS .....	10
<i>Impeller and Casing</i> .....	10
<i>Impeller</i> .....	10
Vanes.....	10
Vane Designs .....	10
Number of Impeller Vanes.....	11
Types of Impeller.....	11
Impeller Diameter .....	12
Impeller Width.....	13
Limitations in Geometry .....	13
Impeller Motion .....	13
<i>Casing</i> .....	14
WEAR PROTECTION .....	15
<i>Abrasion</i> .....	15
<i>Erosion</i> .....	15
<i>Corrosion</i> .....	16
<i>Effects of Erosion on Pump Components</i> .....	16
<i>Wear Protection</i> .....	17
Selection of Wear Material .....	17
<i>Parameters for Selection</i> .....	17
<i>Seals</i> .....	18
<i>Critical parameters for the selection of seals</i> .....	18
<i>Shaft Seals</i> .....	18
Basic function of shaft seal .....	18
Type of leakage.....	18
Location and type of seals .....	18
Flushing seals (see diagram).....	19
Seals without flushing.....	19
Centrifugal seals .....	19
Centrifugal seal limitation (see diagram) .....	20
Dynamic seal — summary of advantages .....	20
<i>Mechanical seals</i> .....	21
Mechanical seal — only option for submersible pumps! .....	21
<i>Slurry pumps without seals — vertical designs</i> .....	22



SHAFTS AND BEARINGS.....	23
<i>Horizontal Slurry pumps</i> .....	23
<i>Pump Shafts and the SFF Factor</i> .....	23
<i>Basic on Bearings</i> .....	23
<i>Bearing Configurations</i> .....	24
Radial Loads.....	24
Axial Loads.....	24
<i>Bearing and Bearing Arrangements</i> .....	24
DRIVES .....	25
<i>Indirect drives</i> .....	25
<i>Drive Arrangements</i> .....	25
Comments on drive arrangements.....	26
<i>V-belt Transmissions (fixed speed drives)</i> .....	26
V-belt transmissions — limitations.....	26
<i>Variable Speed Drive</i> .....	27
HYDRAULIC PERFORMANCE .....	28
<i>Head and Pressure</i> .....	28
<i>Suction Head &amp; Lift</i> .....	29
Hydraulic conditions on the suction side.....	29
<i>Vapour pressure and cavitation</i> .....	30
SLURRY PUMP SYSTEMS.....	31
<i>Sump Arrangements</i> .....	31
Horizontal Sump Pump.....	31
Floor Sumps.....	32
Multiple Pump Installations.....	32
<i>Pump in Series</i> .....	32
<i>Pumps in Parallel</i> .....	32
OTHER PUMPS .....	33
<i>Diaphragm Pumps</i> .....	33
History.....	33
Design.....	33
Applications.....	34
Requirements.....	34
Features of an AODD Pump.....	35
Preserving Pump Life.....	36
Accessories.....	36
Summary.....	37
<i>Peristaltic Pumps</i> .....	37
Screw Pumps.....	38



## Introduction to Pumps

### **What is this module about?**

This unit is about how we manage and use pumps within the processing plant

### **What will you learn in this module?**

When you have completed this module, you will be able to:

- Define what a pump is
- State the types of pumps used at SDGM and identify their location
- Explain how different types of pumps work
- Identify the different configuration arrangements of pumps
- List the different components of a pump
- Troubleshoot pumping problems

### **What do you have to do to complete this unit?**

You will need to complete all the training tasks in your workbook, the review exercise and the assessment given to you by your supervisor.

Discuss the competency standards for this unit with the Training Coordinator or your supervisor.

### **What resources can you use to help?**

If you need more information about topics in this unit, then you should approach:

- Your work mates and supervisor
- The training coordinator
- Maintenance personnel





## Introduction

In all wet industrial processes "hydraulic transportation of solids" is a technology, moving the process forward between the different stages of Solid/Liquid mixing, Solid/Solid separation, Solid/Liquid separation, etc.

The types of solids that can be transported can be almost anything that is hard, coarse, heavy, abrasive, crystalline, sharp, sticky, flaky, long fibrous, frothy.

You name it - it can be transported hydraulically!

In most applications the liquid is the only "carrier". In 98% of the industrial applications the liquid is water.

The mixture of solids and liquids is normally referred to as a "slurry". Slurry can be described as a two-phase medium (liquid/solid). Slurry mixed with air (common in most chemical processes) is described as a three phase fluid medium (liquid/solid/gas).

In theory there are no limits to what can be hydraulically transported. Just look at the performance of hydraulic transportation of solids in connection with the glaciers and the big rivers. In practice the limitations in flow for slurry pump installations are from 1 m<sup>3</sup>/hr up to 20,000 m<sup>3</sup>/hr. The lower limit is determined by the dramatic increase of costs for large slurry pumps.

The limitation for solids is the geometrical shape and the risk of blocking the passage through the slurry pump. The maximum practical size of material to be mass transported in a slurry pump is approximately 200mm. However, individual lumps of material passing through a large dredge pump can be up to 350mm.



## Definitions

### What is a Pump?

Pumps are the driving force required to transport liquids through pipe work, from one place to another.

### What is a Slurry Pump?

By definition slurry pumps are heavy and robust version of a centrifugal pump, capable of handling tough and abrasive duties.

### Slurry Pump - Name by Duty

The term Slurry Pump, as stated, covers various types of heavy-duty centrifugal pumps used for hydraulic transportation of solids.

A more precise terminology is to use the classification of solids handled in various pump applications.

Slurry Pumps cover pumping of mud/clay, silt and sand in size range of solids up to 2mm.

Size ranges are:

Mud/clay	<2 microns
Silt	2 - 50 microns
Sand, fine	50 - 100 microns
Sand, medium	100 - 500 microns
Sand, coarse	500 - 2000 microns

Sand & Gravel Pumps cover pumping of, shingle and gravel in the 2 to 8mm size range.

Gravel Pumps cover pumping of solid sizes up to 50mm.

Dredge Pumps cover pumping of solid sizes up to and above 50mm.

### Slurry Pump - Name by Application

Process applications also provide the terminology, typically:

Froth Pumps define by application the handling of frothy slurries, mainly in flotation.

Carbon Transfer Pumps define the gentle hydraulic transportation of carbon in CIP (carbon in pulp) and CIL (carbon in leach) circuits.

Sump Pumps, also an established name typically operating pumps from floor sumps, submerged pump houses, but having dry bearings and drives.

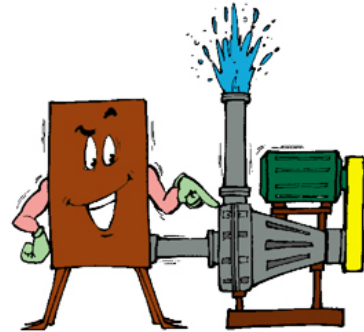


Submersible pumps the entire unit, including, drive, is submersed.

## Installation of Slurry Pumps

### Dry Installations

Most Horizontal Slurry Pumps are installed dry, where the drive and bearings are kept out of the slurry and the "wet end" is closed. The pumps are free standing, clear from the surrounding liquid.

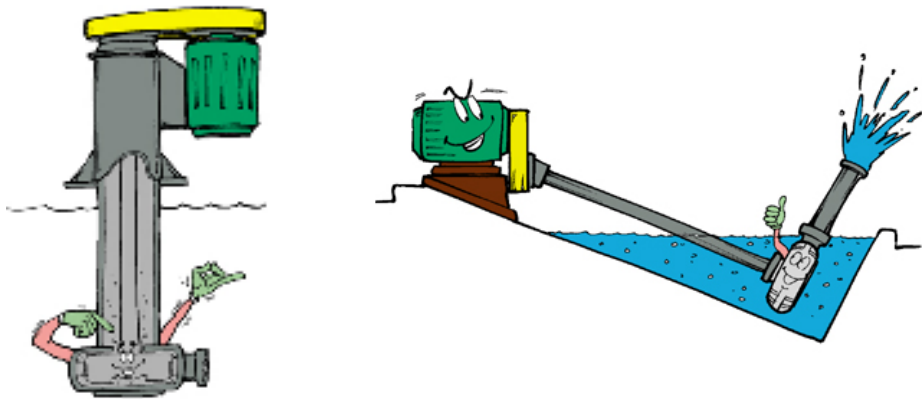


The Vertical Tank Pump has an open sump with the pump casing mounted directly to the underside of the tank. The cantilever impeller shaft, with its bearing housing and drive mounted on the tank top, rotates the impeller inside the pump casing. The slurry is fed from the tank into the "wet end" around the shaft and is discharged horizontally from the outlet. There are no shaft seals or submerged bearings in the design.

### Semi Dry Installations

A special arrangement can be used for dredging applications, where horizontal pumps are used with the "wet end" (and bearings) flooded. This calls for special sealing arrangements for the bearings.

The Sump Pump has a flooded "wet end" installed at the end of a cantilever shaft (no submerged bearings) and a dry drive



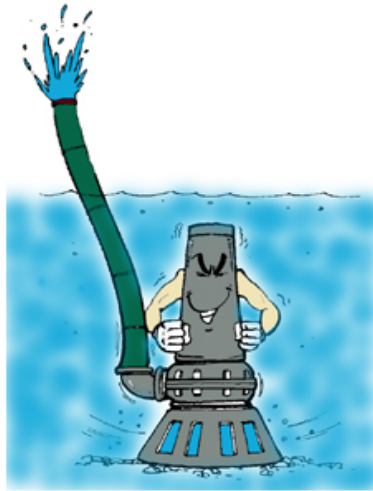
### Wet Installations

For certain slurry pump applications there is a need for a fully submersible pump.

For example, lifting slurry from a sump with largely fluctuating free slurry levels.



In this case both housing and drive are flooded requiring a special design and sealing arrangement.





## Mechanics

In Comparison with most other process equipment, A Slurry Pump is uncomplicated in design.

Despite simplicity of design there are few machines in heavy industry that work under such harsh conditions.

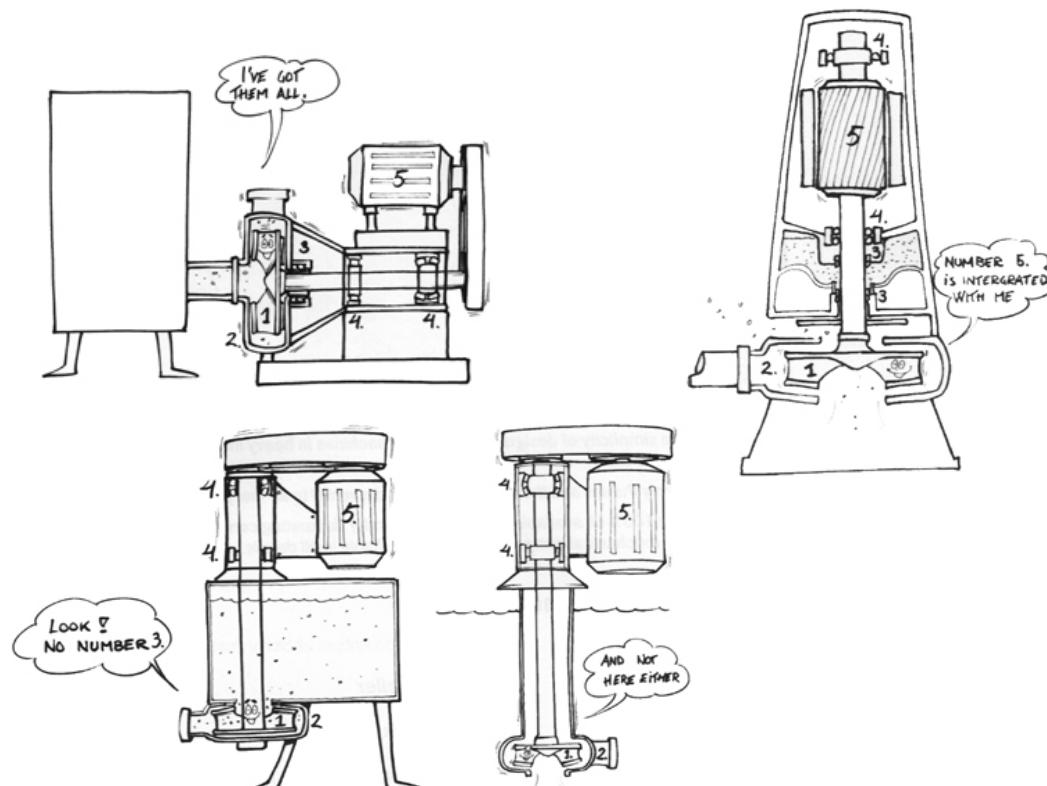
The slurry pumps and their systems are fundamental to all wet processes.

Working 100% of available operating time under fluctuating conditions of flow, solids and content, the mechanical design has to be very reliable in all details.

## Basic Components

The basic components of all Slurry Pumps are:

1. The impeller
2. The casing
3. The sealing arrangement
4. The bearing assembly
5. The drive



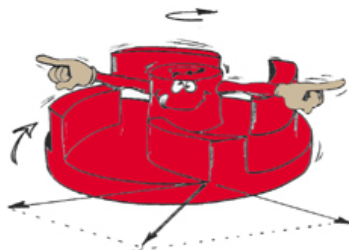


## Components

### Impeller and Casing

The pump impeller and casing are the key components of all slurry pumps. The pump performance is governed by the impeller and casing design

Other mechanical components serve to seal, support and protect this hydraulic system of impeller and casing while the design of the rest of the pump is not.



Here you can see the kinetic/hydraulic forces generated by the  
Slurry Pump impeller vanes.

### Impeller

Without understanding the function of a slurry pump impeller, we will never understand why and how a pump is designed and functions.

The impeller = an energy converter

The function of the rotating impeller is to impart kinetic energy to the slurry mass and accelerate it.

A part of this kinetic energy is subsequently converted to pressure energy before leaving the impeller.

Apart from the strict hydraulic transformation this is, in slurry itself to convey the energy by "hydraulic drag forces". These drag forces are used in a number of hydraulic machines for wet processing.

### Vanes

The impeller vanes are the heart of the impeller. The rest of the impeller design is just there to carry, protect and balance the impeller vanes during operation.

### Vane Designs

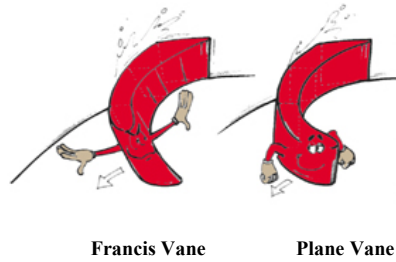
Slurry pump impellers have external and internal vanes

*External vanes.* These vanes also known as pump out or expelling vanes are shallow and located on the out side of the impeller. These vanes aid pump sealing and efficiency.



*Internal vanes.* Also known as main vanes. They actually pump the slurry.

Normally two types of vane design are used in slurry pumps, the Francis Vane or Plain Vanes.

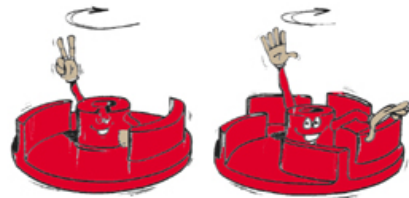


As the Francis vane is more effective in energy conversion, it is used when efficiency is of prime concern, although the advantage is less clear cut with wide slurry impellers.

The drawback of the Francis vane is that its design is more complicated to produce and also takes on more wear when pumping slurries with coarse particles. Therefore Plane vanes are used when pumping coarser particles.

**Number of Impeller Vanes**

More vanes give higher efficiency. This means that the maximum number vanes is always used whenever practical. (The exception is torque flow.)



Impellers can have two or more vanes depending on the application

Limitations are created by the vane thickness required for good wear life and need to pass a minimum particle size.

Maximum number of vanes in practice is five, which are used on metal impellers with a diameter exceeding 300mm and rubber exceeding 500mm.

Below these diameters the vane area related to the impeller area is getting critical (too large vane area, giving too much friction) and efficiency starts to drop and blocking can occur.

**Types of Impeller**

The design of the slurry pump impeller is not related to a closed or open configuration. Production aspects determine this and what type of applications the impeller will be used on.

***Closed Impellers***

Closed impellers are by nature more efficient than an open impeller, due to reduction of "short circuiting" leakage over vanes. The efficiency is less affected by wear.



*Limitations.* The closed impeller with its confined design is naturally more prone to clogging when coarse particles are encountered. The phenomenon is more critical with the smaller impellers.

### ***Open Impellers***

Open impellers are used to overcome the limitations of a closed design and depend on impeller diameter, size or structure of the solids, presence of entrained air, high viscosity, etc.

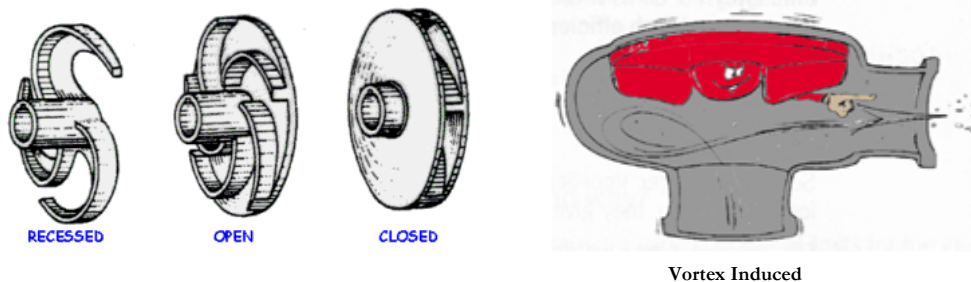
*Limitations.* The efficiency is slightly lower than for closed impellers.

### ***Vortex/Induced Flow Impellers***

Vortex/Induced flow impellers are used when impeller blockage is critical or when particles are fragile.

The impeller is pulled back in the casing. Only a limited volume of the flow is in contact with the impeller giving gentle handling of the slurry and large solids capability.

*Limitations.* The efficiency is significantly lower than for a closed or even open impeller.



### ***Basic Rules***

Closed impellers are used for slurries with coarse particles for highest efficiency and best wear life.

Open impellers are used for slurries with high viscosity, entrained air and when blockage problems can be foreseen.

Vortex/Induced Flow impellers are used for large, soft solids, stringy materials or for "gentle" handling, or fragile particles, high viscosity and entrained air.

### **Impeller Diameter**

The diameter of an impeller governs the amount of head produced at any speed.

The larger the diameter of the impeller the greater the head produced.

A large diameter impeller running very slow would produce the same head as a smaller impeller running much faster (key aspect when it comes to wear).

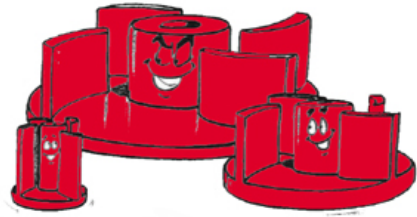




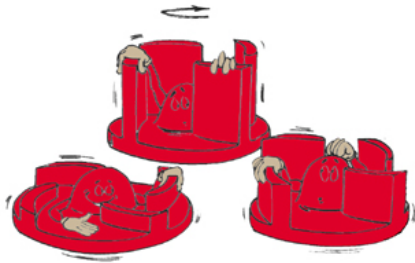
For highly abrasive duties large impellers are used giving long life and reasonable efficiencies.

Even if larger impellers are more expensive and have slightly lower efficiency, they give better pay off in highly abrasive duties.

For abrasive duties where wear is not the primary concern, smaller impellers are more economical, and offer better efficiency.



**Impeller Width**



The width of the impeller governs the flow of the pump at any speed.

A large width impeller running slowly could produce the same flow rate as a thinner impeller running faster, but most important - the velocity relative to vane and shroud would be considerable higher. (Key aspect when it comes to wear).

Compared to water pumps and depending on the "wear profile", slurry pumps normally have impellers that are not only larger but very much wider.

**Limitations in Geometry**

Naturally there are various practical limits for the geometry of slurry pump impellers.

These limits are set by:

The optimal hydraulic performance of each pump size.

The need for product standardisation

The production cost for the impeller and casing/liner.

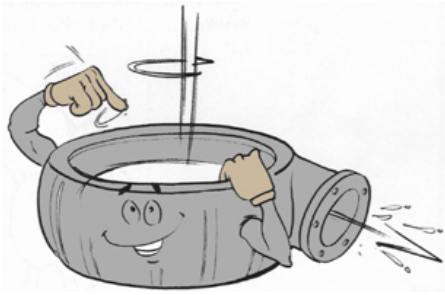
**Impeller Motion**

The motion if the impeller, contrary to popular belief, flings the particle out of the pump with convex side of the vane. The particle is not cupped by the vane and then forced out.





## Casing

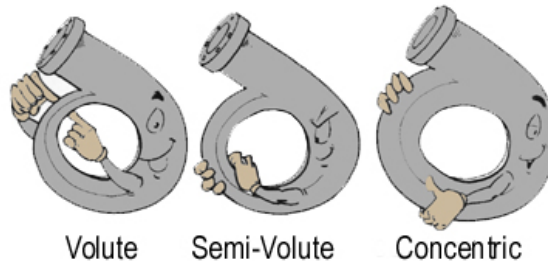


One function of the casing is to pick up the flow coming from the entire circumference of the impeller, converting it into a desirable flow pattern and directing it to the pump outlet. Another important function is to reduce the flow velocity and convert its kinetic energy to pressure energy.

The casing and the impeller are matched together to give the best flow pattern (and energy conversion) possible.

The volute form give more efficient energy conversion compared to the concentric form and around the ideal flow/head duty point it gives very low radial loads on the impeller.

Form most hard metal pumps the volute is normally one solid piece. This design is the most

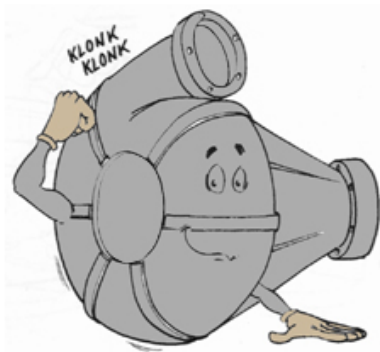


cost effective in manufacturing and there are no practical requirements for splitting the volute into two halves.

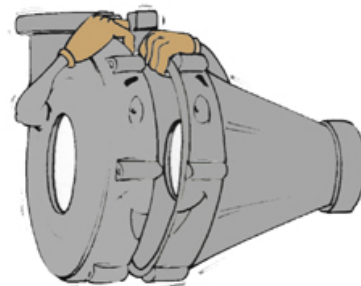
Some rubber-lined pumps also use a solid volute, especially for the smaller sizes, where it is more practical and economic to use a solid volute.

Splitting a casing adds expense to a pump and is only done when necessary.

This eases replacement of parts particularly for large rubber lines



Solid Casing



Split Casing



## Wear Protection

In a Slurry Pump the impeller and inside of the casing are always exposed to the slurry and have to be protected accordingly against wear.

Material selection for impeller and casing is just as important as the pump selection itself.

There are three different conditions that create wear in a Slurry Pump.

- Abrasion
- Erosion
- Corrosion

### Abrasion

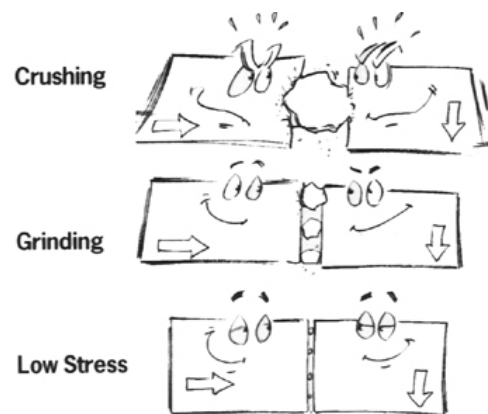
There are three major types of abrasion:

- Crushing
- Grinding
- Low Stress

In Slurry Pumps we have mainly grinding and low stress abrasion. Abrasion rate is dependent on particle size and hardness.

Abrasion only occurs in two areas in a Slurry Pump.

1. Between impeller and stationary inlet.
2. Between shaft sleeve and the stationary packing.



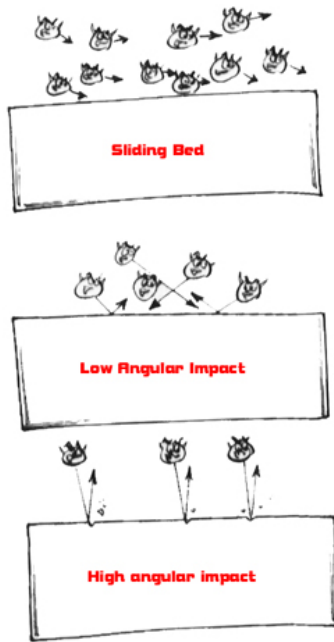
### Erosion

This is the dominant wear in Slurry Pumps. The reason is that particles in the slurry hit the material surface at different angles.

Erosion wear is heavily influenced by how the pump is operated. Erosion wears with lower as well as higher flows.

For reasons that are not well understood, erosion wear can also increase dramatically if the pump is allowed to operate on “snore”; that is, taking air into the inlet pipe.

It has been suggested that this may be caused by cavitation, due to the pump surface vibrating as the air flows over them. This is, however, difficult to accept as air bubbles generally suppress cavitation by moving to fill the vapour cavities.



There are three major types of erosion.

- Sliding Bed
- Low Angular Impact
- High Angular Impact

## Corrosion

The corrosion (and chemical attacks) of the wet parts in a slurry pump is a complex phenomena both for metal and elastomer material

## Effects of Erosion on Pump Components

### Impeller

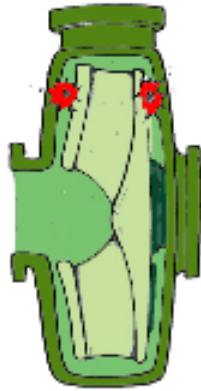
The impeller is subject to impact wear (high and low) mainly in the eye, on the gland side shroud (A), when the flow turns 90 on the leading edge of the vane (B).

Sliding bed and low angular impact occur along the vanes between the impeller shrouds (C).

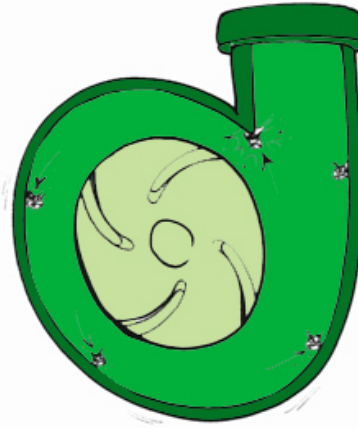
Side liners (inlet and back liners) are subject to sliding bed and crushing and grinding abrasion.

The volute is subject to impact wear on the cut water. Sliding bed and low angular impact wear occurs in the rest of the volute.





Wear on the Liner



Wear on the Volute

### **Wear Protection**

There are some major options in selecting wear protection of Slurry Pumps:

Impeller and casing in Hard Metal in various alloys of white iron and steel.

Impeller in elastomer and casing protected by elastomer liners. Elastomers are normally rubber in various qualities or polyurethane.

Combination of impeller of hard metal and elastomer-lined casings.

### **Selection of Wear Material**

The choice of wear parts is a balance between resistance to wear and cost of wear parts.

There are two strategies for resisting wear:

The wear material has to be hard to resist the cutting action of the impinging solids or the wear material has to be elastic to be able to absorb the shocks and rebound of particles!

### **Parameters for Selection**

The selection of wear parts is normally based on the following parameters:

- Solid size (solid S.G., shape and hardness)
- Slurry temperature
- pH and Chemicals
- Impeller speeds

The dominant wear materials in slurry pumps are hard metal and soft elastomers.



## Seals

If the impeller — casing designs are principally the same for all of our Slurry Pumps, this is definitely not the case when it comes to the seals for these hydraulic systems.

### Critical parameters for the selection of seals

Horizontal: Slurry leakage (flooded suction), air leakage (suction lift). Shaft deflection and inlet head

Vertical: Designed without shaft seals

Submersible: Slurry leakage, electrical connections

### Shaft Seals

Where the shaft passes into the casing leakage (air or slurry) is prevented by the use of various shaft seals

#### Basic function of shaft seal

The basic function of a shaft seal is quite simply to plug the hole in the casing where the shaft passes through, thereby restricting (if not stopping) leakage.

### Type of leakage

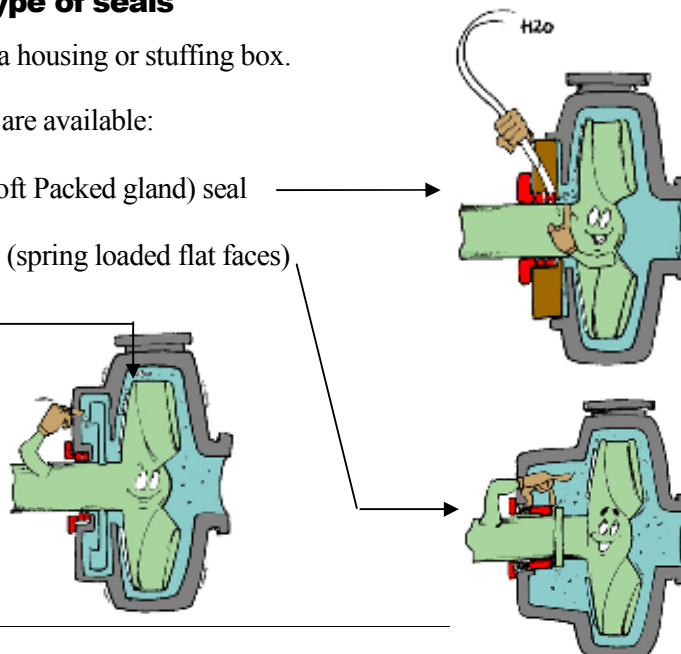
With flooded suction, leakage is generally liquid leaving the pump, where as, on a suction lift “leakage” can be air entering the pump.

### Location and type of seals

Seals are located in a housing or stuffing box.

Three basic designs are available:

- Soft Packing (Soft Packed gland) seal
- Mechanical seal (spring loaded flat faces)
- Dynamic seal



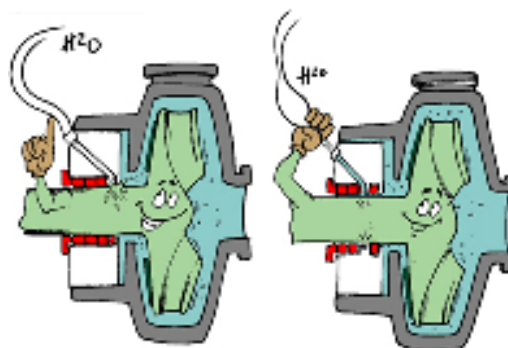


## Flushing seals

For most Slurry Pumps the flushing liquid is clear water, to provide best possible sealing life the water should be of good quality without any solid particles.

Where some slurry dilution is acceptable, soft packing seals are normally the first choice, with two options:

Full flow flushing type for the case when dilution of slurry is no problem



*Typical flushing quantities for full flow: 10 — 90 litres/min (depending of pump size)*

Low flow flushing type when dilution is a minor problem

*Typical flushing quantities for low flow: 0.5 — 10 litres/min (depending on pump size)*

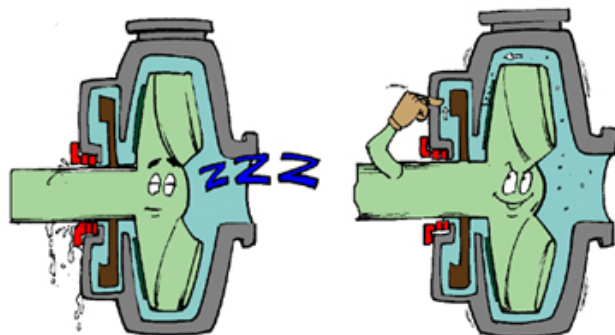
Note! The full flow soft packing alternative (when applicable) provides normally the longest “seal life” for Slurry Pumps.

Mechanical seals are also available with or without flushing. If flushing is accepted, a soft packing box should always be considered, provided external leakage is acceptable.

## Seals without flushing

In order to provide a reliable seal without flush water, *centrifugal seals (expellers)* are utilised.

### Centrifugal seals



An expeller used in conjunction with a packed stuffing box is described as a centrifugal seal.

Whilst centrifugal seals have been around for many years, it is only in recent time that design and material technology have advanced to the point where a high proportion of Slurry Pumps now supplied, incorporate an expeller.

The centrifugal seal is only effective when the pump is running.

When the pump is stationary, the shaft packing provides a conventional static seal, but using fewer packing rings than in a conventional stuffing box.



### Expeller — description

The expeller is in effect, a secondary impeller positioned behind the main impeller, housed in its own seal chamber, close to the main pump casing.

Operating in series with the impeller back shroud pump out vanes, the expeller prevents the liquid from leaking out of the stuffing box, ensuring a dry seal.

“This dry seal is achieved because the total pressure produced by the pump out vanes and the expeller, is greater than the pressure produced by the main pumping vanes of the impeller plus the inlet head.

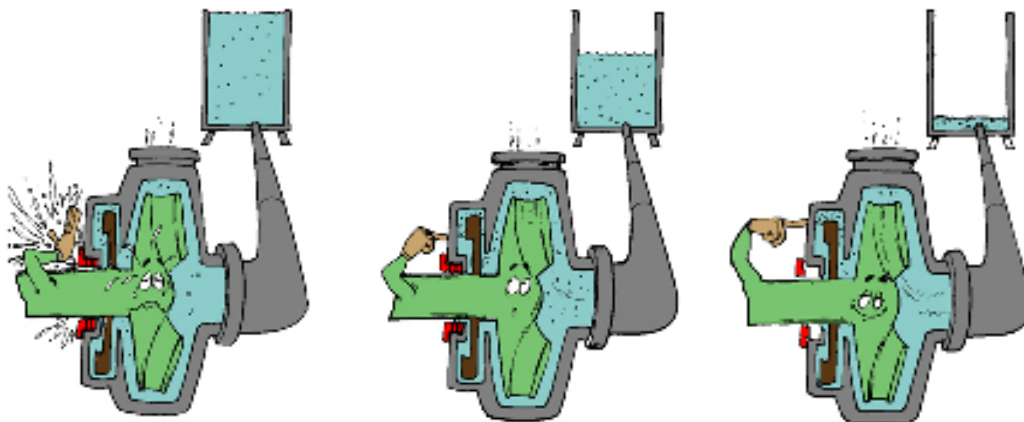
Stuffing box pressure, with a centrifugal seal, is therefore reduced to atmospheric pressure.

### Centrifugal seal limitation

All centrifugal seals are limited in the amount of inlet head they can accept in relation to the rated pump head.

The limit for acceptable inlet head is, in the first instance, set by the ratio of expeller diameter to impeller main vane diameter.

Varying from design to design, most expellers will seal providing the inlet head does not exceed 10 % of the rated discharge head for standard impellers.



### Dynamic seal — summary of advantages

- “No flush water required”
- “No dilution by flush water”
- “Reduced maintenance of packings”
- “Zero gland leakage during operation”





## Mechanical seals

Mechanical seals without flushing are a concept, which must be considered in, cased where dynamic expeller seals are not possible (see limitation above).

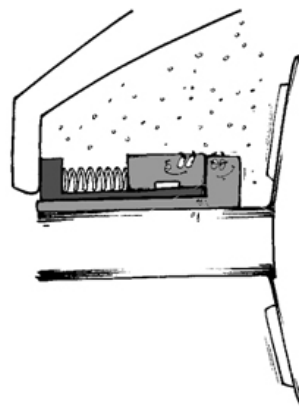
These seals are high precision, water lubricated, water-cooled seals running with such tolerances that slurry particles cannot penetrate the sealing surfaces and destroy them.

Mechanical seals are very sensitive to shaft deflection and vibrations. A rigid shaft and bearing arrangement is crucial for successful operation.

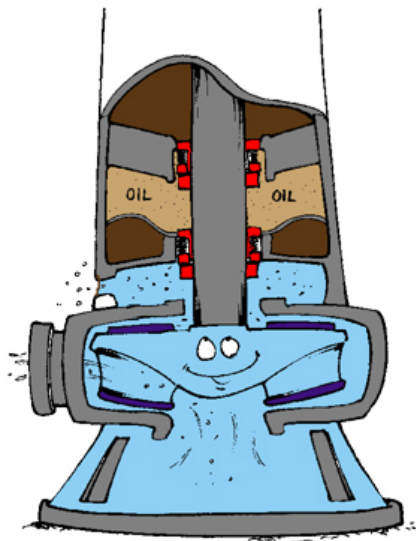
If the mechanical seal is not submerged in liquid, a friction between the sealing surfaces will generate heat, causing the faces to fail within seconds. This can happen if the impeller pump out vanes are too effective.

However, the largest drawback is the cost, which is very high.

The development work for more cost effective and reliable mechanical seals are ongoing and this type of seal will be more frequent as time goes by.



### Mechanical seal — only option for submersible pumps!



When sealing the bearings of an electrical motor in a submersible pump there are no alternatives to mechanical seals. The sealing arrangement consists of two independent mechanical seals, running in oil.

At the impeller side the sealing surfaces are tungsten carbide against tungsten carbide and on the motor side carbon against ceramic.

Note! On these pumps there is also a small expelling disc attached to the shaft behind the impeller to protect the seals.

This is not an expeller as described for the horizontal pumps!

It is more of a flinger or mechanical protection disc, preventing particles from the slurry damaging lower mechanical seals.

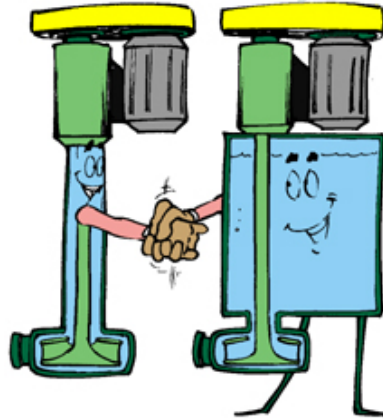


### **Slurry pumps without seals — vertical designs**

The two main reasons for development of the vertical slurry pumps were:

To utilise dry motors, protected from flooding

To eliminate sealing problems





## Shafts and Bearings

### Horizontal Slurry pumps

Impellers are supported on a shaft, which is in turn carried on anti friction bearings.

Bearings are generally oil or grease lubricated.

In our slurry pumps the impeller is always mounted at the end of the shaft (overhang design).

Drive to the shaft is normally via belts and pulleys or a flexible coupling (with or without a gearbox).

### Pump Shafts and the SFF Factor

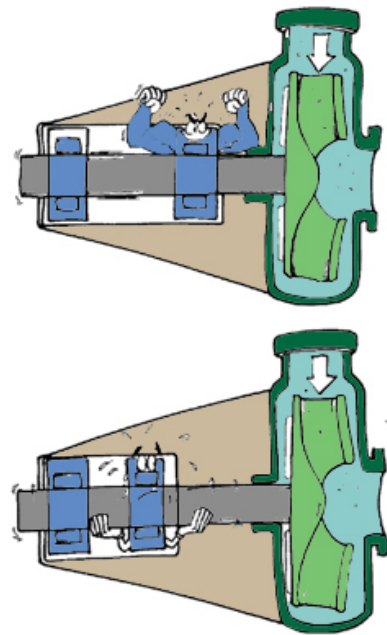
As the impellers of slurry pumps are subject to higher loads than the clean water pumps, it is essential that the shaft is of robust design.

The shaft flexibility factor (SFF) relates to the shaft diameter at the shaft seal  $D(\text{mm})$ , to the cantilevered length (from the wet end bearing to the impeller centre line)  $L(\text{mm})$  and is defined as  $L^3/D^4$ . This is a measure of the susceptibility to deflection (which is critical to the shaft sealing and bearing life).

Typical SFF values for horizontal pumps are 0.2-0.75

Clean liquid SFF values are typically 1-5.

Note! The shaft deflection occurs both horizontal and vertical slurry pumps although the longer — the “overhang” the greater the deflection for the same radial load!



### Basic on Bearings

The life calculated of a bearing is the  $L_{10}$  life. This is the number of hours in which 10% of the bearings operating under the conditions would be expected to fail.

The average life is approximately four times the  $L_{10}$  life.

Bearings will, of course fail much sooner if contaminated by solids.



## Bearing Configurations

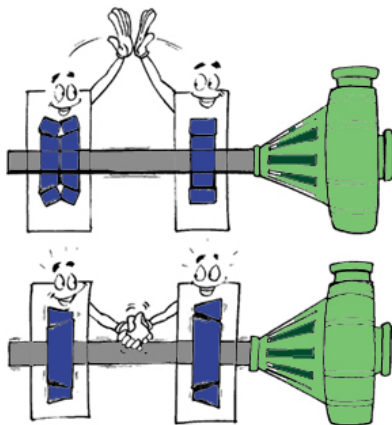
### Radial Loads

On duties where low flow rates at high heads are encountered, impeller radial loads are high and double wet end bearing arrangements are utilised to give an  $L_{10}$  bearing life in excess of 40,000 hours

### Axial Loads

On duties such as multistage series pumping where each pump immediately follows the other (i.e. pumps are not spaced down the line), high axial loads are encountered due to high inlet heads in the second and subsequent stages. To meet the minimum bearing life requirement double dry end bearings may be required.

## Bearing and Bearing Arrangements



In a slurry pump we have both radial and axial forces affecting the shaft and bearings.

Selection of bearings follows two schools of thought:

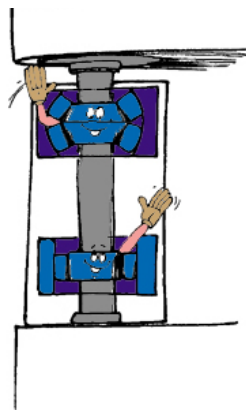
The first arrangement with a bearing at the wet end taking up radial forces only and a bearing at the drive end taking both axial and radial forces.

The second arrangement using taper roller bearings in both positions taking axial and radial loads in both positions.

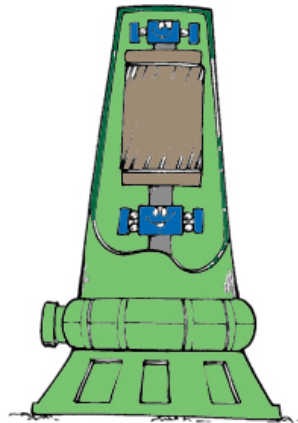
In the vertical design where the cantilever is extremely long the first bearing arrangement is used.

In the submersible pumps "greased for life" bearings are used in all positions, giving a compact and reliable design.

Vertical pump bearing arrangement



Submersible pump bearing arrangement



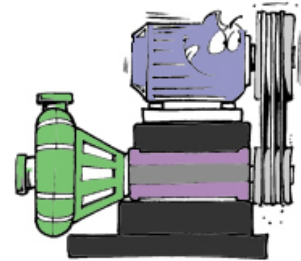


## Drives

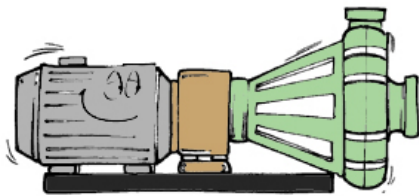
There are two basic drive designs for Slurry Pumps:

1. Indirect drives used for horizontal and vertical pumps, comprising motor (in various drive arrangements) and transmission (V-belt/Polybelt or gearbox).

This concept gives freedom to select low cost (4-pole) motors and drive components according to local industry standard. Good flexibility is also provided for altering the pump performance by a simple speed change.



2. Direct drives are always used in submersible pumps and where application dictates on horizontal and vertical pumps.



This drive concept being an integral part of the pump gives restrictions both in supply of components and adjusting pump performance.

### Indirect drives

By far the most common drive is the squirrel cage induction motor, which is economical, reliable and produced worldwide.

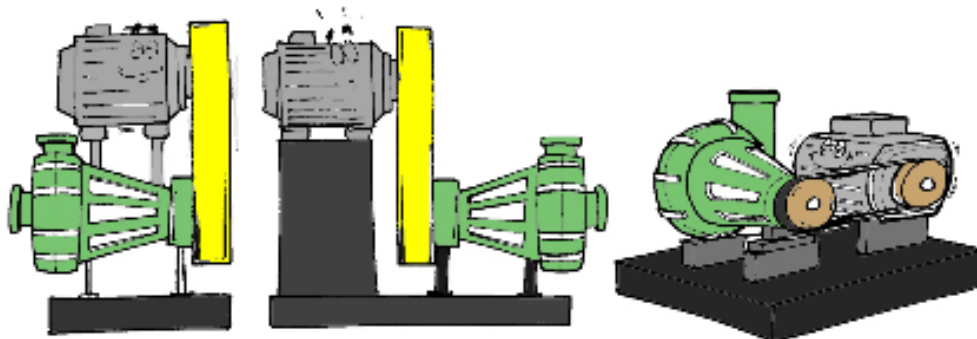
The practice in sizing pump motors is to have a minimum service factor above the calculated absorbed power of 15%.

The margin allows for uncertainties in the duty calculations and duty modifications at a later date.

With V-Belt drives it is normal to select four pole motors, as this provides the most economical drive arrangement.

### Drive Arrangements

There are several drive arrangements available for electric motors with belt drives, i.e. overhead, reverse overhead and side mounted.





**Comments on drive arrangements**

The most common drive arrangements are the side and overhead mounted motors. Overhead mounting is generally the most economical and lifts the motor off the floor away from spillage.

If the pump is of the “pull out method” design and assembled on a “sliding maintenance base”, servicing can be drastically simplified.

*Limitations overhead mounted:*

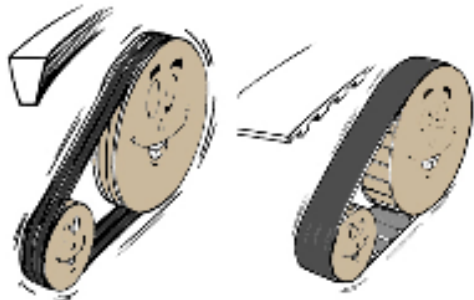
The size of the motor is limited by the size of the pump frame.

If the overhead mounting cannot be used, use side mounted motors (with slide rails for belt tensioning)

**V-belt Transmissions (fixed speed drives)**

Slurry Pump impeller diameters (hard metal or elastomers) cannot easily be altered so for a change in performance a speed change is necessary. This is normally done with a V-belt drive. By changing one or both pulleys the pump can be “fined tuned” to achieve the duty point even when applications are changed.

Provided the belts are tensioned correctly, modern V-belts drive are extremely reliable with a life expectancy of 40,000 hours and a power loss of less than 2%.



**V-belt transmissions — limitations**

When pump speed is too low (dredge pumping) or when the power is too high, V-belts are not suitable.

In these cases gearboxes or gear belts must be used.

The gear belt drives are becoming more and more popular, giving the dynamic flexibility of a V-belt drive in combination with lower tension.



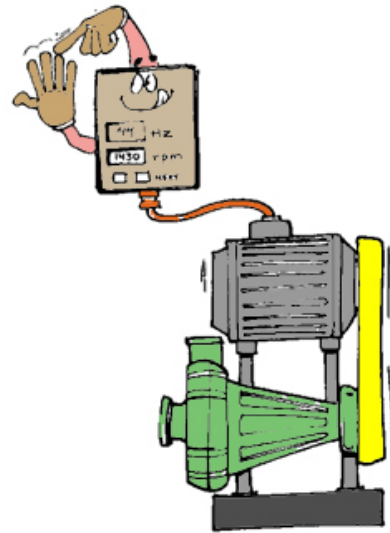
## Variable Speed Drive

For certain applications (varying flow conditions, long pipe lines, etc.) variable speed drives should be used.

With variable speed drives tying the speed to a flow meter can closely control the flow of a centrifugal pump. Changes in concentration or particle size have a minimal effect on flow rate.

Should a pipeline start to block, the speed will increase to keep flow velocity constant and help prevent blockage.

Modern electronic drives, particularly variable frequency drives have many advantages (can be used with standard motors) and are widely used.





## Hydraulic Performance

To really understand a Slurry Pump and its system, it is essential to have a basic understanding of the performance of a, slurry pump and how it works together with the piping system of the installation.

The hydraulic performance of a slurry pump is dependent on two equally important hydraulic considerations.

1. The hydraulic conditions within the slurry pump and the system it is feeding covering:

“performance of the slurry pump (outlet head and capacity)”

“discharge piping and slurry system (friction losses)”

“slurry effects on pump performance”

2. The hydraulic conditions on the inlet side of the pump covering:

“slurry inlet head or lift — positive or negative”

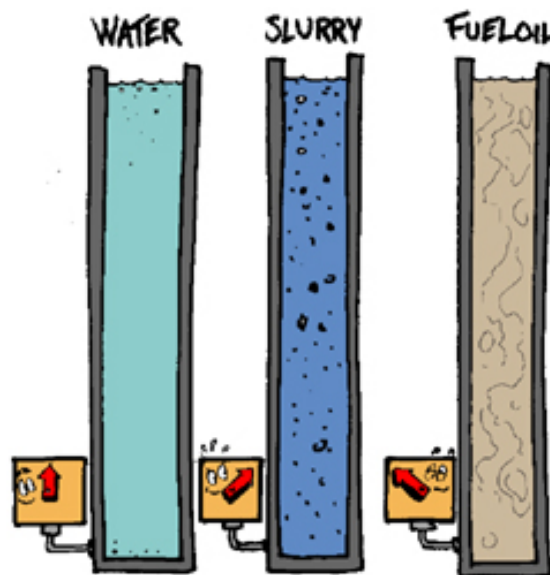
“barometric pressure (depending on altitude and climate)”

“inlet piping (friction losses)”

“slurry temperatures (affecting vapour pressure of slurry)”

## Head and Pressure

It is important to understand the difference between head and pressure when it comes to performance of a slurry pump. “Centrifugal pumps generate head not pressure”!!







*Example*

For a pump producing 51.0 metres of head of water, the gauge pressure would be 5.0 bar.

On a heavy slurry of S.G. 1.5, the 51.0 metres would show a gauge reading of 7.5 bar.

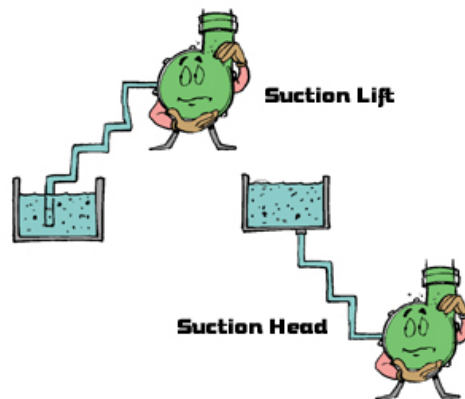
On a light fuel oil duty of S.G. 0.75, the 51.0 metres would show a gauge reading of 3.75 bar.

Note!: for the same head, gauge reading and required pump power will vary with S.G.

**Suction Head & Lift**

A Suction Head exists when the liquid is taken from an open to atmosphere tank where the liquid level is above the centerline of the pump suction, commonly known as a Flooded Suction.

A Suction Lift exists when the liquid is taken from an open to atmosphere tank where the liquid level is below the centerline of the pump suction.



**Hydraulic conditions on the suction side**

To ensure that a slurry pump performs satisfactorily, the liquid must be at all times be above the vapour pressure inside the pump.

This is achieved by having sufficient pressure on the suction (inlet) side of the pump.

This required pressure is called:

Net Positive Suction Head, referred to as NPSH

Should the inlet pressure for any reason be too low, the pressure in the pump inlet would decrease down to the lowest possible pressure of the pumped liquid, the vapour pressure.



## Vapour pressure and cavitation

When vapour pressure is reached vapour bubbles start to form following the liquid through the impeller to locations with higher pressure.

In these locations the vapour bubbles will collapse (by implosions) giving extremely high, but also extremely local pressures (up to 10,000 bar).

These mini implosions are called cavitation. If the cavitation increase, the amounts of vapour bubbles will severely restrict the available cross sectional flow area and it can actually vapour lock the pump, thus preventing liquid from passing the impeller.

When the vapour bubbles move through the impeller to a higher-pressure region, they collapse with such a force that mechanical damage can occur.

Mild cavitation may produce a little more than a reduction in efficiency and moderate wear. Severe cavitation will result in excessive noise, vibration and damage. (see diagram)

Cavitation is not, as is sometimes stated, due to air in the liquid, but is the liquid boiling at ambient temperature, due to the reduction in pressure. At sea level atmospheric pressure is 1 bar and water boils at 100C. At an altitude of 2800m atmospheric pressure reduces to 0.72 bar and water boils at 92C.

A major effect of cavitation is a marked drop in efficiency, caused by a drop-off in capacity and head.





## Slurry Pump Systems

Installed in a piping system a slurry pump must be rated against both the static head, and delivery pressure and all friction losses to be able to provide the required flow rate.

If the slurry pumping system resistance is overestimated the slurry pump will:

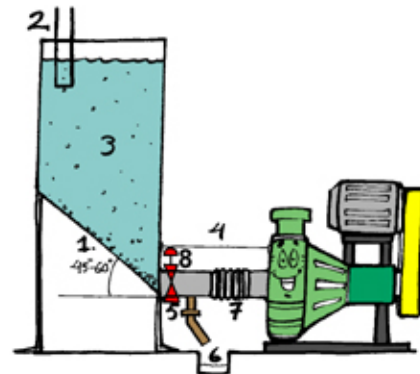
- Give greater flow when required
- Absorb more power than expected
- Run the risk of overloading the motor
- Cavitate on poor suction conditions
- Suffer from higher wear than expected
- Suffer gland problems

## Sump Arrangements

Below are some guidelines for the design of pump sumps for slurries:

### Horizontal Sump Pump

1. Sump bottom should have an angle of at least 45°. Fast settling particles may need up to 60°.
2. Sump feed should be below the liquid surface to avoid air entrainment.
3. Sump volume should be as small as possible. Sizing parameter is retention time for slurry; down to 15 seconds for coarse particles and up to 2 minutes for fine particles.
4. Sump connection to the slurry pump should be as short as possible. As a basic rule it should be 5 x pipe diameter in length and have the same size as the pump inlet. Pipe lengths longer than 10 x pipe diameter should be avoided.
5. Drain connection on the inlet pipe.
6. Flexible inlet connection that is reinforced since vacuum can be created.
7. Full bore shut off valve.





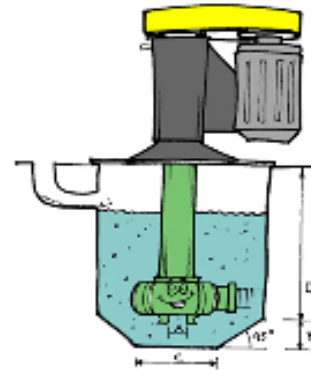
**Floor Sumps**

Sump volume as small as possible (to avoid sedimentation)

Sump depth from pump inlet (B) to be two times the pump inlet diameter (A)

Sump bottom (flat section C) to be 4-5 times the pump inlet diameter (A). 45 degrees slope to sump walls.

Sump depth — (D) should be selected considering required retention time and the necessary standard pump lower frame length to suit this depth.



**Multiple Pump Installations**

There are two cases when we need multiple installations of slurry pumps.

“When the head is too high for a single pump”

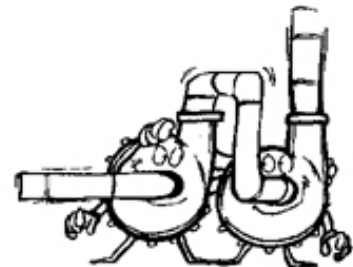
“When the flow is too great for a single pump”

**Pump in Series**

When the required head is not achieved with a single pump, two (or more) pumps can be operated in series.

For two pumps in series the discharge from the first stage pump is connected directly to the second pump, effectively doubling the head produced.

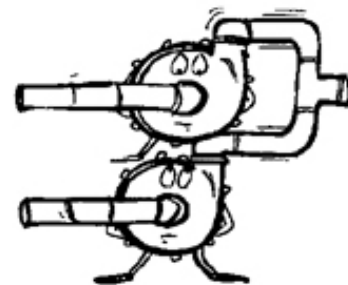
For two identical pump in series, the system will have the same efficiency as the individual pumps.



**Pumps in Parallel**

When the required flow is not achievable with a single pump, two (or more) pumps can be operated in parallel.

For two pumps in parallel the discharge from both pumps is connected to the same line.





## Other Pumps

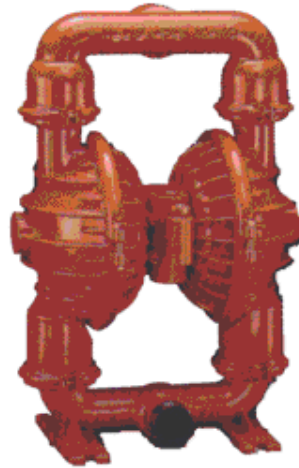
Other pumps used at SDGM are of the Positive Displacement type. The ones used are:

- Diaphragm Pumps
- Screw Pumps
- Peristaltic pumps

By definition, PD pumps displace a known quantity of liquid with each revolution of the pumping elements (i.e., gears, rotors, screws, vanes). PD pumps displace liquid by creating a space between the pumping elements and trapping liquid in the space. The rotation of the pumping elements then reduces the size of the space and moves the liquid out of the pump.

### Diaphragm Pumps

Once known as a pump of last resort, Air-Operated Double Diaphragm (AODD) pumps, commonly referred to as air pumps or diaphragm pumps, are today's "pump of choice" in many applications. They can be used in a wide variety of process, transfer and circulation pumping requirements, will pump virtually any fluid, including very thick materials, and a variety of features make them cost-effective to operate and maintain. In addition, air valve improvements that feature anti-stalling, non-icing and lube-free technology have all but eliminated the reliability problems that traditionally frustrated AODD pump operators and maintenance technicians. This versatility and durability makes the air pump one of the most useful tools available for industry today.



### History

The AODD pump was designed more than 40 years ago as a pump for dewatering applications in the construction industry. It was built out of aluminum with neoprene elastomers to dewater slime, sludge and mud from drilling and digging sites. With the invention of more reliable air valve systems, more versatile construction materials, more durable elastomers and numerous accessories, applications for AODD pumps have evolved.

### Design

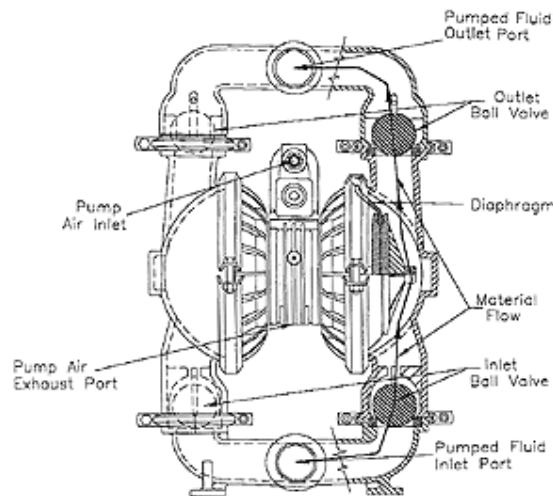
The AODD pump has two flexible diaphragms mounted vertically, sealed around the water chamber perimeter and connected with a common shaft (see diagram). The fluids transfer through a ported manifold. Either a suction stroke or a discharge stroke is used in conjunction with check balls to obtain a reciprocating movement. Compressed air is valved alternately behind one diaphragm and then the other for suction and discharge of the product to create one pump cycle. The cubic feet per minute (cfm) psi of air used and the viscosity of the



product control pump cycles. This positive displacement pump can obtain a one to one ratio of volume of material being drawn to that pumped.

### Applications

Today, in addition to dewatering applications, AODD pumps are used in a wide variety of industries to pump materials such as paint, harsh chemicals, food products, glues, inks, beer and wine, oils, lubricants and resins. Thanks to the inventions of materials of construction—as well as new innovations in diaphragms and check valve materials—the pump can comfortably process almost any fluid under 100,000 SSU. Typical construction materials include aluminium, cast iron, stainless steel, Hastelloy®, polypropylene, PVDF Kynar® and Teflon®. Elastomers are available in neoprene, Buna N, Nordel®, Viton®, thermoplastics



and Teflon®. By a specific matching of the materials, one can apply the pump to move fine wine or caustic soda and many fluids within the pH levels of 0—14.

### Requirements

If your pumping requirements fall within the following parameters, an AODD pump may perform as well or better than other types of positive displacement pumps.

- Flow — The AODD pump can have infinite flow ranges up to about 275 gpm as a maximum; the minimum can be less than a gallon per minute.
- Total Dynamic Head (TDH) — The AODD pump can handle a distance of about 250' of head in a system. With proper placement and sequencing of pumps in line, this distance can be increased.
- Maximum particle size pumped — Due to the design of a ball or flap valve pump; the maximum solids handling is 3" in diameter with some pumps.
- Suction inlet pressure — AODD pumps cannot exceed between 10 and 15 psi inlet pressure, depending on the type of elastomer. A Teflon® diaphragm will be more sensitive.



- Pressures — Originally designed as a 1:1 ratio pump—100 psi air inlet will equal 100 psi discharge pressure at the discharge outlet of the pump—AODD pumps can now provide a 2:1 and even 3:1 ratio for pressures to exceed 300 psi.
- Temperature — AODD pumps will tolerate 212°F for the outer shell or wetted section of the pump. Elastomers can handle up to 350°F in intermittent duty.

### **Features of an AODD Pump**

Several features exclusive to AODD pumps make them easy and relatively inexpensive to maintain. The AODD pump:

- can run dry indefinitely without damaging costly internal wear parts or burning up an expensive motor.
- has no seals or packing glands. This pump is sealless; therefore, the need to replace costly seals is not a factor.
- has infinite variable flow and discharge pressures. Consequently, one pump can do the job of many simply by controlling the air pressure or valves on the discharge side of the pump.
- can be deadheaded or will stop if the pump discharge clogs without damage to the pump. This allows for error within the pumping system. If the system is designed to shut down the pump when certain pressures are achieved (like a filter press application), no harm is done to the pump.
- can be operated submerged. If the material of the pump is compatible with the material it is pumping (and the exhaust is ported out of the liquid) this pump can be submerged like many sump pumps.
- is self-priming. The pump can start up on a dry or wet prime and maintains prime because of its design. This characteristic works well in suction lift requirements.
- can handle pressures of 125 psi inlet air (9 Bar). This enables the pump to handle an inlet pressure greater than typical “plant air” capabilities.
- does not have any close-fit, sliding or rotating parts. Because there is less to go wrong, an AODD pump is ideal for difficult industrial applications.
- is designed for quick assembly and disassembly. This makes the AODD one of the simplest types of pumps to tear down and rebuild. • is very portable. Small and lightweight, the pump can be placed on dollies or hand-portable carts and is easily carried from job to job.
- requires low maintenance. With good application and proper preventative measures, this pump can require little attention.
- is shear-sensitive. By design, these pumps handle high shear materials such as paints and foods with care, providing a good positive displacement.



- is effective on viscous material. If it pours, the AODD can pump it. Proper placement and materials of construction will increase the ability of this pump to handle very viscous materials.
- is available spark free. Because the power source is air, not electricity, it can pump highly volatile fluids, with proper placement and grounding.

With the invention of more reliable air distribution systems, the AODD pump has become a pump of choice in the 90s compared to the old standard, if nothing else works.

### **Preserving Pump Life**

Like all pieces of equipment, “an ounce of prevention is worth a pound of cure.” This holds true with the AODD pump as well. Here are some tips in maximising the life span of an AODD pump.

Proper installation will prevent many headaches (see diagram).

Flexible hose connections will lower pulsation and, if necessary, a pulsation dampener or standpipe can be installed to reduce product surge.

Air line size, length and condition is critical to pump operations. For example, most manufacturers prefer an air line diameter of at least ½”. Volumetric air pressure is as important to the pump as psi.

Filter, regulator and lubricator units will aid in the operation of the pump. A filter is most critical and a combination of a regulator/lubricator will be a convenience for the operator. This accessory should be placed as close to the air inlet of the pump as possible.

If the pump needs lubrication, the amount and type are critical. Consult your manufacturer for guidelines.

Avoid excess air pressure, particularly in the start-up mode. All too often, too much air pressure is introduced to the pump, causing premature diaphragm failure and inefficient pumping. Air pressure and oil do not fall under the category of “more is better.”

Periodically check and tighten the pump’s bolts. Routine tightening will aid in reducing leaks and problems with the pump and its performance.

Excess product inlet pressure can be controlled with pump placement or accumulators and valves.

### **Accessories**

Many items have been developed recently to make the AODD pump more desirable for process applications. All of the following items will make the AODD unit a more efficient piece of equipment.

Pulsation dampeners curtail the naturally inherent pulsations of an AODD pump. The units are effective on the discharge side of the pump and, in some cases, must be installed on the suction side.





Solenoid valves and electronic control devices are designed to regulate the amount of air introduced into the pump through a PLC panel or computer. The need to control the pump in a process application necessitates the addition of this accessory. Many options are available today for these controls and you can consult the pump manufacturer for advice on which device works best for your job.

Leak detection systems are available for customers pumping expensive products or highly hazardous materials. These systems are designed to turn off the pump when a diaphragm ruptures and a leak is detected, thus preventing waste or emission of the material into the environment. Many manufacturers produce these systems. Some brands can also turn on another pump. This will enable the process to continue uninterrupted.

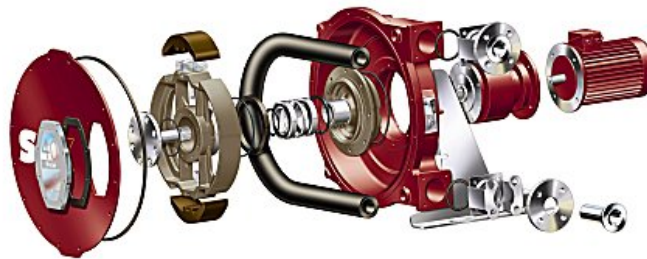
Float control switches work in cooperation with a solenoid valve to turn a pump on and off in a liquid level concern (typical in sump applications).

Filters, regulators and lubricators will help control the air quality and extend the pump's operating life.

### **Summary**

The Air Operated Double Diaphragm pump has come a long way from the early days of pumping driller's mud. When properly installed and maintained, the AODD pump can be the pump of choice for the job.

### **Peristaltic Pumps**



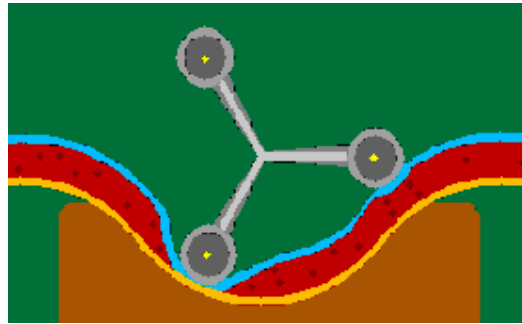
A composite reinforced hose is enclosed within a casing that is flanged at both ends. The flanges are connected to the suction and discharge lines of the system.

Within the casing is a rotor with two pressing shoes at opposite points about its centre line and mounted on a shaft with two bearings. As the rotor rotates, the hose is totally compressed by the shoes and the product contained within the hose is pushed forward.

At the front of the pump is a removable cover with inspection window and level indicator. The pump casing is filled to approximately the half way level with specially compounded (food grade) lubricant which also functions as a coolant. The patented hose is constructed from rubber laminations with patented internal reinforcement, which ensures that compression forces are evenly applied across its full width.



The enormous restitution ability of the hose means the hose can immediately recover to its normal size after each shoe has passed, drawing in more fluid ready for the next cycle.



Action of a PD pump

### Screw Pumps

Screw pumps carry fluid in the spaces between the screw threads. The fluid is displaced axially as the screws mesh.

Single screw pumps are commonly called progressive cavity pumps. They have a rotor with external threads and a stator with internal threads. The rotor threads are eccentric to the axis of rotation.

Multiple screw pumps have multiple external screw threads. These pumps may be timed or untimed.

