Slurry Pump Basic

Basic guidelines in slurry pumping
Introducing the pump sizing
software - Metso PumpDim™
for Windows™

SLURRY PUMP BASIC

WEAR PROTECTION

SEALS

SHAFTS AND BEARINGS

DRIVES FOR SLURRY PUMPS

HYDRAULIC PERFORMANCE

TECHNICAL DESCRIPTIONS

APPLICATION GUIDE

SIZING

INTRODUCTION TO METSO PumpDim™

MISCELLANEOUS

CHEMICAL RESISTANCE TABLES

PRIVATE NOTES

HISTORY

Slurry pumps – history

Whilst Denver and Sala, later forming business area Pumps & Process within the Svedala Group (which in September 2001 became Metso), were both very active in slurry pumping, they did not originally offer their own pump designs.

Both companies started as mineral process equipment manufacturers. Denver concentrating on flotation as the key product and Sala offering both flotation and magnetic separation as their major products.

Following a period of success with mineral processing equipment, it soon became very obvious that there was an urgent need to become active in the supply of slurry pumps.

The first vertical pump, manufactured 1933.

Horizontal slurry pumps

Slurry pumping, being the foundation of all wet mineral processing, was becoming more and more important to customers of both Denver and Sala.

Denver's answer was to take on a licence for the Allis Chalmers design of the SRL (**S**oft **R**ubber **L**ined) slurry pump.

The developed version of this pump was the foundation for Denver's slurry pump programme for many decades and is still considered by many to be an industry standard.

In 1984 Denver acquired the Orion hard metal slurry pump range, which, in parallel with the SRL, has been developed over the years; both designs complementing each other.

The acquisition of Thomas Foundries in 1989 added a range of very large dredge and aggregate hard metal pumps to the Denver programme.

In Sala's case the situation was similar. Sala's customers continued to request that slurry pumps should be supplied together with mineral processing equipment, thus providing for the first time, a complete package.

The licence agreement - signed by Sala was for an English design, the Vac-seal slurry pump.

In the early 60's Sala developed a new range of medium duty slurry pumps. This range known as VASA (Vac seal - Sala) was in the late 70's complemented with the heavy duty version VASA HD.

Vertical froth pumps

The use of flotation as a mineral separation method required a further development of slurry pumps.

As early as 1933, a vertical "open pump" was developed in a Swedish flotation plant. This design was necessary due to the often very complicated circuits that existed in these plants.

The reagents and level control technology were not particularly advanced. Variations of froth flow in different parts of the circuit caused air blockages with conventional slurry pumps.

For the first time, the "open pump" with its integral feed tank provided de-aeration, stability and self regulation; properties, which these days are taken for granted.

Vertical sump and tank pumps

As many plant floors were flooded, customers also tried to develop a pump concept able to cope with the work of keeping the plant floor clean of slurry. Accordingly, the "sump pump" was developed.

The birth of the first operational sump pump for these clean up purposes was in the mid 40's, again designed specifically to meet a need.

Both the vertical tank pump and the vertical sump pump were developed within the Boliden Mining Company throughout the 40's. Sala was a regular supplier of these pumps to Boliden on a subcontract basis, until 1950 when Sala signed an agreement to start production under licence.

These pump lines were then successfully marketed by Sala together with the VASA programme.

Throughout the years these vertical pumps have been further developed and established as a Sala product. The licence agreement ended in the early 70's when Boliden acquired Sala. In addition to the vertical tank pump, a special froth pump has since been developed, further refining the basic froth handling concept.

Metso's sump pump is today a world-wide industry standard for sump pumping.

When Svedala Pumps & Process was formed in 1992, it was decided to streamline and update all pump ranges, in order to better serve the market with "state of the art" slurry pumps.

In September 2001 Svedala was acquired by the Finnish company Metso.

A totally new Slurry Pump range for both horizontal and vertical pumps has since then been developed, and is covered by this handbook.

INTRODUCTION

Hydraulic transportation of solids

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.

These wet industrial processes are further described in section 15.

What type of solids?

Solids 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 !

What type of liquids?

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

Other types of liquids may be chemical solutions like acids and caustics, alcohol, light petroleum liquids (kerosene), etc.

Definition of a slurry

The mixture of solids and liquids is normally referred to as a "slurry"!

A slurry can be described as a two phase medium (liquid/solid).

Slurry mixed with air (common in many chemical processes) is described as a three phase fluid medium (liquid/solid/gas).

What are the limitations in flow?

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 a slurry pump installation are from **1 m³/hour** up to **20 000 m³/hour.**

The lower limit is determined by the efficiency drop for smaller pumps.

The higher limit is determined by the dramatic increase of costs for large slurry pumps (compared with multiple pump installations).

What are the limitations for solids?

The limitation for the solids is the geometrical shape and size and the risk of blocking the passage through a slurry pump.

The maximum practical **size** of material to be mass transported in a slurry pump is approximately **200 mm.**

However, individual lumps of material passing through a large dredge pump can be up to **350 mm** (depending on the dimensioning of the wet end).

Slurry pumps as a market concept

Of all centrifugal pumps installed in the process industry, the ratio between slurry and other pumps for liquid is **5 : 95**

If we look at the operating costs for these pumps, the ratio is nearly the opposite **80 : 20**

This gives a very special profile to slurry pumping and the market concept has been formulated as follows:

"Install a pump on clean liquid and forget about it"!

"Install a pump on slurry and you have a service potential for the rest of its life"!

This is valid both for the end user and the supplier.

The aim of this handbook is to give guidance in the sizing and selection procedure for various slurry pump applications in order to minimise costs for hydraulic transportation of solids!

BASIC DEFINITIONS

Why slurry pumps?

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

"Slurry pump should also be considered as a generic term, to distinguish it from other centrifugal
pumps mainly intended for clear liquids".

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 the various pump applications.

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

Size ranges are:
Mud/clay minus 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 2-8 mm size range

Gravel pumps cover pumping of solid sizes up to 50 mm

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 for pumps operating from floor sumps, submerged pump houses, but having dry bearings and drives.

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

Slurry pump – dry or semi dry?

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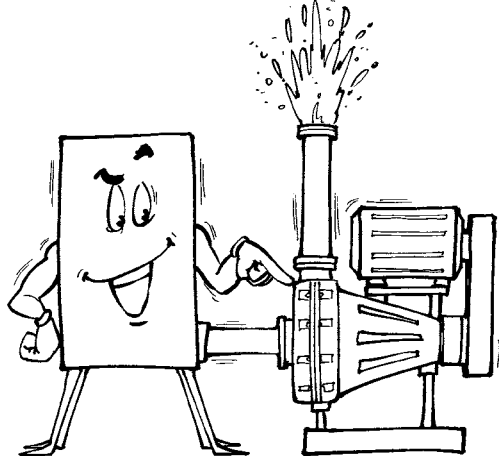
The vertical tank pump has an open sump with the pump casing mounted directly to the underside of the tank. The cantilever impeller shaft, with its bearing housing and drive mounted on the tank top, rotates the impeller inside the pump casing. The slurry is fed from the tank into the "wet end" around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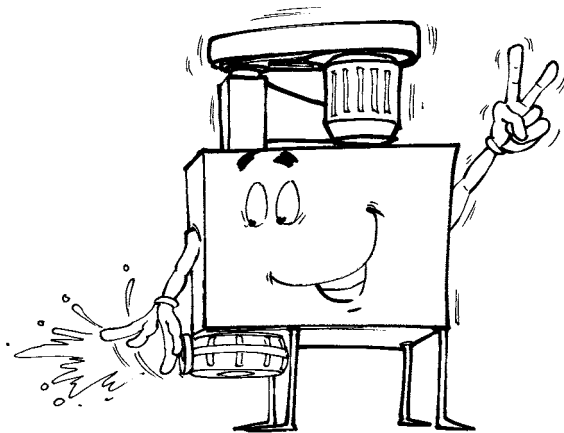
Semi dry installations

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.
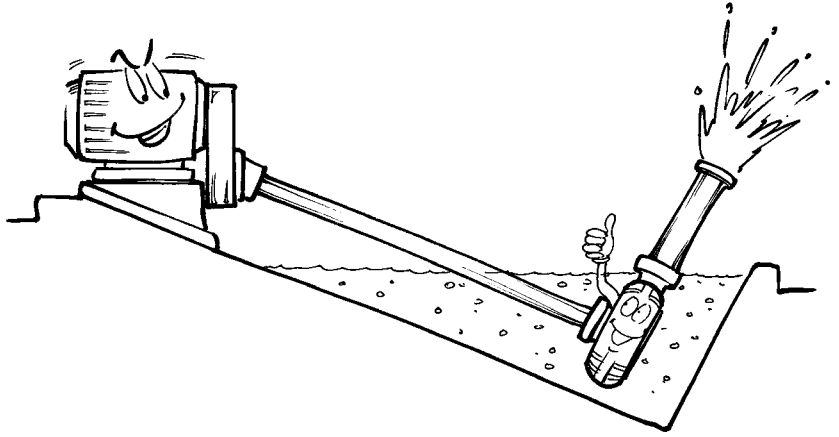
The sump pump has a flooded "wet end" installed at the end of a cantilever shaft (no submerged bearings) and a dry drive.
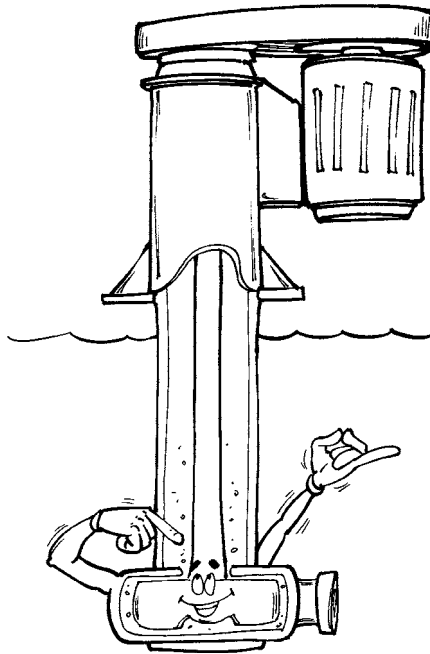
Wet installations

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.
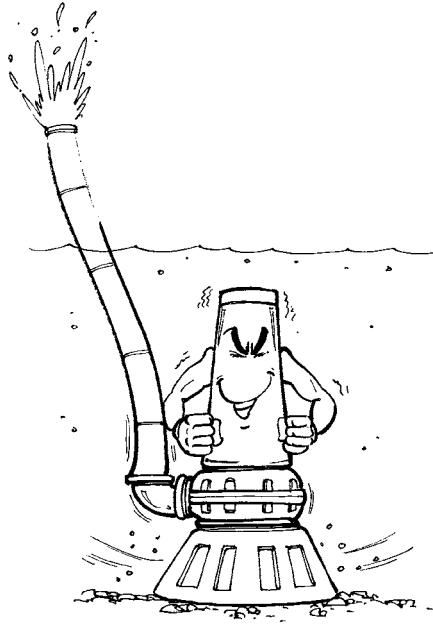
Slurry pumps and wear conditions

To ensure good service performance under a variety of working conditions and applications, the following guidelines are used to select pump design by classification.

- Highly abrasive
- Abrasive
- Mildly abrasive

Summary:

All pumps in the slurry pump range are centrifugal pumps!
"Slurry pump" is a generic definition!

All slurry pumps are in practice named after the given application:

- slurry pumps
- Gravel pumps
- Dredge pumps
- Sump pumps
- Froth pumps
- Carbon transfer pumps
- Submersible pumps

There are principally three different designs:

- Horizontal and vertical tank (dry installation)
- Vertical sump (semi dry installation)
- Tank (dry installation)
- Submersible (wet installation)

Slurry pump designs are selected and supplied according to the wear conditions

- Highly abrasive
- Abrasive
- Mildly abrasive

Basic definitions

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 content, etc, 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

Basic designs

Horizontal
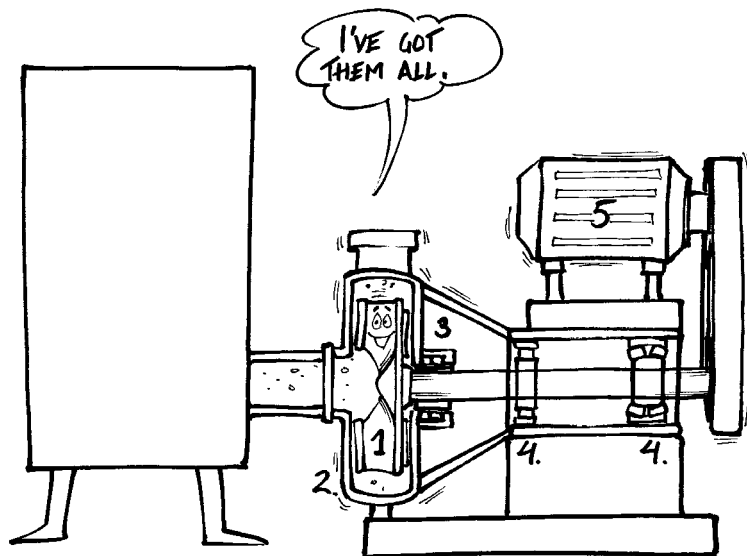
Vertical

Tank
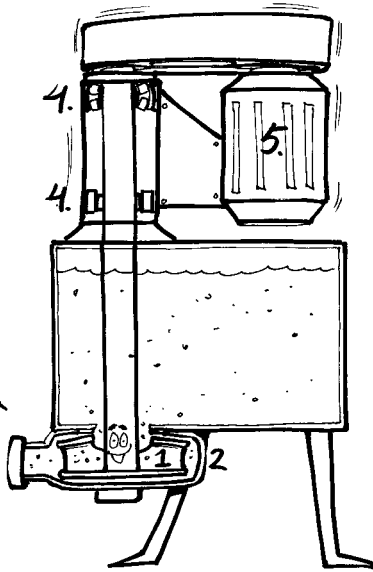
Sump
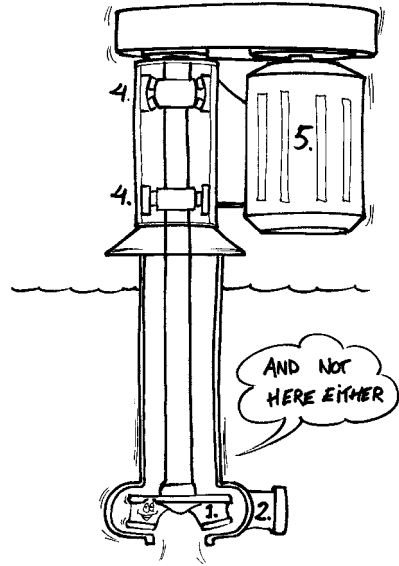
Submersible
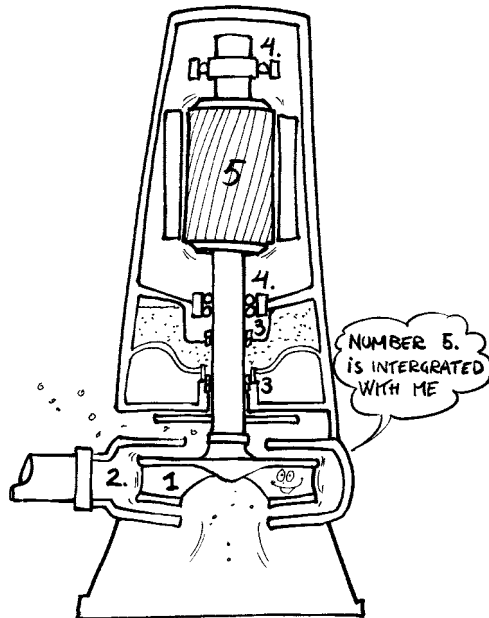
SLURRY PUMP - COMPONENTS

In this section we shall look closer into the design of the various components of the slurry pump

Impeller/casing
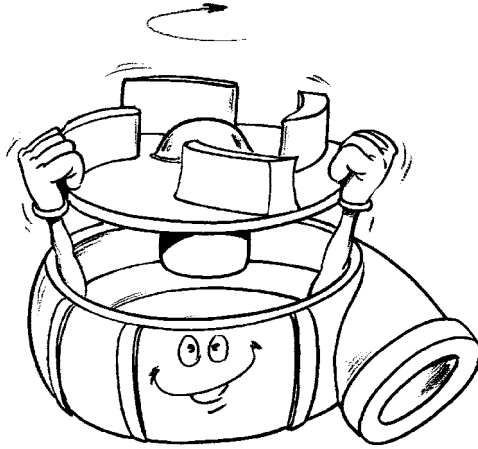
Pump impeller and casing – the key components of all slurry pumps

The pump performance of all slurry pumps is governed

– by the impeller and casing design.

Other mechanical components serve to seal, support and protect this hydraulic system of impeller and casing.

For all four types of slurry pump, the design principles for the hydraulic system (impeller and casing) are more or less the same

– while the design of the rest of the pump is not.

Pictures showing the same hydraulic components for submersible, vertical and horizontal design.
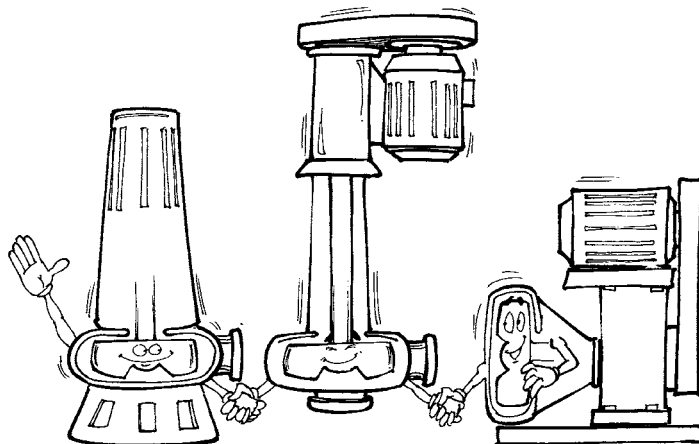
The slurry pump impeller

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 pumps, partly achieved by the special capacity of the solids in the slurry itself to convey energy by "hydraulic drag forces". These drag forces are used in a number of hydraulic machines for wet processing (classifiers, clarifiers, separators etc.)

Energy conversion done?

Below you can see the kinetic/hydraulic forces generated by the slurry pump impeller vanes
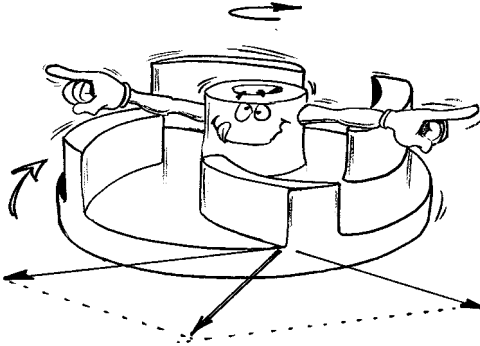
"The impeller vanes are the heart of the impeller. The rest of the impeller design is just there to carry, protect and balance the impeller vanes during operation"!

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 outside of the impeller shrouds. These vanes aid pump sealing and efficiency.

Internal vanes

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

Normally we use two types of main vane design in slurry pumps:

Francis vane   or   Plain vane
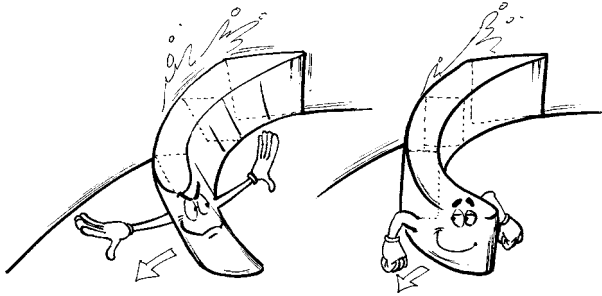
When to use Francis or Plain?

"As the Francis vane is more effective in energy conversion, it is used when efficiency is of prime concern, although the advantages are 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 Plain vanes are used when pumping coarse particles.

Number of impeller vanes?

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

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

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

Below these diameters, the vane area relative to the impeller area becomes critical (too large vane area, giving too much friction) and efficiency starts to drop and blocking can occur.
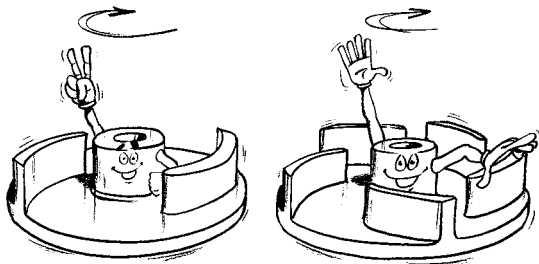
Semi-open or closed impeller?

The design of the slurry pump impeller is not related to a closed or open configuration. This is determined by production aspects and what type of applications the impeller will be used on.

Closed impellers

Closed impellers are by nature more efficient than open impellers, due to the reduction of "short circuiting" leakage over the vanes.

The efficiency is less affected by wear.
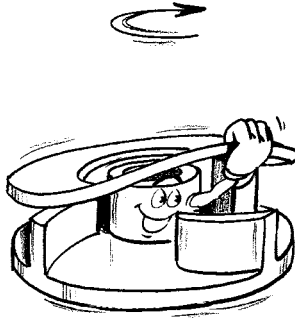
"If you are looking for efficiency - use a closed impeller whenever possible!"

Limitations

The closed impeller with its confined design is naturally more prone to clogging when coarse particles are encountered.

This phenomenon is more critical with the smaller impellers.

Semi-open impellers

Semi-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.
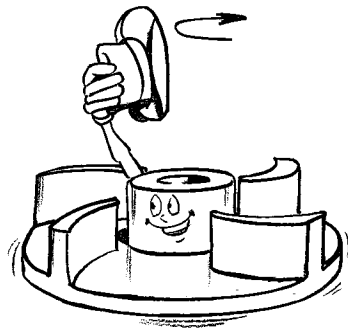
Limitations

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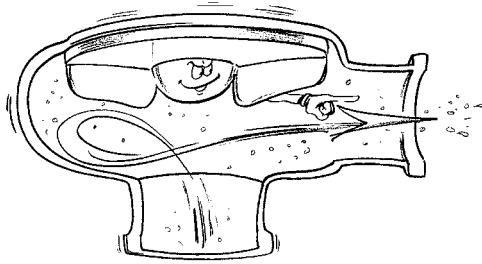
The impeller is pulled back in the casing . Only a limited volume of the flow is in contact with the impeller giving gentle handling of the slurry and large solids capability.

Limitations

The efficiency is significantly lower than for closed or even semi-open impellers.

Basic rules

Closed impellers are used for slurries with coarse particles for highest efficiency and best wear life – check maximum solids size.

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, see section Wear Protection.
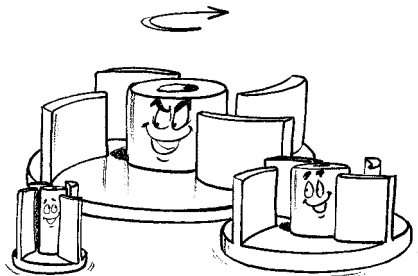
What will be the correct diameter?

The factors that have guided Metso in this respect are:

For highly abrasive duties we want a **long wear life and reasonable efficiency!**
For abrasive and mildly abrasive duties we want **reasonable wear life and high efficiency!**

To make it simple:

For highly abrasive duties we use large impellers giving long life and reasonable efficiencies.

So even if larger impellers are more expensive and have slightly lower efficiency, they give a 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.

This relation is known as:

IMPELLER ASPECT RATIO (IAR) = Impeller diameter / Inlet diameter

e.g.

for highly abrasive duties we use IAR = 2.5:1

for abrasive duties we use IAR = 2.0:1

for mildly abrasive duties we can use IAR of less than 2.0:1

All the above parameters have been considered when designing the Metso slurry pump ranges, giving optimal operation economy at various duties.

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 considerably higher (a key aspect when it comes to wear, see section 6).
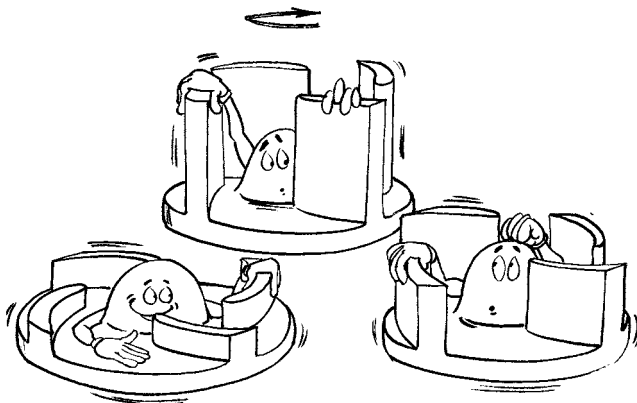
Remember:

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 and why?

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"

Practical considerations from these limitations provide a harmonious product range.

The Slurry Pump 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.
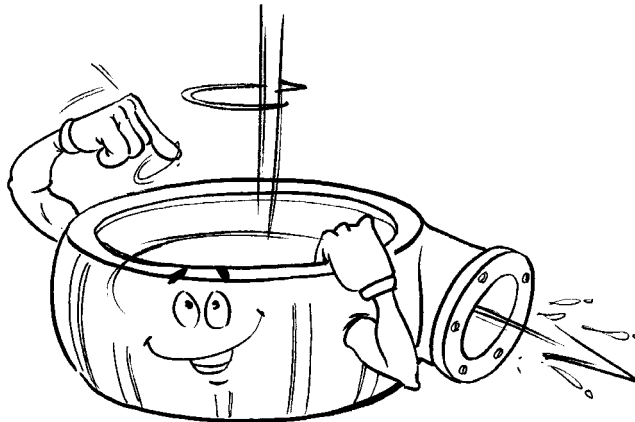
What about the shape of the casing?

The casing and the impeller are matched together to give the best flow pattern (and energy conversion) possible.
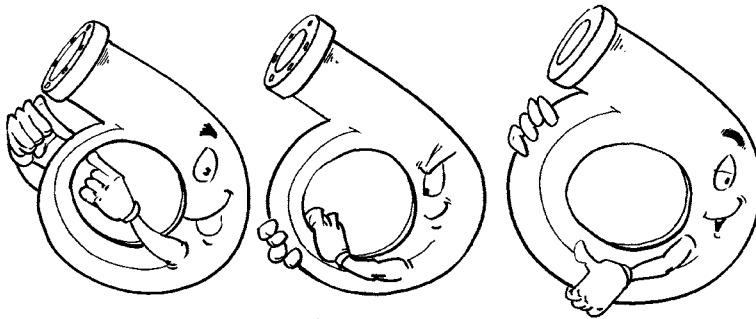
Volute   **Semi-Volute**   **Concentric**

Volute or concentric?

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

Split or solid casings?

Solid casing

For most hard metal pumps the volute is normally in 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.

KLONK KLONK
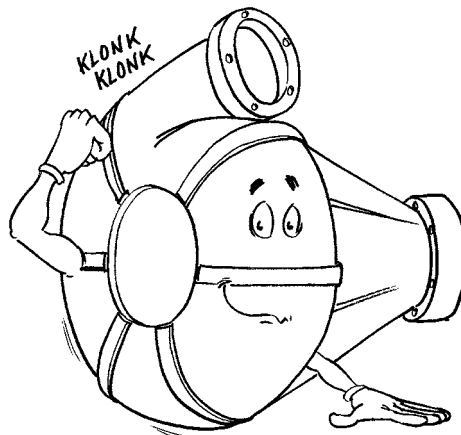
Split casing

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

This eases replacement of parts particularly for larger rubber lined pumps.
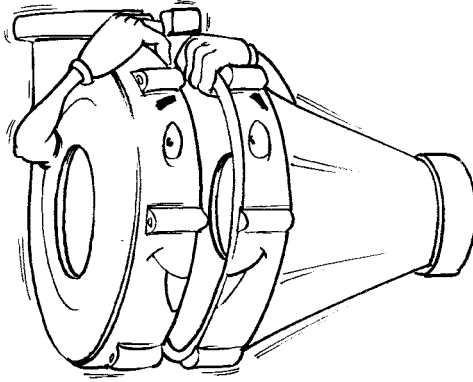
WEAR PROTECTION

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
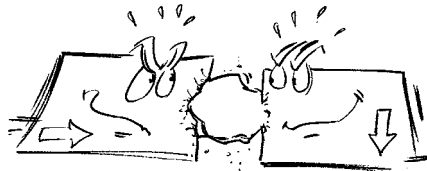
Grinding
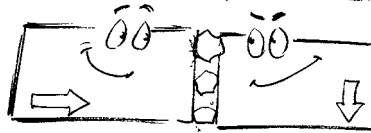
Low Stress
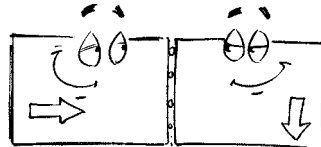
In slurry pumps we have mainly grinding and low stress abrasion.

Abrasion rate is dependent on particle size and hardness.

Abrasion only occurs in two areas in a slurry pump

1. Between impeller and the 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 wear is, in general, at a minimum at the BEP flow rate, and increases with lower as well as higher flows. See section Best Efficiency Point (BEP).

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. See page 84 for sump design.

It has been suggested that this may be caused by cavitation, due to the pump surfaces 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. See page 64 for a description of cavitation.

There are three major types of erosion:

Sliding bed

Low angular impact

High angular impact
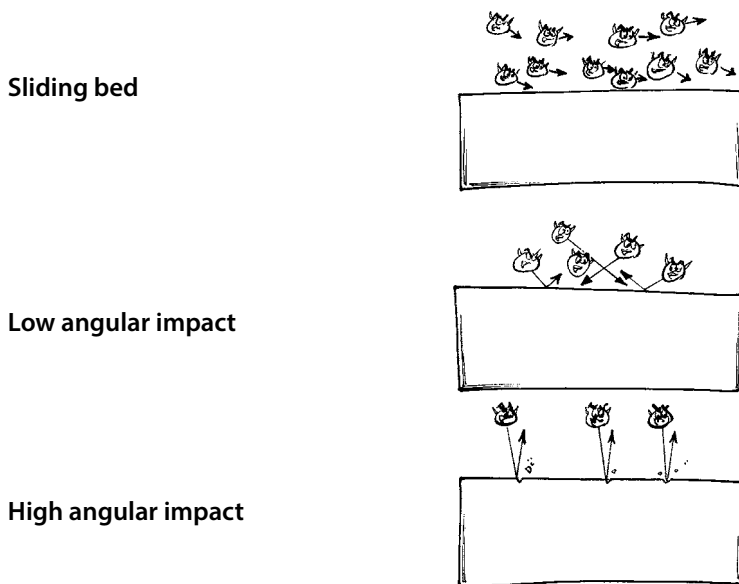
Effect of erosion on pump components

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).
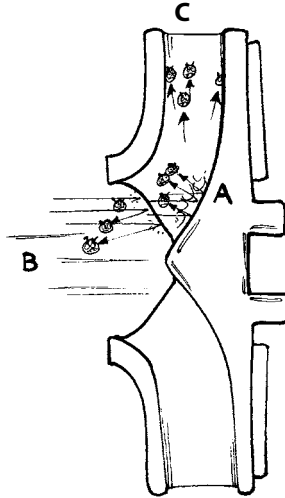
Side liners (inlet and back liners)

Side liners are subject to **sliding bed** and **crushing and grinding abrasion.**
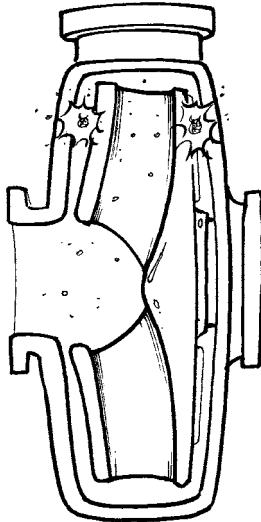
Volute

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.
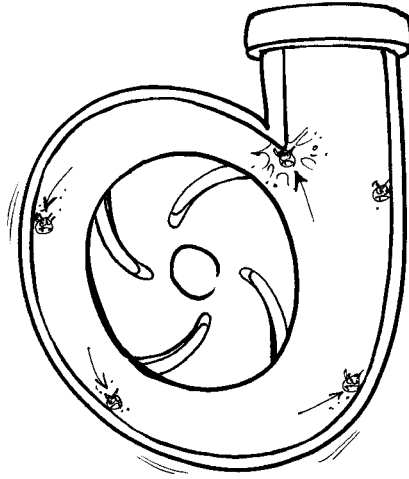
Corrosion

The corrosion (and chemical attacks) of the wet parts in a Slurry Pump is a complex phenomenon both for metal and elastomer material.

For guidance, chemical resistance tables for metals and elastomer material are given on page 35 and in section Chemical Resistance Tables.

Wear protection – what options?

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 elastomers 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 materials

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 cutting action of 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 speed

The dominant wear materials in slurry pumps are **hard metal and soft elastomers.** Metso supplies a wide range of qualities for both.

Ceramics are available as an option for some ranges.

See the table on next page for general guidance.

Wear protection

Effect of particle size on material selection

TABLE 1 Classification of pumps according to solid particle size (Sand hardness particles).

Tyler standard sieve series			Particle description	General pump classification
Particle Size				
In	mm	Mesh		
3				
2				
1,5			Screen shingle gravel	
1,050	26,67			
0,883	22,43			
0,742	18,85			
0,624	15,85			
0,525	13,33			
0,441	11,20			
0,371	9,423			
0,321	7,925	2,5		
0,263	6,68	3		
0,221	5,613	3,5		Rubber-lined pumps, closed impeller; particles must be round
0,185	4,699	4		
0,156	3,962	5		
0,131	3,327	6		
0,110	2,794	7		
0,093	2,362	8		Rubber-lined pumps, closed impeller
0,078	1,981	9	Very coarse sand	
0,065	1,651	10		
0,055	1,397	12		
0,046	1,168	14		
0,039	0,991	16	Coarse sand	
0,0328	0,833	20		
0,0276	0,701	24		
0,0232	0,589	28		Polyure-thane pumps & Rubber-lined pumps open impeller
0,0195	0,495	32	Medium sand	
0,0164	0,417	35		
0,0138	0,351	42		
0,0116	0,295	48		
0,0097	0,248	60		
0,0082	0,204	65	Fine sand	
0,0069	0,175	80		
0,0058	0,147	100		
0,0049	0,124	115		
0,0041	0,104	150		
0,0035	0,089	170		
0,0029	0,074	200	Silt	
0,0024	0,061	250		
0,0021	0,053	270		
0,0017	0,043	325		
0,0015	0,038	400		
	0,025	a500	Pulverized	
	0,020	a625		
	0,010	a1250		
	0,005	a2500		
	0,001	a12500	Mud clay	

Pump classification groups: Hard iron pumps; Austenitic manganese steel pumps; Dredge pump; Sand and gravel pump; Sand pump; Hard Iron Pumps; Slurry pump.

Selection of wear material – Metals

Metal is generally more tolerant to abuse than rubber and is the best choice for coarse material.

Metals used are mainly:

High Chrome Irons

Standard material
Wear resistant high chrome iron with a nominal hardness of 650 BHN. Can be used at pH values down to 3,5 pending chloride content, see figure below. Standard material for most pump ranges.

30% Cr
is used for more corrosive applications, see figure below

Manganese steel
Manganese steel with hardness up to 350 BHN. Mainly used in dredging applications.

Alloy selection for corrosion applications
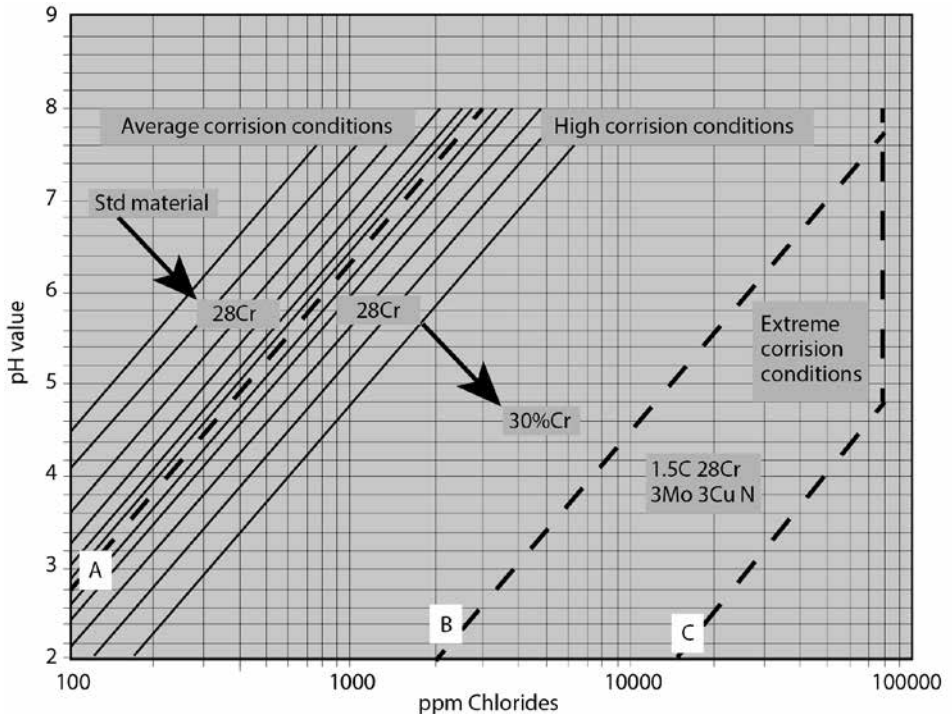
1. Dashed lines A, B, and C are from "FGD Sleeve and gland selection guide"

2. There is NO sharp boundry between average and high corrosion, thus the same material can be used on either side of line A, depending on precense of other ions besides Cl ion.

A. If no other ions are present, use lower Cr material

B. If Sulfate and/or Phosphate ions are present (50<ppm<2000), then use the higher Cr content material.

C. For either Sulphate and/or Phosphate ions >2000 ppm, go to next higher corrosion field.

Selection of wear material – Elastomers

Natural rubber is by far the major elastomer in slurry pumping. Most cost effective for fine solids.

Generally, depending on their sharpness and density, particle sizes of up to 5-8 mm can be pumped.

Warning!

Oversize scrap and sharp particles can destroy the wear parts, especially the impeller.

The elastomer families

Natural rubbers

Synthetic rubbers and polyurethane

The Natural rubber qualities are:

Natural rubber 110   Soft liner material

Natural rubber 168   High strength impeller material

Natural rubber 134   High performance liner material

Natural rubber 129   High performance material with extra mechanical strength

These materials come as standard materials with different pump ranges.

Synthetic rubber qualities:

Metso can supply a wide range of other synthetic rubbers. These materials are mainly used when natural rubber can not be used. The major types are listed in the table on next page, which can be used as a general guide for elastomer selection.

There are more different types of **Polyurethane** than there are steel types. The comparison between polyurethanes should be done with great care. Metso uses a special **MDI**-type of polyurethane.

Polyurethane is available for most pump ranges and offers excellent wear resistance for finer particles (<0,15 mm), but it is at the same time less sensitive to oversized scrap than rubber. It has its peak performance in low angular impact and sliding wear. It is commonly used in flotation circuit pumps when oil or hydrocarbon reagents are used.

For other synthetic rubbers, see table on the next page.

Material	Physical properties		Chemical properties			Thermal properties	
	Max. Impeller Tip Speed (m/s)	Wear resistance	Hot water, diluted acids	Strong and oxidising acids	Oils, hydro carbons	Highest service temp.(°C) Continuously	Occasionally
Natural rubbers	27	Very good	Excellent	Fair	Bad	(-50) to 65	100
Chloroprene 452	27	Good	Excellent	Fair	Good	90	120
EPDM 016	30	Good	Excellent	Good	Bad	100	130
Butyl	30	Fair	Excellent	Good	Bad	100	130
Polyurethane	30	Very good	Fair	Bad	Good	(-15) 45-50	65

For exact data on chemical resistance, see tables in section 19.

Something about ceramic liners

Although ceramic has a high resistance against wear, temperature and most chemicals, it has never really been accepted as a day-to-day standard in Slurry Pumping.

Being both brittle and expensive to manufacture.

Development work on ceramic continues in an attempt to improve its acceptability.

Wear protection

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
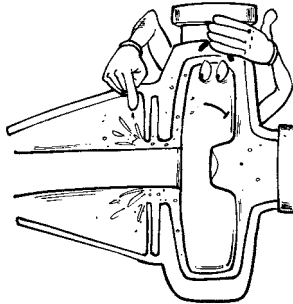
Vertical: Designed without shaft seals
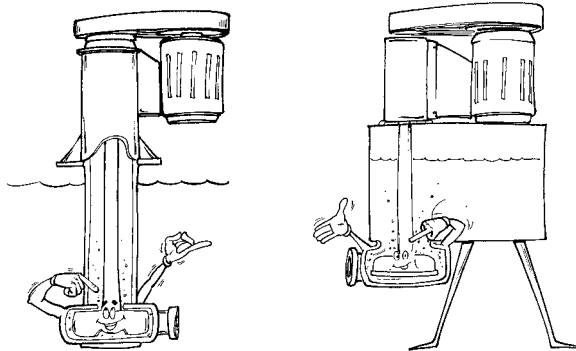
Submersible: Slurry leakage, electrical connections
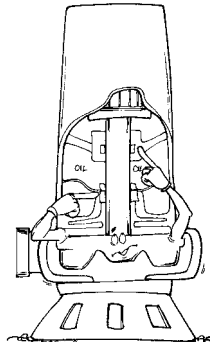
Shaft seals

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

"The shaft seal is the most important function in any Slurry pump."

"The selection of the correct seal for any application is essential."

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.
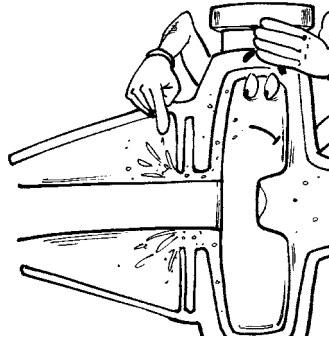
Type of leakage

With flooded suction, leakage is generally liquid leaving the pump, whereas, 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**
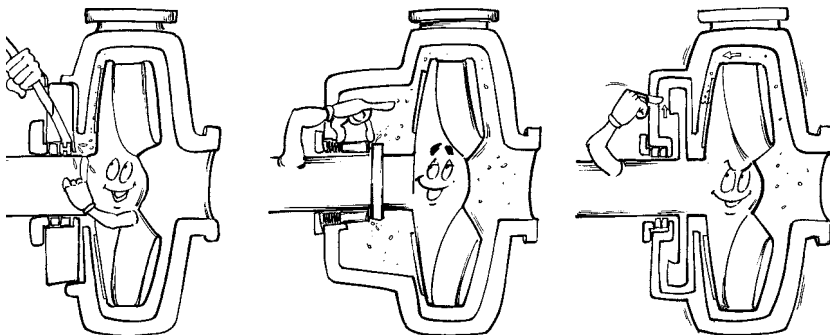
Flushing seals

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 on 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 option (when applicable) normally provides the longest "seal life" for slurry pumps

Full Flow	Low Flow
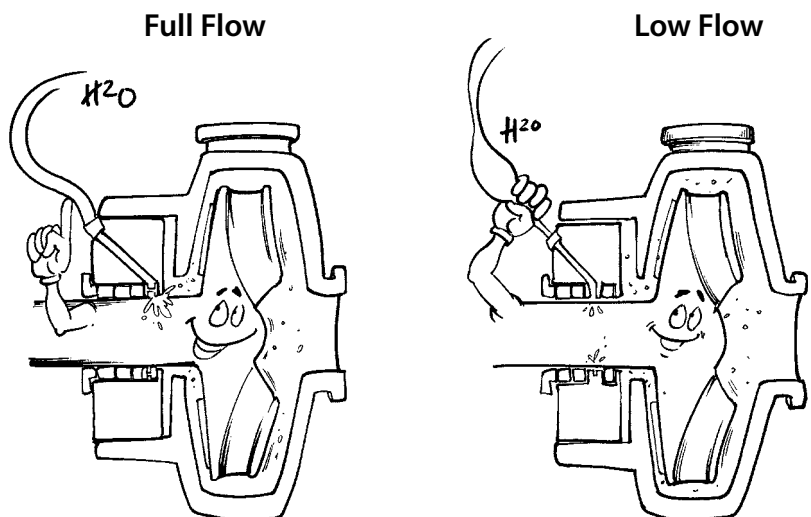
Mechanical seals are also available with or without flushing. If flushing is to be used (flush gland configurations are economical and easier to service) a soft packing box should always be considered, provided external leakage is acceptable.

Regarding mechanical seals without flushing, see following pages.

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, a conventional static seal is provided by the shaft packing, but uses fewer packing rings then in a conventional stuffing box.

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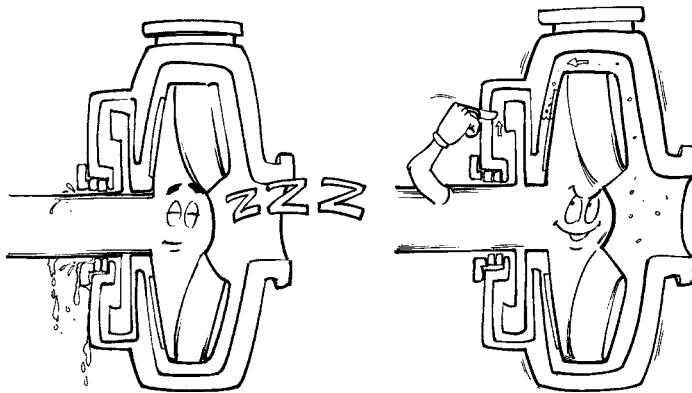
The expeller is in effect, a secondary impeller positioned behind the main impeller, housed in its own seal chamber, close to the main pump casing.

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 limitations

All centrifugal seals are limited in the amount of inlet head they can seal relative to the operating 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 operating discharge head for standard impellers. Exact calculations are done by our sizing software PumpDim™.
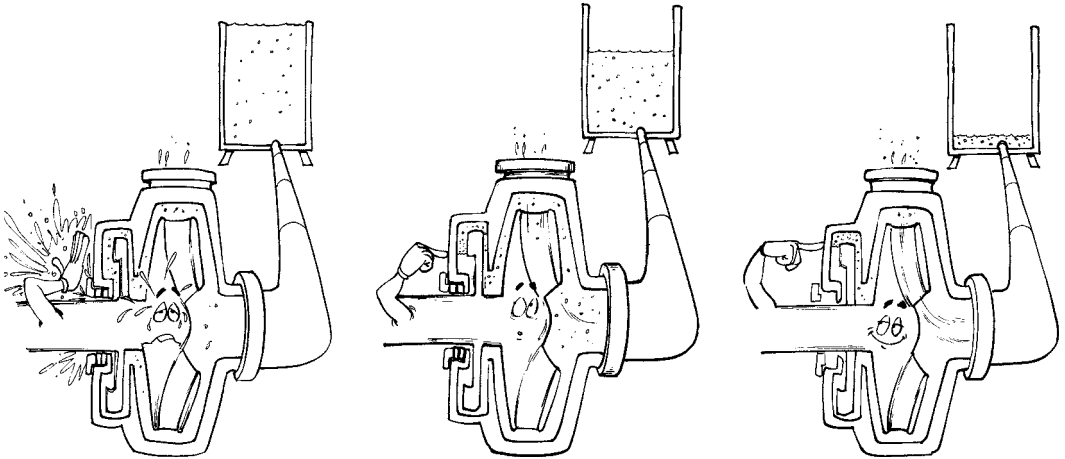
Dynamic seal - summary of advantages

" No flush water required"

" No dilution by flush water"

" Reduced maintenance of packings"

" Zero gland leakage during operation"

Mechanical seals

Mechanical seals without flushing must be considered in cases where dynamic expeller seals are not possible (see limitations above).

These are high precision, water lubricated, water-cooled seals running with such tolerances that slurry particles cannot penetrate the sealing surfaces and destroy them.
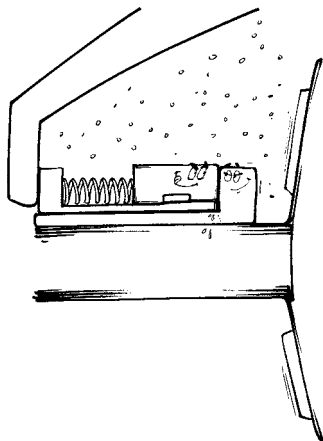
Mechanical seals are very sensitive to shaft deflection and vibrations. A rigid shaft and bearing arrangement is crucial for successful operation.

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

However, the largest draw back is the cost, which is very high.

The development work for more cost effective and reliable mechanical seals is ongoing and this type of seal is as of today a viable option also for slurry pumps.

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.
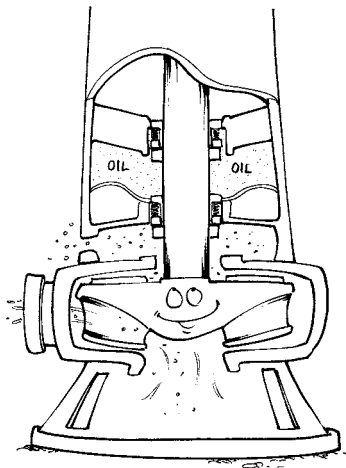
The sealing arrangement consists of two independent mechanical seals, running in oil.

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 above for the horizontal pumps!

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

Slurry pumps without seals - vertical designs

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

- To utilize dry motors, protected from flooding
- To eliminate sealing problems.
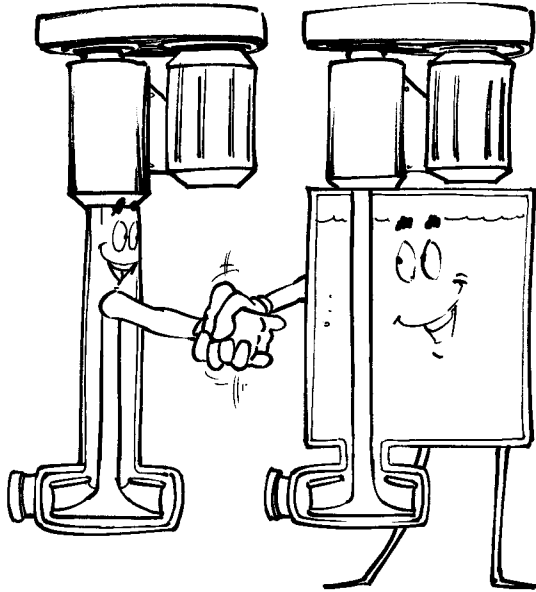
SHAFTS AND BEARINGS

Transmission designs

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).

Pumps shafts and the SFF factor

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

The shaft flexibility factor (SFF) relates the shaft diameter at the shaft seal D(mm), to the cantilevered length (from the wet end bearing to the impeller centre line) L(mm) and is defined as L^3/D^4.

This is a measure of the susceptibility to deflection (which is critical to shaft sealing and bearing life.

Typical SFF values for horizontal slurry pumps are 0.2 – 0.75.

Clean liquid SFF values are typical 1 – 5.

Note! Shaft deflection occurs in both horizontal and vertical slurry pumps although the longer the "overhang" the greater the deflection for the same radial load!
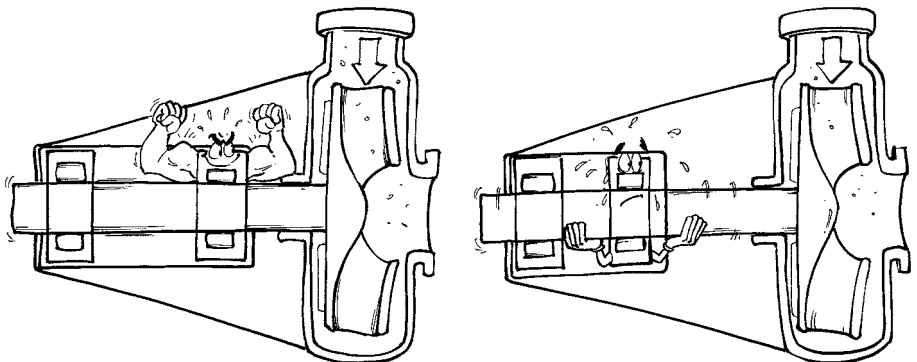
Basic on bearings

L$_{10}$-life

The bearing life is calculated using the ISO 281 method.

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

The average life is approximately four times the **L$_{10}$** life.

Most Metso slurry pumps are sized for a minimum **L$_{10}$** life of 40,000 hours (i.e. 160,000 hours average life).

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

Bearing configurations

Radial loads

On duties such as filter press filling and pressurising, 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 (i.e. 10% failure in 40,000 hours). See chapter 12 for more details on radial loads.

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 the high inlet head on the second and subsequent stages. To meet the minimum bearing life requirement double dry end bearings may be required. See chapter Best Efficiency Point for more details on axial loads.

Bearings and bearing arrangements

In a slurry pump we have both radial and axial forces acting on the shaft and the 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 up both axial and radial forces.

The second arrangement using taper roller bearings (of standard, mass produced types) in both positions taking axial and radial loads.

Selection of bearings

In the slurry pump range both arrangements are used, varying with the pump range.

First arrangement
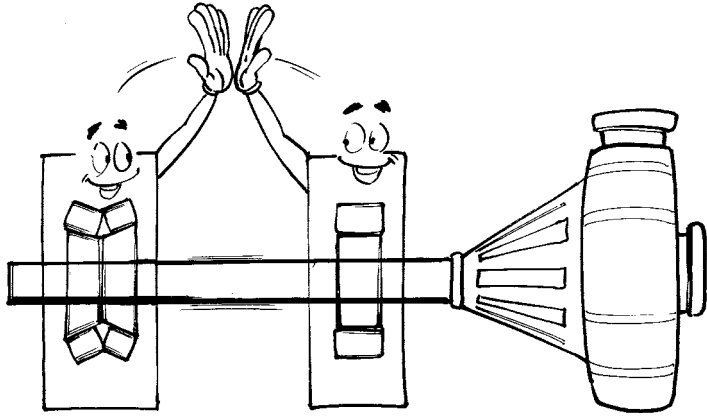
Second arrangement
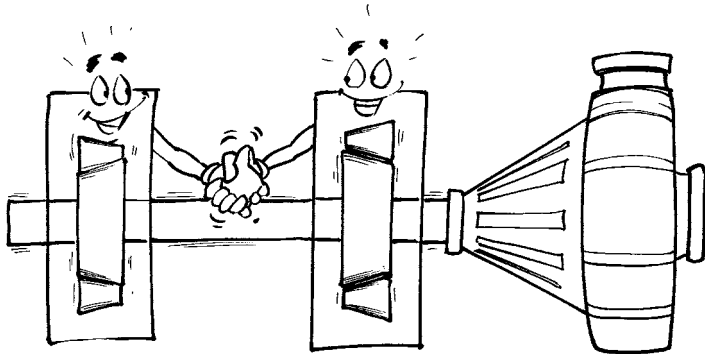
In the vertical design where the cantilever is extremely long the first bearing arrangement is used.
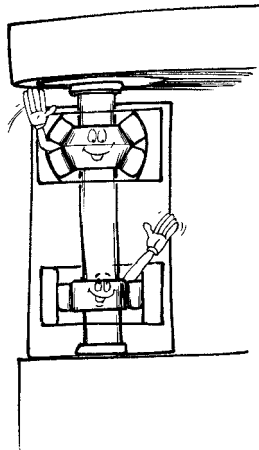
DRIVES FOR SLURRY PUMPS

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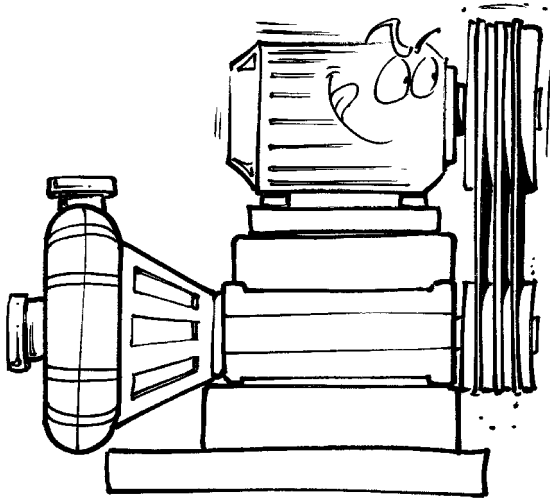
This concept gives freedom to select low cost (4-pole) motors and drive components according to local industry standard. Good flexibility is also provided for altering the pump performance by a simple speed change.

2. Direct drives are always used in the submersible pumps and where application dictates on horizontal and vertical pumps.
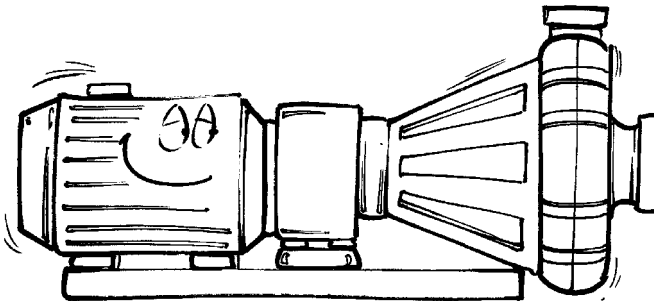
This drive concept being an integral part of the pump causes problems both in supply of components and altering pump performance.

Indirect drives

Selection of motors

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

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

This 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.
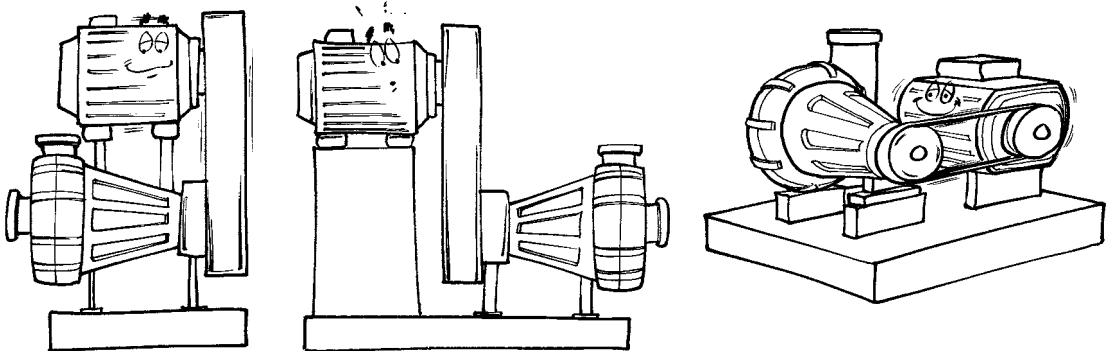
Comments on drive arrangements

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 "back pull out" design and assembled on a "sliding maintenance base", servicing can be significantly simplified.

Limitations overhead mounted:

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

If 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 changes 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 "fine tuned" to achieve the duty point even when applications are changed.

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

Typical maximum speed ratio for V-belt drives is 5:1 with 1500 rpm motors and 4:1 with 1800 rpm motors.
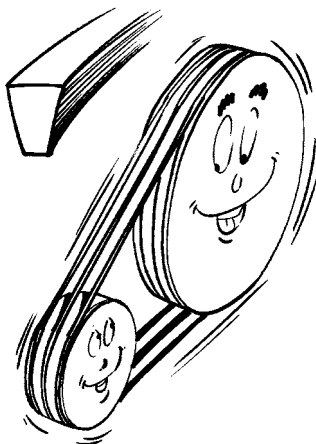
V-belt transmissions – limitations

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.
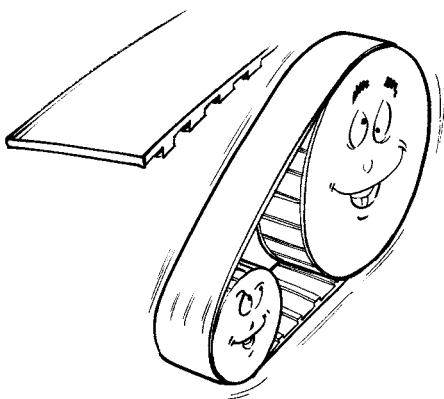
Variable speed drives

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

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

Should a pipe line 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.
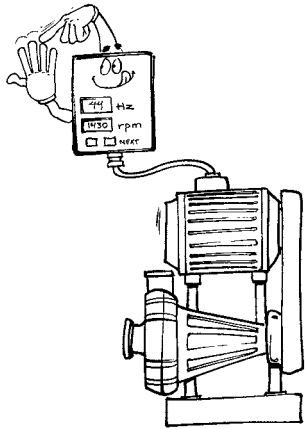
Variable speed drives – limitations

Only price, which is considerable, prevents wider use!!

Something about "combustion engine" drives

In remote areas, or green field construction sites, temporary or emergency pumping equipment is often powered by industrial diesel engines. Supplied ready to run on composite pump bedframes, a diesel powered pump set provides variable performance in relation to variable engine speed.
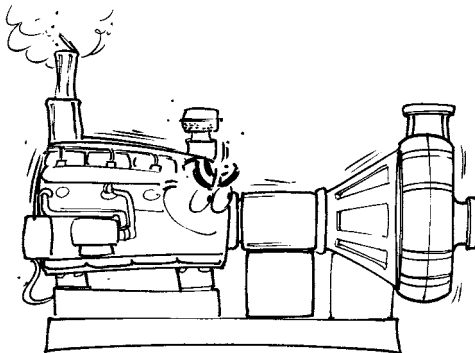
HYDRAULIC PERFORMANCE

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:

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

"performance of the pump (outlet head and capacity)"

"discharge piping and slurry system (friction losses)"

"slurry effects on pump performance"

II. **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 temperature (affecting vapour pressure of slurry)"

For optimal operation these two hydraulic conditions must be considered and are equally important!!

Pump curves

The performance of a slurry pump is normally illustrated by the use of clear water performance curves.

The basic curve for performance is the **Head / Capacity (HQ)** curve, showing the relation between the discharge head of the slurry and the capacity (volume flow) at constant impeller speed.

Types of H/Q pump curves
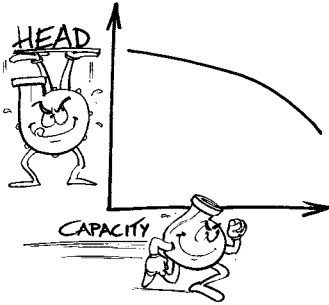
Comments:

Rising curve to shut valve	Sometimes specified (stable)
Dropping curve to shut valve	Sometimes unacceptable (unstable)
Steep curve	Sometimes desirable
Flat curve	Most Slurry Pumps
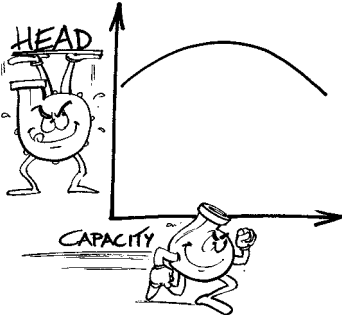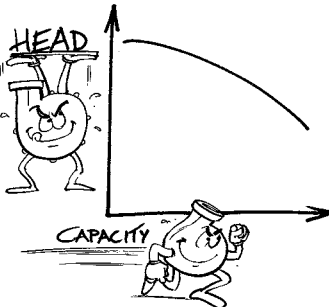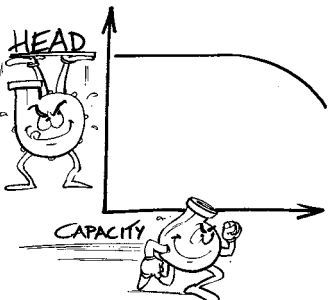
Hydraulic performance – what curves are needed?

For a complete description of the performance of a slurry pump we need the following curves:

1. Differential head of the pump as function of the flow (HQ curve)

2. Efficiency curve as function of the flow

3. Power (input) as function of the flow

4. Cavitation characteristics as function of the flow (NPSH)
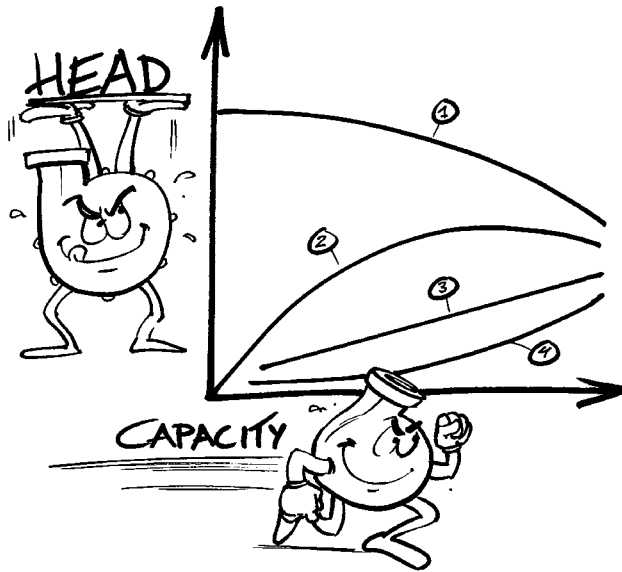
Note!

All the curves for head, power and efficiency are valid only if the head on the pump inlet is sufficient. If this is not the case, the pump performance will be reduced or will fail, read about NPSH further on.

H/Q curves- pump affinity laws

To be able to describe the performance of a slurry pump at various impeller speeds or impeller diameters we need to draw a range of curves. This is done by using the pump affinity laws.

Laws for fixed impeller diameter

For change in speed with a fixed impeller diameter the following laws apply where:

H = Head   Q = Capacity   N = Speed   P = Power

With Q1, H1 & P1 at a given speed N1 and Q2, H2 &P2 at the new speed N2 are calculated:

$Q1/Q2 = N1/N2$	or	$Q2 = Q1x\ N2/N1$
$H1/H2 = (N1/N2)^2$	or	$H2 = H1x\ (N2/N1)^2$
$P1/P2 = (N1/N2)^3$	or	$P2 = P1(N2/N1)^3$

Efficiency remains approximately the same.
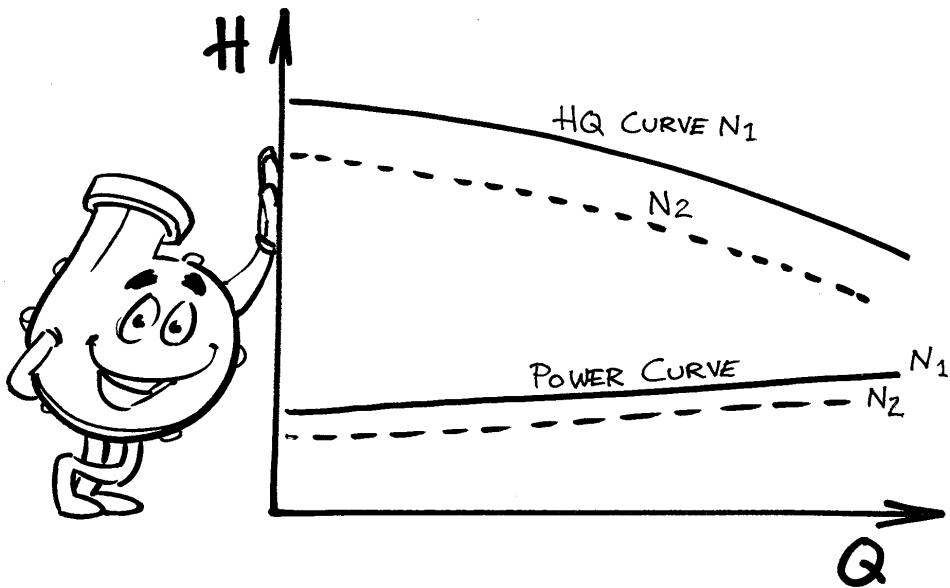
Laws for fixed impeller speed

For a change in impeller diameter with a fixed speed the following laws apply where:

H = Head,   Q = Capacity   D = Diameter   P = Power

With Q1, H1 & P1 at a given diameter D1 & Q2, H2 & P2 at the new diameter D2 are calculated:

$Q1/Q2 = D1/D2$	or	$Q2 = Q1 \times D2/D1$
$H1/H2 = (D1/D2)^2$	or	$H2 = H1(D2/D1)^2$
$P1/P2 = (D1/D2)^3$	or	$P2\text{-}= P1 \times (D2/D1)^3$
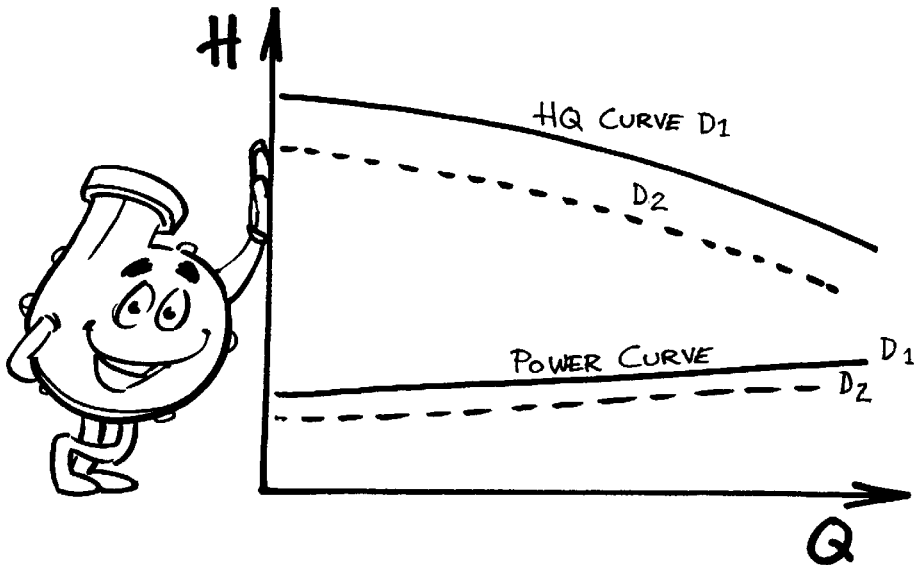
Slurry effects on pump performance

As mentioned before, pump performance curves are based on clear water tests. Therefore corrections are needed when pumping slurries.

A given slurry must be treated as either settling or non-settling (viscous).

Generally slurries with particle size <50 micron are treated as non-settling (viscous).

Pump performance with settling slurries

For settling slurries and manual calculations, Cave's correlation is the most common method of allowing for the effects of solids on pump performance.

Later methods like the Metso method which include pump size effect are utilized when sizing softwares like PumpDim™ are used. These methods are more accurate and the Cave method is often too conservative.

This provides a derating factor HR/ER derived from the average solid particle size, (d_{50}), density and concentration. HR, the Head Ratio, is equal to ER, the Efficiency Ratio.

Slurry head/HR = Water curve head.

Slurry efficiency = Water efficiency x ER.

Water head (and flow rate) are used to determine pump speed and water efficiency. Slurry head and slurry efficiency are used to calculate power.
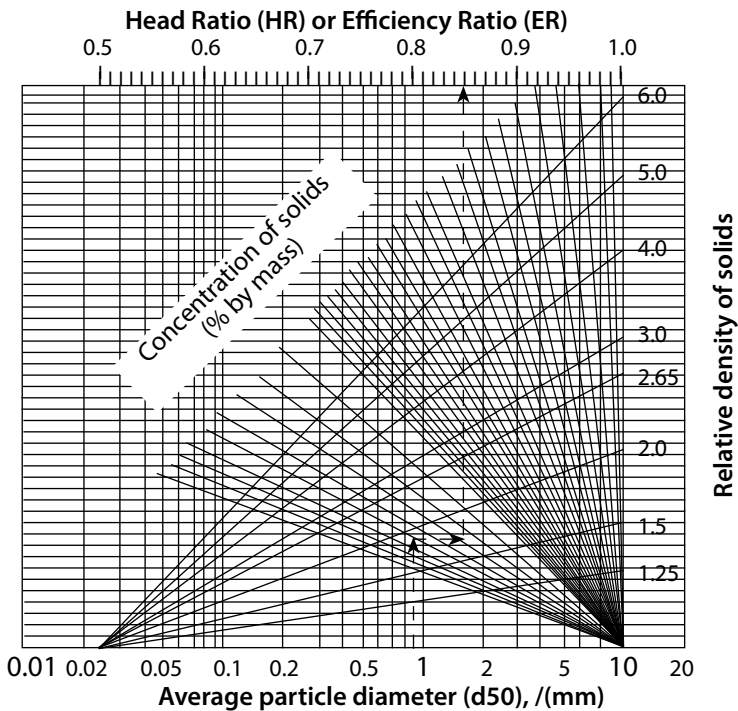
Derating of known water performance for slurry duties in terms of differential head and efficiency. HR/ER - Head and Efficiency Ratio.

Pump performance with non-settling (viscous) slurries

For viscous slurries, pump performance is derated in accordance with the American Hydraulics Institute guidelines.

These charts use the <u>true</u> viscosity to derate the pump, and not the <u>apparent</u> viscosity. See page 11:87 and onwards for the difference between <u>true</u> and <u>apparent</u> viscosity.

It should be noted that derating for Head, Efficiency and Flow are calculated from the rated pump B.E.P., and not the duty point.

For slurry pumps, these derating factors can be taken as <u>very conservative</u> as all development work by the American Hydraulics Institute was undertaken on process pumps with narrow impellers. Slurry pumps traditionally use very wide impellers and are therefore less affected.
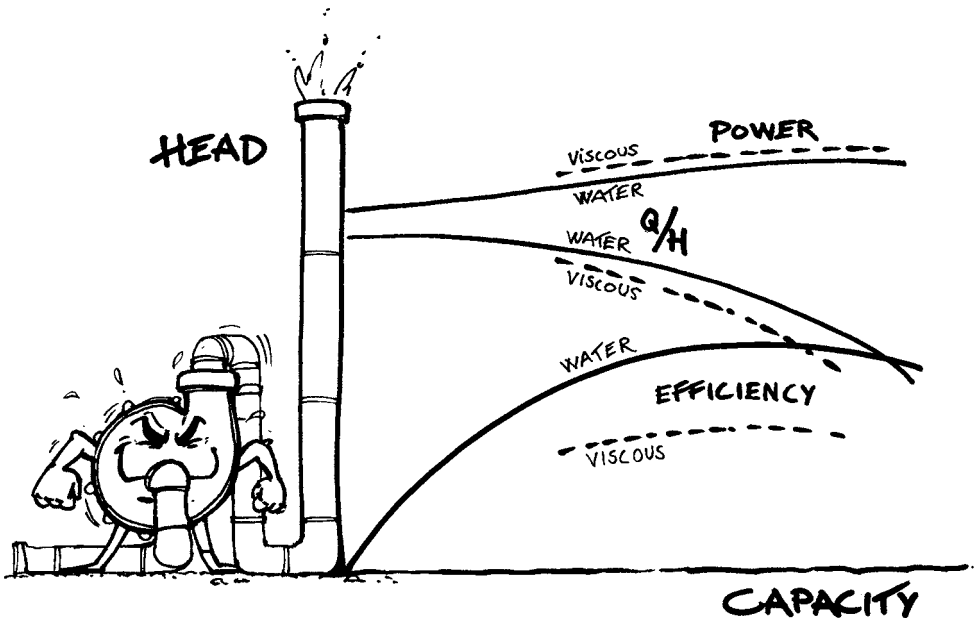
Typical curve for non settling slurries

PERFORMANCE CORRECTION CHART
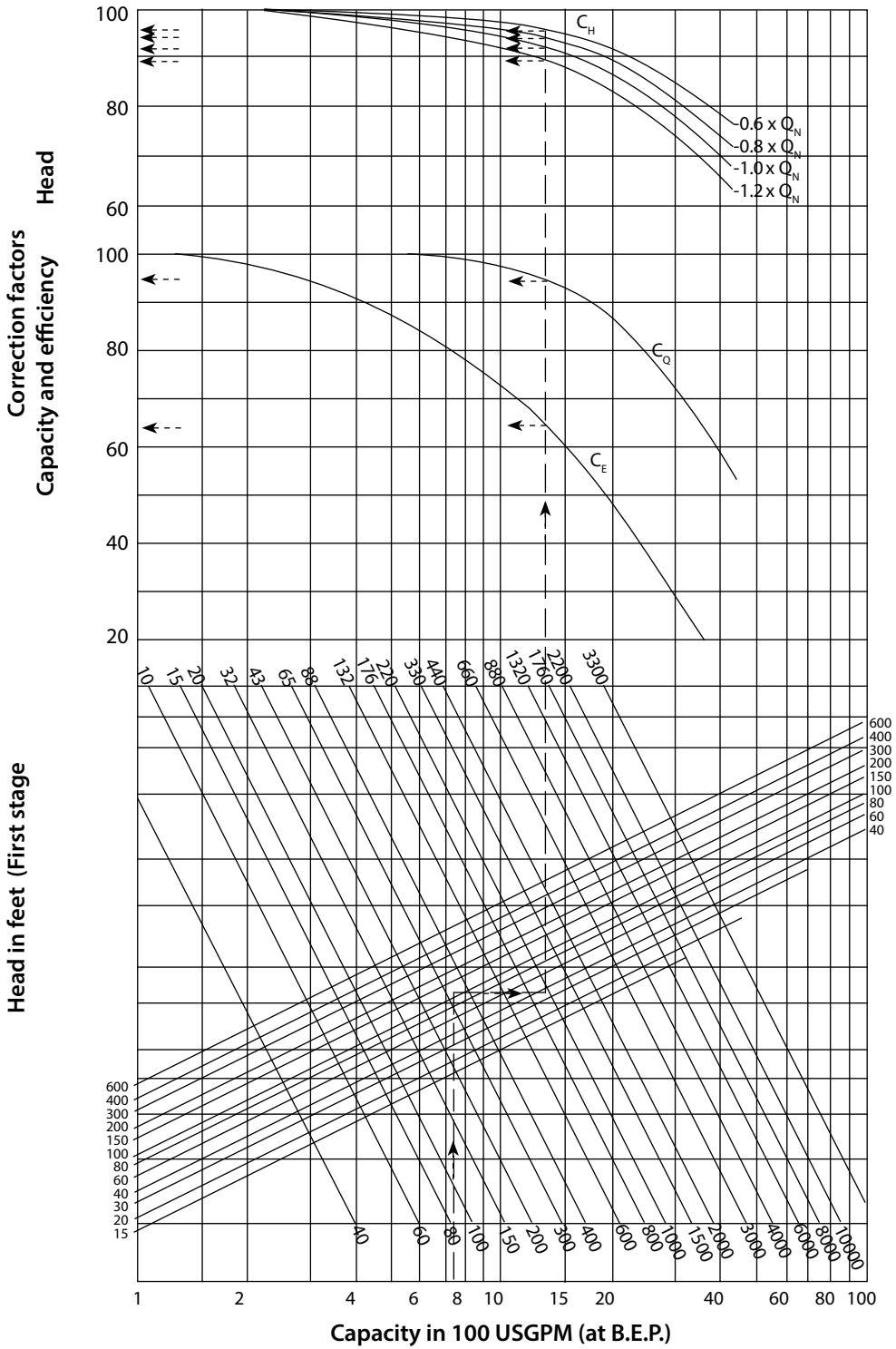
Fig. 63 PERFORMANCE CORRECTION CHART
Correction chart for viscous liquids

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 m (167 ft) of head of water, the gauge pressure would be 5.0 bar (72.5 psi).

On a heavy slurry of S.G 1.5, the 51.0 m (167 ft) would show a gauge reading of 7.5 bar (108.8 psi).

On a light fuel oil duty of S.G 0,75, the 51.0 m (167 ft) would show a gauge reading of 3.75 bar (54.4 psi).
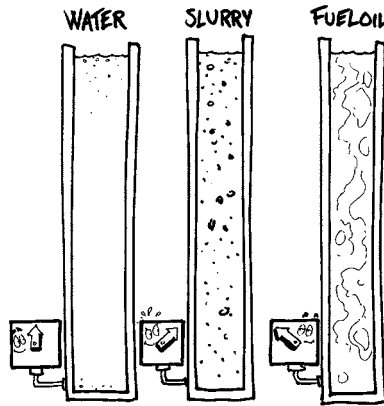
Note! For the same head, gauge reading and required pump power will vary with S.G.

Problem with measuring head with a gauge

Even if the gauge is marked to show metres it really measure pressure.

If your S.G. is changing, what is your pump head??
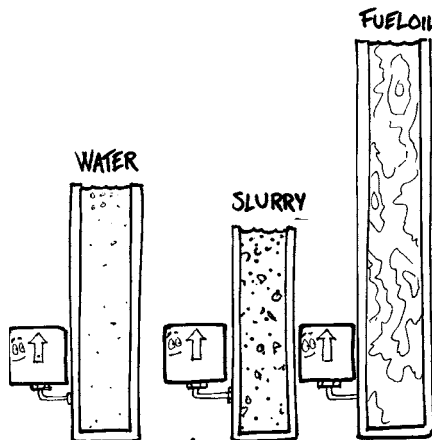
Hydraulic conditions on the inlet side

Net Positive Suction Head (NPSH)

To ensure that a slurry pump performs satisfactorily, the liquid must 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.
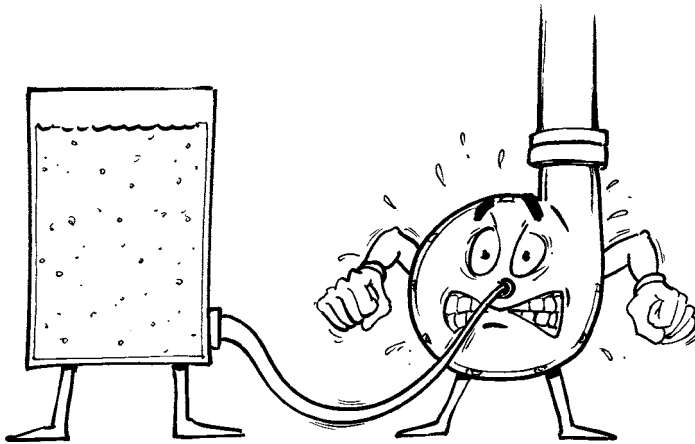
*The name NPSH is an international nomenclature standard and is used in most languages.

Vapour pressure and cavitation

When the local pressure drops to the liquid vapour pressure, vapour bubbles start to form. These bubbles are carried by the liquid to locations with higher pressure, where they collapse (implode) creating extremely high local pressures (up to 10,000 bar), which can erode the pump surfaces.

These mini explosions are called **cavitation,** see also page 10:65.
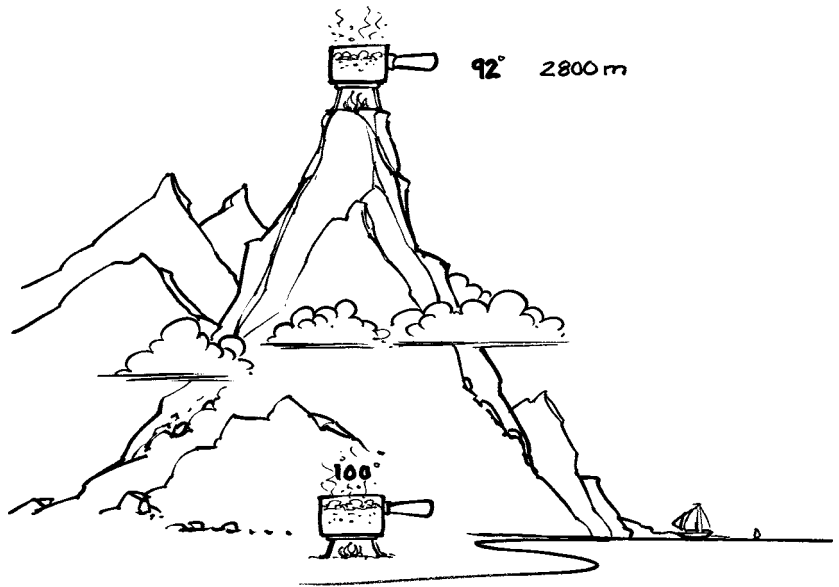
Cavitation is not, as sometimes stated, generated by air in the liquid. It is the liquid boiling at ambient temperature, due to the reduction in pressure. At sea level atmospheric pressure is 1 bar and water boils at 100° C. At an altitude of 2 800 m atmospheric pressure reduces to 0,72 bar and water boils at 92° C. See also table on page 10-66 and diagram on page 10-67.

A major effect of cavitation is a marked drop in pump efficiency, caused by a drop-off in capacity and head. Vibrations and mechanical damage can also occur.

Cavitation is mainly an issue when:

• The site is at high altitude

• When operating on a suction lift. See also page 10:69

• When pumping liquids with a high temperature

Too low NPSH will cause cavitation!!

It is important to check the NPSH under both the sizing procedure and at start up.

How to calculate NPSH?

How do we know what NPSH (inlet head) we are looking for?

For all pumps there is always a **required** value for the NPSH known as NPSHR. This value is not calculated, it is a property of the pump.

On all pump curves this required value of NPSH is shown for various flows and speeds.

The given system must provide the **available** NPSH, known as NPSHA.
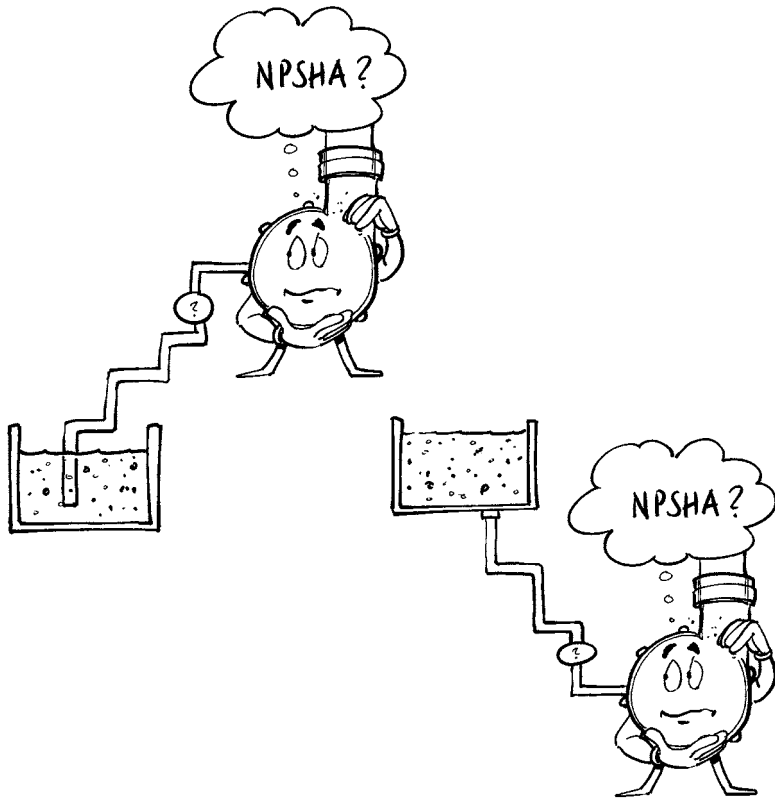
Now we have to check the **available** value of NPSH , (NPSHA), on the suction side.

Note! The value of available NPSHA, must always exceed the value of the required NPSHR !

NPSH - calculations

We have to summarise all pressure heads and deduct all losses in the piping system on the inlet side

Some useful figures:

Atmospheric pressure in water head (metres) required to generate
1 ATM pressure at different altitudes (**m**etres **A**bove **S**ea **L**evel).

mASL	H_2O Head (m)
0	10,3
1 000	9,2
2 000	8,1
3 000	7,1
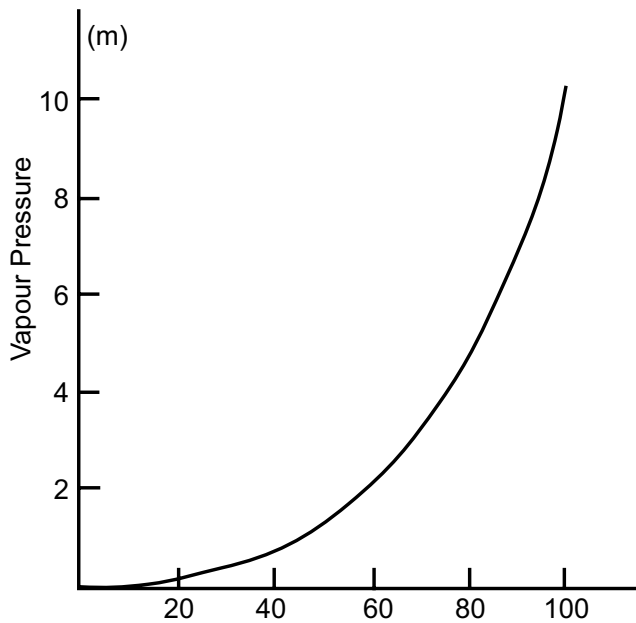
Curve showing vapour pressure for water at different temperatures (°C.)

Formula for calculation of NPSHA

NPSH A = ATM pressure in m water + (-) static Head - system losses – vapour pressure

Example:

Installation of a Slurry Pump type Metso HM 150 at high altitude, e.g. Chuquicamata, Chile.

Duty:	65 m head at 440 m³/hour
Plant location:	2.800 m above sea level gives atm pressure 7.3 m
Feed point location:	lift 2.0 m (2.0 m below pump inlet)
Friction in inlet pipes:	0.5 m
Average operating temp:	22 °C, giving a vapour pressure 0.3 m

NPSHA is 7.3 - 2.0- 0.5- 0.3 = 4.5 m

NPSHR according to pump performance curve is 6. 0 m

Available NPSHA is 1.5 m too low !!

The same installation in northern Europe at sea level would have given a value for available NPSH of 7.5 m.

Available NPSHA is OK!

Hydraulic performance

Cavitation – a summary

If NPSHA is less than NPSHR liquid will vaporise in the eye of an impeller.

If the cavitation increases, 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.
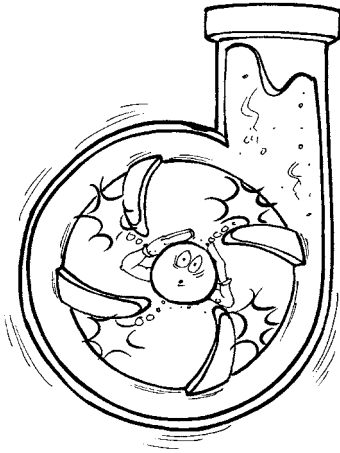
When the vapour bubbles move through the impeller to a higher pressure region, they collapse with such force that mechanical damage can occur.
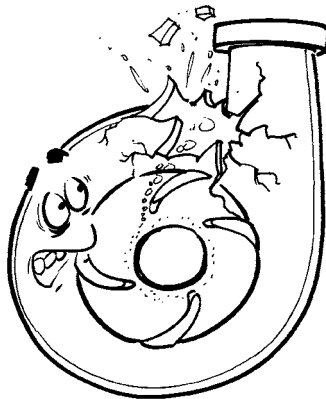
Mild cavitation may produce a little more than a reduction in efficiency and moderate wear. Severe cavitation will result in excessive noise, vibration and damage.

Note!

Slurry pumps suffer less damage by cavitation due to their heavy design, wide hydraulic passages and material used, compared to process pumps.

Pumps operating on a suction lift

When calculating the pump duty in the "high Andes " on page 10:67 above, the suction was critical.

Normally, the standard slurry pump will operate satisfactorily on suction lift applications, however only within the limits of the pump design, meaning

"Required NPSHR is lower than available NPSHA!"

Maximum suction lift is easily calculated for each application, using the following formula.

Max. possible suction lift = atms. pressure - NPSHR - vapour pressure.

Priming of Slurry Pumps
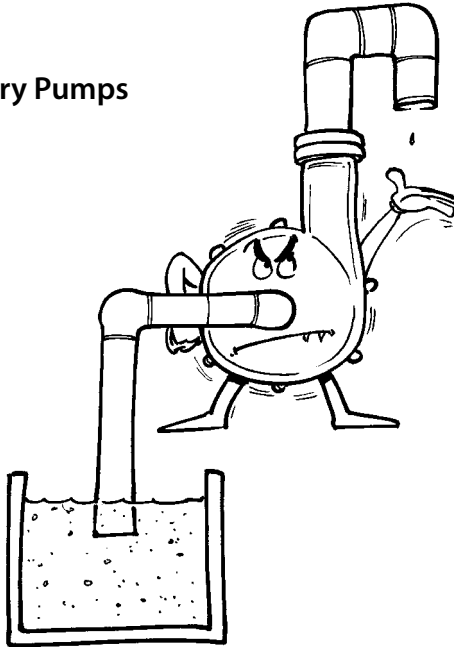
For any centrifugal pump we need to replace the air on the wet side with liquid!

It can be done manually, but usually these applications occur in an industrial environments, where we need an automatic device.

Automatic priming

One way of automatic priming is to use a **"vacuum assisted self priming"** system.
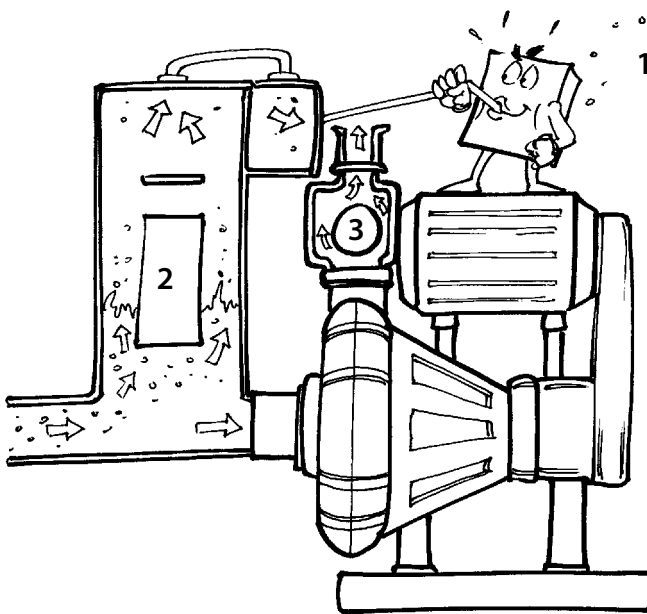
The system requires these basic components added to the Slurry Pump:

1. **Vacuum pump** continuously driven from the main pump shaft, evacuating air from the pump casing.

2. **Priming tank,** bolted to the pump suction side, regulating the water level and protecting the vacuum pump from the ingress of liquid.

3. **Discharge, non return valve,** fitted to the pump outlet, isolating the outlet line during priming conditions.

Froth pumping

Pumping of froth (from flotation or other processes) is a classical problem area of Slurry Pumping.

How does froth affect the hydraulic performance?

In a **horizontal** pump system the problem occurs when frothy slurry gets into contact with the rotating impeller.

In this situation the froth starts to rotate in the pump inlet.
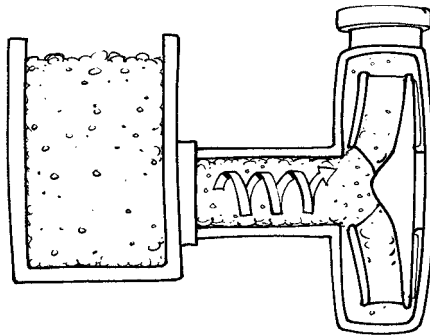
The centrifugal force creates a separation of liquid and air, throwing the liquid outwards and the air collecting at the centre.

The trapped air blocks the path of slurry into the pump and the hydraulic performance of the pump is diminished.

The liquid level in the sump now starts to rise, the inlet pressure increases, compressing the trapped air until the slurry reaches the impeller vanes again.
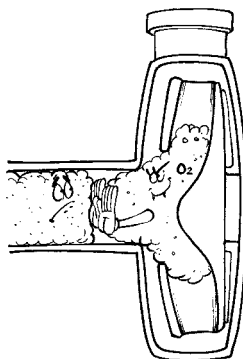
Now pumping starts again and the trapped air is swept away.

However then a new "airlock" will start to build up and the change in performance is repeated, and will continue to be repeated.

The result is an oscillating performance
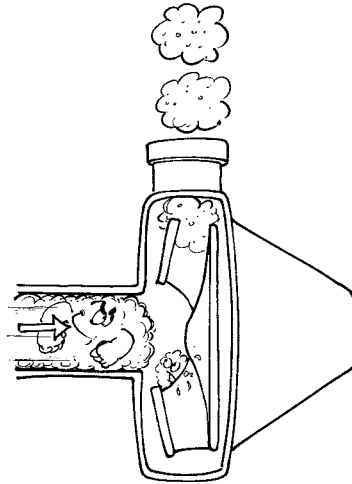
Froth sizing of horizontal pumps

If horizontal Slurry Pumps are the only option, the following rules should be followed to get improved hydraulic performance.

6-10 m
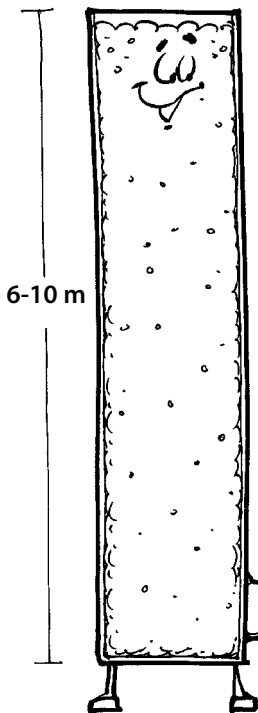
Over-size the pump!

– A large inlet allows more air to escape

– A wider pump inlet is harder to obstruct

Pump throttling must be avoided!

– Inlet pipe must be at least the same size as the outlet pipe

Sump height must be increased!

– To be effective the sump must have a height of 6-10 m

Vertical slurry pumps – the optimal choice for froth pumping

The vertical slurry pumps were originally developed for fluctuating slurry flows and **...froth pumping.**

The two vertical slurry pumps of type VT and VS (below) can both be used for froth pumping.

The **VT slurry pump** (below) consists of a pump and a pump tank integrated into one unit. The pump casing is located under the tank, and connected to the tank through a hole in the bottom of the tank.

The air, concentrated at the centre of the impeller is simply released upwards along the shaft.
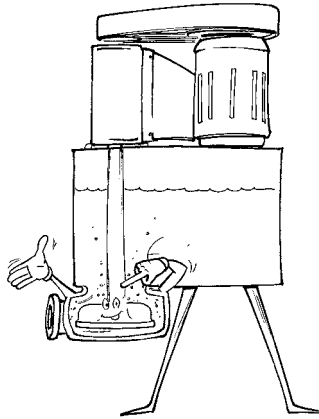
The **VS slurry pump** (below) has the feed entrance from the bottom of the casing. The impeller has operating vanes on the lower side and small sealing vanes on the top side.

In the basic design of the VS pump the casing has two spray holes Through these holes the casing is constantly de-aerated.
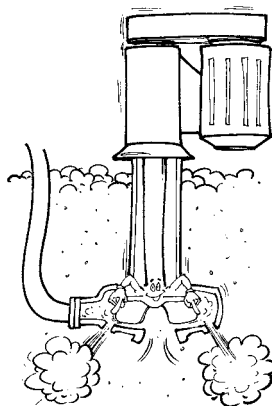
The VF – designed for froth pumping

The VF (vertical froth pump) is specifically designed for froth pumping.
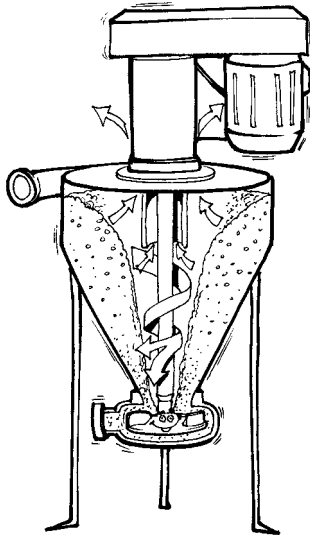
Design criteria

*   The pump shaft is located in the centre of the tank.
*   The tank is conical and covered.
*   The tank has a tangential feed inlet

Function

The tangential feed gives a strong vortex action in the conical tank, similar to the function of a hydrocyclone.

The shear and centrifugal forces in this vortex breaks up (or destroys) the binding between the air bubbles and the solids and separates free air and slurry.

The free air is released upwards along the centre shaft giving blockage free performance.

The covered tank with its patented vortex finder increases performance and reduces spillage.

Advantages

Increased capacity through the pump system.

Reduced spillage around the pump at high loads.

SLURRY PUMP SYSTEMS

General

Having looked at the suction (inlet) side of the slurry pump, we must now look closer at the outlet side, where we have to consider the hydraulic losses in the slurry system.

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

The duty point will be where the pump performance curve crosses the system head curve.
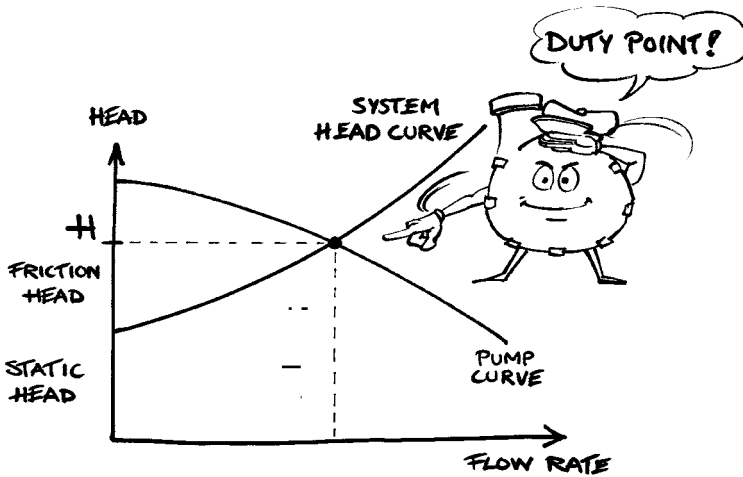
Note!

Never over estimate the system resistance. If over estimated, the slurry pump will:

- **Give a greater flow than required**
- **Absorb more power than expected**
- **Run the risk of overloading the motor (and in worst cases suffer damage)**
- **Cavitate on poor suction conditions**
- **Suffer from a higher wear rate than expected**
- **Suffer gland problems**

Always use the best estimate of system head. Add safety margins to the calculated power only.

Basic on pipe systems

The pipe system
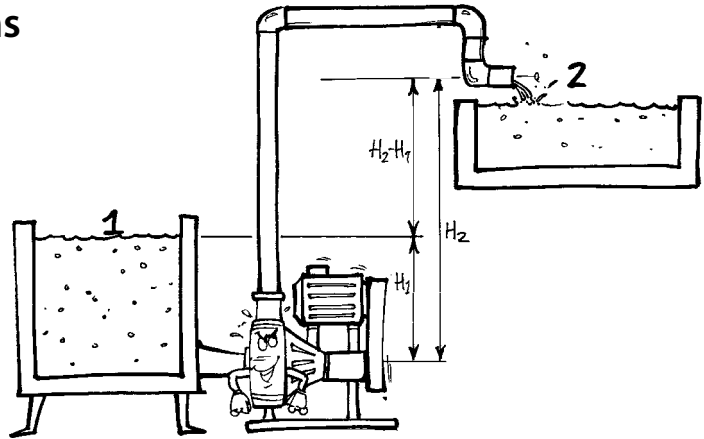
The total head in a liquid is the sum of the static head (gravitational energy), pressure head (strain energy) and velocity head (kinetic energy). The head (energy) the pump has to supply to the liquid to gain the required flow rate is the difference between the total head at the outlet flange and the total head at the inlet.

As we do not know the conditions at the pump flanges, we must select one point on each side of the pump, where we do, and then allow for pipe work losses between these points and the flanges to determine the total head at the flanges.

In the diagram above the total head is known at the liquid surface in the feed tank (Point 1) and the outlet pipe exit (Point 2).

At point 1 Static Head $= H_1$

Pressure Head   = 0 (atmospheric pressure)

Velocity Pressure = 0 (practically no velocity)

Therefore Pump Inlet Head $= H_1$ – inlet pipe losses

At point 2 Static Head $= H_2$

Pressure Head   = 0 (atmospheric pressure)

Velocity Head $= V_2^2 / 2g$

Where V_2 = Flow velocity at Point 2 in m/s

g   = Gravitational constant = 9.81 m/s²

Therefore Pump outlet head $= H_2 + V_2^2 / 2g$ + outlet pipe losses

Pump differential head (PHD) = Outlet head – inlet head

PHD $= (H_2 + V_2^2 / 2g$ + outlet pipe losses$) - (H_1 -$ Inlet pipe losses$)$

In practice the velocity head is small (3.0 m/s gives a velocity head of 0.46 m), and is therefore often ignored.

Then   PHD $= H_2 - H_1$ + outlet losses + inlet losses

Friction losses

Straight pipes

Similar to a voltage drop in a power cable, there are friction losses in a pipe system.

Friction loss in a straight pipe varies with:

- **Diameter**
- **Length**
- **Material (roughness)**
- **Flow rate (velocity)**

The friction loss can either be:

1. Looked up in a table

2. Extracted from a Moody diagram.

3. Calculated from semi-empirical formula, such as the Hazen & William Formula.

If friction calculation software such as Metso's PumpDim™ for Windows™ is not used then we recommend that you use the diagram on the next page.

Friction losses

Fittings

When a system includes valves and fittings, an allowance for additional friction is needed.

The most common method for calculation of friction loss caused by fittings is called the "Equivalent pipe length" method. This method can be used for liquids other than water, i.e. viscous and non-Newtonian flows. The fitting is treated as a length of straight pipe giving equivalent resistance to flow. See table on page 80.

TEL – Total Equivalent Length

TEL = Straight pipe length + equivalent length of all pipe fittings.

Velocities and friction losses for clear water in smooth steel pipes – Calculation chart

Friction losses are based on Hazen and William's formula with C = 140.

Example, shown by dotted line: 2000 l/min. (530 USGPM) in 150 mm dia. pipe gives velocity 1.9 m/sec (6.2 FPS) friction loss 2.2%.

Velocity in pipe

Friction losses, metres/100 metres pipe

Flow L/min
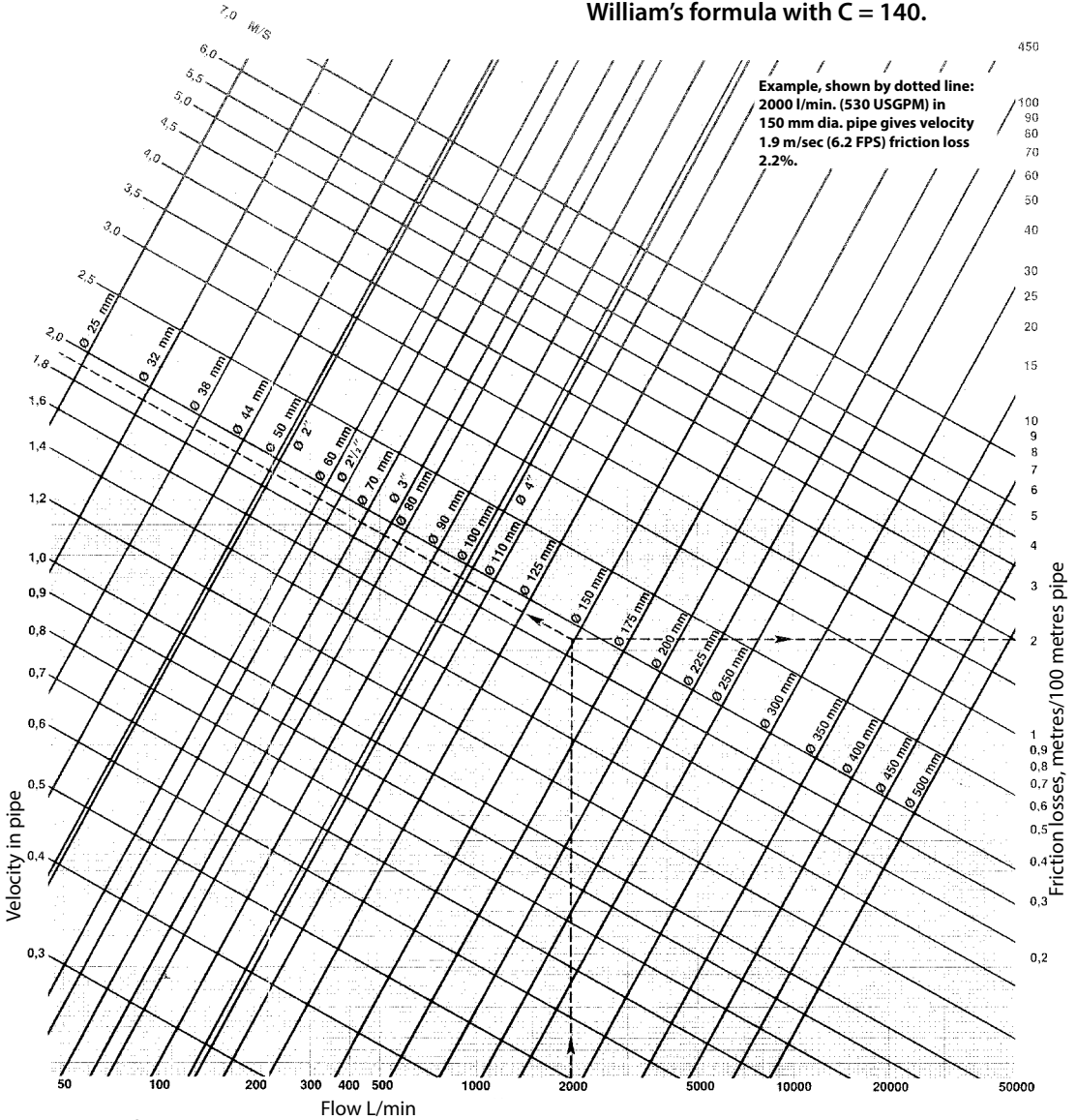
Pumping of slurries
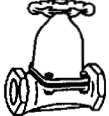
When calculating the pipe friction losses for a slurry (suspension of solid particles in water) it is avisable to allow for a certain increase when compared with the losses for clean water. Up to concentrations of around 15 percent by volume one may assume that the suspension will behave as water. For higher concentrations friction losses should be corrected by a factor taken from the diagram below.

Calculated values must be used for rough estimates only
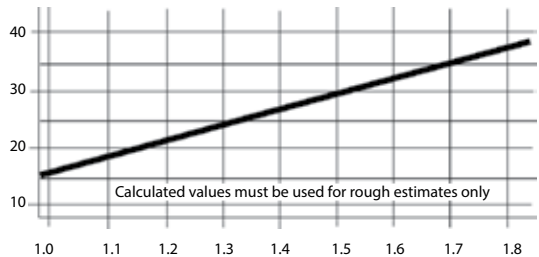
VALVES, FITTINGS, HEAD LOSSES

Approx. resistance of valves and fittings frequently used on slurry pipelines.

Pipe Size N.B	R>3xN.B. Long Radius Bend	R=2xN.B. Short Radius Bend	Elbow	Tee	R>10xN.B. Rubber Hose	Dia-phr. Full Open	Full Bore Valve	Plug Lub Valve Rect Way
25	0,52	0,70	0,82	1,77	0,30	2,60	-	0,37
32	0,73	0,91	1,13	2,40	0,40	3,30	-	0,49
38	0,85	1,09	1,31	2,70	0,49	3,50	1,19	0,58
50	1,07	1,40	1,67	3,40	0,55	3,70	1,43	0,73
63	1,28	1,65	1,98	4,30	0,70	4,60	1,52	0,85
75	1,55	2,10	2,50	5,20	0,85	4,90	1,92	1,03
88	1,83	2,40	2,90	5,80	1,01	-	-	1,22
100	2,10	2,80	3,40	6,70	1,16	7,60	2,20	1,40
113	2,40	3,10	3,70	7,30	1,28	-	-	1,58
125	2,70	3,70	4,30	8,20	1,43	13,10	3,00	1,77
150	3,40	4,30	4,90	10,10	1,55	18,30	3,10	2,10
200	4,30	5,50	6,40	13,10	2,40	19,80	7,90	2,70
250	5,20	6,70	7,90	17,10	3,00	21,00	10,70	3,50
300	6,10	7,90	9,80	20,00	3,40	29,00	15,80	4,10
350	7,00	9,50	11,00	23,00	4,30	29,00	-	4,90
400	8,20	10,70	13,00	27,00	4,90	-	-	5,50
450	9,10	12,00	14,00	30,00	5,50	-	-	6,20
500	10,30	13,00	16,00	33,00	6,10	-	-	7,30

Length in metres of straight pipe giving equivalent resistance to flow.

Slurry effects on friction losses

As for pump performance, friction losses are also affected by slurries since they behave differently to clear water. The slurry has to be treated either as settling or non-settling (viscous).

Generally, slurries with particle size <50 micron are treated as non-settling.

Friction losses settling slurries

The assessment of friction losses for settling slurries is very involved, and best accomplished on computer software such as Metso PumpDim™ for Windows™.

However, for short runs of pipe at higher velocities, head loss can be taken as equal to the water losses. For approximate estimations the correction factor on the bottom of page 80 can be used.
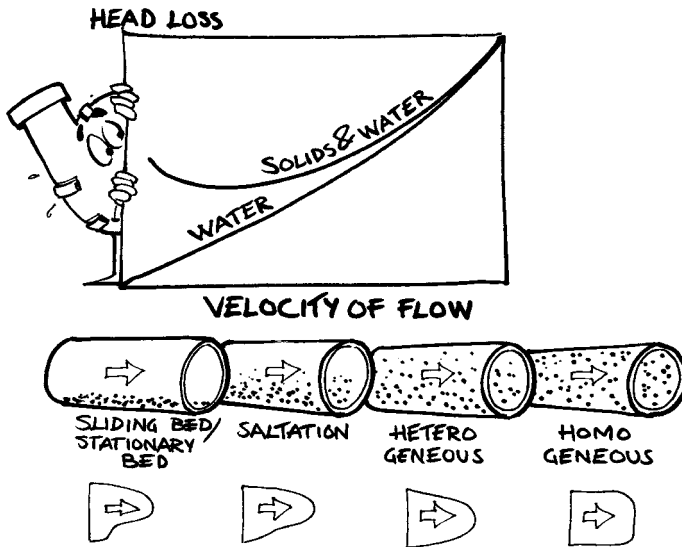
At low velocities, head loss is difficult to predict, and there is a real risk of solids settling out and blocking the pipe.

The minimum velocity nomogram on next page will provide a safe minimum velocity.

PIPE DIAMETER D (m)

PARTICLE DIAMETER d (mm) FOR GRAINS WITH Sg = 2.65

VELOCITY AT LIMIT OF STATIONARY DEPOSIT V_{sm} (m/s) FOR GRAINS WITH Sg = 2.65

RELATIVE DENSITY Sg

V_{sm} (m/s) FOR GRAINS WITH Sg = 2.65
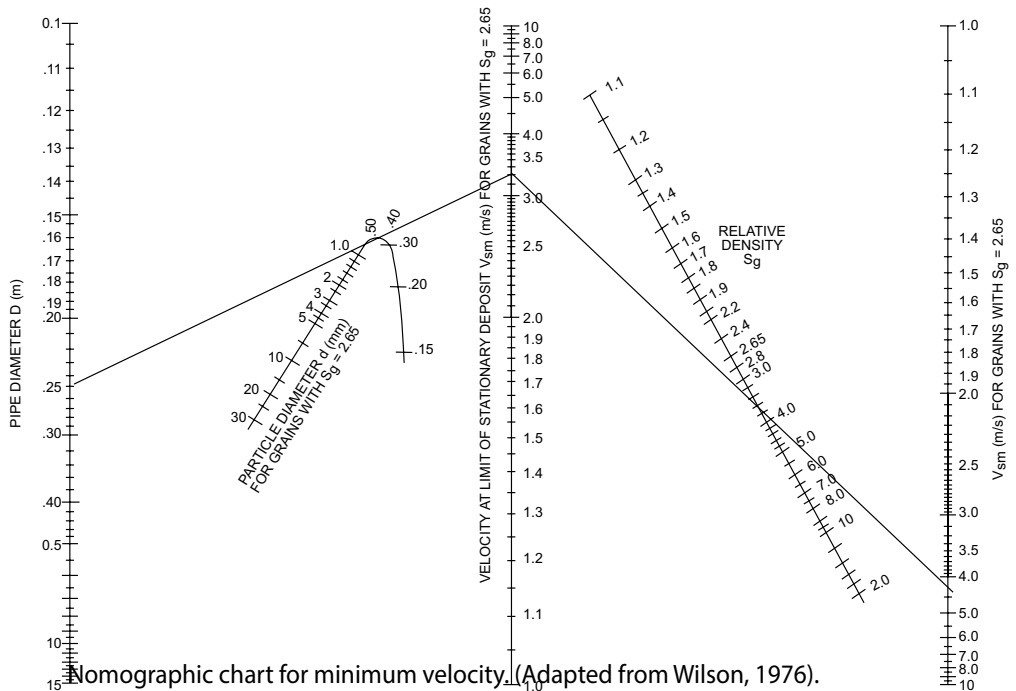
Nomographic chart for minimum velocity. (Adapted from Wilson, 1976).

Example:	Pipe dia 250 mm	= 0,250 m
	Particle size	= 0,5 mm (Worst case)
	Particle S. G.	= 3,8 kg/dm³
	Minimum velocity	= 4,5 m/s

Friction losses non-settling slurries

Friction loss assessments for non-settling slurries are best accomplished with the aid of computer software.

However, there are numerous methods of making assessments manually, although these can prove difficult with all the variables.

Whatever method is used, full rheology of the viscous solution is necessary for any accurate assessment.

Assumptions can be made but these can prove very inaccurate.

Summary:

It is very important that all the losses in a slurry system are calculated **in the best way possible,** enabling the pump to balance the total system resistance, operate at the correct duty point, giving correct head and capacity!

Use computer software PumpDim™ for Windows™.

Sump arrangements

Below you will find some useful guidelines for the design of pump sumps for slurries:

Horizontal pump sump
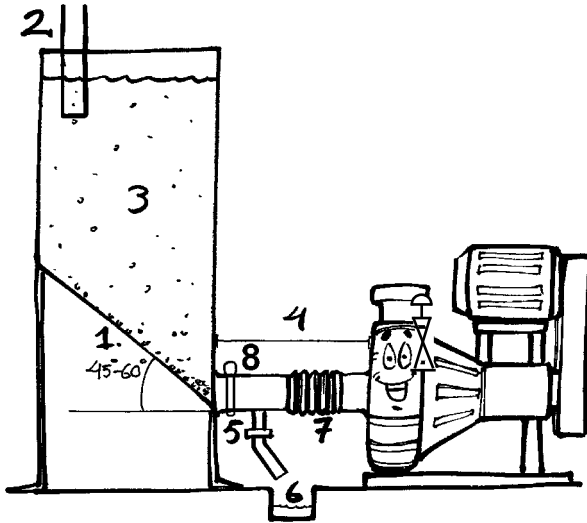
1. Sump bottom should have an angle of at least 45°. Fast settling particles may need up to 60° .

2. Sump feed should be below the liquid surface to avoid air entrainment. This is especially important with frothy slurries.

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 then 10 x pipe diameter should be avoided.

The following should be included on the sump connection:

5. **Drain connection** on the inlet pipe. It's recommended to have a floor channel **(6)** under the drain to recover the slurry.

7. **Flexible inlet connection** that is reinforced since vacuum can be created.

8. Full bore **shut off valve.**

Separate sumps are preferred for standby pump installations. This will avoid settling out in the standby pump sump when not in use.

Floor sumps
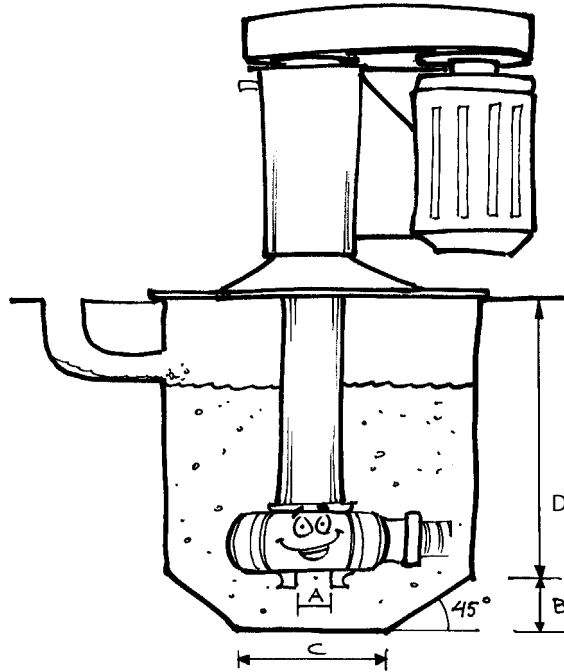
Sump volume as small as possible (to avoid sedimentation).

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"

Pumps in series

When the required head is not achieved with a single pump, two (or more) pumps can be operated in series.
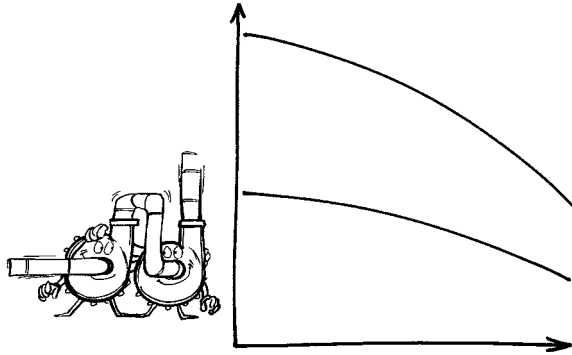
For two pumps in series the discharge from the first stage pump is connected directly to the second pump, effectively doubling the head produced.

For two identical pumps 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.
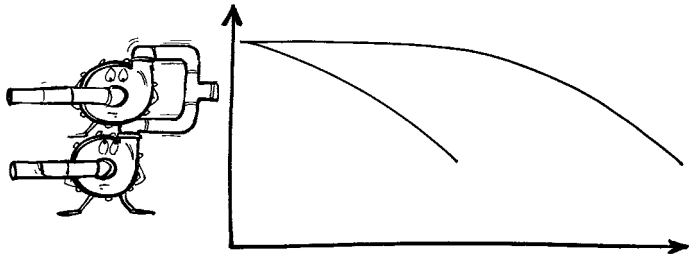
Basics about viscosity

In slurry pumping we are always coming across the word "viscosity".

Viscosity = the slurry's ability to flow

This ability to flow is dependent on the **internal friction** in the slurry, i.e. the capability to transfer shear stress (or movement) within the slurry.

Generally, there are two types of liquid when discussing this ability to flow:

Newtonian and Non-Newtonian

Newtonian

A Newtonian liquid's movement or shear rate is linear and proportional to the input of kinetic energy which creates a shear stress in the slurry.
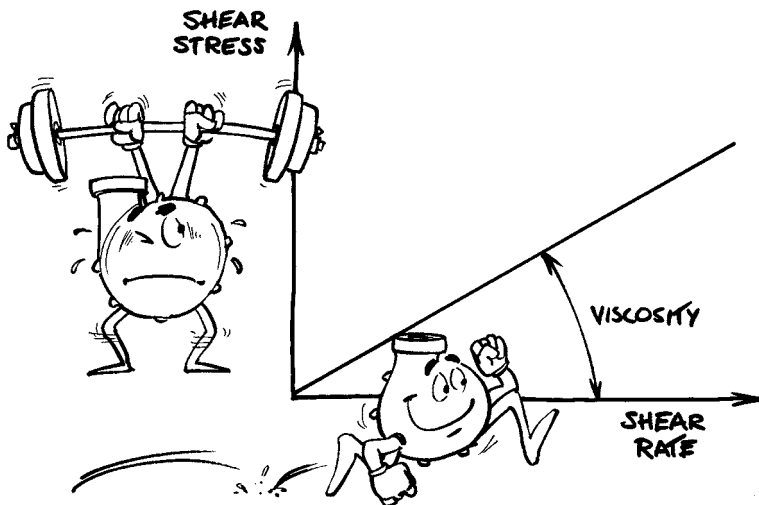
Viscosity is defined as the tangent of the angle and is constant for a Newtonian slurry.

Typical Newtonian liquids are water and oil.

Non-Newtonian

Most high concentration fine particle slurries are non-Newtonian and have what is known as **"plastic"** behaviour.

This means that energy must be put into the slurry in order to start flow, e.g. a fine sediment in the bottom of a bucket needs to be helped by knocking the bottom to get it to flow out. When the energy level is reached the relation between liquid movement and energy is a straight line.
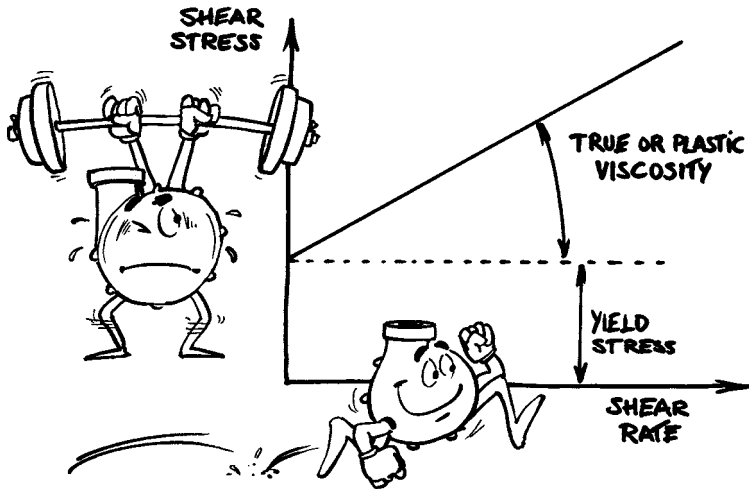
To establish friction losses - or effects on pump performance for "plastic" slurries the true plastic dynamic viscosity and the energy level (yield stress) for the float point have to be verified.

We can provide test work to verify these parameters.

Apparent viscosity

The apparent viscosity is often mistakenly assumed the same as the true or plastic dynamic viscosity.
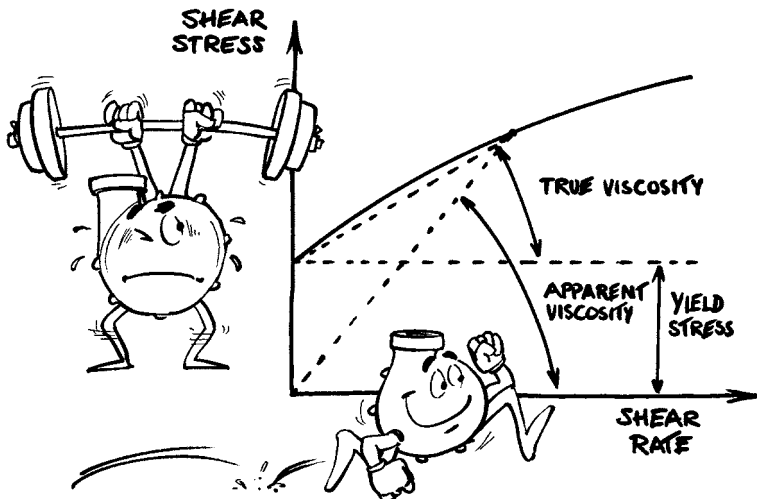
The apparent viscosity changes with shear rate as shown in the diagram above. The true viscosity should be used in all pump calculations, together with the yield stress where appropriate.

Other non-Newtonian fluids

There are other non-Newtonian fluids in which the shear stress is not linear with shear rate. **"Dilatant"** fluids where viscosity increases with energy input, (e.g. organic polymers and paper pulp).

Pseudo plastic fluids decrease in viscosity with energy input (e.g. paints, inks, mayonnaise).

All non-Newtonian behaviours above are **not time dependent.**

There are also some **time dependent** non Newtonian fluids. **Rheopexic** fluids increase in viscosity with time for a given energy input, (e.g. bentonite and other "hydrophilic" slurries), and thixotropic fluids decrease in viscosity with time (e.g. non-drip paint).

BEST EFFICIENCY POINT (BEP)

The hydraulic performance of a slurry pump naturally affects the mechanical load on various parts of the pump design.

For all centrifugal slurry pumps there is only one point which is really ideal for the particular slurry pump involved - the Best Efficiency Point (BEP).
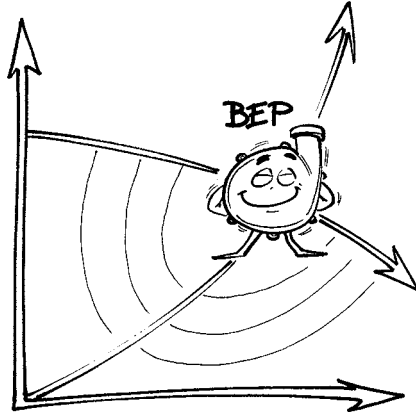
This point is located at the intersection of the best efficiency line and the line relating differential head to volumetric flow rate at a particular pump speed.

"BEP - the optimal operating point for the pump!"

Why is this point so important?

Hydraulic effect of efficiency point operation

To fully understand the importance of operating at (or close to) the best efficiency point we have to study the hydraulic behaviour in the pump.
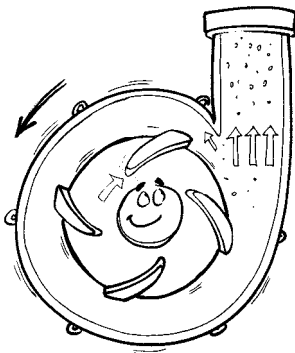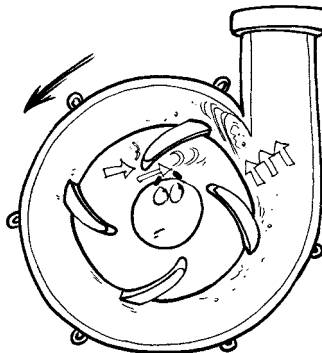
BEP operation   Below BEP operation   Over BEP operation
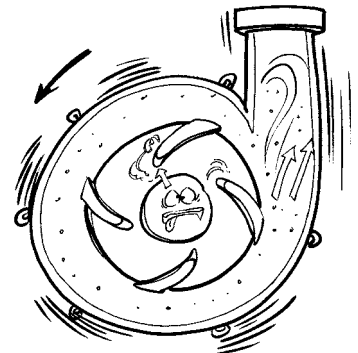
If we look at the hydraulic effects on the page before we can notice the following effect on the slurry pump design.

Radial load

Within a centrifugal pump casing there are unbalanced pressures acting on the impeller, causing the pump shaft to deflect.

In theory, this radial force applied to the impeller is negligible at the best efficiency point (BEP).

At increased speed and flows both above and below BEP, the radial force increases significantly.
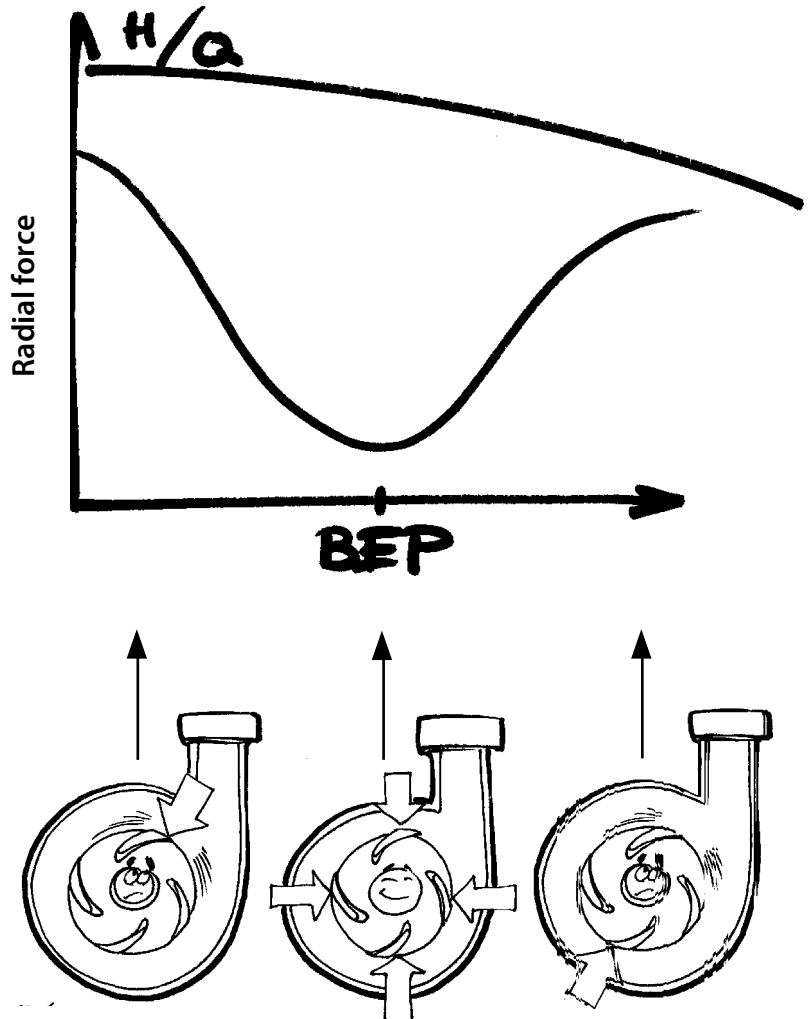
Axial load

Pressure distributed on the front and back shrouds of a pump impeller create an axial load towards the pump inlet.

For slurry pumps which are of end suction type, the inlet pressure acting on the shaft cross-sectional area creates an axial load away from the pump inlet.

The summation of these two forces gives a resulting axial loading on the shaft.

With a low inlet pressure (head) this net force acts towards the pump inlet, but with vanes on the back shrouds, this force is normally balanced.

As the inlet head increases, the force acts away from the pump inlet.

Effects of shaft deflection

Varying impeller loads cause the impeller and shaft to deflect. This shaft deflection has an adverse effect on the shaft sealing as well as bearing life.

Excessive shaft deflection will cause mechanical seals to fail and packed stuffing boxes to leak.

As shaft packings not only seal a stuffing box, but act as a hydrodynamic bearing, excessive shaft sleeve wear could also occur following operation under high radial load/shaft deflection.
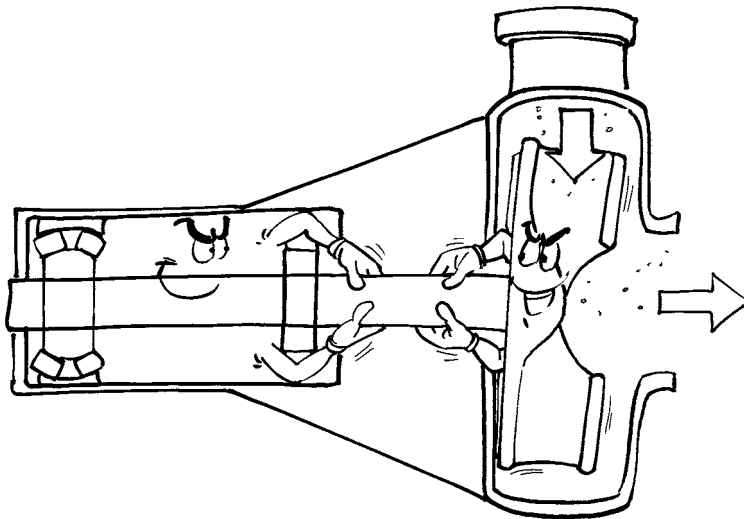
Operating at BEP – summary

"Selection of a pump that operates at or very near its BEP is preferable, although not always possible with a limited range of pumps.

At BEP, radial load and shaft deflection are at a minimum, thereby ensuring good shaft seal and bearing life.

Power absorbed is at a minimum and smooth hydraulic flow is assured.

For slurry pumps, the minimum of turbulence and recirculation at BEP also equate to minimum wear".

NOMENCLATURE AND FEATURES

Metso slurry pump program

Nomenclature

Horizontal pumps

Type **XM**	=	E**X**tra Heavy Duty Slurry Pump with **M**etal Wear Parts
Type **XR**	=	E**X**tra Heavy Duty Slurry Pump with **R**ubber Wear Parts
Type **HM**	=	**H**eavy Duty Slurry Pump with **M**etal Parts
Type **HR**	=	**H**eavy Duty Slurry Pump with **R**ubber Parts
Type **HG**	=	**H**eavy Duty **G**ravel Pump
Type **HP**	=	**H**eavy Duty High **P**ressure Pump
Type **HT**	=	**H**eavy Duty **T**unneling Pump
Type **MM**	=	**M**ining Duty Slurry Pump with **M**etal Parts
Type **MR**	=	**M**ining Duty Slurry Pump with **R**ubber Parts

Vertical pumps

Type **VT**	=	**V**ertical Slurry Pump of **T**ank type with metal or rubber parts
Type **VF**	=	**V**ertical Slurry Pump of **F**roth type with metal or rubber parts
Type **VS**	=	**V**ertical Slurry Pump of **S**ump type with metal or rubber parts
Type **VSHM**	=	**V**ertical Slurry Pump of **S**ump type, **H**eavy duty with **M**etal parts
Type **VSHR**	=	**V**ertical Slurry Pump of **S**ump type, **H**eavy duty with **R**ubber parts
Type **VSMM**	=	**V**ertical Slurry Pump of **S**ump type, **M**ining duty with **M**etal parts

Features and sizes

HIGHLY ABRASIVE DUTY PUMPS

Range	XM	XR	VASA HD	HM	HR
Material	Hard Metal	Elastomers	Elastomers / Hard Metal	Hard Metal	Elastomers
Frame	X	X	VASA HD	O	O

Features

High Impeller Aspect Ratio

Robust Construction

Back Pull-out (not XM)

High Efficiency

Effective Dry Gland Sealing

Designed for highly abrasive, maximum duty and aggressive environment

INLET SIZES (mm)

800	
600	XM
400	XR
200	VASA HD / HM / HR
50	
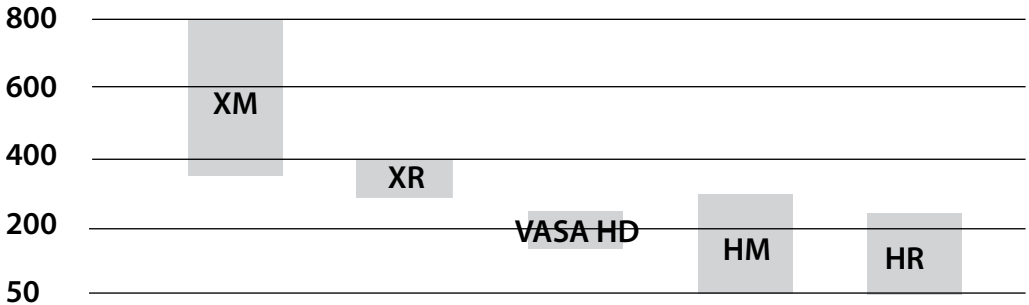
Features and sizes

ABRASIVE DUTY PUMPS

Range	**MM**	**MR**
Material	**Hard Metal**	**Elastomers**
Frame	**O**	**O**

Features
Medium Impeller Aspect Ratio

Compact Cost Effective Construction

Back Pull-out

High Efficiency

Effective Dry Gland Sealing

Designed for abrasive, medium
duty and aggressive environment

INLET SIZES (mm)

500 ——————————————————————————————
400 ——————————————————————————————
MM
300 ——————————————————————————————
MR
200 ——————————————————————————————
100 ——————————————————————————————
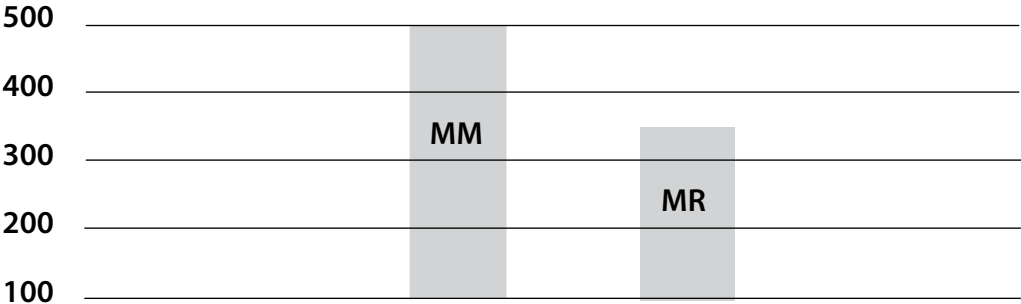
Features and sizes

VERTICAL PUMPS

Type	SUMP	SUMP	FROTH	TANK
Range	VSHR	VS VSHM VSMM	VF	VT
Material	Elastomer	Hard Metal/ Elastomer	Hard Metal/ Elastomer	Hard Metal/ Elastomer
Frame	V	V	V	V

Features

Cantilever design

No shaft seals

Lay out flexibility

Simple installation

Robust design and easy to maintain

Common wet end parts for VF/VT range

Rubber/metal interchangeability

OUTLET SIZES (mm)

		VSMM	VS	VF	VT
VSHR	VSHM				

350
250
200
50
40
25
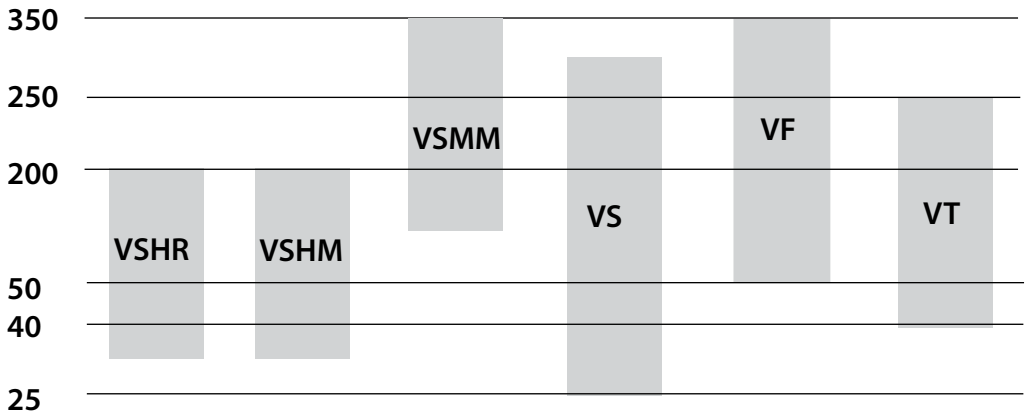
Features and sizes

SLURRY SEAL
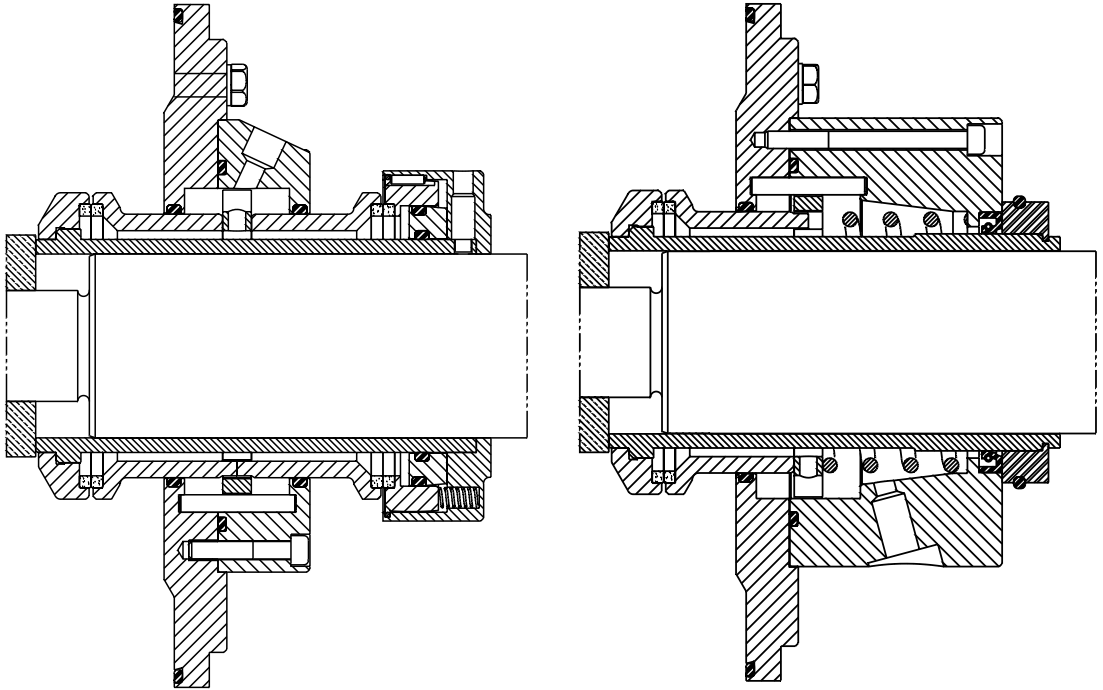
Features

- Designed to fit the pump
- Adjustable stationary seal ring ± 12 mm
- High tech silicon carbide on all seal faces
- Patented design with the springs located on atmospheric side. Protected from both product and barrier

Frame	Seal Type	Item No.	Frame	Seal Type	Item No.
250	BA-047,5-WW107/WW187	SA 981 205	250	BF-047,5-WW177	SA 981 199
300	BA-063--WW107/WW187	SA 981 206	300	BF-063-WW177	SA 981 200
400	BA-075-WW107/WW187	SA 981 207	400	BF-075-WW177	SA 981 201
500	BA--095-WW107/WW187	SA 981 208	500	BF-095-WW177	SA 981 202
600	BA-111,7-WW107/WW187	SA 981 209	600	BF-111,7-WW177	SA 981 203
750	BA-120-WW107/WW187	SA 981 210	750	BF-120-WW177	SA 981 204

TECHNICAL DESCRIPTION

General

If you look at a breakdown of the relative operating costs for a "normal" slurry pump installation you will find the factors that guide our design of slurry pumps.
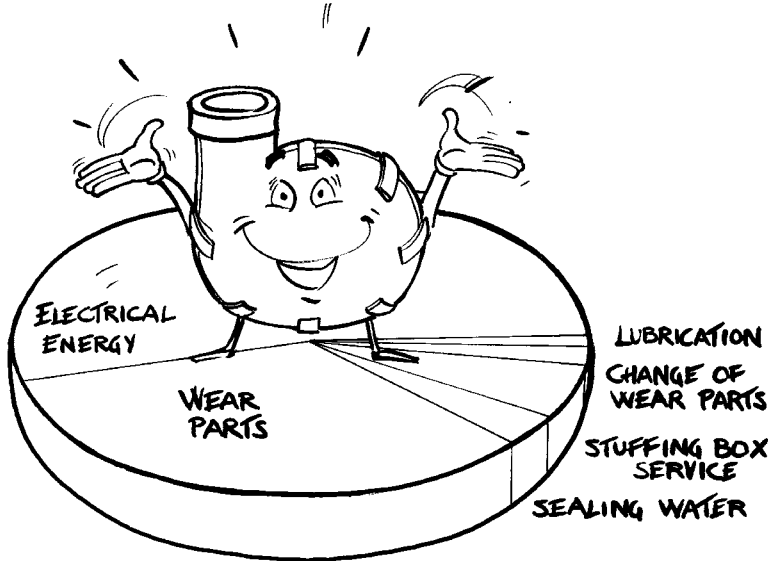
1. High efficiency and minimised solids effect on efficiency drop **giving** lower power consumption.

2. New wear materials, both elastomers and metal, of good design **giving** long life for wear parts.

3. Service features in the design **giving** short shut down cycles and low maintenance costs.

4. Modern sealing designs **giving** low down time and costs for shaft sealing.

These are our contributions to good operation and economy using Metso slurry pumps as described in this section.

The slurry pump program

Thomas X Series of
Extra Heavy Duty Slurry Pumps
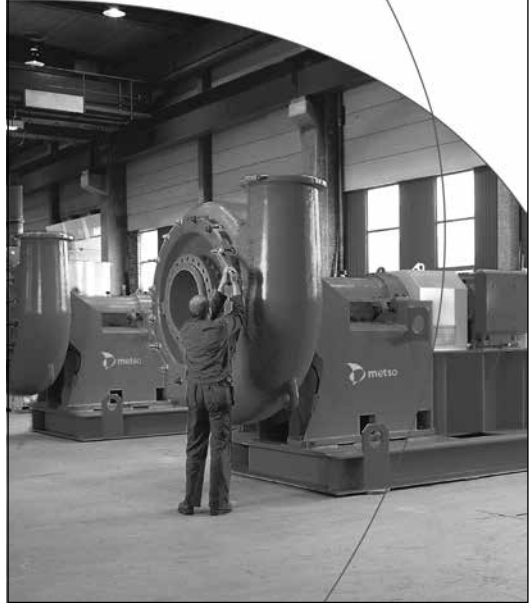
The Orion Series of
Heavy & Mining Duty
Horizontal Slurry Pumps

The SALA Series of
Vertical Sump Pumps

The SALA Series of
Vertical Froth Pumps

metso
Expect results

The SALA Series of
Vertical Tank Pumps
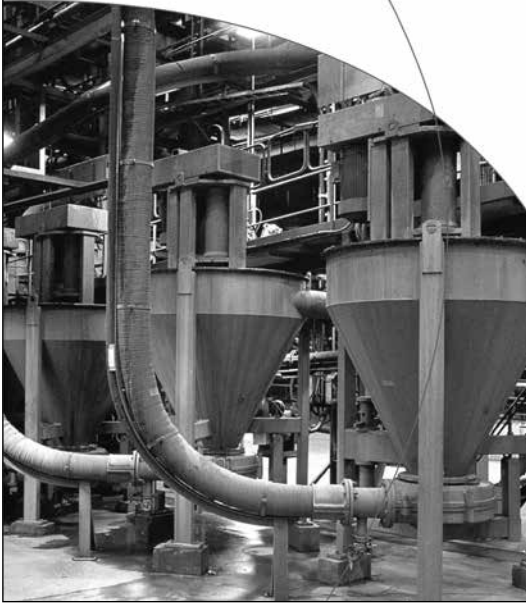
metso
Expect results
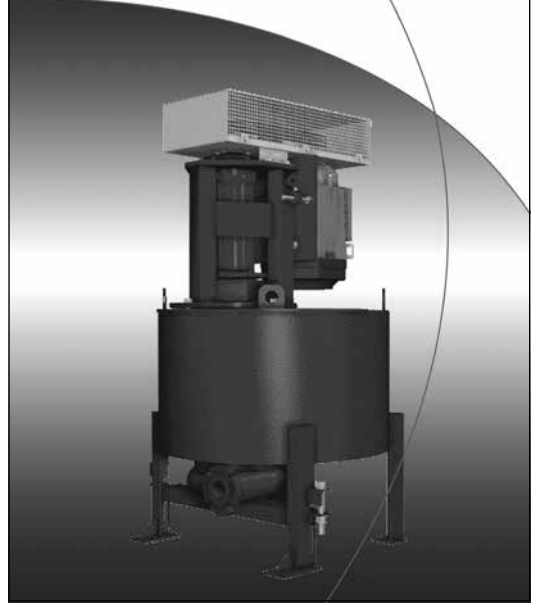
The Thomas Series of
Dredge Pumps

metso
Expect results

The Thomas "Simplicity" Series of
Dredge Pumps

metso
Expect results

Technical description
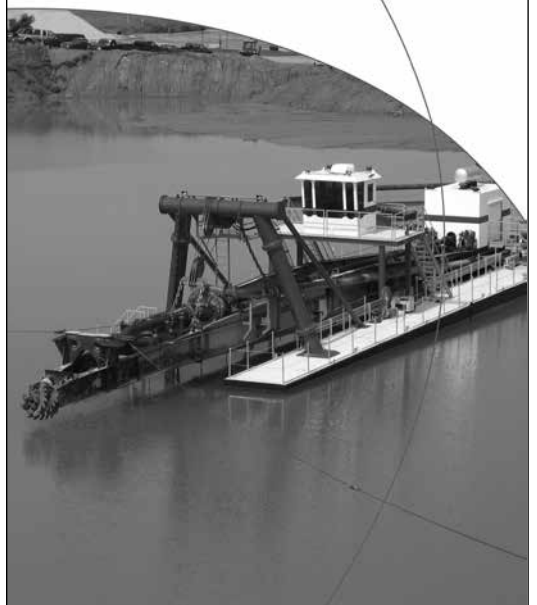
Slurry Pump
Wet End Conversion Kit

Mechanical Slurry Seal
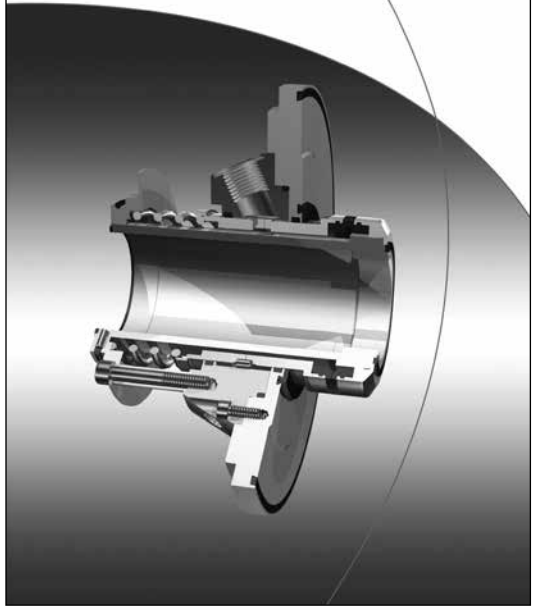
Denver SRL®
Rubber replacement parts
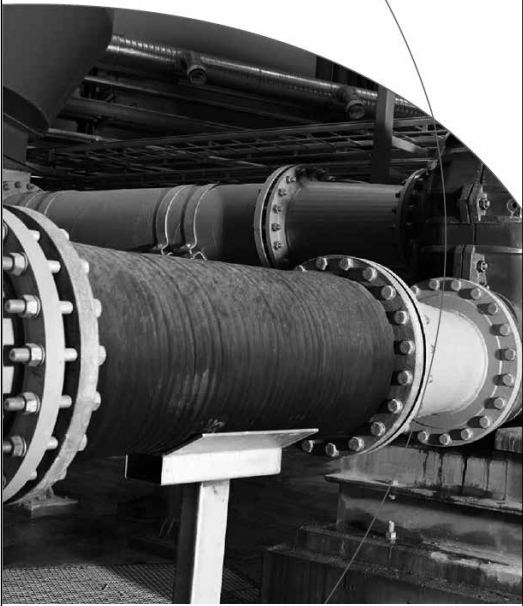
Slurry pump range MD

The Metso series hard metal and rubber lined mill discharge pumps
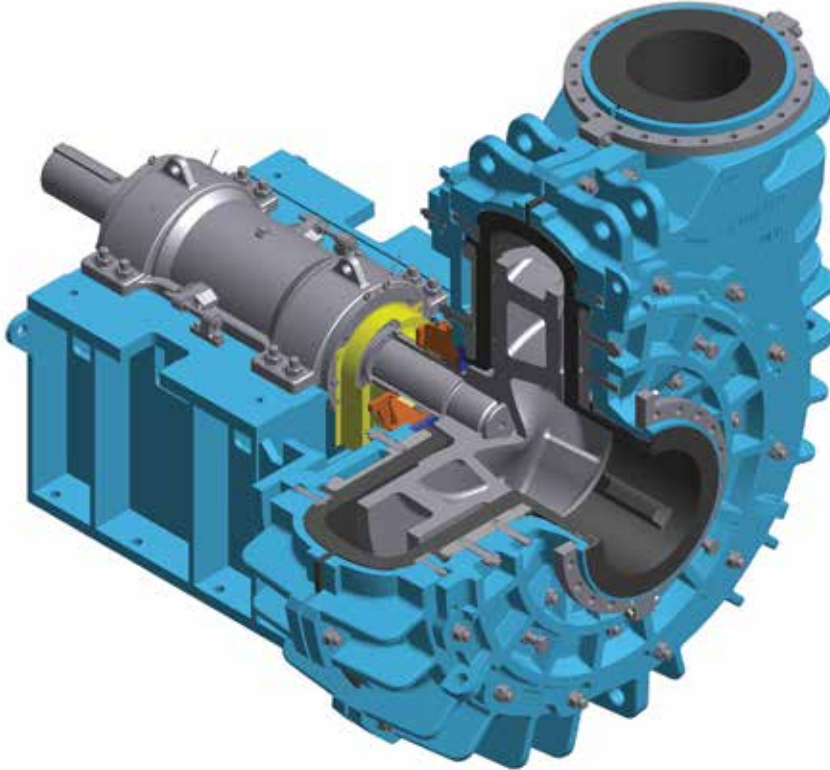
Summary of design features

- High sustained efficiency
- Even hydraulic wear
- Longer operating life
- Oversized robust steel shaft
- Extra thick casings and liners at known points of wear
- Back pull-out option for ease of maintenance
- Self contained oil or grease lubricated bearing cartridge assembly with non contact labyrinth seals for maintenance free operation
- Bearing housing arranged to accept temperature and vibration sensors
- Split stuffing box gland and gland guard
- Various shaft seal options including Metso EnviroSet™
- Modular design with good interchangeability of parts
- Loose steel flange connections

See data sheets on next page.

Slurry pump range MD

Selection charts
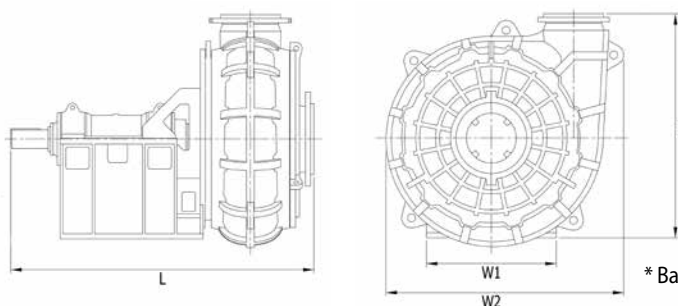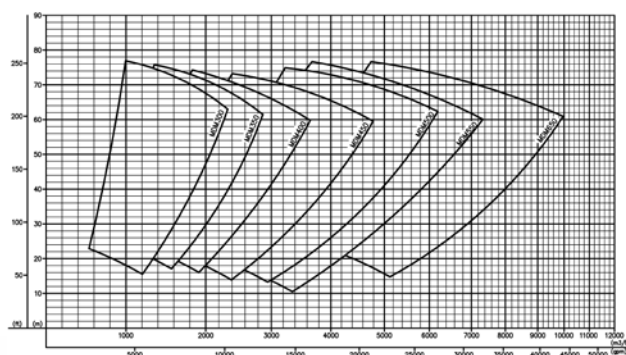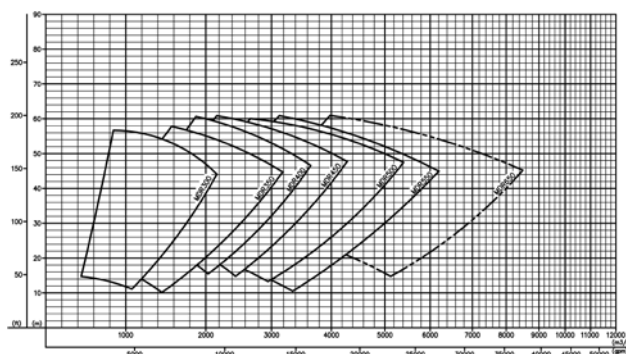
* Bare shaft pump weight

Model	Inlet		Outlet		H		L		W1		W2		Weight *	
	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	kg	lb
MDM300	300	12	250	10	1400	55,1	2246	88,4	900	35,4	1485	58,5	4845	10660
MDM350	350	14	300	12	1750	68,9	2473	97,3	1000	39,4	1678	66,1	7655	16840
MDM400	400	16	350	14	1940	76,4	2876	113,2	1300	51,2	1915	75,4	12065	26545
MDM450	450	18	400	16	2020	79,5	2940	115,7	1300	51,2	2104	82,8	14245	31335
MDM500	500	20	450	18	2145	84,4	3042	119,7	1300	51,2	2380	93,7	18105	39830
MDM550	550	22	450	18	2145	84,4	3059	120,4	1300	51,2	2380	93,7	18130	39885
MDR300	300	12	250	10	1300	51,2	1830	72,0	940	37,0	1519	59,8	3045	6700
MDR350	350	14	300	12	1346	53	2215	87,2	900	35,4	1772	69,8	4680	10300
MDR400	400	16	350	14	1940	76,4	2876	113,2	1300	51,2	1915	75,4	10610	23395
MDR450	450	18	400	16	2020	79,5	2940	115,7	1300	51,2	2227	87,7	12525	27560
MDR500	500	20	450	18	2145	84,4	3042	119,8	1300	51,2	2519	99,2	17460	38415
MDR550	550	22	450	18	2145	84,4	3059	120,4	1300	51,2	2519	99,2	17470	38435

Slurry pump range XM

The Thomas series of extra heavy duty hard metal slurry pumps

The XM (hard metal), extra heavy duty slurry pump range is designed for the most arduous pumping applications. The rugged "wet end" is designed with extra thick metal sections at known points of wear and the high aspect ratio impeller ensures excellent performance with long wear life.
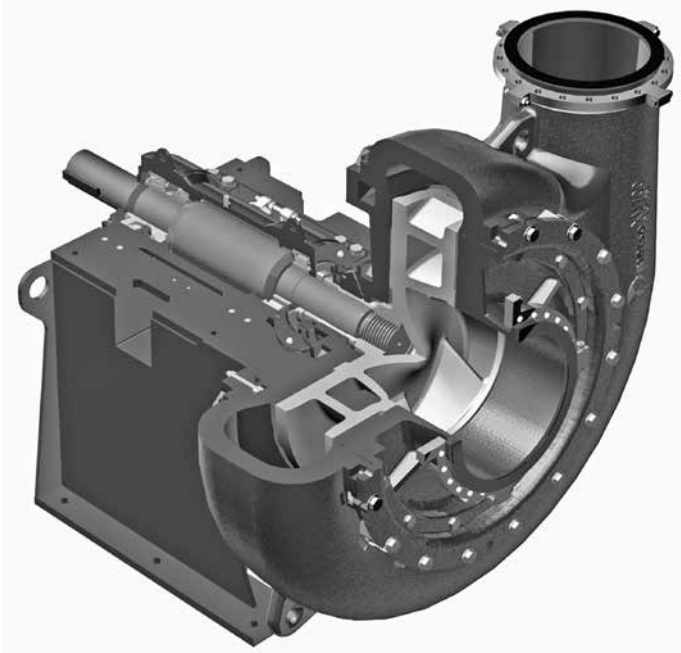
Summary of design features

- Modular design technology
- Robust construction designed for highly abrasive, maximum duty
- Thick volute casings and heavy duty solids handling impellers, with high aspect ratio, and carefully matched, high efficiency, hydraulics for even wear
- Materials used are the very best available, providing both excellent wear properties and corrosion resistance
- Self contained bearing cartridge assembly with oversized shaft and grease/oil lubricated anti-friction bearings
- Various shaft seal options
- Ease of maintenance
- Maintenance slide base option

PUMP DESIGNATION

XM 350

Pump range ——————⌐   ⌐—————— Inlet size (mm)

Selection chart

Pump dimensions
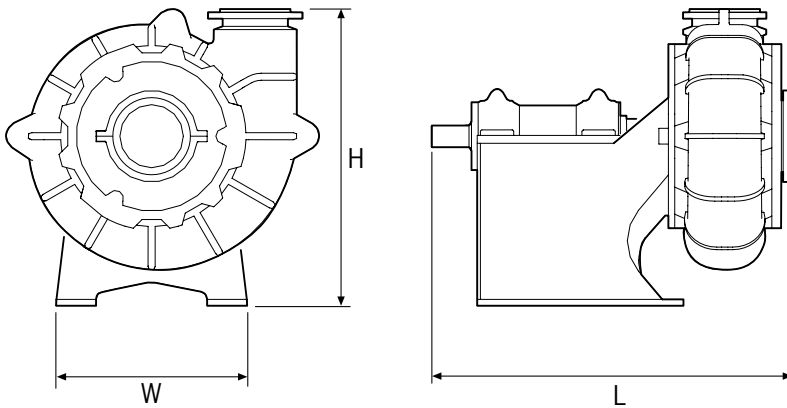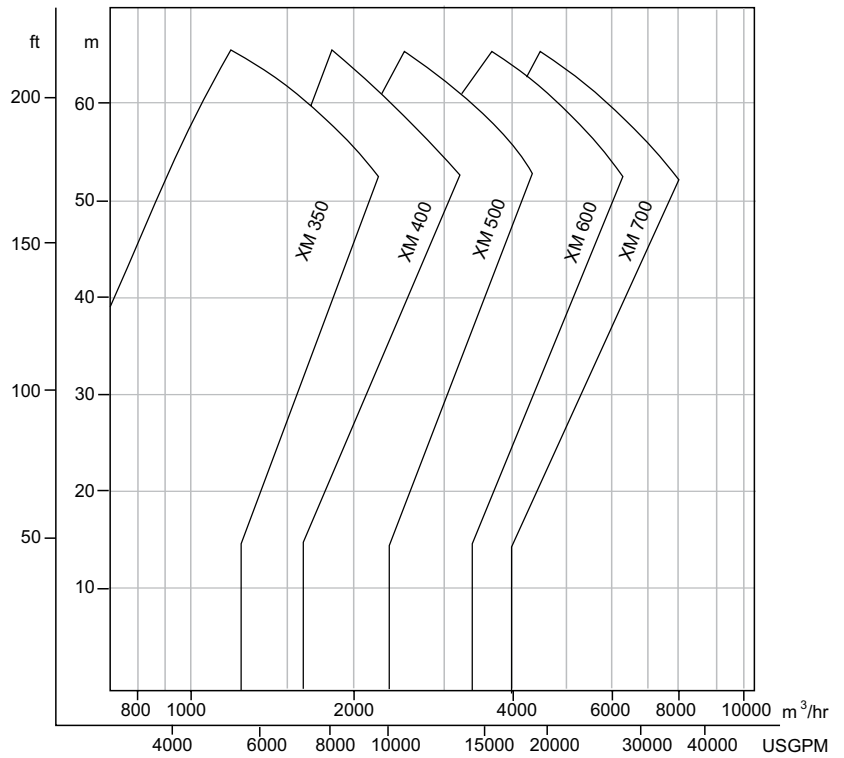
Model	Inlet mm (inch)	Outlet mm (inch)	H mm (inch)	L mm (inch)	W mm (inch)	Weight* ton	Weight* (lb)
XM350	350 (14)	300 (12)	1 727 (68)	1 808 (71)	1 110 (44)	5	11 023
XM400	400 (16)	350 (14)	1 881 (74)	1 980 (78)	1 204 (47)	6,7	14 770
XM500	500 (20)	450 (18)	2 150 (85)	2 145 (84)	1 380 (54)	9,8	21 649
XM600	600 (24)	550 (22)	2 468 (97)	2 308 (91)	1 566 (62)	14,9	33 014
XM700	700 (28)	650 (26)	2 560 (100)	2 324 (91)	1 565 (62)	19,9	43 940

*Bare shaft weight

The Thomas series of "Simplicity" dredge pumps

The Thomas "Simplicity" dredge pump is engineered for your specific operation.

Years of operation and many design improvements have resulted in a pump which will give you lowest operating cost of any pump in the industry when handling abrasive materials.

The rugged wet-end parts are designed to feature extra heavy metal sections at points of extreme wear – the extra weight pays off in performance and low maintenance cost.

No other dredge pump manufacturer offers the wide range of wear-resistant alloys as provided by Metso. Matching the correct alloy to your specific application will give you the best performance and lowest cost.
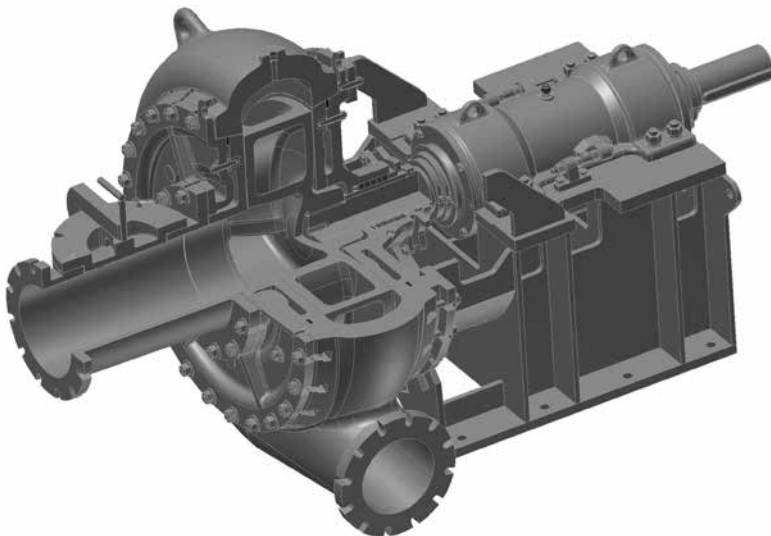
Summary of design features

- Optional rotation – Right or left hand rotation
- Optional discharge positions
- Suction adapter with clean out
- Three and four vane impellers available
- Amor-lok seal on the side liners for metal to metal fit
- Knock out ring for easy impeller removal
- Wide range of alloys for pump wear parts
- Over size bearings and shaft for longer life
- Cantilevered design
    - Less shaft deflection
    - Better packing and bearing life
    - 360º crescent support
    - No case feet required

Performance chart

Pump Size Inches	Impeller Size Inches	Deck mounted pumps						Underwater pumps		
		12 ft./sec Velocity		17 ft./sec Velocity		21 ft./sec Velocity		17 ft./sec Velocity TPH		
		*GPM	**TPH	*GPM	**TPH	*GPM	**TPH	*GPM	Min.	Max.
4	18,00	480	17.6	680	39	830	62	N/A	N/A	N/A
6	24,00	1058	39	1 540	88	1 900	108	1 540	154	193
8	30,00	1880	69	2 650	151	3 280	246	2 650	265	332
10	36,40	2940	108	4 160	237	5 190	389	4 160	416	520
12	36,40	4230	155	6 000	342	7 390	553	6 000	600	750
14	36,40	5160	190	7 300	417	9 025	700	7 300	730	913
16	40,46	6830	250	9 600	547	12 000	899	9 600	960	1 200
18	46,00	8640	317	12 400	706	15 190	1137	12 400	1 240	1 550
20	46,52	10 820	397	15 400	877	19 000	1423	15 400	1 540	1 925
24	52,00	15 000	550	22 400	1 275	28 000	2097	22 400	2 240	2 800

* Gallons per minute   **Tons per hour of coarse sand

Available pump models, sizes and discharge positions

Pump size	No. of vanes	Maximum
8x6 F24	3	4.5"
8x6 F24	4	4.0"
10x8 H30	3	6.0"
10x8 H30	4	5.5"
12x10 J36	3	6.7"
12x10 J36	4	5.8"
14x12 L40	3	6.9"
14x12 L40	4	6.0"
16X14 N40	3	6.9"
16X14 N40	4	6.0"
18X16 P40WD	3	9.8"
18x16 P40WD	4	7.4"
18x16 P46	3	9.8"
18x16 P46	4	7.4"
22x20 T46WD	3	12.5"
22x20 T46WD	4	8.5"
22x20 T52ND	4	9.0"
22x20 T52WD	3	12.5"
22x20 T52WD	4	10.0"
24x24 T52WD	3	12.5"
24x24 T52WD	4	10.0"

Left-hand
Bottom discharge

Left-hand rotation

Left-hand
Top horizontal discharge

Right-hand rotation

Right-hand
Top vertical discharge

Right-hand rotation

Left-hand
Top vertical discharge

Left-hand rotation

Right-hand
Bottom discharge

Right-hand rotation

Right-hand
Top horizontal discharge

Left-hand rotation
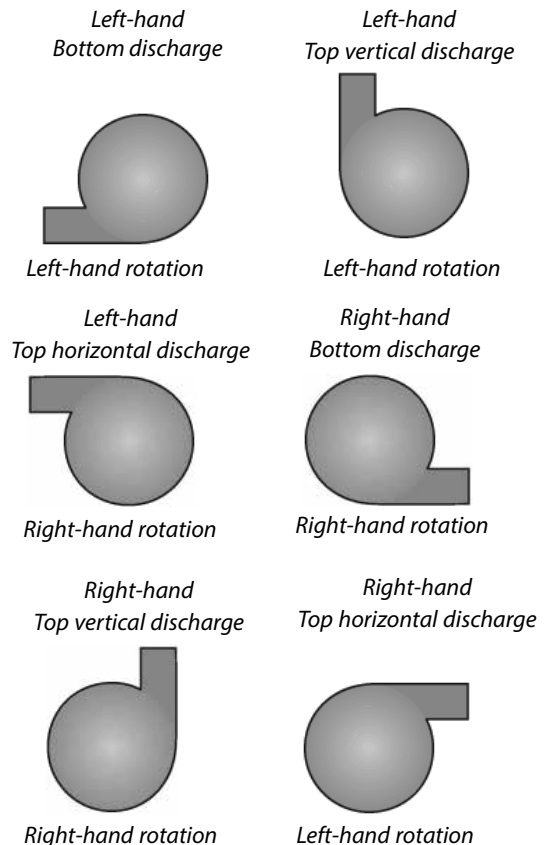
Slurry pump range VASA HD and XR

The Sala and Thomas series of extra heavy duty rubber lined slurry pumps

The VASA HD and XR (rubber lined), extra heavy duty slurry pump range is designed for the most arduous pumping applications. The rugged "wear end" is designed with extra thick rubber sections at known points of wear and the high aspect ratio metal impeller, also available in rubber, ensures excellent performance with long wear life.
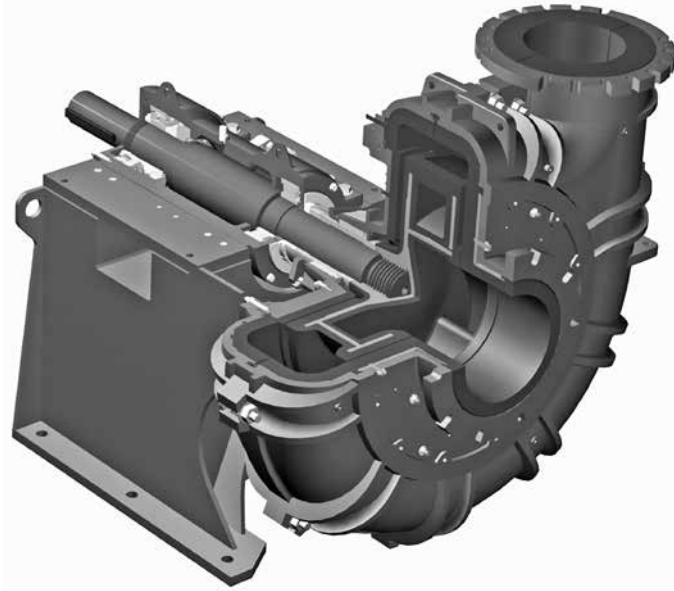
Summary of design features

- Modular design technology
- Robust construction, with "back pull-out" feature, designed for highly abrasive, maximum duty and aggressive environments
- Thick volute casing liners and heavy duty solids handling impellers with high aspect ratio, and carefully matched, high efficiency, hydraulics for even wear
- Materials used are the very best available, providing both excellent wear properties and corrosion resistance.
- Self-contained bearing cartridge assembly with oversized shaft and grease lubricated anti-friction bearings
- Various shaft seal options
- Maintenance slide base option
- Ease of maintenance

PUMP DESIGNATION

XR 350

Pump range ———┘   └——— Inlet size (mm)

Selection chart
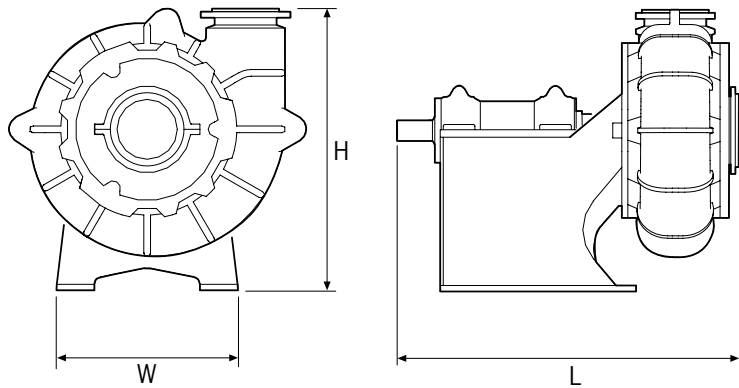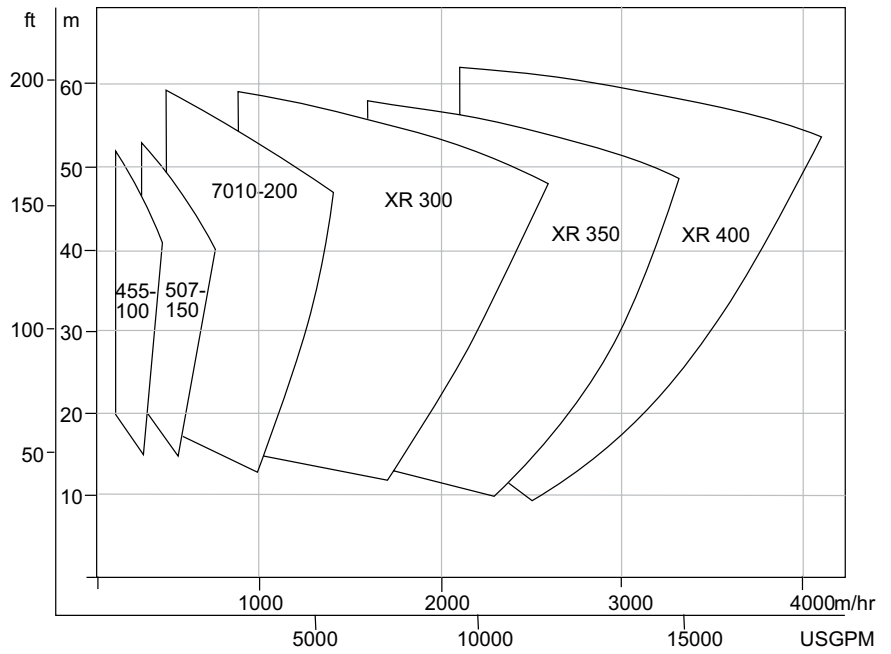
Pump dimensions

Model	Inlet mm (inch)	Outlet mm (inch)	H mm (inch)	L mm (inch)	W mm (inch)	Weight* ton (lb)
VASA HD455-100	150 (6)	100 (4)	825 (33)	1171 (46)	610 (24)	0,9 (2 016)
VASA HD507-150	200 (8)	150 (6)	1 055 (42)	1 554 (61)	700 (28)	1,5 (3 360)
VASA HD7010-200	250 (10)	200 (8)	1 400 (55)	1 724 (68)	950 (37)	2,9 (6 496)

Model	Inlet mm (inch)	Outlet mm (inch)	H mm (inch)	L mm (inch)	W mm (inch)	Weight* ton (lb)
XR300	300 (12)	250 (10)	1340 (53)	1827 (72)	940 (37)	3,0 (6 720)
XR350	350 (14)	300 (12)	1 727 (68)	1 808 (71)	1 110 (44)	4,2 (9 305)
XR400	400 (16)	350 (14)	1 881 (74)	1 980 (78)	1 204 (47)	5,3 (11 823)

Bare shaft weight

The Orion series of heavy duty rubber lined and hard metal slurry pumps type HR and HM

The HR (rubber lined) and HM (hard metal), heavy duty slurry pump ranges are designed for the toughest pumping applications. The excellent hydraulic design, with extra thick sections at known points of wear and the high aspect ratio impeller ensure excellent performance with long wear life.
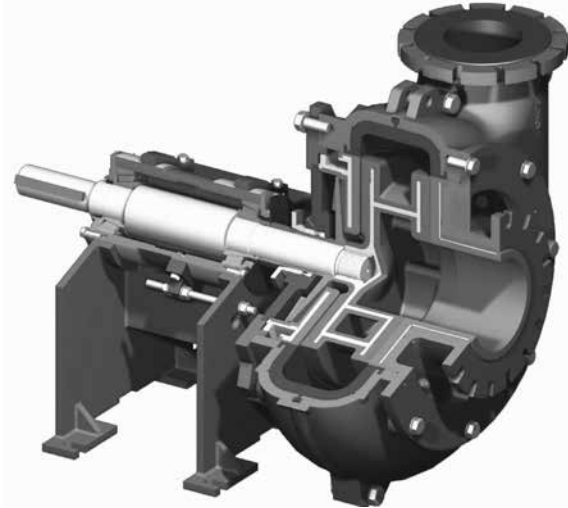
HR wet end
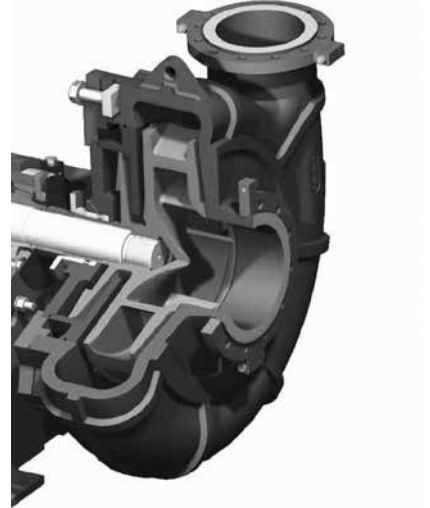
HM wet end

Summary of design features

- Modular design technology and back pull-out feature
- Robust construction
- Thick volute casing/liner and solids handling, large diameter, impeller with carefully matched, high efficiency, hydraulics for even wear
- Double adjustment for sustained efficiency
- Materials used are the very best available, providing both excellent wear properties and corrosion resistance
- Self-contained bearing cartridge assembly with oversized pump shaft and anti-friction bearings
- Various shaft seal options
- Ease of maintenance
- Maintenance slide base option

PUMP DESIGNATION

HR or HM 100

Pump range: HR rubber ———
Pump range: HM metal ———
——— Inlet size (mm)

Selection chart

Pump dimensions

Model	Connection dimensions				General dimensions						Total weight* Double adjustment		Total weight* Single adjustment	
	Inlet		Outlet		H		L		W					
	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	kg	lbs	kg	lbs
HM50 ●	50	2	32	1,5	433	17	713	28	360	14	160	353	136	300
HM75 ●	75	3	50	2	438	17	734	29	360	14	200	441	161	355
HM100 ●	100	4	75	3	505	20	880	35	424	17	320	705	250	551
HM150 ●	150	6	100	4	630	25	1 025	40	545	21	550	1 213	440	970
HM200	200	8	150	6	855	34	1 258	50	686	27	1 220	2 690	1 010	2 227
HM250	250	10	200	8	1 030	41	1 463	58	830	33	2 040	4 497	1 660	3 660
HM300	300	12	250	10	1 150	45	1 591	63	1 000	39	2850	6 283	1 900	4 189
HR50	50	2	32	1,5	428	17	709	28	360	14	180	397	126	278
HR75	75	3	50	2	463	18	729	29	360	14	220	485	145	320
HR100	100	4	75	3	555	22	913	36	424	17	330	728	270	595
HR150	150	6	100	4	713	28	1 097	43	545	21	630	1 389	510	1 124
HR200	200	8	150	6	965	38	1 295	51	686	27	1 250	2 756	1 065	2 348
HR250	250	10	200	8	1 125	44	1 550	61	830	33	2 110	4 652	1 715	3 781

Bare shaft weight ● These pumps are available with fully recessed induced vortex impeller.

The Orion series of mining duty rubber lined and hard metal slurry pumps type MR and MM

The MR (rubber lined) and MM (hard metal) mining duty, slurry pump ranges are designed to provide an economical solution to all slurry pump applications. Excellent hydraulic designs maximise efficiency throughout the life of the pump and selection of wear part materials from the extensive Metso ranges of metals and elastomers ensure long wear life.
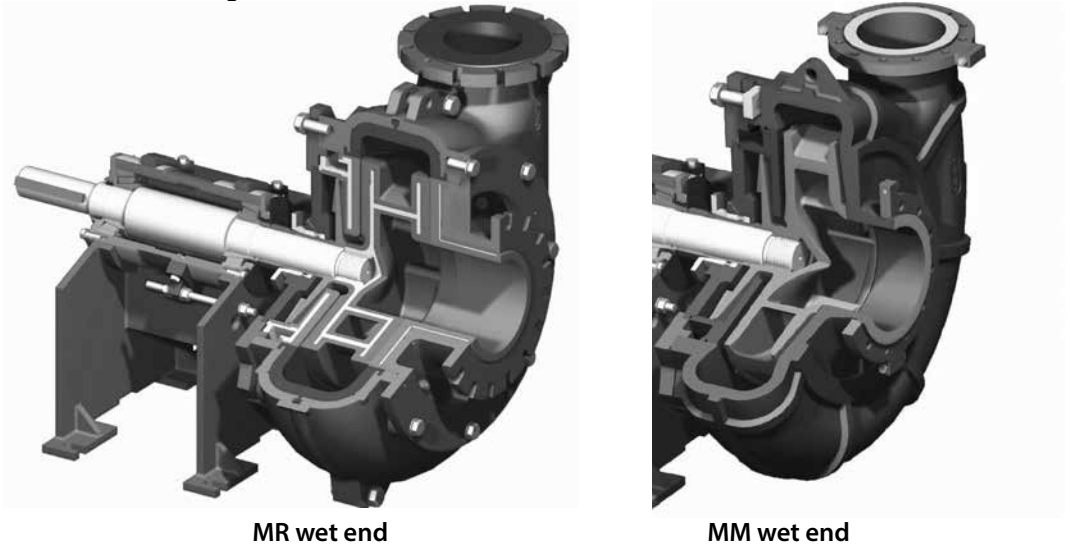
MR wet end

MM wet end

Summary of design features

- Modular design technology and back pull-out feature
- Robust construction
- Solids handling, medium diameter impeller with carefully matched, high efficiency, hydraulics for even wear
- Double adjustment for sustained efficiency
- Materials used are the very best available, providing both excellent wear properties and corrosion resistance
- Self contained bearing cartridge assembly with oversized pump shaft and grease lubricated taper roller bearings
- Various shaft seal options
- Ease of maintenance
- Maintenance slide base option

PUMP DESIGNATION

MR or MM 100

Pump range: MR rubber

Pump range: MM metal

Inlet size (mm)

Selection chart

Pump dimensions

Model	Connection dimensions				General dimensions						Total weight*		Total weight*	
	Inlet		Outlet		H		L		W		Double adjustment		Single adjustment	
	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	kg	lbs	kg	lbs
MM100 ●	100	4	75	3	454	18	730	29	360	14	230	507	170	375
MM150 ●	150	6	100	4	527	21	889	35	424	17	370	816	275	606
MM200 ●	200	8	150	6	710	28	1 073	42	545	21	650	1 433	525	1 157
MM250	250	10	200	8	885	35	1 245	49	686	27	1 350	2 976	1 095	2 414
MM300	300	12	250	10	1 055	42	1 483	58	830	33	2 150	4 740	1 775	3 913
MM350	350	14	300	12	1 080	43	1 527	60	830	33	2 300	5 071	1 960	4 321
MM400	400	16	350	14	1 250	49	1 620	64	1 000	39	3 000	6 614	2 105	4 641
MM500	500	20	450	18	1 726	68	2 180	86	1 110	44	—	—	5 980	13 184
MM600	600	24	500	20	2075	81.7	2352	93	1204	47	—	—	7957	17 505
MR100	100	4	75	3	456	18	741	29	360	14	260	573	150	331
MR150	150	6	100	4	507	20	919	36	424	17	420	926	270	595
MR200	200	8	150	6	683	27	1 092	43	545	21	740	1 631	490	1 080
MR250	250	10	200	8	878	35	1 303	51	686	27	1 540	3 395	960	2 116
MR300	300	12	250	10	1 035	41	1 506	59	830	33	2 450	5 401	1 520	3 351
MR350	350	14	300	12	1 257	49	1 665	66	1 000	39	—	—	1 600	5 732
MR500	489	20	438	18	2 064	81	2 689	106	1 204	47	—	—	8 030	17 703

*Bare shaft weight   ● These pumps are available with fully recessed induced vortex impeller.

The Sala series of vertical tank pumps VT

Metso´s tank pumps are designed for abrasive slurry service and feature simple maintenance and robust design.

Metso is now introducing the next generation of the integrated tank pump type VS developed from the old SALA tank pump type SPV.
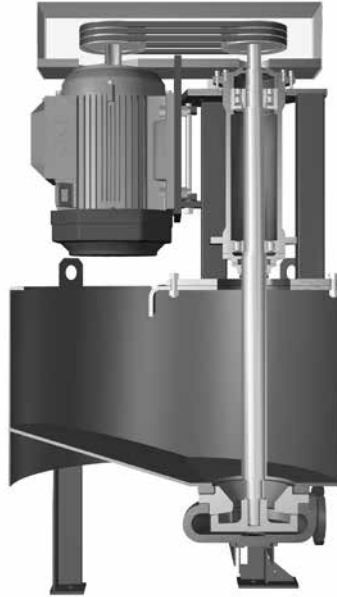
Summary of design features

- Pump, pump sump and motor in one integrated unit for flexible layout and simple installation.
- Open sump and vertical inlet prevents air blocking and gives a smooth operation.
- Oversize bearings, for added life and minimum maintenance. Double protection sealing arrangement against penetration of slurry.
- Cantilever shaft with no submerged bearings or seals. Shaft made of alloy steel, for superior strength and toughness.
- Easily replaced wear parts and metal/rubber interchangeability.

PUMP DESIGNATION:

VT 100 O

Pump range ⎯⎯

Discharge size (mm) ⎯⎯

⎯⎯ Impeller type

Selection chart
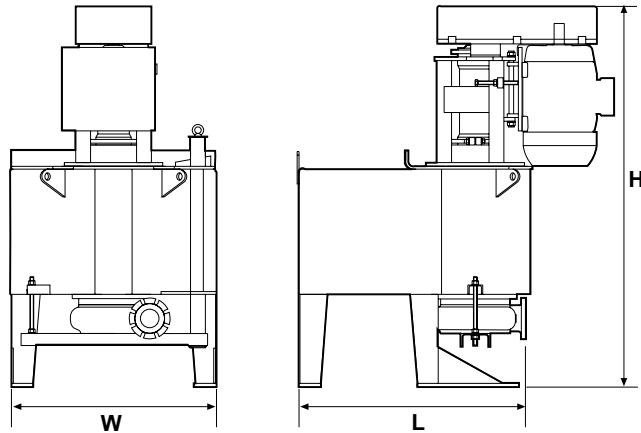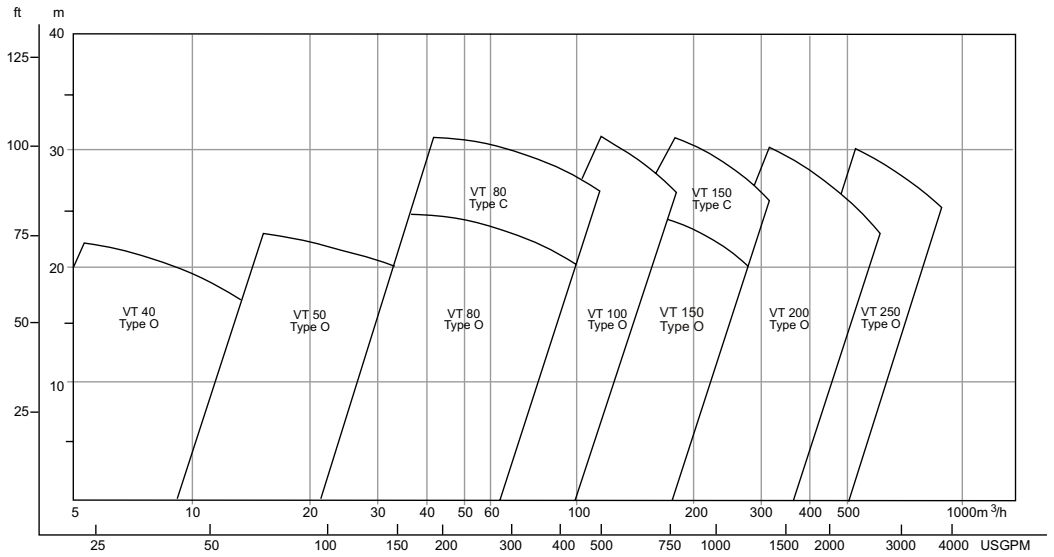
Pump dimensions

Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight** kg/lb	Sump volume m³/USG
VT 40 (1.5) lab	955 (37,5)	640 (25)	400 (16)	90/198	0,03/8
VT 40 (1.5)	1 030 (40,5)	740 (29)	610 (24)	110/243	0,06/16
VT 50 (2)	1 470 (58)	1 035 (41)	1 010 (40)	305/672	0,25/66
VT 80 (3)	1 880 (74)	1 015 (40)	1 060 (42)	580/1279	0,33/87
VT100 (4)	2 050 (81)	1 225 (48)	1 100 (43)	825/1819	0,57/150
VT150 (6)	2 160 (85)	1 285 (50,5)	1 100 (43)	925/2039	0,57/150
VT200 (8)	3 105 (122)	1 710 (67)	1 510 (59)	2 655/5853	1,26/333
VT 250 (10)	3 105 (122)	1 760 (69)	1 510 (59)	2 785/6140	1,26/333

*VT50 (2), VT = Vertical Tank, 50 (2) = outlet size mm (inch).

** Weight figures are for metal parts. For rubber parts reduce weight by 10%.

The Sala Series of vertical froth pumps VF

Metso's froth pumps are designed to increase the pumpability of frothy suspensions. The principal of operation is similar to that of hydrocyclone separation.

Air is separated from the slurry in a vortex created by the impeller rotation and the tangential inlet to the pump's conical sump. This results in a more efficient pumping at higher capacities and a smooth operation free from fluctuations.

Summary of design features

- Pump, pump sump and motor in one integrated unit for flexible layout and simple installation.

- Open sump and vertical inlet prevents air blocking.

- Oversize bearings, for added life and minimum maintenance. Double protection sealing arrangement against penetration of slurry.

- Cantilever shaft and made of alloy steel, for superior strength and toughness, with no submerged bearings or seals.

- Easily replaced wear parts and metal/rubber interchangeability.

PUMP DESIGNATION

VF 100

Pump range ——————   —————— Outlet size (mm)

Selection chart
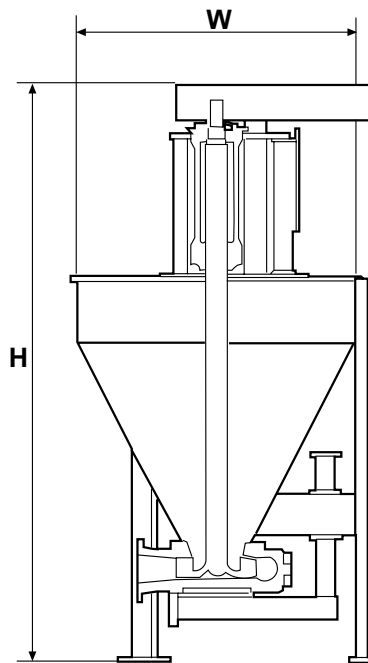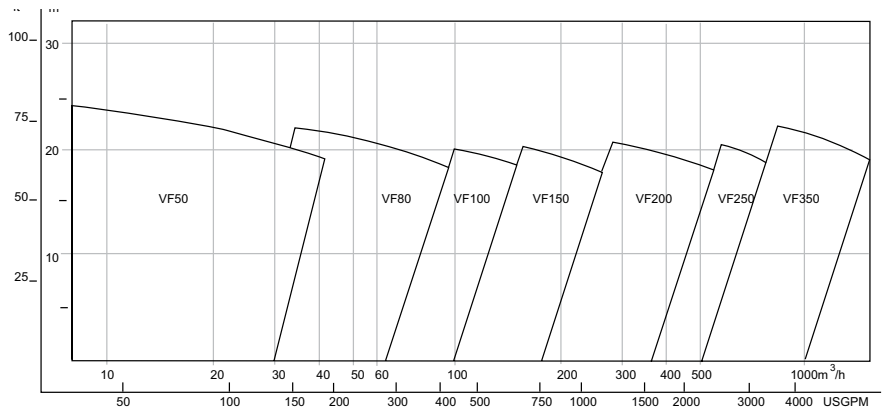
Pump dimensions

Model	H mm (inch)	W mm (inch)	Weight** kg/lb	Sump volume m³/USG
VF50 (2)*	1 600 (63)	800 (31)	355/783	0,14/37
VF80 (3)	2 250 (88)	1 000 (39)	605/1 334	0,37/98
VF100(4)	2 700 (106)	1 400 (55)	975/2 150	0,82/217
VF150(6)	2 700 (106)	1 400 (55)	1 095/2 414	0,82/217
VF200(8)	3 760 (148)	1 850 (73)	2 700/5 952	2,30/607
VF250(10)	3 760 (148)	1 850 (73)	2 900/6 392	2,30/607
VF350(14)	4 500 (177)	2 150 (85)	5 555/12 245	3,50/925

*VF50 (2), VF = Vertical Froth, 50 (2) = outlet size mm (inch).

** Weight figures are for metal parts. For rubber parts reduce weight by 10%.

The Sala Series of vertical sump pumps VS

All Metso sump pumps are designed specifically for abrasive slurries and feature robust design with ease of maintenance.

Developed from the old SALA sump pump, type VASA G, the Metso type VS is the next generation heavy duty sump pump.

Like its predecessor, the VS sump pump range is one of the strongest, toughest and reliable high volume ranges available on the market.   It is for this reason that the range is preferred throughout the world by most heavy industries.
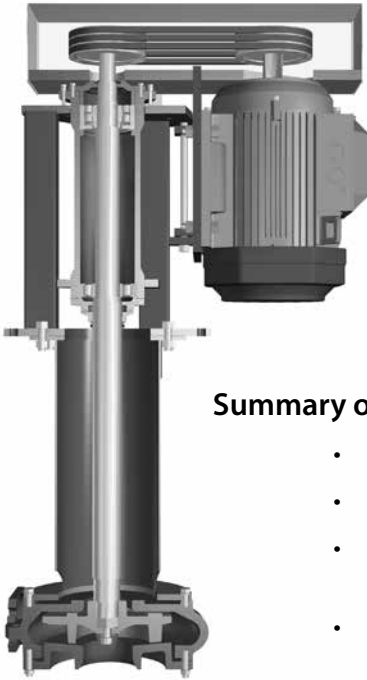
Summary of design features

- Simple installation
- Cantilever design without submerged bearings or shaft seal
- Bearing assembly with double protection sealing arrangement to prevent ingress of slurry
- Materials used are the very best available , providing both excellent wear properties and corrosion resistance
- Wear parts are available in a variety of different materials with full interchangeability
- Range of impeller options

PUMP DESIGNATION

VS 100 L120 O4S

Pump range

Outlet Size (mm)

Casing and agitation type option

Frame Length (cm)

Selection chart
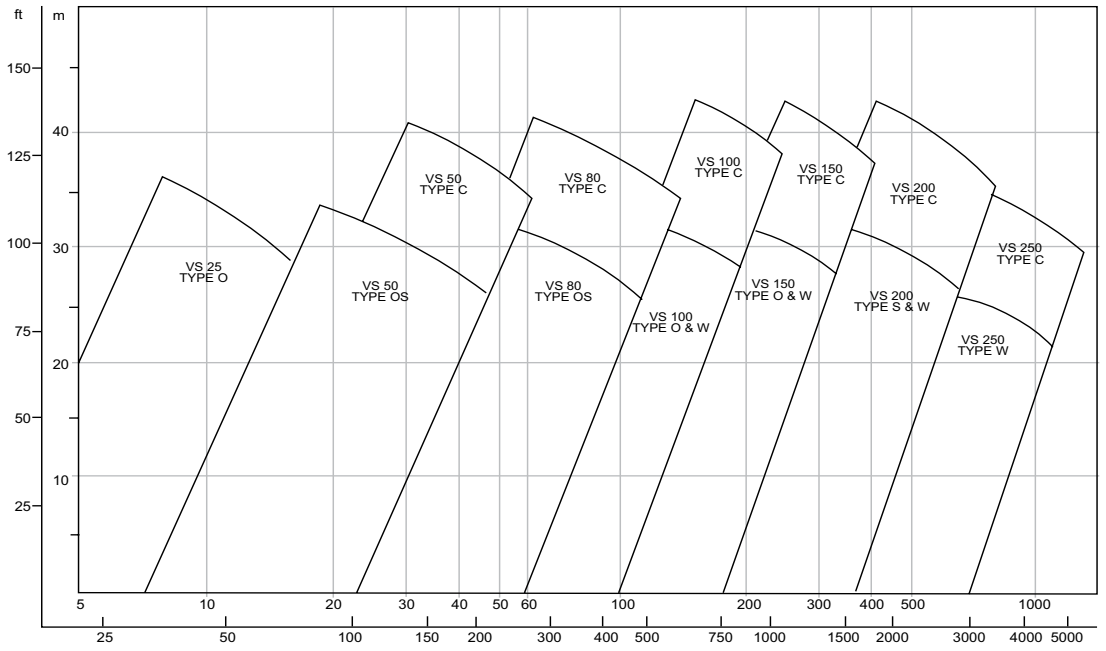
Chart axes labels:
- Left axis: ft — 150, 125, 100, 75, 50, 25
- Left axis: m — 40, 30, 20, 10
- Curves labeled: VS 25 TYPE O, VS 50 TYPE C, VS 50 TYPE OS, VS 80 TYPE C, VS 80 TYPE OS, VS 100 TYPE C, VS 100 TYPE O & W, VS 150 TYPE C, VS 150 TYPE O & W, VS 200 TYPE C, VS 200 TYPE S & W, VS 250 TYPE C, VS 250 TYPE W
- Bottom axis (upper): 5, 10, 20, 30, 40, 50, 60, 100, 200, 300, 400, 500, 1000
- Bottom axis (lower): 25, 50, 100, 150, 200, 300, 400, 500, 750, 1000, 1500, 2000, 3000, 4000, 5000

Pump dimensions
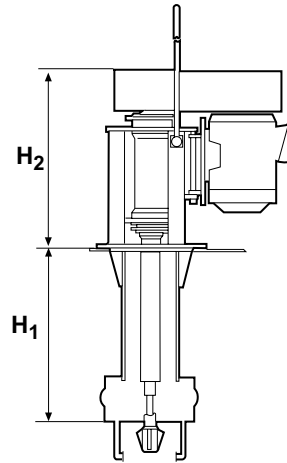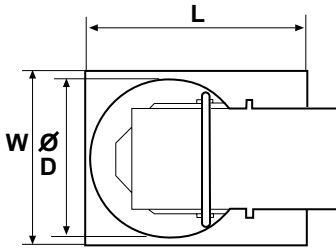
Pump	H1	H₂	D**	L**	W**	Weight***
Size*	mm (inch)	mm (inch)	mm (inch)	mm (inch)	mm (inch)	kg/lb
VS25 (1)	800 (32)	585 (23)	400 (15¾)Ø			130/287
VS25 (1)	1200 (48)	865 (34)	530 (20¾)Ø			350/772
VS25 (1)	1500(60)	865 (34)	530 (20¾)Ø			375/827
VS25 (1)	1800 (72)	865 (34)	530 (20¾)Ø			395/871
VS50 (2) ●	800 (32)	585 (23)	400 (15¾)Ø			220/485
VS50 (2) ●	1200 (48)	865 (34)	530 (20¾)Ø			480/1 058
VS50 (2) ●	1500 (60)	865 (34)	530 (20¾)Ø			510/1 124
VS50 (2) ●	1800 (72)	865 (34)	530 (20¾)Ø			540/1 190
VS80 (3)	800 (32)	870 (34¼)	530 (20¾)Ø			435/959
VS80 (3) ●	1 200 (48)	975 (38½)	565 (22¼)Ø			545/1 202
VS80 (3) ●	1 500 (60)	975 (38½)	565 (22¼)Ø			580/1 279
VS80 (3) ●	1 800 (72)	975 (38½)	565 (22¼)Ø			615/1 356
VS100(4)	8 00 (32)	850 (33½)	530 (20¾)Ø			465/1 025
VS100(4)	1 200 (48)	960 (37¾)	565 (22¼)Ø			575/1 268
VS100(4) ●	1 500 (60)	960 (37¾)	565 (22¼)Ø			610/1 345
VS100(4) ●	1 800 (72)	960 (37¾)	565 (22¼)Ø			645/1 422
VS150(6) ●	1 200 (48)	965 (38)	565 (22¼)Ø			680/1 499
VS150(6) ●	1 500 (60)	1 285 (50½)		800 (31½)	800 (31½)	1 415/3 120
VS150(6) ●	1 800 (72)	1 285 (50½)		800 (31½)	800 (31½)	1 470/3 241
VS200(8) ●	1 200 (48)	1 285 (50½)		800 (31½)	800 (31½)	1 675/3 693
VS200(8) ●	1 500 (60)	1 285 (50½)		800 (31½)	800 (31½)	1 725/3 803
VS200(8) ●	1 800 (72)	1 285 (50½)		800 (31½)	800 (31½)	1 775/3 913
VS250(10)	1 500 (60)	1 420 (56)		800 (31½)	800 (31½)	2 200/4 850
VS250(10)	1 800(72)	1 420 (56)		800 (31½)	800 (31½)	2 280/5 027

*VS25 (1) = Vertical sump; 25 = outlet mm; (1) = outlet inch

** ØD or LxW is the pump base plate dimension. Optional base plate incl. discharge pipe also available.

*** Weight figures are for metal parts. For rubber parts reduce weight by 10%.

● These pumps are available in acid proof version with all wetted parts fully covered with natural rubber or chloroprene.

The Sala series of vertical sump pumps VSHM, VSHR/VSMM

The VSH and VSM pumps are a new combination of our classic VS sump pumps and our Orion series horizontal pump wet ends.

This provides a major advantage to the customer: the same wet end parts are used for both horizontal slurry pumps and sump pumps, thus reducing parts inventory and simplifying maintenance.

It does also make it possible to generate a higher TDH, pump head.

PUMP DESIGNATION

VSHM150 L120 C5

- 5 vane closed impeller
- Frame length (cm)
- HM150 is the horizontal pump wear parts (150 is the inlet size, mm)
- Pump range
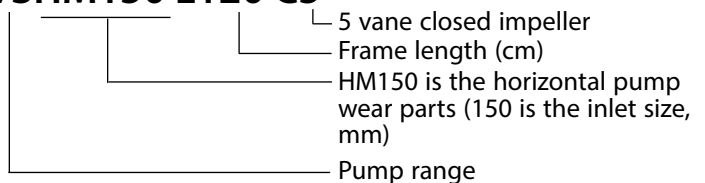
Selection charts
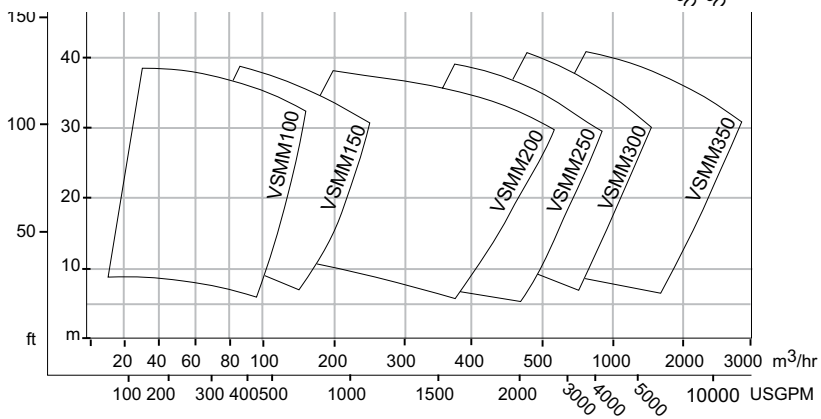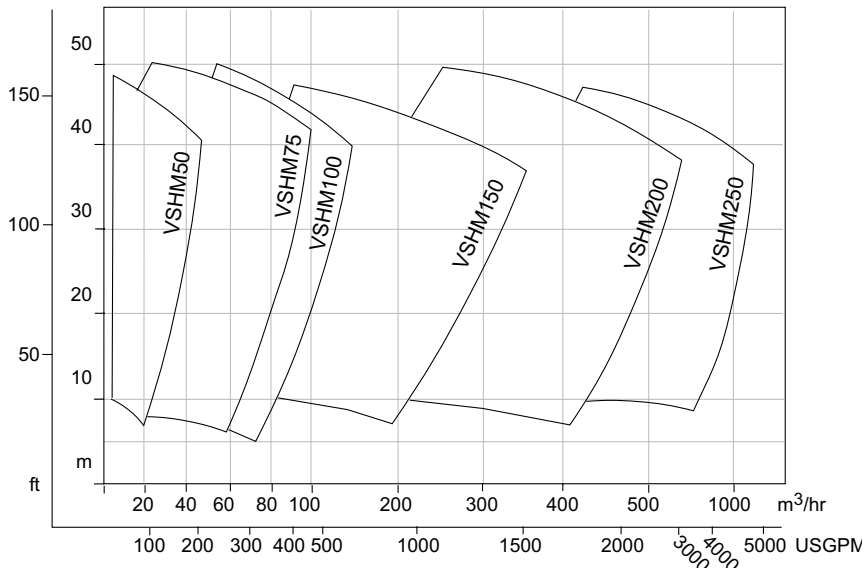
Pump dimensions
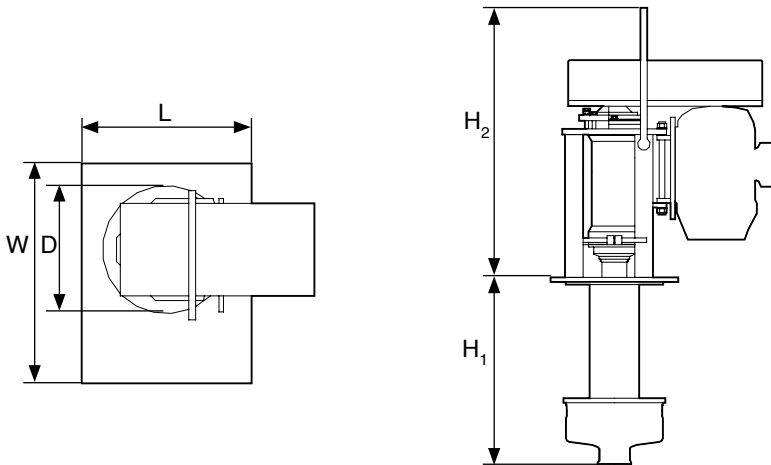
Pump Size		Outlet mm (inch)	H₂* mm (inch)	D** mm (inch)	L Opt. base plate mm (inch)	W mm (inch)	Weight ***	
							kg	lb
VSHM50	●	32 (1,25)	870 (34)	Ø 530 (20 ¾)	600 (23 ½)	600 (23 ½)	390/405/420	860/893/926
VSHR50		32 (1,25)	870 (34)	Ø 530 (20 ¾)	600 (23 ½)	600 (23 ½)	380/395/410	838/871/904
VSHM75	●	50 (2)	870 (34)	Ø 530 (20 ¾)	600 (23 ½)	600 (23 ½)	(L120) 415	915
VSHM75	●	50 (2)	980 (38)	Ø 565 (22 ¼)	600 (23 ½)	600 (23 ½)	(L150/180) 530/565	1 168/1 245
VSHR75		50 (2)	870 (34)	Ø 530 (20 ¾)	600 (23 ½)	600 (23 ½)	399/424/449	880/935/990
VSHM100	●	75 (3)	980 (38)	Ø 565 (22 ¼)	750(29 ½)	600 (23 ½)	535/565/605	1 180/1 246/1334
VSHR100		75 (3)	980 (38)	Ø 565 (22 ¼)	750 (29 ½)	600 (23 ½)	555/585/625	1 224/1 290/1378
VSHM150	●	100 (4)	1280 (50)	☐800 (31 ½)	1 200 (47 ¼)	900 (35 ½)	1 314/1366/1418	2 897/3 012/3127
VSHR150		100 (4)	1280 (50)	☐800 (31 ½)	1 200 (47 ¼)	900 (35 ½)	1 405/1460/1515	3 098/3 219/3340
VSHM200		150 (8)	1280 (50)	☐800 (31 ½)	1 200 (47 ¼)	900 (35 ½)	1 650/1710/1770	3 638/3 770/3903
VSHR200		150 (8)	1280 (50)	☐800 (31 ½)	1 200 (47 ¼)	900 (35 ½)	1 680/1740/1796	3 704/3 836/3960
VSHM250		200 (10)	1420 (56)	☐800 (31 ½)	1 360 (53 ½)	1 220 (48)	2 310/2400/2480	5 093/5 291/5468
VSHR250		200 (10)	1420 (56)	☐800 (31 ½)	1 360 (53 ½)	1 220 (48)	2 365/2455/2535	5 214/5 413/5589
VSMM100	●	75 (3)	870 (34)	Ø 530 (20 ¾)	600 (23 ½)	600 (23 ½)	430/465/500	948/1 025/1103
VSMM150	●	100 (4)	980 (38)	Ø 565 (22 ¼)	750 (29 ½)	600 (23 ½)	560/590/630	1 235/1 301/1389
VSMM200	●	150 (6)	1280 (50)	☐800 (31 ½)	1 200 (47 ¼)	900 (35 ½)	1 390/1445/1500	3 065/3 186/3307
VSMM250		200 (10)	1280 (50)	☐800 (31 ½)	1 200 (47 ¼)	900 (35 ½)	1 720/1780/1840	3 792/3 925/4057
VSMM300		300 (12)	1420 (56)	☐800 (31 ½)	1 360 (53 ½)	1 220 (48)	2 490/2570/2650	5 490/5 666/5843
VSMM350		300 (14)	1420 (56)	☐800 (31 ½)	1 360 (53 ½)	1 220 (48)	– /2745/2825	– /6 052/6 228

*Frame length (H₁) is available in 120, 150, 180 cm (48, 60, 72 inch) except VSMM350 which is available in 150, 180 cm (60, 72 inch).

** D Ø or ☐ is bearing frame base plate. Larger optional base plate or mounting plate incl. discharge pipe also available.

*** Weight figures are for metal parts, and for different frame lengths (L120 / L150 / L180).

● These pumps are available with the fully recessed induced vortex impeller.

Frame and wet-end modular configurations

FRAME 1200 — XM500 XR500

FRAME 1400 — XM600 XM700

FRAME 1500 — XM600 XM700

FRAME 750 — HM300 HR300 MM400 MR350 XG250

FRAME 900 — XM350 XR350 MM500

FRAME 1000 — XM400 XR400 XG350 MR500

FRAME 250 — HM50 HM75 HR50 HR75 MM100 MR100

FRAME 300 — HG100 HM100 HP100 HR100 MM150 MR150

FRAME 400 — HG150 HM150 HMPT100 HP150 HR150 MM200 MR200

FRAME 500 — HG200 HM200 HR200 MM250 MR250

FRAME 600 — HG250 HH200 HM250 HMPT150 HR250 MM300 MM350 MR300 HMP150

Slurry Seal

The Metso cartridge mechanical seals type BA and BF are designed to handle light to medium slurry duties.

The seals are designed as a slide in unit and can be fitted to any of the following pumps without modifications:

HR/HM Heavy duty pumps

MR/MM Mining duty pumps (frame 250 and larger)

Both seals can tolerate bearing cartridge adjustments of ±12 mm, without having to reset the seal.
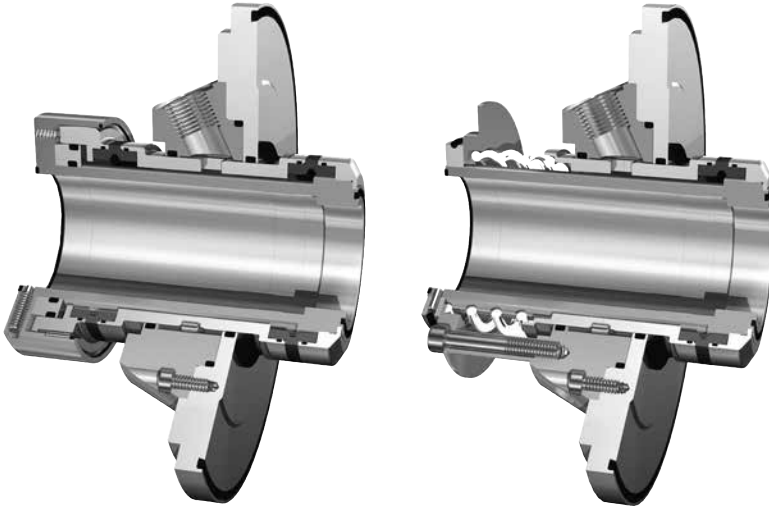
BA double seals

Temperature: Max. 70°C*
Max. pump press.:   40 bar
Speed: 3000 rpm
* "O"-rings in Viton® rubber

BF single seals

Temperature: Max. 70°C*
Max. pump press.:   30 bar
Speed: 3000 rpm

Material selection

- Seal faces – Sintered silicon carbide

- Elastomers – Viton®, other elastomers such as EPDM or Perfluor on request.

- Springs in Hastelloy C

- Metal parts – AISI 316, other materials such as Titanium or Hastelloy C on request.

Quench / Barrier liquid requirements

Double seal type BA

Sealing liquid (water) pressure to be 1-2 bar above pump discharge pressure.

Single seal type BF

Sealing liquid (water) pressure at maximum pressure 0,4 bar.

Recommended Quench / Barrier liquid flow
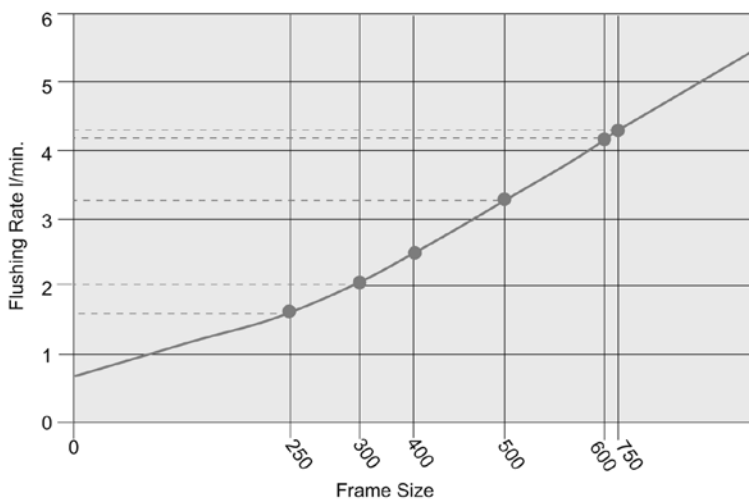
Use table below to calculate actual flush water quantity required

Water quality		rpm	factor
Solid particles:	max 10 mg/l	700	0,2
Particle size:	10 - 50 µm	1 150	0,3
Permanganate value:	max 30 (free from humus)	1 400 / 1 750	0,4 / 0,5
Ferro content:	max 1 mg/l	2 100	0,6
Hardness value:	max 10° dH	2 450	0,7
Critical particle size:	2-5 µm (avoid)	2 800	0,8
Minimum flushing rate:	0,5 l/min	3 150	0,9
Maximum quench/		3 500	1,0
barrier liquid temperature: 110°C*		l/min x rpm factor = total flushing rate	
* "O"-rings in Viton® rubber.			

The Sala series of vertical ST pumps recessed and channel impeller

Vertical torque flow pumps type STGVA

The ST-Pump range consists of tough, general purpose slurry pumps particularly known for their Induced Flow impellers. The hydraulic design provides a very gentle handling of the slurry. The proven low attrition of pumped particles has made it the Industrial Standard for Carbon Transfer in Gold Leaching processes.

The "Cloggless" performance of the Induced Flow impellers also makes this product range ideal for all applications where large or long, stringy solids will be handled.

Vertical wet pit design for pulpy solids and corrosives. With single suction and no shaft sealing the STGVA pump offers outstanding design features.

Cantilever design

The heavy duty pump shaft moves freely under the bearing housing. There are no journal bearings below the liquid level to maintain. The pump has no stuffing box and thus does not require sealing water.

Metallurgy

Hydraulic parts are available from stock in cast iron and stainless steel and high chrome. Some sizes are also available with rubber lined or polyurethane wear parts. The pump frame assemblies below the base plate are available in carbon steel and stainless steel. Other materials are available upon request.

Vortex impeller available

This recessed impeller is located out of the flow pattern. The pumping effect is performed by the vortex that the impeller generates in the slurry. The passage through the vortex pump is fully open, therefore it is especially suited for pumping fibres and similar material.

V-belt drive

This permits simple cost-effective adjustment of pump flow rate.

'STGVA' pumps are designed for severe pumping problems of corrosion, abrasion and temperature extremes in the chemical, minerals processing, pulp and paper, brewing, food and other industries.

Performance charts
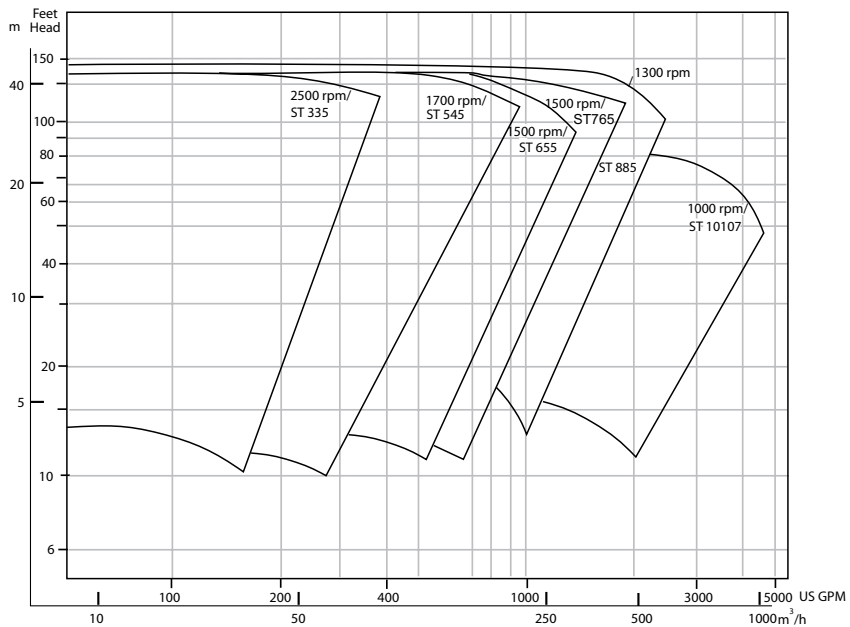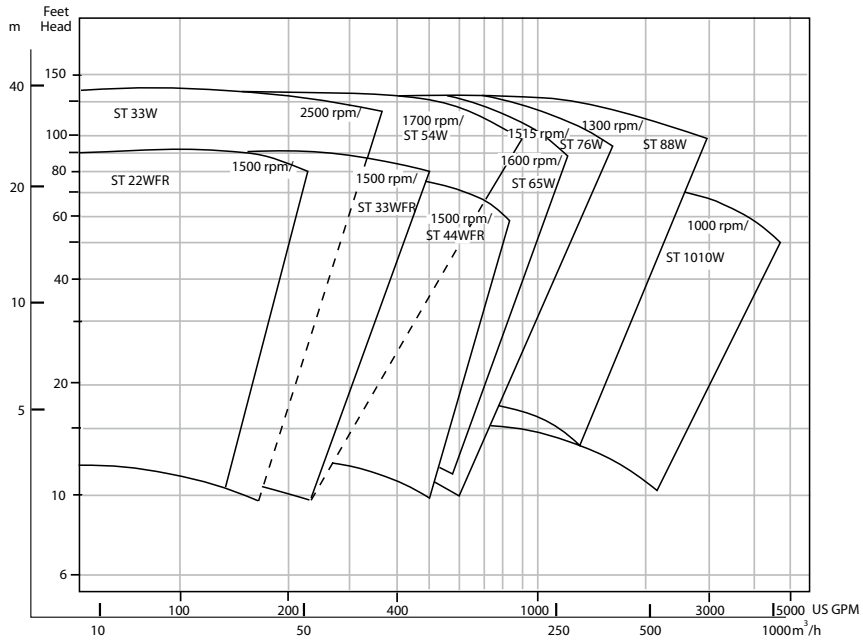
Pump dimensions

Pump type STGVA frame l.	Measures in inch (mm)					Max.motor nema hp	(IEC kW)	Mass lbs (kg)
	A	B	D	E	F			
22WFR L80	24 (600)	24 (600)	2 (51)	32 (810)	35 (870)	286T 30	(180 L) (22)	770 (350)
22WFR L120/150/180	24 (600)	24 (600)	2 (51)	32 (810)	50/62/74 (1270/1570/1870)	286T 30	(180 L) (22)	850/905/960 (385/410/435)
33WFR L80	24 (600)	24 (600)	3 (76)	32 (810)	36 (900)	286T 30	(180 L) (22)	795 (360)
33WFR L120/150/180	24 (600)	24 (600)	3 (76)	32 (810)	51/63/75 (1 300/1 600/1 900)	286T 30	(180 L) (22)	870/925/980 (395/420/445)
44WFR L80	24 (600)	24 (600)	4 (102)	32 (810)	37 (930)	286T 30	(180 L) (22)	820 (370)
44WFR L120/150/180	24 (600)	24 (600)	4 (102)	32 (810)	52/64/76 (1 330/1 630/1 930)	286T 30	(180 L) (22)	890/945/1 000 (405/430/455)
33 L80	24 (600)	24 (600)	3 (76)	32 (810)	31.5 (800)	286T 30	(180 L) (22)	730 (330)
33 L120/150/180	24 (600)	24 (600)	3 (76)	32 (810)	48/59/71 (1 200/1 500/1 800)	286T 30	(180 L) (22)	805/860/915 (365/390/415)
54 L80	30 (750)	24 (600)	4 (102)	32 (810)	33 (837)	324T 40	(200 L) (30)	880 (400)
54 L120/150/180	30 (750)	24 (600)	4 (102)	38 (955)	48/59/71 (1 200/1 500/1 800)	365T 75	(250 S) (55)	1 375/1 420/1 465 (625/645/665)
65 L80	35 (900)	30 (750)	5 (127)	33 (810)	34 (865)	324T 40	(200 L) (30)	1 035 (470)
65 L120/150/180	35 (900)	30 (750)	5 (127)	38 (955)	48/60/72 (1 230/1 530/1 830)	365T 75	(250 S) (55)	1 545/1 585/1 630 (700/720/740)
76 L110	35 (900)	30 (750)	6 (152)	38 (955)	44 (1 112)	365T 75	(250 S) (55)	1 630 (740)
76 L150/L180	35 (900)	30 (750)	6 (152)	48 (1 210)	59/71(1 505/1 805)	444T 125	(280 S) (90)	2 730/2 900 (1 240/1 315)
88 L110	47 (1 200)	35 (900)	6 (152)	38 (860)	44 (1 122)	365T 75	(250 S) (55)	1 980 (900)
88 L150/180	47 (1 200)	35 (900)	8 (203)	48 (1 215)	60/71 (1 515/1 815)	445T 150	(280 M) (110)	3 080/3 250 (1 400/1 475)
1010 L110	54 (1 360)	35 (900)	10 (254)	38 (960)	48 (1 230)	365T 75	(250 S)(55)	2 200 (1 000)
1010 L150/180	54 (1 360)	35 (900)	10 (254)	48 (1 215)	64/76 (1 623/1 923)	445T 150	(280 M) (110)	3 300/3 470 (1 500/1 575)
1414 L150/180	60 (1 525)	54 (1 360)	14 (356)	55 (1 400)	59/71 (1 513/1 813)	447T 200	(280 S) (90)	6 170/7 270 (2 800/3 300)

Section A-A

Technical description
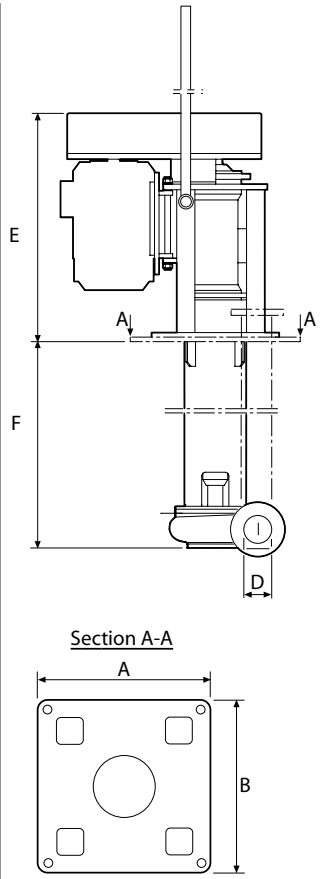
The Sala series of horizontal torque flow pumps type STHM
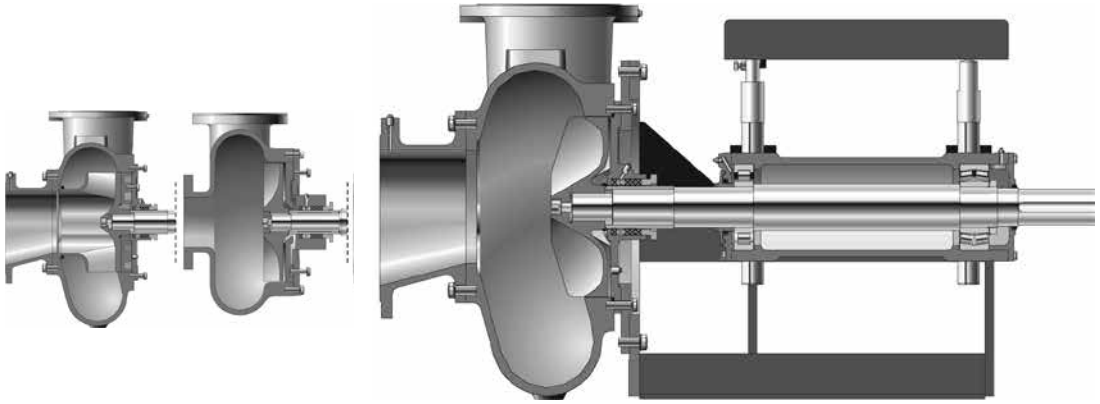
The STHM pumps are also available with alternative impeller designs which allow optimum adaption to different media - from heavy suspensions to clean liquids.

Vortex or channel impeller

Vortex impeller for heavy suspension and liquid/gas mixture. Channel impeller for light suspensions and clean liquids.

V-belt drive

This permits alteration of the pump's performance without opening the pump.

Bearing assembly

Cartridge type with grease lubricated roller bearings designed for more than 60 000 operating hours.

Shaft seal

Standard stuffing box with seal water. Optional mechanical seals.

Pumping parts

Standard pumping parts in cast iron, stainless steel, high chrome and some sizes in Polyurethane or rubber lined. Other materials are available upon request.

Motor bed plate

Overhead motor bed plate gives compact installation with extra motor protection and simple belt tensioning.

Vortex impeller

The vortex impeller is recessed in the back of the pump casing, giving a free passage through the casing. The pump can normally pump anything that can pass through the connecting pipes.

Performance charts
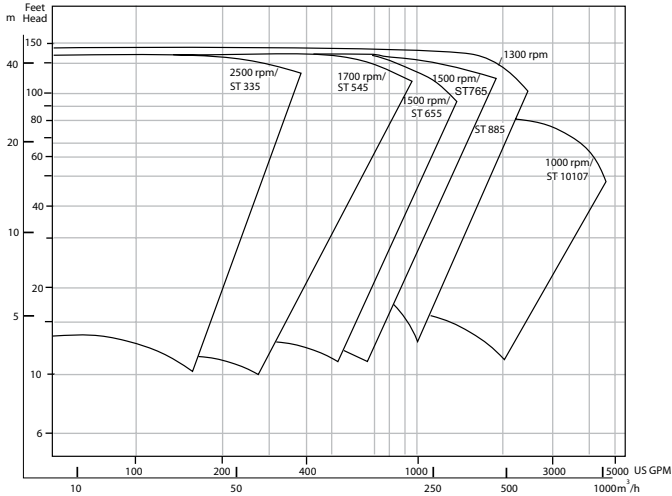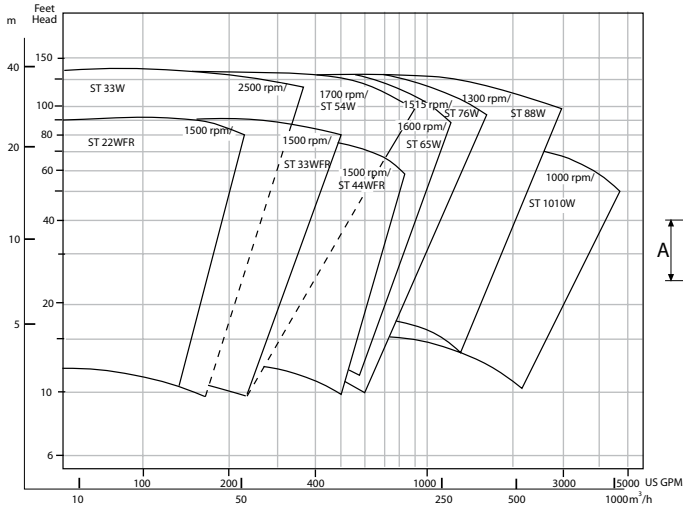
Pump dimensions
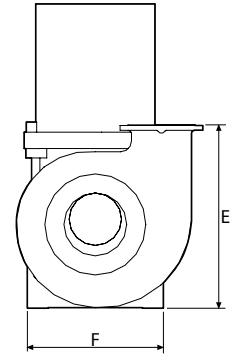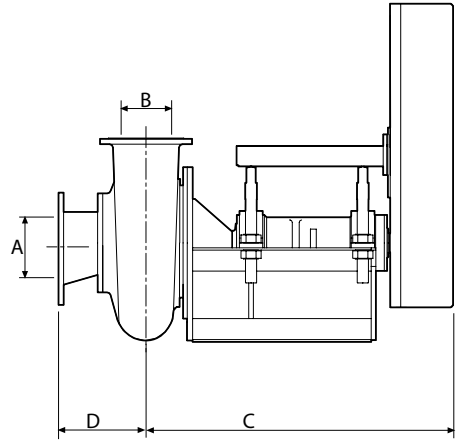
Pumps with vortex impeller are identified with W, e.g. STHM 76 W.

**Pumps with channel impeller are identified with a digit, e.g. STHM 76 5. The digit specifies number of vanes in the impeller.*

Pump type STHM size	Measures in inch (mm)						nema hp	Max.motor (IEC) (kW)	Weight lbs (kg)
	A	B	C	D	E	F			
22WFR	2 (51)	2 (51)	31.5 (802)	4 (100)	18.3 (465)	15.4 (390)	286T 30	(180 L) (22)	330 (150)
33WFR	3 (76)	3 (76)	31.5 (802)	4.5 (116)	19.3 (490)	15.4 (390)	286T 30	(180 L) (22)	355 (160)
44WFR	4 (102)	4 (102)	32 (813)	5.2 (133)	19.9 (505)	15.4 (390)	286T 30	(180 L) (22)	385 (175)
33	3 (76)	3 (76)	30.2 (768)	7.5 (190)	18.5 (470)	15.4 (390)	286T 30	(180 L) (22)	330 (150)
44	4 (102)	4 (102)	31.5 (803)	8.3 (210)	20 (510)	17 (430)	326T 50	(225 S) (37)	650 (295)
54	6 (152)	4 (102)	40.7 (1 035)	8.3 (210)	20.9 (530)	17 (430)	326T 50	(225 S) (37)	650 (295)
65	6 (152)	5 (127)	45.5 (1 159)	8.7 (222)	25.5 (650)	19.7 (500)	365T 75	(250 S) (55)	840 (380)
76	8 (203)	6 (152)	46 (1 169)	9.5 (241)	26.4 (670)	19.7 (500)	365T 75	(250 S) (55)	915 (415)
88	10 (254)	8 (203)	49 (1 248)	11 (279)	31.8 (810)	25.6 (650)	444T 125	(280 S) (90)	1 050 (475)
1010	12 (305)	10 (254)	50.8 (1 292)	14.8 (375)	34.5 (880)	25.6 (650)	444T 125	(280 S) (90)	1 155 (525)
1414	14 (356)	14 (356)	62.5 (1 590)	20 (511)	46.3 (1 175)	29.5 (749)	447T 125	(280 S) (90)	1 600 (725)

APPLICATION GUIDE

General

This section is a guide to the selection of the correct slurry pump range for various applications.

As previously stated the sizing of the slurry pump and its system is very important.

Equally important is to choose the right type of slurry pump for the process application in question

The slurry pump range presented in this handbook represents a broad coverage of applications for hydraulic transport of solids.

Remember!

The use of slurry pumps for hydraulic transport of solids is limited mainly by your imagination!

Selection by duty or industrial application?

To be as practical as possible this application guide is divided in two parts.

Selection by duty

In this section we are selecting the optimal slurry pump simply against the specified pump duty.

Selecting against duty means selecting pumps considering parameters like:

- Solids   (size, shape, density etc.)
- Head   (max., high, low,)
- Liquid   (corrosive, thixotropic, frothy)

This guide is strictly based on technical performance reflecting various **Solid/Liquid** parameters!

Selection by industrial applications

This section is more of a practical guide, based on experience from our customers day to day applications, working in very different industrial environments.

How to pump

- wood chips
- mill scales
- mineral tailings
- leaching residue
- industrial waste
- etc.

How to feed

- a hydrocyclone
- a pressure filter
- a tube press
- a flotation machine
- etc.

The guide is structured according to practical experience from hydraulic transportation of solids in following industrial segments:

- Mineral (Metallic & Industrial)
- Construction
- Coal
- Waste & Recycling
- Power & FGD
- Pulp & Paper
- Metallurgy
- Chemical
- Mining & tunnelling

Selection - by solids

Duty: Coarse particles

Comments: Everything larger than 5 mm is considered to be coarse.

Don't use rubber pumps, metal pumps only.

Upper practical limit in particle size is normally 50 mm.

Limitation is the impact on the impeller.

Note: Particle diameter max. 1/3 of the pipe diameter.

Recommendation: XM and HM ranges.

Duty: Fine particles

Comments: If the particles are fine and sharp - use rubber.

If particles are fine and smooth - use rubber or metal.

Recommendation: H and M ranges.

Duty: Sharp (abrasive) particles

Comments: If sizes are below 5 mm - use rubber.

If particles are above 5 mm - use metal.

Recommendation: X, H and M ranges.

Duty: High percent solids

Comments: You have to be careful if the percent solids is getting close to 40% by volume. Above 50% the slurry is impossible to handle with centrifugal pumps. Only vertical tank pumps are able to handle applications with really high percent solids.

Recommendation: VT range.

Duty: Low percent solids

Comments: Choose the lightest and most cost effective pumps.

Recommendation: M range.

Duty: Fibrous particles

Comments: The problem is blocking of particles and air blocking. Use induced flow impellers (Vortex).

Recommendation: H and V range.

Duty: One size particles

Comments: When all fine particles are removed from the slurry the solid settling rate can be critical and can call for severe derating of the pump. Pumping efficiency goes down for all pump types.

Recommendation: All pump ranges.

Duties related to head and volume

Duty: High head

Comments: Normally metal pump applications due to the high peripheral speed on the impeller. If you need rubber lined pumps, series pumping may be needed.

Max. head on hard metal pump 125 m.

Max. head on rubber impeller 45 m.

Note! High rate of wear at high speeds for centrifugal pumps.

Recommendation: XM, XR and HM, or staged HR.

Duty: Varying head at constant flow

Comments: Use a multi-speed drive or a variable (frequency control) drive.

Recommendation: All ranges.

Duty: Varying flow at constant flow

Comments: Use variable (frequency control) drives.

Recommendation: All ranges.

Duty: High suction lift

Comments: Metal pumps are preferred due to risk of rubber lining collapse on high suction lifts.

Max. practical suction lift 5 - 8 m depending on S.G.

Pumps are not self-priming, i.e. you need a priming device.

The pump and inlet pipe need to be filled with liquid before starting.

Recommendation: XM, HM and MM.

Duty: High flow

Comments: Use parallel pump installations, see page 86.

Risk for cavitation, see section "Hydraulic performance".

Recommendation: All ranges.

Duty: Low flow

Comments: Compare to *BEP**, see section "Best efficiency point".

At low flows rubber linings can overheat. Use metal.

Be careful if heads are high and flow is low.

Open vertical pumps have no problems.

*BEP = Best Efficiency Point

Recommendation: Try to use VS, VT and VF ranges.

Duty: Fluctuating flow

Comments: Use horizontal pumps with variable speed drive or fixed speed vertical pumps.

Recommendation: VT, VF or VS. Horizontals; all types with variable speed drives.

Duties related to slurry type

Duty: Fragile slurries

Comments: Use induced flow impellers (fully recessed).

Both metal and rubber pumps can be used. Both horizontal and vertical pumps can be used.

Recommendation: All ranges.

Duty: Hydrocarbon slurries (oil and reagents contaminated)

Comments: Natural rubber is out.

Be careful with seal material of natural rubber. Use synthetic seals.

Use metallic pumps or wear parts in polyurethane.

Recommendation: All ranges.

Duty: High temperature (greater than 100° C) slurries

Comments: (Temperature limit for natural rubber is 60° C). See section 6 for synthetic rubbers.

Practical limit for operating temperature is 135° C. Above this temperature the bearings can be over-heated!

Recommendation: All horizontal ranges.

Duty: Frothy slurries

Comments: Use a froth pump of vertical design.

Recommendation: VF range.

Duty: Hazardous slurries

Comments: Warning! This case has to be referred back to the pump sales support departments.

Shaft sealing is critical from explosion point of view. Normally closed pump systems are used.

Recommendation: Horizontal ranges.

Duty: Corrosive slurries (low pH)

Comments: For acidic duties use rubber or elastomer.

For metal pumps with chrome iron parts the acid limit is pH 2,5.

Sea water slurries (containing chlorides) must have a rubber pump.

Note! $CuSO_4$ (used in flotation circuits) is extremely corrosive, use rubber pumps.

Recommendation: All ranges.

Duty: High viscosity fluids (Newtonian)

Comments: Pumping becomes critical when viscosity gets up to 5 times the viscosity of water.

With this restriction basically any pump in our range can be used, if properly sized.

Recommendation: All sizes.

Duty: High viscosity fluids (non-Newtonian)

Comments/Recommendation: These applications are very tricky and should be referred back to the pump sales support staff.

Duties related to mixing

Duty: Mixing

Comments: Tank pumps are excellent as mixers.

When mixing water and solids look up the correct ratio between liquid and solids.

Recommendation: VT and VF range.

Selection of slurry pumps - by industrial application

This selection guide is based on practical experience from various Slurry pump applications within the following industrial segments:

- Metallic and industrial minerals
- Construction
- Coal
- Waste & recycling
- Power & FGD
- Pulp & paper
- Metallurgy
- Chemical
- Mining & tunnelling

Industrial segment: Metallic & industrial minerals

Application: Pumps for grinding circuits

Comments: Our ranges X and H are specially designed for grinding circuits (incl. cyclone feed).

For particles sizes below 5 mm use rubber. If possible, mix flows containing coarse and fine particles together for better slurry stability.

Recommendation: XR and XM, HR and HM.

Application: Pumps for froth

Comments: The VF range is specially designed for froth pumping.

Be cautious for heads greater than 15 m.

Recommendation: VF.

Application: Pumps for floor sumps

Comments: Use sump pumps type VS with metallic wear parts, since there often is a risk for oversize tramp material coming into floor sumps.

If rubber must be used, put a strainer in front of the pump or around the pump.

Recommendation: VS range.

Application: Pumps for tailing

Comments: Depending on particle size both rubber and metal pumps can be used. For long distances installations (in series), see section "Slurry pump systems".

Recommendation: X and H ranges, both rubber and metal.

Application: Pumps for hydrocyclone feed

Comments: For sharp classification use horizontal pumps type X or H. For dewatering cyclones use tank pumps.

Recommendation: X, H and VT ranges.

Application: Pumps for pressure filter feed

Comments: High head needed with variable speed control (alternatively two-speed drive).

Avoid rubber due to low flow head build up.

Application: Pumps for tube press feed

Comments: Small flow and high head, use metal pumps of type HM.

One pump can feed many tubes by a slurry distribution ring.

Recommendation: HM range.

Application: Pumps for leaching

Comments: See corrosive slurries, page 142.

Application: Pumps for dense media (heavy media)

Comments: High inlet head and high percent solids in combination with low discharge head can cause expeller seal leakage problems.

Recommendation: HM range.

Application: Pumps for general purpose (mineral)

Comments: Horizontal pumps of type MM and MR are ideal for normal duty in mineral process circuits. If the wear is extreme, use the X and H ranges.

Rubber is normally preferred in "hard rock" concentrators.

For special applications use the vertical pumps.

Recommendation: All ranges.

Industrial segment: Construction

Application: Pumps for wash water (sand and gravel)

Comments: Normally, the vertical pumps type VS and VT are used. Horizontal pump of the M range is also suitable.

Recommendation: V and M range.

Application: Pumps for sand transportation

Comments: Horizontal pumps with rubber lining are preferred.

Recommendation: MR.

Application: Pumps for tunnel dewatering

Comments: As front pumps use drainage pumps. For the first transportation stage, vertical pump type VS is normally used.

For horizontal distant pumping use HM range.

For cuttings from full face boring (TBM:s) use HM and MM pumps.

For small tunnels (micro bore) use small HM.

Recommendation: H, M and VS range. (No rubber due to oil.)

Industrial segment: Coal

Application: Pumps for coal washing

Comments: Generally metal pumps are used because of risk for oversized tramp material.

Recommendation: HM and MM ranges.

Application: Pumps for froth (coal)

Comments: Use vertical pump type VF.

Recommendation: VF.

Application: Pumps for dense media (coal)

Comments: See dense media, page 145.

Application: Pumps for coal/water mixtures

Comments: Use conventional pumps M ranges.

Recommendation: MR ranges.

Application: Pumps for general purpose (coal)

Comments: Coal industry normally does not use rubber pumps.

Recommendation: Use HM and MM.

Industrial segment: Waste & recycling

Application: Pumps for effluent handling

Comments: Light-duty application. Use either horizontal or vertical pumps. Metal pumps is the first selection.

Recommendation: HM, MM and V ranges.

Application: Hydraulic transportation of light waste

Comments: Use horizontal pumps with Vortex induced flow impellers.

Recommendation: HM and MM ranges.

Application: Pumps for soil treatment

Comments: See minerals above. Pump type VT are recommended for mobile and semi-mobile plants (no leaking seal and easy to transport and install).

Recommendation: All ranges.

Industrial segment: Power & FGD

Application: Pumps for FGD reactor feed (lime)

Comments: Normally the mineral applications use X, H and M ranges, all with rubber and/or metal parts.

Rubber for high chloride concentrations.

Recommendation: X, H and M ranges.

Application: Pumps for FGD reactor discharge (gypsum)

Comments: See lime pumps on page 147.

Recommendation: X, H and M ranges

Application: Bottom ash pumping

Comments: Metal pumps are preferred due to temperature and particle size.

Use horizontal pumps of type X and H.

Recommendation: XM and HM ranges.

Application: Fly ash pumping

Comments: Metal is normally used due to risk of oil contamination.

If rubber must be used (low pH) look out for any oil or other chemicals.

Recommendation: X, H, M and VS ranges.

Industrial segments: Pulp & Paper

Application: Pumps for liquors

Comments: On black liquors rubber is not to be recommended (due to risk of turpentine).

Standard recommendations: H and M ranges (metal parts).

Recommendation: HM and MM range.

Application: Pumps for lime and caustic mud

Comments: These applications are normally of high temperature. Therefore metal parts are recommended.

Recommendations: HM and MM.

Application: Pumps for reject pulp (containing sand)

Comments: Normally light duty, but metal parts are recommended. Normally we are competing with stainless steel pumps.

Recommendation: MM range.

Application: Pumps for solids from debarking

Comments: For sand and bark we have developed an extra long vertical pump type VS.

Use metal parts and induced flow impeller (Vortex).

Recommendation: VS range.

Application: Pumps for hydraulic transportation of wood chips

Comments: Use induced flow pumps (Vortex) of H and M type.

Recommendation: HM and MM ranges.

Application: Pumps for paper filler and coating slurries

Comments: No rubber allowed due to colour contamination.

Recommendation: HM, MM, VS and VT ranges. (Only metal parts.)

Application: Floor spillage pumps

Comments: Use a vertical pump of type VS. Sometimes stainless steel parts are required due to low pH.

Recommendation: VS range.

Industrial segment: Metallurgy

Application: Pumps for mill scale transportation

Comments: First choice is vertical pump type VS with induced flow impeller and metallic parts.

Horizontal pumps use type HM with metal parts only

Recommendation: HM and VS ranges.

Application: Pumps for slag transportation

Comments: Same considerations as for "Mill Scale" above.

Application: Pumps for wet scrubber effluents

Comments: Normally we recommend pump of horizontal type M range or vertical pumps of VS range.

If pH is very low use rubber.

If pH is very low and temperature is very high use stainless steel parts or synthetic rubber.

Recommendation: MR and VS ranges.

Application: Pumps for iron powder transportation

Comments: See dense media pumps above.

Application: Pumps for machine tool cuttings

Comments: No rubber parts can be used due to oil.

Vertical pump of type VS and horizontal pumps type M.

Recommendation: VS and MM.

Industrial segment: Chemical

Application: Pumps for acid slurries

Comments: First recommendation is horizontal pumps with rubber or stainless parts. For extremely abrasive slurries use horizontal pump type HR.

Recommendation: MR and HR ranges.

Application: Pumps for brines

Comments: Very corrosive applications. Can also be abrasive (crystals).

Polyurethane can be used to avoid crystallization on pump parts.

Recommendation: HM, HR, MM, MR and VS (polyurethane parts).

Application: Pumps for caustics

Comments: Both rubber and metal pumps can be used. Easy application.

Recommendation: MM, MR, PM and VS ranges.

Industrial segment: Mining

Application: Pumps for hydraulic back filling (with or without cement)

Comments: Watch out for deslimed tailings! Use horizontal pumps of type H or M with rubber or metal parts.

Recommendation: H and M ranges.

Application: Pumps for mine water (with solids)

Comments: Normal recommendation is horizontal pumps type HM (multi stage if required).

Watch out for corrosion!

Recommendation: HM.

SIZING

Modern sizing procedures for slurry pumps are computerised and easy to handle, as in Metso's PumpDim™ for Windows™. It is important that we know the steps for sizing slurry pumps and the relationship between them, to ensure that these procedures are correctly understood.

The following manual procedure is approximate and gives reasonable accuracy, except in extreme applications.

The sizing steps

Step 1.

Establish if the slurry/liquid is a:

Clear liquid

Non-settling (viscous) slurry (Particle size <50 micron)

Settling slurry

Step 2.

Set up the duty details. These vary depending on the type of liquid according to Step 1. Common details are:

Flow or tonnage

Static lift (head)

Friction losses given or pipe system known/selected

Chemical properties like pH value, content of chlorides, oil, etc.

Other liquid/slurry details as below

Clear liquids

When clear water - no further liquid details are required. For other clear liquids the following is needed.

- Liquid S.G.

- Liquid dynamic viscosity. If kinematic viscosity is given, see conversion factors on page 165.

Slurries

For slurries a number of details are required. According to the following formulae certain combinations of these data are required to be able to calculate all of them.

Sm = Slurry S.G.

Cv = Concentration by Volume %

Cw = Concentration by Weight %

S = Solids S.G.

Q = M^3/H flowrate

tph = Tonnes per hour (solids)

Slurry Formula:

$$Sm = \frac{100 - Cv}{100 - Cw}$$

$$Sm = \frac{Cv\,(S-1)\,+1}{100}$$

$$Cv = \frac{Sm-1}{S-1}\ x\ 100$$

$$Cv = 100 - [\,(100-Cw)\ x\ Sm\,]$$

$$Cw = 100 - \left[\frac{100-Cv}{Sm}\right]$$

$$Cw = \frac{100\ x\ S}{100 + \frac{(S-1)}{Cv}}$$

$$Q = tph\ x\ \left[\frac{1}{S} + \left(\frac{100}{Cw} - 1\right)\right]$$

For non-settling (viscous) slurries also the plastic dynamic viscosity and max. particle size are required.

For **settling slurries** max. and average particle sizes (d50) is required.

Solids tonnage or slurry flow?

As a comment to the above formulae it is very important to understand the difference between **"percent solids by weight" and "percent solids by volume".**

Percent solids by weight is the normal way of explaining a slurry.

e.g. Magnetite slurry, 40 percent solids by weight.

Limestone slurry, 40 percent solids by weight.

This is due to the practice that production in general is measured as tonnes (solids)/hour.

e.g. Magnetite feed to the circuit is 300 tonnes/hour as a slurry 40% by weight.

Limestone feed to the circuit is 300 tonnes/hour as a slurry 40% by weight.

These are useless figures for a slurry pump man as pumps are volumetric machines and must be sized on flow.

If we look on the flow conditions of the above slurries we will find that:

The magnetite slurry (with a solids S.G. of 4.6) gives a slurry flow of 515 m^3/hour.

The limestone slurry (with a solids S.G. of 2.6) gives a slurry flow of 565 m^3/hour.

As tonnage these capacities are equal, hydraulically they are not.

Step 3.

For settling slurries only.

Check that the actual velocity in the pipe is higher than the critical velocity for stationary deposition. Refer to the diagram on page 83 using maximum particle size, solids S.G. and pipe diameter.

If a pipe diameter has not been specified, the best way to arrive at one is to select the first pipe size giving a velocity above 3 m/s. This pipe size should be checked to ensure that the actual velocity is greater than the critical velocity. Use the diagram on page 83 for velocities in different pipe diameters at a given flow.

If the actual velocity is less or greater than, the critical velocity, the exercise should be repeated for one size of pipe smaller, or larger, to check that you use the largest pipe possible to ensure that settling does not take place.

NOTE!!!   Always use the minimum anticipated flow value to calculate the pipe velocity.

Step 4.

Calculate total discharge head according to section "Slurry pump systems".

Additional process equipment needing pressure must also be considered. For hydrocyclones the inlet pressure normally is specified in kPa or bar.

These figures have to be converted to head in meter slurry column (divide the pressure by the density of the fluid) and has to be added to the head calculated according to section "Slurry pump systems".

Step 5.

The next step is to select wet end wear part material.

– Select material from the max. particle size according to table on page 32. For clear liquids metal pumps are the first choice. Check chemical resistance of the selected material from page 35 and tables in pages 185 to 189.

Step 6.

Now we have to select the right type of pump by considering the operating costs, taking into account wear, maintenance and energy.

Depending on the application it can be a horizontal, vertical or submersible Slurry Pump.

It can also be a pump for extreme, heavy or normal wear conditions.

From the section "Application guide" you can see which type of pump we recommend for various industrial applications. From this, together with the wet end material selected, you can select a suitable pump range from the sections "nomeclature and features" and "Technical description".

Now to the size of the pump. From previous steps above we now know the slurry flow rate and total discharge head.

We now have to find the pump size for this duty.

This can be done from the pump selection chart, see section "Technical description".

To be able to proceed and select a required pump speed and installed motor power, a complete clear water performance curve for the selected pump is required. Contact your local Metso house for support.

Step 7

Since the pump performance curves are based on clear water, corrections are required if other liquids or a slurry is pumped.

Clear water

Mark your flow and total discharge head point on the upper section of the clear water performance curve according to the figure below.
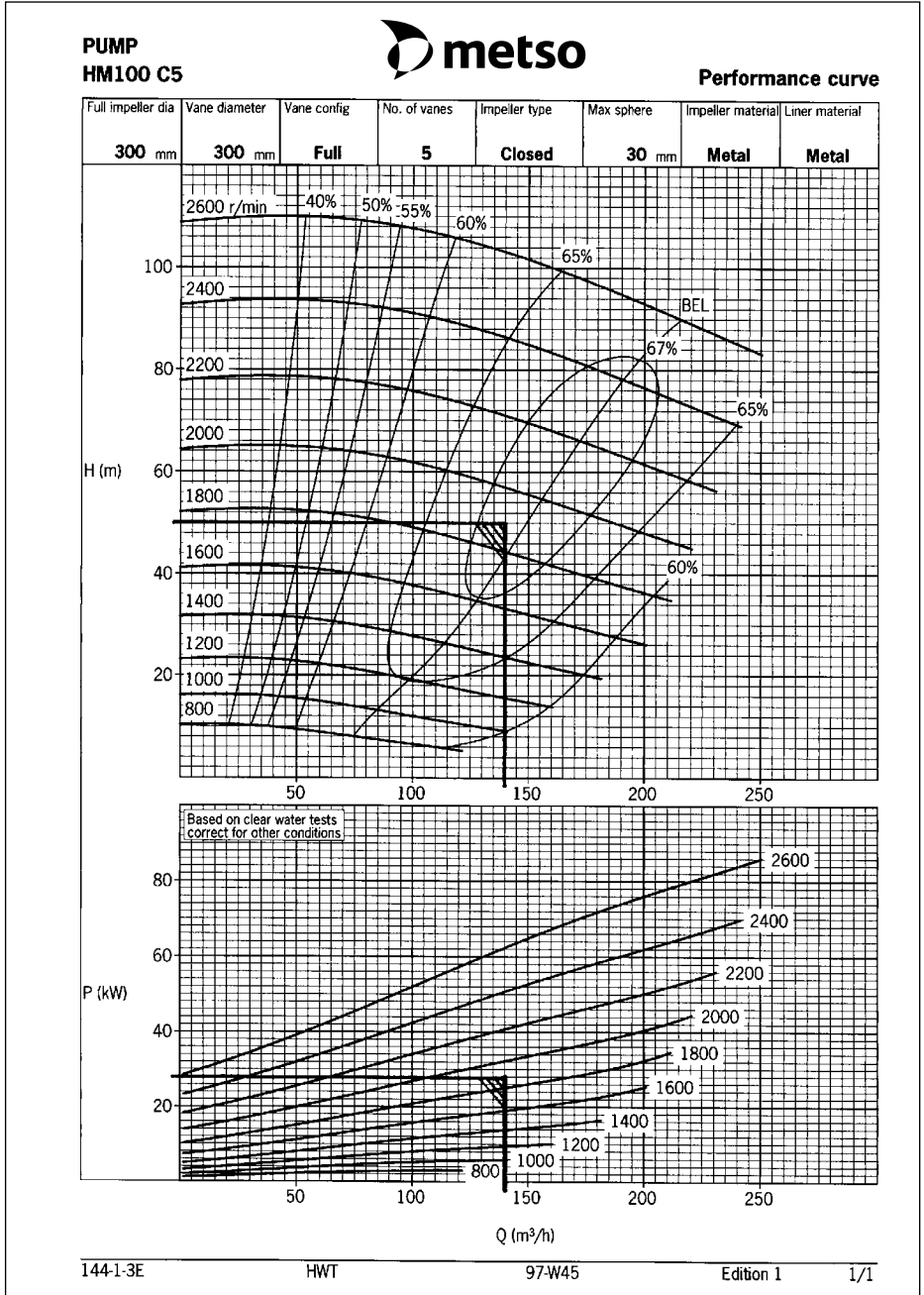
From this you can estimate the required pump speed or calculate it from the formulae on page 58. According to the example above the speed is 1880 r/min.

Then take the required power from the lower part of the performance curve using the duty flow and speed rotation.

For **settling slurries** see diagram on page 60 using average particle size d50, solids S.G. and concentration by weight. From this the HR/ER Factor can be established.

Divide the total discharge head by the HR factor. Since the factor is <1, the corrected total discharge head will get a higher value.

Mark your flow and corrected total discharge head point on the performance curve according to the figure under clear water.

From this you can estimate the required pump speed or calculate it from the formulae on page 58.

Then take the required clear water power from the clear water performance curve. Multiply the power by the relative density.

Relative density = Slurry density / Clear water density

Then you have the required slurry power on the pump shaft.

For **non-settling** slurries or viscous liquids the diagram on page 68 is used to correct the pump performance. For non-settling slurries the true plastic dynamic viscosity is needed, which can be found by the rheogram established by testwork.

For other Newtonian liquids with a different viscosity to clear water the viscosity can be given as either a kinematic or dynamic viscosity. See conversion factors in section "Miscellaneous".

From the (plastic) dynamic viscosity, flow and total discharge head the efficiency CN and flow CQ correction factors can be taken. The head correction factor CH is dependent on how close to the best efficiency (1,0 = best efficiency) the pump will operate.

Divide your duty flow and head with the correction factors above and mark them on the clear water curve as described above.

From this you can estimate the required pump speed or calculate it from the formulae on page 58.

Then take the required clear water power from the performance curve. Multiply the power by the relative density. Finally you have the duty speed and required slurry power on the pump shaft.

Check - for cavitation

According to section "Hydraulic performance" we need to check also the hydraulic situation on the inlet side (The NET POSITIVE SUCTION HEAD = NPSH).

If the losses in the pump inlet pipe are too high (suction lift), the slurry has a high temperature or the site is at a high altitude we might get cavitation.

Step 8

Next we have to select the correct motor size. It is recommended that a 15% safety margin is added on to the required power. The next larger motor size available is selected.

Step 9

Select a suitable drive to get the motor speed to meet the required pump speed. See section 9 for general guidelines. Consult drive suppliers or your local Metso house for recommendations.

Summary of sizing

The day to day tool for sizing slurry pumps is the PumpDim™ software. You can register for a copy on the form given in section "Introduction to PumpDim™. This basically follows the same sizing route as given above, but is simple and quick to use, and automatically carries out many mechanical checks such as bearing life, shaft deflection and critical speeds.

Good Luck!!!

INTRODUCTION TO METSO PumpDim™

Introduction

Metso PumpDim™ for Windows™

PumpDim™ for Windows™ is primarily a program for sizing and selecting Metso's pumps. It can size a pump for a specified duty point or a pipe system, pumping clear water, viscous liquids or a suspension of solids in a liquid.

The software is available upon registration fee. Please copy and fill in the enclosed registration form or go to www.metso.com/pumps for registration form on internet.

What can the software do?

The program considers and/or calculates for example the following parameters:

- Critical flow velocity to avoid settling of particles in pipes.
- The complete pipe head loss system curve when static head, pipes, fittings and other components are specified.
- Pumping of froth when a froth factor is specified.
- Effect of solids on the generated pump head and pump efficiency.
- Recommends material for the pump wet end considering particle size and distribution.
- Selects pump size for the specified duty and calculates required pump speed.
- Calculates shaft deflection and bearing life at the duty point.
- Recommends motor size and drive for the duty.
- Calculates slurry density based on particle and liquid density and concentration and/or tonnage. Calculates actual flow through an existing installation based on pipe system, slurry properties and pump speed i.e. determining circulating load in mill discharge applications.

Limitations

The results from PumpDim™ are representative for settling slurries with "normal" particle size and distribution, such as those found in mineral processing industries, with concentrations lower than 40% by volume.

Homogenous slurries with particles essentially smaller than 50 um i.e. clays, cement slurries, coating and filler quality calcium carbonates that have a non-Newtonian behaviour, need to be treated as a viscous liquid. The true slurry plastic dynamic viscosity, yield stress and flow index need to be known. These parameters can be established from test work carried out by Metso Minerals, or other laboratory.

For particles with a flaky or fibrous shape i.e. some mill scale applications and paper pulp applications need special considerations. Please consult Metso Minerals application specialists.

Contact us if you have any further questions.

Copyright and guarantees

The program has been developed by Metso and remains our property at all times. It shall be returned upon request. The software is Metso's copyright and shall not be copied or passed to third parties without our written permission.

Any information gained from the software is advisory only, and implies no legal binding offer or warranty, unless confirmed by Metso.

Any questions regarding the software shall be addressed to the local Metso office.

Registration form

Please copy this form and send it to your local Metso office according to the back page of this handbook, or send the data by e-mail to PumpDim@metso.com.

See also www.metso.com/pumps for registration form on internet.

Name ....

Title..

Company..

Address..

State/City ....

Zip/Post Code...

Phone ....

Fax ....

E-mail...

Introduction to Metso PumpDim™

MISCELLANEOUS

Conversion factors

Length
1 inch = 25.4 mm
1 foot = 0.305 m

Area
1 square inch = 645 mm^2 = 6.45 cm^2
1 square foot = 0.0929 m^2 = 929 cm^2

Volume
1 cubic inch = 16.4 cm^3
1 cubic foot = 28.3 l
1 UK gallon = 4.55 l
1 US gallon = 3.79 l

Mass
1 pound (lb) = 0.454 kg
1 ounce (oz) = 28.3 g
1 short ton = 907 kg

Spec. gr.
1 lb/in^3 = 27.7 t/m^3 = 27.7 g/cm^3
1 lb/ft^3 = 16.0 kg/m^3

Force
1 kp (kgf) = 9.81 N
1 lbf = 4.45 N

Energy
1 kWh = 3.60 MJ
1 kcal = 4.19 kJ
1 Btu = 1.06 kJ

Power
1 kcal/h = 1.16 W
1 hp = 746 W

Pressure
1 bar = 14.5 psi = 100 kPa
1 bar = 100 kPa

1 kp/cm^2 = 98.1 kPa
1 atm = 760 torr = 101 kPa
1 lbf/in^2 (psi) = 6.89 kPa = 0.07031 kp/cm^2
1 torr (mm Hg) = 133 Pa

Torque
1 ft. lb = 1.356 Nm

Dynamic viscosity

N s/m^2	N s/mm^2	P	cP
1	10^{-6}	10	10^3
10^6	1	$10 \cdot 10^6$	10^9
0,1	$0,1 \cdot 10^{-6}$	1	100
10^{-3}	10^{-9}	$10 \cdot 10^{-3}$	1

Kinematic viscosity = dynamic viscosity density

m^2/s	St (Stoke)	mm^2/s cSt
1	$10 \cdot 10^3$	10^6
10^{-6}	$10 \cdot 10^{-3}$	1
$0,1 \cdot 10^{-3}$	1	100

Flow
1 usgpm = 0.23 m^3/h
1 lgpm = 0.276 m^3/h

Velocity
1 fps = 0,3408 m/s
1 fpm = 18.288 m/min

Concentration clarity
ppm = parts per million = mg/l
ppb = parts per billion = mg/m^3
SS = suspended solids
TS = total solids (incl. dissolved solids)

Tyler standard scale

Mesh	Micron	Mesh	Micron	Mesh	Micron
$2^{1}/_{2}$	8000	14	1180	80	180
3	6700	16	1000	100	150
$3^{1}/_{2}$	5600	20	850	115	125
4	4750	24	710	150	106
5	4000	28	600	170	90
6	3350	32	500	200	75
7	2800	35	425	250	63
8	2360	42	355	270	53
9	2000	48	300	325	45
10	1700	60	250	400	38
12	1400	65	212	500	25

Density of solids

	Mineral	Relative Density		Mineral	Relative density
A	Albite	2.6	**F**	Feldspar Group	2.6-2.8
	Almandine	4.3		Ferberite	7.5
	Anatase	3.9		Flint	2.6
	Andradite	3.8		Fluorite	3.2
	Apatite	3.2		Franklinite	5.1-5.2
	Arsenopyrite	5.9-6.2			
	Asbestos	2.4-2.5	**G**	Gahnite	4.6
	Azurite	3.8		Galena	7.5
				Goethite	4.3
B	Baddeleyite	5.6		Gold	15.6-19.3
	Barite	4.5		Graphite	2.1-2.2
	Bauxite	2.6		Grossularite	3.5
	Beryl	2.7-2.8		Gypsum	2.3
	Biotite	3.0-3.1			
	Bismuth	9.8	**H**	Halite	2.5
				Hematite	5.2
C	Calcite	2.7		Hornblende	3.1-3.3
	Cassiterite	7.0		Huebnerite	6.7-7.5
	Celestite	4.0		Hypersthene	3.4
	Cerussite	6.6			
	Chalcocite	5.5-5.8	**I**	Ilmenite	4.7
	Chalcopyrite	4.1-4.3			
	Chlorite	2.6-3.2	**K**	Kaolinite	2.6
	Chromite	5.1		Kyanite	3.6-3.7
	Chrysocolla	2.0-2.3			
	Cinnabar	8.1	**L**	Lepidolite	2.8-2.9
	Cobaltite	6.0-6.3		Limonite	2.2-2.4
	Colemanite	2.4			
	Copper	8.9	**M**	Magnesite	3.0
	Corundum	3.9-4.1		Magnetite	4.7
	Covellite	4.7		Malachite	4.0
	Cryolite	3.0		Magnite	4.3
	Cuprite	5.8-6.2		Marcasite	4.6-4.9
				Martite	5.2
D	Diamond	3.5		Microcline	2.6
	Diopside	3.3-3.4		Microlite	5.5
	Dolomite	1.8-2.9		Molybdenite	4.7-5.0
				Monazite	4.9-5.5
				Mullite	3.2
E	Epidote	3.4		Muscovite	2.8-3.0

	Mineral	Relative density
N	Nepheline Syenite	2.6
	Niccolite	7.6-7.8
O	Olivine	3.3-3.5
	Orpiment	3.4-3.5
	Orthoclase	2.5-2.6
P	Petalite	2.4
	Platinum	14.0-21.5
	Pyrite	5.0
	Pyrochlore	4.2-4.4
	Pyrolusite	4.7-5.0
	Pyroxene	3.1-3.6
	Pyrrhotite	4.6-4.7
Q	Quartz	2.7
R	Realgar	3.6
	Rhodochrosite	3.7
	Rhodonite	3.6-3.7
	Rutile	4.2-4.3
S	Scheelite	6.1
	Serpentine	2.5-2.7
	Siderite	3.9
	Sillimanite	3.2
	Silver	10.1-11.1
	Smithsonite	4.1-4.5
	Sphalerite	3.9-4.0
	Sphene	3.3-8.6
	Spinel	3.6
	Spodumene	3.1-3.2
	Stannite	4.3-4.5
	Stibnite (Antimonite)	4.6
	Sulphur	2.1
	Sylvite	2.0

	Mineral	Relative density
T	Talc	2.7-2.8
	Tantalite	5.2-8.2
	Tetrahedrite	5.0
	Thorite	4.5-5.4
	Topaz	3.5-3.6
	Tourmaline	2.9-3.2
U	Uraninite	11.0
V	Vermiculite	2.4-2.7
W	Wolframite	6.7-7.5
	Wollastonite	2.8-2.9
Z	Zeolite	2.0-2.5
	Zincite	5.7
	Zircon	4.7

Other solids of varying composition:

Slag	1.5-4
Soil	1.5-2.8
Ash (fly)	1.5-3.5
Ash (bottom)	1.5-3
Wet scrubber effluent	2-5
Mill scale	4.9-5.2

Water and solids – Pulp density data

A = Solids by weight [%]
B = Pulp density [ton/m³]
C = Pulp volume [m³/ton solids]

Density of solids: 1.4

A	B	C	A	B	C
1	1.003	99.714	41	1.133	2.153
2	1.006	49.714	42	1.136	2.095
3	1.009	33.048	43	1.140	2.040
4	1.012	24.714	44	1.144	1.987
5	1.014	19.714	45	1.148	1.937
6	1.017	16.381	46	1.151	1.888
7	1.020	14.000	47	1.155	1.842
8	1.023	12.214	48	1.159	1.798
9	1.026	10.825	49	1.163	1.755
10	1.029	9.714	50	1.167	1.714
11	1.032	8.805	51	1.171	1.675
12	1.036	8.048	52	1.174	1.637
13	1.039	7.407	53	1.178	1.601
14	1.042	6.857	54	1.182	1.566
15	1.045	6.381	55	1.186	1.532
16	1.048	5.964	56	1.190	1.500
17	1.051	5.597	57	1.195	1.469
18	1.054	5.270	58	1.199	1.438
19	1.057	4.977	59	1.203	1.409
20	1.061	4.714	60	1.207	1.381
21	1.064	4.476	61	1.211	1.354
22	1.067	4.260	62	1.215	1.327
23	1.070	4.062	63	1.220	1.302
24	1.074	3.881	64	1.224	1.277
25	1.077	3.714	65	1.228	1.253
26	1.080	3.560	66	1.232	1.229
27	1.084	3.418	67	1.237	1.207
28	1.087	3.286	68	1.241	1.185
29	1.090	3.163	69	1.246	1.164
30	1.094	3.048	70	1.250	1.143
31	1.097	2.940	71	1.254	1.123
32	1.101	2.839	72	1.259	1.103
33	1.104	2.745	73	1.264	1.084
34	1.108	2.655	74	1.268	1.066
35	1.111	2.571	75	1.273	1.048
36	1.115	2.492	76	1.277	1.030
37	1.118	2.417	77	1.282	1.013
38	1.122	2.346	78	1.287	0.996
39	1.125	2.278	79	1.292	0.980
40	1.129	2.214	80	1.296	0.964

Density of solids: 1.8

A	B	C	A	B	C
1	1.004	99.556	41	1.223	1.995
2	1.009	49.556	42	1.230	1.937
3	1.014	32.889	43	1.236	1.881
4	1.018	24.556	44	1.243	1.828
5	1.023	19.556	45	1.250	1.778
6	1.027	16.222	46	1.257	1.729
7	1.032	13.841	47	1.264	1.683
8	1.037	12.056	48	1.271	1.639
9	1.042	10.667	49	1.278	1.596
10	1.047	9.556	50	1.286	1.556
11	1.051	8.646	51	1.293	1.516
12	1.056	7.889	52	1.301	1.479
13	1.061	7.248	53	1.308	1.442
14	1.066	6.698	54	1.316	1.407
15	1.071	6.222	55	1.324	1.374
16	1.077	5.806	56	1.331	1.341
17	1.082	5.438	57	1.339	1.310
18	1.087	5.111	58	1.347	1.280
19	1.092	4.819	59	1.355	1.250
20	1.098	4.556	60	1.364	1.222
21	1.103	4.317	61	1.372	1.195
22	1.108	4.101	62	1.380	1.168
23	1.114	3.903	63	1.389	1.143
24	1.119	3.722	64	1.398	1.118
25	1.125	3.556	65	1.406	1.094
26	1.131	3.402	66	1.415	1.071
27	1.136	3.259	67	1.424	1.048
28	1.142	3.127	68	1.433	1.026
29	1.148	3.004	69	1.442	1.005
30	1.154	2.889	70	1.452	0.984
31	1.160	2.781	71	1.461	0.964
32	1.166	2.681	72	1.471	0.944
33	1.172	2.586	73	1.480	0.925
34	1.178	2.497	74	1.490	0.907
35	1.184	2.413	75	1.500	0.889
36	1.190	2.333	76	1.510	0.871
37	1.197	2.258	77	1.520	0.854
38	1.203	2.187	78	1.531	0.838
39	1.210	2.120	79	1.541	0.821
40	1.216	2.056	80	1.552	0.806

Water and solids – Pulp density data (US)

A = Solids by weight [%]
B = Pulp S. G.
C = Pulp volume USG/ston solids

Density of solids: 1.4

A	B	C	A	B	C
1	1.003	23897	41	1.133	516
2	1.006	11914	42	1.136	502
3	1.009	7920	43	1.140	489
4	1.012	5923	44	1.144	476
5	1.014	4725	45	1.148	464
6	1.017	3926	46	1.151	452
7	1.020	3355	47	1.155	441
8	1.023	2927	48	1.159	431
9	1.026	2594	49	1.163	421
10	1.029	2328	50	1.167	411
11	1.032	2110	51	1.171	401
12	1.036	1929	52	1.174	392
13	1.039	1775	53	1.178	384
14	1.042	1643	54	1.182	375
15	1.045	1529	55	1.186	367
16	1.048	1429	56	1.190	359
17	1.051	1341	57	1.195	352
18	1.054	1263	58	1.199	345
19	1.057	1193	59	1.203	338
20	1.061	1130	60	1.207	331
21	1.064	1073	61	1.211	324
22	1.067	1021	62	1.215	318
23	1.070	973	63	1.220	312
24	1.074	930	64	1.224	306
25	1.077	890	65	1.228	300
26	1.080	853	66	1.232	295
27	1.084	819	67	1.237	289
28	1.087	787	68	1.241	284
29	1.090	758	69	1.246	279
30	1.094	730	70	1.250	274
31	1.097	705	71	1.254	269
32	1.101	680	72	1.259	264
33	1.104	658	73	1.264	260
34	1.108	636	74	1.268	255
35	1.111	616	75	1.273	251
36	1.115	597	76	1.277	247
37	1.118	579	77	1.282	243
38	1.122	562	78	1.287	239
39	1.125	546	79	1.292	235
40	1.129	531	80	1.296	231

Density of solids: 1.8

A	B	C	A	B	C
1	1.004	23859	41	1.223	478
2	1.009	11876	42	1.230	464
3	1.014	7882	43	1.236	451
4	1.018	5885	44	1.243	438
5	1.023	4687	45	1.250	426
6	1.027	3888	46	1.257	414
7	1.032	3317	47	1.264	403
8	1.037	2889	48	1.271	393
9	1.042	2556	49	1.278	382
10	1.047	2290	50	1.286	373
11	1.051	2072	51	1.293	363
12	1.056	1891	52	1.301	354
13	1.061	1737	53	1.308	346
14	1.066	1605	54	1.316	337
15	1.071	1491	55	1.324	329
16	1.077	1391	56	1.331	321
17	1.082	1303	57	1.339	314
18	1.087	1225	58	1.347	307
19	1.092	1155	59	1.355	300
20	1.098	1092	60	1.364	293
21	1.103	1035	61	1.372	286
22	1.108	983	62	1.380	280
23	1.114	935	63	1.389	274
24	1.119	892	64	1.398	268
25	1.125	852	65	1.406	262
26	1.131	815	66	1.415	257
27	1.136	781	67	1.424	251
28	1.142	749	68	1.433	246
29	1.148	720	69	1.442	241
30	1.154	692	70	1.452	236
31	1.160	666	71	1.461	231
32	1.166	643	72	1.471	226
33	1.172	620	73	1.480	222
34	1.178	598	74	1.490	217
35	1.184	578	75	1.500	213
36	1.190	559	76	1.510	209
37	1.197	541	77	1.520	205
38	1.203	524	78	1.531	201
39	1.210	508	79	1.541	197
40	1.216	493	80	1.552	193

Water and solids – Pulp density data

A = Solids by weight [%]
B = Pulp density [ton/m³]
C = Pulp volume [m³/ton solids]

Density of solids: 2.0

A	B	C	A	B	C
1	1.005	99.500	41	1.258	1.939
2	1.010	49.500	42	1.266	1.881
3	1.015	32.833	43	1.274	1.826
4	1.020	24.500	44	1.282	1.773
5	1.026	19.500	45	1.290	1.722
6	1.031	16.167	46	1.299	1.674
7	1.036	13.786	47	1.307	1.628
8	1.042	12.000	48	1.316	1.583
9	1.047	10.611	49	1.325	1.541
10	1.053	9.500	50	1.333	1.500
11	1.058	8.591	51	1.342	1.461
12	1.064	7.833	52	1.351	1.423
13	1.070	7.192	53	1.361	1.387
14	1.075	6.643	54	1.370	1.352
15	1.081	6.167	55	1.379	1.318
16	1.087	5.750	56	1.389	1.286
17	1.093	5.382	57	1.399	1.254
18	1.099	5.056	58	1.408	1.224
19	1.105	4.763	59	1.418	1.195
20	1.111	4.500	60	1.429	1.167
21	1.117	4.262	61	1.439	1.139
22	1.124	4.045	62	1.449	1.113
23	1.130	3.848	63	1.460	1.087
24	1.136	3.667	64	1.471	1.063
25	1.143	3.500	65	1.481	1.038
26	1.149	3.346	66	1.493	1.015
27	1.156	3.204	67	1.504	0.993
28	1.163	3.071	68	1.515	0.971
29	1.170	2.948	69	1.527	0.949
30	1.176	2.833	70	1.538	0.929
31	1.183	2.726	71	1.550	0.908
32	1.190	2.625	72	1.563	0.889
33	1.198	2.530	73	1.575	0.870
34	1.205	2.441	74	1.587	0.851
35	1.212	2.357	75	1.600	0.833
36	1.220	2.278	76	1.613	0.816
37	1.227	2.203	77	1.626	0.799
38	1.235	2.132	78	1.639	0.782
39	1.242	2.064	79	1.653	0.766
40	1.250	2.000	80	1.667	0.750

Density of solids: 2.6

A	B	C	A	B	C
1	1.006	99.385	41	1.337	1.824
2	1.012	49.385	42	1.349	1.766
3	1.019	32.718	43	1.360	1.710
4	1.025	24.385	44	1.371	1.657
5	1.032	19.385	45	1.383	1.607
6	1.038	16.051	46	1.395	1.559
7	1.045	13.670	47	1.407	1.512
8	1.052	11.885	48	1.419	1.468
9	1.059	10.496	49	1.432	1.425
10	1.066	9.385	50	1.444	1.385
11	1.073	8.476	51	1.457	1.345
12	1.080	7.718	52	1.471	1.308
13	1.087	7.077	53	1.484	1.271
14	1.094	6.527	54	1.498	1.236
15	1.102	6.051	55	1.512	1.203
16	1.109	5.635	56	1.526	1.170
17	1.117	5.267	57	1.540	1.139
18	1.125	4.940	58	1.555	1.109
19	1.132	4.648	59	1.570	1.080
20	1.140	4.385	60	1.585	1.051
21	1.148	4.147	61	1.601	1.024
22	1.157	3.930	62	1.617	0.998
23	1.165	3.732	63	1.633	0.972
24	1.173	3.551	64	1.650	0.947
25	1.182	3.385	65	1.667	0.923
26	1.190	3.231	66	1.684	0.900
27	1.199	3.088	67	1.702	0.877
28	1.208	2.956	68	1.720	0.855
29	1.217	2.833	69	1.738	0.834
30	1.226	2.718	70	1.757	0.813
31	1.236	2.610	71	1.776	0.793
32	1.245	2.510	72	1.796	0.774
33	1.255	2.415	73	1.816	0.754
34	1.265	2.326	74	1.836	0.736
35	1.275	2.242	75	1.857	0.718
36	1.285	2.162	76	1.879	0.700
37	1.295	2.087	77	1.901	0.683
38	1.305	2.016	78	1.923	0.667
39	1.316	1.949	79	1.946	0.650
40	1.327	1.885	80	1.970	0.635

Water and solids – Pulp density data (US)

A = Solids by weight [%]
B = Pulp S. G.
C = Pulp volume USG/ston solids

Density of solids: 2.0

A	B	C	A	B	C
1	1.005	23845	41	1.258	465
2	1.010	11863	42	1.266	451
3	1.015	7869	43	1.274	438
4	1.020	5871	44	1.282	425
5	1.026	4673	45	1.290	413
6	1.031	3874	46	1.299	401
7	1.036	3304	47	1.307	390
8	1.042	2876	48	1.316	379
9	1.047	2543	49	1.325	369
10	1.053	2277	50	1.333	359
11	1.058	2059	51	1.342	350
12	1.064	1877	52	1.351	341
13	1.070	1724	53	1.361	332
14	1.075	1592	54	1.370	324
15	1.081	1478	55	1.379	316
16	1.087	1378	56	1.389	308
17	1.093	1290	57	1.399	301
18	1.099	1212	58	1.408	293
19	1.105	1141	59	1.418	286
20	1.111	1078	60	1.429	280
21	1.117	1021	61	1.439	273
22	1.124	969	62	1.449	267
23	1.130	922	63	1.460	261
24	1.136	879	64	1.471	255
25	1.143	839	65	1.481	249
26	1.149	802	66	1.493	243
27	1.156	768	67	1.504	238
28	1.163	736	68	1.515	233
29	1.170	706	69	1.527	227
30	1.176	679	70	1.538	223
31	1.183	653	71	1.550	218
32	1.190	629	72	1.563	213
33	1.198	606	73	1.575	208
34	1.205	585	74	1.587	204
35	1.212	565	75	1.600	200
36	1.220	546	76	1.613	196
37	1.227	528	77	1.626	191
38	1.235	511	78	1.639	187
39	1.242	495	79	1.653	184
40	1.250	479	80	1.667	180

Density of solids: 2.6

A	B	C	A	B	C
1	1.006	23818	41	1.337	437
2	1.012	11835	42	1.349	423
3	1.019	7841	43	1.360	410
4	1.025	5844	44	1.371	397
5	1.032	4646	45	1.383	385
6	1.038	3847	46	1.395	374
7	1.045	3276	47	1.407	362
8	1.052	2848	48	1.419	352
9	1.059	2515	49	1.432	342
10	1.066	2249	50	1.444	332
11	1.073	2031	51	1.457	322
12	1.080	1850	52	1.471	313
13	1.087	1696	53	1.484	305
14	1.094	1564	54	1.498	296
15	1.102	1450	55	1.512	288
16	1.109	1350	56	1.526	280
17	1.117	1262	57	1.540	273
18	1.125	1184	58	1.555	266
19	1.132	1114	59	1.570	259
20	1.140	1051	60	1.585	252
21	1.148	994	61	1.601	245
22	1.157	942	62	1.617	239
23	1.165	894	63	1.633	233
24	1.173	851	64	1.650	227
25	1.182	811	65	1.667	221
26	1.190	774	66	1.684	216
27	1.199	740	67	1.702	210
28	1.208	708	68	1.720	205
29	1.217	679	69	1.738	200
30	1.226	651	70	1.757	195
31	1.236	625	71	1.776	190
32	1.245	602	72	1.796	185
33	1.255	579	73	1.816	181
34	1.265	557	74	1.836	176
35	1.275	537	75	1.857	172
36	1.285	518	76	1.879	168
37	1.295	500	77	1.901	164
38	1.305	483	78	1.923	160
39	1.316	467	79	1.946	156
40	1.327	452	80	1.970	152

Water and solids – Pulp density data

A = Solids by weight [%]
B = Pulp density [ton/m³]
C = Pulp volume [m³/ton solids]

Density of solids: 2.8

A	B	C	A	B	C
1	1.006	99.357	41	1.358	1.796
2	1.013	49.357	42	1.370	1.738
3	1.020	32.690	43	1.382	1.683
4	1.026	24.357	44	1.394	1.630
5	1.033	19.357	45	1.407	1.579
6	1.040	16.024	46	1.420	1.531
7	1.047	13.643	47	1.433	1.485
8	1.054	11.857	48	1.446	1.440
9	1.061	10.468	49	1.460	1.398
10	1.069	9.357	50	1.474	1.357
11	1.076	8.448	51	1.488	1.318
12	1.084	7.690	52	1.502	1.280
13	1.091	7.049	53	1.517	1.244
14	1.099	6.500	54	1.532	1.209
15	1.107	6.024	55	1.547	1.175
16	1.115	5.607	56	1.563	1.143
17	1.123	5.239	57	1.578	1.112
18	1.131	4.913	58	1.595	1.081
19	1.139	4.620	59	1.611	1.052
20	1.148	4.357	60	1.628	1.024
21	1.156	4.119	61	1.645	0.996
22	1.165	3.903	62	1.663	0.970
23	1.174	3.705	63	1.681	0.944
24	1.182	3.524	64	1.699	0.920
25	1.191	3.357	65	1.718	0.896
26	1.201	3.203	66	1.737	0.872
27	1.210	3.061	67	1.757	0.850
28	1.220	2.929	68	1.777	0.828
29	1.229	2.805	69	1.797	0.806
30	1.239	2.690	70	1.818	0.786
31	1.249	2.583	71	1.840	0.766
32	1.259	2.482	72	1.862	0.746
33	1.269	2.387	73	1.884	0.727
34	1.280	2.298	74	1.907	0.708
35	1.290	2.214	75	1.931	0.690
36	1.301	2.135	76	1.955	0.673
37	1.312	2.060	77	1.980	0.656
38	1.323	1.989	78	2.006	0.639
39	1.335	1.921	79	2.032	0.623
40	1.346	1.857	80	2.059	0.607

Density of solids: 3.0

A	B	C	A	B	C
1	1.007	99.333	41	1.376	1.772
2	1.014	49.333	42	1.389	1.714
3	1.020	32.667	43	1.402	1.659
4	1.027	24.333	44	1.415	1.606
5	1.034	19.333	45	1.429	1.556
6	1.042	16.000	46	1.442	1.507
7	1.049	13.619	47	1.456	1.461
8	1.056	11.833	48	1.471	1.417
9	1.064	10.444	49	1.485	1.374
10	1.071	9.333	50	1.500	1.333
11	1.079	8.424	51	1.515	1.294
12	1.087	7.667	52	1.531	1.256
13	1.095	7.026	53	1.546	1.220
14	1.103	6.476	54	1.563	1.185
15	1.111	6.000	55	1.579	1.152
16	1.119	5.583	56	1.596	1.119
17	1.128	5.216	57	1.613	1.088
18	1.136	4.889	58	1.630	1.057
19	1.145	4.596	59	1.648	1.028
20	1.154	4.333	60	1.667	1.000
21	1.163	4.095	61	1.685	0.973
22	1.172	3.879	62	1.705	0.946
23	1.181	3.681	63	1.724	0.921
24	1.190	3.500	64	1.744	0.896
25	1.200	3.333	65	1.765	0.872
26	1.210	3.179	66	1.786	0.848
27	1.220	3.037	67	1.807	0.826
28	1.230	2.905	68	1.829	0.804
29	1.240	2.782	69	1.852	0.783
30	1.250	2.667	70	1.875	0.762
31	1.261	2.559	71	1.899	0.742
32	1.271	2.458	72	1.923	0.722
33	1.282	2.364	73	1.948	0.703
34	1.293	2.275	74	1.974	0.685
35	1.304	2.190	75	2.000	0.667
36	1.316	2.111	76	2.027	0.649
37	1.327	2.036	77	2.055	0.632
38	1.339	1.965	78	2.083	0.615
39	1.351	1.897	79	2.113	0.599
40	1.364	1.833	80	2.143	0.583

Water and solids – Pulp density data (US)

A = Solids by weight [%]
B = Pulp S. G.
C = Pulp volume USG/ston solids

Density of solids: 2.8

A	B	C	A	B	C
1	1.006	23811	41	1.358	430
2	1.013	11829	42	1.370	417
3	1.020	7834	43	1.382	403
4	1.026	5837	44	1.394	391
5	1.033	4639	45	1.407	378
6	1.040	3840	46	1.420	367
7	1.047	3270	47	1.433	356
8	1.054	2842	48	1.446	345
9	1.061	2509	49	1.460	335
10	1.069	2242	50	1.474	325
11	1.076	2025	51	1.488	316
12	1.084	1843	52	1.502	307
13	1.091	1689	53	1.517	298
14	1.099	1558	54	1.532	290
15	1.107	1444	55	1.547	282
16	1.115	1344	56	1.563	274
17	1.123	1256	57	1.578	266
18	1.131	1177	58	1.595	259
19	1.139	1107	59	1.611	252
20	1.148	1044	60	1.628	245
21	1.156	987	61	1.645	239
22	1.165	935	62	1.663	232
23	1.174	888	63	1.681	226
24	1.182	845	64	1.699	220
25	1.191	805	65	1.718	215
26	1.201	768	66	1.737	209
27	1.210	734	67	1.757	204
28	1.220	702	68	1.777	198
29	1.229	672	69	1.797	193
30	1.239	645	70	1.818	188
31	1.249	619	71	1.840	184
32	1.259	595	72	1.862	179
33	1.269	572	73	1.884	174
34	1.280	551	74	1.907	170
35	1.290	531	75	1.931	165
36	1.301	512	76	1.955	161
37	1.312	494	77	1.980	157
38	1.323	477	78	2.006	153
39	1.335	460	79	2.032	149
40	1.346	445	80	2.059	145

Density of solids: 3.0

A	B	C	A	B	C
1	1.007	23805	41	1.376	425
2	1.014	11823	42	1.389	411
3	1.020	7829	43	1.402	398
4	1.027	5831	44	1.415	385
5	1.034	4633	45	1.429	373
6	1.042	3834	46	1.442	361
7	1.049	3264	47	1.456	350
8	1.056	2836	48	1.471	340
9	1.064	2503	49	1.485	329
10	1.071	2237	50	1.500	319
11	1.079	2019	51	1.515	310
12	1.087	1837	52	1.531	301
13	1.095	1684	53	1.546	292
14	1.103	1552	54	1.563	284
15	1.111	1438	55	1.579	276
16	1.119	1338	56	1.596	268
17	1.128	1250	57	1.613	261
18	1.136	1172	58	1.630	253
19	1.145	1101	59	1.648	246
20	1.154	1038	60	1.667	240
21	1.163	981	61	1.685	233
22	1.172	930	62	1.705	227
23	1.181	882	63	1.724	221
24	1.190	839	64	1.744	215
25	1.200	799	65	1.765	209
26	1.210	762	66	1.786	203
27	1.220	728	67	1.807	198
28	1.230	696	68	1.829	193
29	1.240	667	69	1.852	188
30	1.250	639	70	1.875	183
31	1.261	613	71	1.899	178
32	1.271	589	72	1.923	173
33	1.282	567	73	1.948	168
34	1.293	545	74	1.974	164
35	1.304	525	75	2.000	160
36	1.316	506	76	2.027	156
37	1.327	488	77	2.055	151
38	1.339	471	78	2.083	147
39	1.351	455	79	2.113	144
40	1.364	439	80	2.143	140

Water and solids – Pulp density data

A = Solids by weight [%]
B = Pulp density [ton/m³]
C = Pulp volume [m³/ton solids]

Density of solids: 3.2

A	B	C	A	B	C
1	1.007	99.313	41	1.393	1.752
2	1.014	49.313	42	1.406	1.693
3	1.021	32.646	43	1.420	1.638
4	1.028	24.313	44	1.434	1.585
5	1.036	19.313	45	1.448	1.535
6	1.043	15.979	46	1.463	1.486
7	1.051	13.598	47	1.477	1.440
8	1.058	11.813	48	1.493	1.396
9	1.066	10.424	49	1.508	1.353
10	1.074	9.313	50	1.524	1.313
11	1.082	8.403	51	1.540	1.273
12	1.090	7.646	52	1.556	1.236
13	1.098	7.005	53	1.573	1.199
14	1.107	6.455	54	1.590	1.164
15	1.115	5.979	55	1.608	1.131
16	1.124	5.563	56	1.626	1.098
17	1.132	5.195	57	1.644	1.067
18	1.141	4.868	58	1.663	1.037
19	1.150	4.576	59	1.682	1.007
20	1.159	4.313	60	1.702	0.979
21	1.169	4.074	61	1.722	0.952
22	1.178	3.858	62	1.743	0.925
23	1.188	3.660	63	1.764	0.900
24	1.198	3.479	64	1.786	0.875
25	1.208	3.313	65	1.808	0.851
26	1.218	3.159	66	1.831	0.828
27	1.228	3.016	67	1.854	0.805
28	1.238	2.884	68	1.878	0.783
29	1.249	2.761	69	1.902	0.762
30	1.260	2.646	70	1.928	0.741
31	1.271	2.538	71	1.954	0.721
32	1.282	2.438	72	1.980	0.701
33	1.293	2.343	73	2.008	0.682
34	1.305	2.254	74	2.036	0.664
35	1.317	2.170	75	2.065	0.646
36	1.329	2.090	76	2.094	0.628
37	1.341	2.015	77	2.125	0.611
38	1.354	1.944	78	2.156	0.595
39	1.366	1.877	79	2.189	0.578
40	1.379	1.813	80	2.222	0.563

Density of solids: 3.4

A	B	C	A	B	C
1	1.007	99.294	41	1.407	1.733
2	1.014	49.294	42	1.421	1.675
3	1.022	32.627	43	1.436	1.620
4	1.029	24.294	44	1.451	1.567
5	1.037	19.294	45	1.466	1.516
6	1.044	15.961	46	1.481	1.468
7	1.052	13.580	47	1.496	1.422
8	1.060	11.794	48	1.512	1.377
9	1.068	10.405	49	1.529	1.335
10	1.076	9.294	50	1.545	1.294
11	1.084	8.385	51	1.563	1.255
12	1.093	7.627	52	1.580	1.217
13	1.101	6.986	53	1.598	1.181
14	1.110	6.437	54	1.616	1.146
15	1.118	5.961	55	1.635	1.112
16	1.127	5.544	56	1.654	1.080
17	1.136	5.176	57	1.673	1.049
18	1.146	4.850	58	1.693	1.018
19	1.155	4.557	59	1.714	0.989
20	1.164	4.294	60	1.735	0.961
21	1.174	4.056	61	1.756	0.933
22	1.184	3.840	62	1.778	0.907
23	1.194	3.642	63	1.801	0.881
24	1.204	3.461	64	1.824	0.857
25	1.214	3.294	65	1.848	0.833
26	1.225	3.140	66	1.872	0.809
27	1.235	2.998	67	1.897	0.787
28	1.246	2.866	68	1.923	0.765
29	1.257	2.742	69	1.950	0.743
30	1.269	2.627	70	1.977	0.723
31	1.280	2.520	71	2.005	0.703
32	1.292	2.419	72	2.033	0.683
33	1.304	2.324	73	2.063	0.664
34	1.316	2.235	74	2.094	0.645
35	1.328	2.151	75	2.125	0.627
36	1.341	2.072	76	2.157	0.610
37	1.354	1.997	77	2.191	0.593
38	1.367	1.926	78	2.225	0.576
39	1.380	1.858	79	2.261	0.560
40	1.393	1.794	80	2.297	0.544

Water and solids – Pulp density data (US)

A = Solids by weight [%]
B = Pulp S. G.
C = Pulp volume USG/ston solids

Density of solids: 3.2

A	B	C	A	B	C
1	1.007	23801	41	1.393	420
2	1.014	11818	42	1.406	406
3	1.021	7824	43	1.420	393
4	1.028	5827	44	1.434	380
5	1.036	4628	45	1.448	368
6	1.043	3829	46	1.463	356
7	1.051	3259	47	1.477	345
8	1.058	2831	48	1.493	335
9	1.066	2498	49	1.508	324
10	1.074	2232	50	1.524	315
11	1.082	2014	51	1.540	305
12	1.090	1832	52	1.556	296
13	1.098	1679	53	1.573	287
14	1.107	1547	54	1.590	279
15	1.115	1433	55	1.608	271
16	1.124	1333	56	1.626	263
17	1.132	1245	57	1.644	256
18	1.141	1167	58	1.663	249
19	1.150	1097	59	1.682	241
20	1.159	1034	60	1.702	235
21	1.169	976	61	1.722	228
22	1.178	925	62	1.743	222
23	1.188	877	63	1.764	216
24	1.198	834	64	1.786	210
25	1.208	794	65	1.808	204
26	1.218	757	66	1.831	198
27	1.228	723	67	1.854	193
28	1.238	691	68	1.878	188
29	1.249	662	69	1.902	183
30	1.260	634	70	1.928	178
31	1.271	608	71	1.954	173
32	1.282	584	72	1.980	168
33	1.293	562	73	2.008	163
34	1.305	540	74	2.036	159
35	1.317	520	75	2.065	155
36	1.329	501	76	2.094	151
37	1.341	483	77	2.125	146
38	1.354	466	78	2.156	143
39	1.366	450	79	2.189	139
40	1.379	434	80	2.222	135

Density of solids: 3.4

A	B	C	A	B	C
1	1.007	23796	41	1.407	415
2	1.014	11813	42	1.421	401
3	1.022	7819	43	1.436	388
4	1.029	5822	44	1.451	376
5	1.037	4624	45	1.466	363
6	1.044	3825	46	1.481	352
7	1.052	3254	47	1.496	341
8	1.060	2826	48	1.512	330
9	1.068	2494	49	1.529	320
10	1.076	2227	50	1.545	310
11	1.084	2009	51	1.563	301
12	1.093	1828	52	1.580	292
13	1.101	1674	53	1.598	283
14	1.110	1543	54	1.616	275
15	1.118	1429	55	1.635	266
16	1.127	1329	56	1.654	259
17	1.136	1240	57	1.673	251
18	1.146	1162	58	1.693	244
19	1.155	1092	59	1.714	237
20	1.164	1029	60	1.735	230
21	1.174	972	61	1.756	224
22	1.184	920	62	1.778	217
23	1.194	873	63	1.801	211
24	1.204	829	64	1.824	205
25	1.214	789	65	1.848	200
26	1.225	753	66	1.872	194
27	1.235	718	67	1.897	189
28	1.246	687	68	1.923	183
29	1.257	657	69	1.950	178
30	1.269	630	70	1.977	173
31	1.280	604	71	2.005	168
32	1.292	580	72	2.033	164
33	1.304	557	73	2.063	159
34	1.316	536	74	2.094	155
35	1.328	515	75	2.125	150
36	1.341	497	76	2.157	146
37	1.354	479	77	2.191	142
38	1.367	462	78	2.225	138
39	1.380	445	79	2.261	134
40	1.393	430	80	2.297	130

Water and solids – Pulp density data

A = Solids by weight [%]
B = Pulp density [ton/m³]
C = Pulp volume [m³/ton solids]

Density of solids: 3.6

A	B	C	A	B	C
1	1.007	99.278	41	1.421	1.717
2	1.015	49.278	42	1.435	1.659
3	1.022	32.611	43	1.450	1.603
4	1.030	24.278	44	1.466	1.551
5	1.037	19.278	45	1.481	1.500
6	1.045	15.944	46	1.498	1.452
7	1.053	13.563	47	1.514	1.405
8	1.061	11.778	48	1.531	1.361
9	1.070	10.389	49	1.548	1.319
10	1.078	9.278	50	1.565	1.278
11	1.086	8.369	51	1.583	1.239
12	1.095	7.611	52	1.601	1.201
13	1.104	6.970	53	1.620	1.165
14	1.112	6.421	54	1.639	1.130
15	1.121	5.944	55	1.659	1.096
16	1.131	5.528	56	1.679	1.063
17	1.140	5.160	57	1.700	1.032
18	1.149	4.833	58	1.721	1.002
19	1.159	4.541	59	1.742	0.973
20	1.169	4.278	60	1.765	0.944
21	1.179	4.040	61	1.787	0.917
22	1.189	3.823	62	1.811	0.891
23	1.199	3.626	63	1.835	0.865
24	1.210	3.444	64	1.860	0.840
25	1.220	3.278	65	1.885	0.816
26	1.231	3.124	66	1.911	0.793
27	1.242	2.981	67	1.938	0.770
28	1.253	2.849	68	1.965	0.748
29	1.265	2.726	69	1.993	0.727
30	1.277	2.611	70	2.022	0.706
31	1.288	2.504	71	2.052	0.686
32	1.301	2.403	72	2.083	0.667
33	1.313	2.308	73	2.115	0.648
34	1.325	2.219	74	2.148	0.629
35	1.338	2.135	75	2.182	0.611
36	1.351	2.056	76	2.217	0.594
37	1.365	1.980	77	2.253	0.576
38	1.378	1.909	78	2.290	0.560
39	1.392	1.842	79	2.329	0.544
40	1.406	1.778	80	2.368	0.528

Density of solids: 3.8

A	B	C	A	B	C
1	1.007	99.263	41	1.433	1.702
2	1.015	49.263	42	1.448	1.644
3	1.023	32.596	43	1.464	1.589
4	1.030	24.263	44	1.480	1.536
5	1.038	19.263	45	1.496	1.485
6	1.046	15.930	46	1.513	1.437
7	1.054	13.549	47	1.530	1.391
8	1.063	11.763	48	1.547	1.346
9	1.071	10.374	49	1.565	1.304
10	1.080	9.263	50	1.583	1.263
11	1.088	8.354	51	1.602	1.224
12	1.097	7.596	52	1.621	1.186
13	1.106	6.955	53	1.641	1.150
14	1.115	6.406	54	1.661	1.115
15	1.124	5.930	55	1.681	1.081
16	1.134	5.513	56	1.703	1.049
17	1.143	5.146	57	1.724	1.018
18	1.153	4.819	58	1.746	0.987
19	1.163	4.526	59	1.769	0.958
20	1.173	4.263	60	1.792	0.930
21	1.183	4.025	61	1.816	0.903
22	1.193	3.809	62	1.841	0.876
23	1.204	3.611	63	1.866	0.850
24	1.215	3.430	64	1.892	0.826
25	1.226	3.263	65	1.919	0.802
26	1.237	3.109	66	1.947	0.778
27	1.248	2.967	67	1.975	0.756
28	1.260	2.835	68	2.004	0.734
29	1.272	2.711	69	2.034	0.712
30	1.284	2.596	70	2.065	0.692
31	1.296	2.489	71	2.097	0.672
32	1.309	2.388	72	2.130	0.652
33	1.321	2.293	73	2.164	0.633
34	1.334	2.204	74	2.199	0.615
35	1.348	2.120	75	2.235	0.596
36	1.361	2.041	76	2.273	0.579
37	1.375	1.966	77	2.311	0.562
38	1.389	1.895	78	2.351	0.545
39	1.403	1.827	79	2.393	0.529
40	1.418	1.763	80	2.436	0.513

Water and solids – Pulp density data (US)

A = Solids by weight [%]
B = Pulp S. G.
C = Pulp volume USG/ston solids

Density of solids: 3.6

A	B	C	A	B	C
1	1.007	23792	41	1.421	411
2	1.015	11810	42	1.435	398
3	1.022	7815	43	1.450	384
4	1.030	5818	44	1.466	372
5	1.037	4620	45	1.481	359
6	1.045	3821	46	1.498	348
7	1.053	3250	47	1.514	337
8	1.061	2823	48	1.531	326
9	1.070	2490	49	1.548	316
10	1.078	2223	50	1.565	306
11	1.086	2006	51	1.583	297
12	1.095	1824	52	1.601	288
13	1.104	1670	53	1.620	279
14	1.112	1539	54	1.639	271
15	1.121	1424	55	1.659	263
16	1.131	1325	56	1.679	255
17	1.140	1237	57	1.700	247
18	1.149	1158	58	1.721	240
19	1.159	1088	59	1.742	233
20	1.169	1025	60	1.765	226
21	1.179	968	61	1.787	220
22	1.189	916	62	1.811	214
23	1.199	869	63	1.835	207
24	1.210	825	64	1.860	201
25	1.220	786	65	1.885	196
26	1.231	749	66	1.911	190
27	1.242	714	67	1.938	185
28	1.253	683	68	1.965	179
29	1.265	653	69	1.993	174
30	1.277	626	70	2.022	169
31	1.288	600	71	2.052	164
32	1.301	576	72	2.083	160
33	1.313	553	73	2.115	155
34	1.325	532	74	2.148	151
35	1.338	512	75	2.182	146
36	1.351	493	76	2.217	142
37	1.365	475	77	2.253	138
38	1.378	457	78	2.290	134
39	1.392	441	79	2.329	130
40	1.406	426	80	2.368	127

Density of solids: 3.8

A	B	C	A	B	C
1	1.007	23789	41	1.433	408
2	1.015	11806	42	1.448	394
3	1.023	7812	43	1.464	381
4	1.030	5815	44	1.480	368
5	1.038	4616	45	1.496	356
6	1.046	3818	46	1.513	344
7	1.054	3247	47	1.530	333
8	1.063	2819	48	1.547	323
9	1.071	2486	49	1.565	313
10	1.080	2220	50	1.583	303
11	1.088	2002	51	1.602	293
12	1.097	1820	52	1.621	284
13	1.106	1667	53	1.641	276
14	1.115	1535	54	1.661	267
15	1.124	1421	55	1.681	259
16	1.134	1321	56	1.703	251
17	1.143	1233	57	1.724	244
18	1.153	1155	58	1.746	237
19	1.163	1085	59	1.769	230
20	1.173	1022	60	1.792	223
21	1.183	965	61	1.816	216
22	1.193	913	62	1.841	210
23	1.204	865	63	1.866	204
24	1.215	822	64	1.892	198
25	1.226	782	65	1.919	192
26	1.237	745	66	1.947	186
27	1.248	711	67	1.975	181
28	1.260	679	68	2.004	176
29	1.272	650	69	2.034	171
30	1.284	622	70	2.065	166
31	1.296	596	71	2.097	161
32	1.309	572	72	2.130	156
33	1.321	550	73	2.164	152
34	1.334	528	74	2.199	147
35	1.348	508	75	2.235	143
36	1.361	489	76	2.273	139
37	1.375	471	77	2.311	135
38	1.389	454	78	2.351	131
39	1.403	438	79	2.393	127
40	1.418	423	80	2.436	123

Water and solids – Pulp density data

A = Solids by weight [%]
B = Pulp density [ton/m³]
C = Pulp volume [m³/ton solids]

Density of solids: 4.2

A	B	C	A	B	C
1	1.008	99.238	41	1.454	1.677
2	1.015	49.238	42	1.471	1.619
3	1.023	32.571	43	1.487	1.564
4	1.031	24.238	44	1.504	1.511
5	1.040	19.238	45	1.522	1.460
6	1.048	15.905	46	1.540	1.412
7	1.056	13.524	47	1.558	1.366
8	1.065	11.738	48	1.577	1.321
9	1.074	10.349	49	1.596	1.279
10	1.082	9.238	50	1.615	1.238
11	1.091	8.329	51	1.636	1.199
12	1.101	7.571	52	1.656	1.161
13	1.110	6.930	53	1.677	1.125
14	1.119	6.381	54	1.699	1.090
15	1.129	5.905	55	1.721	1.056
16	1.139	5.488	56	1.744	1.024
17	1.149	5.120	57	1.768	0.992
18	1.159	4.794	58	1.792	0.962
19	1.169	4.501	59	1.817	0.933
20	1.180	4.238	60	1.842	0.905
21	1.190	4.000	61	1.868	0.877
22	1.201	3.784	62	1.895	0.851
23	1.212	3.586	63	1.923	0.825
24	1.224	3.405	64	1.952	0.801
25	1.235	3.238	65	1.981	0.777
26	1.247	3.084	66	2.011	0.753
27	1.259	2.942	67	2.043	0.731
28	1.271	2.810	68	2.075	0.709
29	1.284	2.686	69	2.108	0.687
30	1.296	2.571	70	2.143	0.667
31	1.309	2.464	71	2.178	0.647
32	1.322	2.363	72	2.215	0.627
33	1.336	2.268	73	2.253	0.608
34	1.350	2.179	74	2.293	0.589
35	1.364	2.095	75	2.333	0.571
36	1.378	2.016	76	2.376	0.554
37	1.393	1.941	77	2.419	0.537
38	1.408	1.870	78	2.465	0.520
39	1.423	1.802	79	2.512	0.504
40	1.438	1.738	80	2.561	0.488

Density of solids: 4.6

A	B	C	A	B	C
1	1.008	99.217	41	1.472	1.656
2	1.016	49.217	42	1.490	1.598
3	1.024	32.551	43	1.507	1.543
4	1.032	24.217	44	1.525	1.490
5	1.041	19.217	45	1.544	1.440
6	1.049	15.884	46	1.563	1.391
7	1.058	13.503	47	1.582	1.345
8	1.067	11.717	48	1.602	1.301
9	1.076	10.329	49	1.622	1.258
10	1.085	9.217	50	1.643	1.217
11	1.094	8.308	51	1.664	1.178
12	1.104	7.551	52	1.686	1.140
13	1.113	6.910	53	1.709	1.104
14	1.123	6.360	54	1.732	1.069
15	1.133	5.884	55	1.756	1.036
16	1.143	5.467	56	1.780	1.003
17	1.153	5.100	57	1.805	0.972
18	1.164	4.773	58	1.831	0.942
19	1.175	4.481	59	1.858	0.912
20	1.186	4.217	60	1.885	0.884
21	1.197	3.979	61	1.913	0.857
22	1.208	3.763	62	1.943	0.830
23	1.220	3.565	63	1.973	0.805
24	1.231	3.384	64	2.003	0.780
25	1.243	3.217	65	2.035	0.756
26	1.255	3.064	66	2.068	0.733
27	1.268	2.921	67	2.102	0.710
28	1.281	2.789	68	2.138	0.688
29	1.294	2.666	69	2.174	0.667
30	1.307	2.551	70	2.212	0.646
31	1.320	2.443	71	2.250	0.626
32	1.334	2.342	72	2.291	0.606
33	1.348	2.248	73	2.333	0.587
34	1.363	2.159	74	2.376	0.569
35	1.377	2.075	75	2.421	0.551
36	1.392	1.995	76	2.468	0.533
37	1.408	1.920	77	2.516	0.516
38	1.423	1.849	78	2.567	0.499
39	1.439	1.781	79	2.620	0.483
40	1.456	1.717	80	2.674	0.467

Water and solids – Pulp density data (US)

A = Solids by weight [%]
B = Pulp S. G.
C = Pulp volume USG/ston solids

Density of solids: 4.2

A	B	C	A	B	C
1	1.008	23783	41	1.454	402
2	1.015	11800	42	1.471	388
3	1.023	7806	43	1.487	375
4	1.031	5809	44	1.504	362
5	1.040	4610	45	1.522	350
6	1.048	3812	46	1.540	338
7	1.056	3241	47	1.558	327
8	1.065	2813	48	1.577	317
9	1.074	2480	49	1.596	307
10	1.082	2214	50	1.615	297
11	1.091	1996	51	1.636	287
12	1.101	1814	52	1.656	278
13	1.110	1661	53	1.677	270
14	1.119	1529	54	1.699	261
15	1.129	1415	55	1.721	253
16	1.139	1315	56	1.744	245
17	1.149	1227	57	1.768	238
18	1.159	1149	58	1.792	231
19	1.169	1079	59	1.817	224
20	1.180	1016	60	1.842	217
21	1.190	959	61	1.868	210
22	1.201	907	62	1.895	204
23	1.212	859	63	1.923	198
24	1.224	816	64	1.952	192
25	1.235	776	65	1.981	186
26	1.247	739	66	2.011	180
27	1.259	705	67	2.043	175
28	1.271	673	68	2.075	170
29	1.284	644	69	2.108	165
30	1.296	616	70	2.143	160
31	1.309	591	71	2.178	155
32	1.322	566	72	2.215	150
33	1.336	544	73	2.253	146
34	1.350	522	74	2.293	141
35	1.364	502	75	2.333	137
36	1.378	483	76	2.376	133
37	1.393	465	77	2.419	129
38	1.408	448	78	2.465	125
39	1.423	432	79	2.512	121
40	1.438	417	80	2.561	117

Density of solids: 4.6

A	B	C	A	B	C
1	1.008	23778	41	1.472	397
2	1.016	11795	42	1.490	383
3	1.024	7801	43	1.507	370
4	1.032	5804	44	1.525	357
5	1.041	4605	45	1.544	345
6	1.049	3807	46	1.563	333
7	1.058	3236	47	1.582	322
8	1.067	2808	48	1.602	312
9	1.076	2475	49	1.622	301
10	1.085	2209	50	1.643	292
11	1.094	1991	51	1.664	282
12	1.104	1810	52	1.686	273
13	1.113	1656	53	1.709	265
14	1.123	1524	54	1.732	256
15	1.133	1410	55	1.756	248
16	1.143	1310	56	1.780	240
17	1.153	1222	57	1.805	233
18	1.164	1144	58	1.831	226
19	1.175	1074	59	1.858	219
20	1.186	1011	60	1.885	212
21	1.197	954	61	1.913	205
22	1.208	902	62	1.943	199
23	1.220	854	63	1.973	193
24	1.231	811	64	2.003	187
25	1.243	771	65	2.035	181
26	1.255	734	66	2.068	176
27	1.268	700	67	2.102	170
28	1.281	668	68	2.138	165
29	1.294	639	69	2.174	160
30	1.307	611	70	2.212	155
31	1.320	585	71	2.250	150
32	1.334	561	72	2.291	145
33	1.348	539	73	2.333	141
34	1.363	517	74	2.376	136
35	1.377	497	75	2.421	132
36	1.392	478	76	2.468	128
37	1.408	460	77	2.516	124
38	1.423	443	78	2.567	120
39	1.439	427	79	2.620	116
40	1.456	411	80	2.674	112

Water and solids – Pulp density data

A = Solids by weight [%]
B = Pulp density [ton/m³]
C = Pulp volume [m³/ton solids]

Density of solids: 5.0

A	B	C	A	B	C
1	1.008	99.200	41	1.488	1.639
2	1.016	49.200	42	1.506	1.581
3	1.025	32.533	43	1.524	1.526
4	1.033	24.200	44	1.543	1.473
5	1.042	19.200	45	1.563	1.422
6	1.050	15.867	46	1.582	1.374
7	1.059	13.486	47	1.603	1.328
8	1.068	11.700	48	1.623	1.283
9	1.078	10.311	49	1.645	1.241
10	1.087	9.200	50	1.667	1.200
11	1.096	8.291	51	1.689	1.161
12	1.106	7.533	52	1.712	1.123
13	1.116	6.892	53	1.736	1.087
14	1.126	6.343	54	1.761	1.052
15	1.136	5.867	55	1.786	1.018
16	1.147	5.450	56	1.812	0.986
17	1.157	5.082	57	1.838	0.954
18	1.168	4.756	58	1.866	0.924
19	1.179	4.463	59	1.894	0.895
20	1.190	4.200	60	1.923	0.867
21	1.202	3.962	61	1.953	0.839
22	1.214	3.745	62	1.984	0.813
23	1.225	3.548	63	2.016	0.787
24	1.238	3.367	64	2.049	0.763
25	1.250	3.200	65	2.083	0.738
26	1.263	3.046	66	2.119	0.715
27	1.276	2.904	67	2.155	0.693
28	1.289	2.771	68	2.193	0.671
29	1.302	2.648	69	2.232	0.649
30	1.316	2.533	70	2.273	0.629
31	1.330	2.426	71	2.315	0.608
32	1.344	2.325	72	2.358	0.589
33	1.359	2.230	73	2.404	0.570
34	1.374	2.141	74	2.451	0.551
35	1.389	2.057	75	2.500	0.533
36	1.404	1.978	76	2.551	0.516
37	1.420	1.903	77	2.604	0.499
38	1.437	1.832	78	2.660	0.482
39	1.453	1.764	79	2.717	0.466
40	1.471	1.700	80	2.778	0.450

Water and solids – Pulp density data (US)

A = Solids by weight [%]
B = Pulp S. G.
C = Pulp volume USG/ston solids

Density of solids: 5.0

A	B	C	A	B	C
1	1.008	23774	41	1.488	393
2	1.016	11791	42	1.506	379
3	1.025	7797	43	1.524	366
4	1.033	5800	44	1.543	353
5	1.042	4601	45	1.563	341
6	1.050	3803	46	1.582	329
7	1.059	3232	47	1.603	318
8	1.068	2804	48	1.623	307
9	1.078	2471	49	1.645	297
10	1.087	2205	50	1.667	288
11	1.096	1987	51	1.689	278
12	1.106	1805	52	1.712	269
13	1.116	1652	53	1.736	261
14	1.126	1520	54	1.761	252
15	1.136	1406	55	1.786	244
16	1.147	1306	56	1.812	236
17	1.157	1218	57	1.838	229
18	1.168	1140	58	1.866	221
19	1.179	1070	59	1.894	214
20	1.190	1007	60	1.923	208
21	1.202	950	61	1.953	201
22	1.214	897	62	1.984	195
23	1.225	850	63	2.016	189
24	1.238	807	64	2.049	183
25	1.250	767	65	2.083	177
26	1.263	730	66	2.119	171
27	1.276	696	67	2.155	166
28	1.289	664	68	2.193	161
29	1.302	635	69	2.232	156
30	1.316	607	70	2.273	151
31	1.330	581	71	2.315	146
32	1.344	557	72	2.358	141
33	1.359	534	73	2.404	137
34	1.374	513	74	2.451	132
35	1.389	493	75	2.500	128
36	1.404	474	76	2.551	124
37	1.420	456	77	2.604	120
38	1.437	439	78	2.660	116
39	1.453	423	79	2.717	112
40	1.471	407	80	2.778	108

CHEMICAL RESISTANCE TABLES

Elastomer Materials

Medium	Natural Rubber	Butyl	EPDM	Nitrile	Chloro-prene	CSM* Hypalone	Poly-urethane
Aluminium Chloride	A	A	A	A	A	A	A
Aluminium Phosphate	A	A	A	A	A	A	A
Ammonium Nitrate	C	A	A	A	B	A	U
Animal Fats	U	B	B	A	B	B	A
Beet Sugar Liquors	A	A	A	A	A	A	
Bleach Solution	U	A	A		C	A	
Brine			A	A	A	A	
Bunker Oil				A			B
Calcium Hydroxide	A	A	A	A	A	A	A
Calcium Hypochlorite	U	A	A	C	C	A	
Chlorine (Wet)	U	C	C		U	C	U
Chrome Plating Solutions	U	U	U	U	U	C	U
Copper Chloride	A	A	A	A	A	A	A
Copper Cyanide	A	A	A	A	A	A	A
Copper Sulfate	B	A	A	A	A	A	A
Creosote	U	U	U	B	C	C	B
Detergent Solutions	B	A	A	A	A	A	U
Diesel Oil	U	U	U	A	B	B	B
Fatty Acids	C	U	U	B	B	B	
Ferric Chloride	A	A	A	A	A	A	A
Ferric Nitrate	A	A	A	A	A	A	
Ferric Sulfate	A	A	A	A	A	A	
Fluorosilic Acid	A			A	A	A	
Fuel Oil	U	U	U	A	B	B	B
Gasoline	U	U	U	A	B	B	A
Glycerine	A	A	A	A	A	A	A
Glycols	A	A	A	A	A	A	B
Hydraulic Oil (Petroleum)	U	U	U	A	B	B	A
Hydrochloric Acid (Hot 37%)	U	C	C	U	U	C	U
Hydrochloric Acid (Cold 37%)	B	A	A	B	B	A	U
Hydrofluoric Acid (Conc) Cold	U	B	B	U	B	A	U
Hydrofluoric Acid (Anhydrous)	U	B	B			A	

*= Chlorosulphonyl-polythylene A = Recommended - little or no effect B = Minor to moderate effect

C = Moderate to severe effect U = Not recommended

Elastomer Materials

Medium	Natural Rubber	Butyl	EPDM	Nitrile	Chloro-prene	CSM* Hypalone	Poly-urethane
Hydrogen Peroxide (90%)	U	C	C	U		C	
Kerosene	U	U	U	A	C	C	B
Lacquers	U	U	U	U	U	U	U
Lacquers Solvents	U	U	U	U	U	U	U
Lead Acetate		A	A	B	B		
Lubrication Oils (Petroleum)	U	U	U	A	B	B	B
Lye	B	A	A	B	B	A	B
Magnesium Chloride	A	A	A	A	A	A	A
Mineral Oil	U	U	U	A	B	B	A
Naphtha	U	U	U	C	C	U	C
Nickel Chloride	A	A	A	A		A	A
Nickel Sulfate	B	A	A	A	A	A	A
Nitric Acid Conc.	U	C	C	U	C	B	U
Nitric Acid Dilute	U	B	B	U	A	A	C
Olive Oil	U	B	B	A	B	B	A
Phosphoric Acid 20%	C	A	A	B	B	A	A
Pickling Solution		C	C			C	
Pine Oil	U	U	U	B	U	U	
Potassium Carbonate	B	B	B	B	B	B	
Salt Water	A	A	A	A	A	A	
Sewage	B	B	B	A	A	A	U
Silicone Greases	A	A	A	A	A	A	A
Silicone Oils	A	A	A	A	A	A	A
Soda Ash	A	A	A	A	A	A	
Sodium Bislulfite	B	A	A	A	A	A	
Sulfite Liquors	B	B	B	B	B	B	
Sulfuric Acid (Dilute)	C	B	B	U	B	A	B
Sulfuric Acid (Conc)	U	B	B	U	U	B	U
Tar. Bituminous	U	U	U	B	C	C	
Transformer Oil	U	U	U	A	B	B	
Transmission Fluid Type A	U	U	U	A	B	B	A
Trichloroethylene	U	U	U	C	U	U	U

*= Chlorosulphonyl-polythylene A = Recommended - little or no effect B = Minor to moderate effect

C = Moderate to severe effect U = Not recommended

HighChrome

Centigrade	20°	60°	100°
Aluminium sulphite	U	U	U
Ammonia, anhydrous	A	A	A
Ammonia, aqueous	A	A	A
Ammonium chloride	A		
Aqua regia	U	U	U
Aromatic solvents	A	A	A
Brines, saturated	U	U	U
Bromide (K) soin.	U	U	U
Calcium chloride	U	U	U
Carbon disulphide	A	A	A
Carbonic acid	A	A	A
Caustic soda & potash	A	A	A
Cellulose paint	No data		
Chlorates of Na, K, Ba	No data		
Chlorine wet	U	U	U
Chlorides of Na, K, Mg	U	U	U
Copper sulphate	U	U	U
Emulsifiers (all conc.)	U	U	U
Ether	A	A	A
Fatty acids (<Cb)	A	A	A
Ferrous sulphate	A	A	A
Fluorine, wet	U	U	U
Fluorosilic acid	U	U	U

A = Recommended - little or no effect B = Minor to moderate effect

C = Moderate to severe effect U = Not recommended

HighChrome

Centigrade	20°	60°	100°
Hydrochloric acid (10%)	U	U	U
Hydrochloric acid (conc.)	U	U	U
Hydrofluoric acid (40%)	U	U	U
Hydrofluoric acid (75%)	U	U	U
Hydrogen sulphide	A	A	A
Hypochlorites	A	B	C
Hypochlorite (Na 12-14%)	A	No data	No data
Lead acetate	A	A	C
Lime (CaO)	A	A	A
Methanol	A	A	A
Milk and its products	A	B	B
Molasses	A	A	A
Naphtha	A	A	A
Naphthalene	A	A	A
Nickel salts	U	U	U
Nitrates of Na, K, NH$_3$	A	A	A
Nitric acid (<25%)	A	A	C
Nitric acid (50%)	A	A	C
Nitric acid (90%)	A	A	C
Nitric acid, fuming	A	B	C
Nitrite (Na)	A	A	A
Oil, diesel	A	A	A
Oils, essential	A	A	A
Oils, lube + aromatic ads.	A	A	A
Oils, mineral	A	A	A
Oils, vegetable & animal	A	A	A

A = Recommended - little or no effect B = Minor to moderate effect

C = Moderate to severe effect U = Not recommended

HighChrome

Centigrade	20°	60°	100°
Petroleum spirits	A	A	A
Phenol	A	A	A
Phosphoric acid (20%)	U	U	U
Phosphorous chlorides	U	U	U
Piperic acid	A	B	C
Sea water	A	A	B
Sodium carbonate	A	A	A
Sodium silicate	A	A	A
Sodium sulphide	U	U	U
Stannic chloride	U	U	U
Starch	A	A	A
Sugar spin, syrups, jams	A	A	A
Sulphates (Na, K, Mg, Ca)	A	A	A
Sulphites	A	A	A
Sulphur	A	A	A
Sulphur dioxide, dry	A	A	A
Sulphur dioxide, wet	A	B	C
Sulphur dioxide (96%)	U	U	U
Sulphur trioxide	U	U	U
Sulphuric acid (<50%)	U	U	U
Sulphur chlorides	U	U	U
Tallow	A	A	A
Tannic acid (10%)	A	A	A
Wetting agents (to 5%)	A	A	A
Zinc chloride	U	U	U

A = Recommended - little or no effect B = Minor to moderate effect

C = Moderate to severe effect U = Not recommended

Private Notes

Private Notes

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