FLYGT

Slurry handbook

Guidelines for slurry pumping

Flygt

ITT Industries

Slurry

A mixture of solids and liquid, generally water. The particles may not be abrasive although this is common.

Table of contents

1. Introduction

- Where are slurry pumps used?
- Can submersible slurry pumps replace other types of pumps?
- Which parts are of special importance in a submersible slurry pump?
- How can slurries be classified?
- Which parameters of the slurry and pipe system are required to be able to dimension a pump correctly?

The purpose of this book is, in a simple way, to describe slurry pumps, slurry pumping and the various parameters required when selecting submersible slurry pumps using FLYPS.

To provide a deeper understanding of the calculations, a manual calculation example is given in the appendix of the book.

If you are not sure about the type of slurry, the choice of pump, the design of the pipe system, etc., you can always contact your Flygt support for advice.

FLYPS

Flygt´s pump selection program is now available with a slurry module which makes it possible to make pump selection based on liquid containing solid particles.

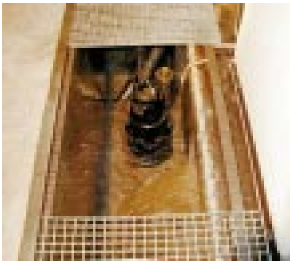
Slurry pumps

Slurry pumps are a heavy and robust version of centrifugal pumps, capable of handling tough and abrasive duties.

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

Applications

Slurry pumps are used to move mixtures of liquid and solids in many industries with a broad spectrum of applications, for example mine drainage, dredging of settling lagoons and pumping of drilling mud.



The purpose can be:

- To pump a medium where abrasive particles are present
- To transport as much solids as possible, hydraulically
- To pump the end product in a process

Flygt submersible pumps are used in many different industrial segments like:

- Iron and steel
- Power generation
- Pulp and paper
- Oil and gas
- Waste water treatment
- Mining
- Mineral processing
- Construction

Chapter 5 gives a brief overview of some common industries and applications for slurry pumps.

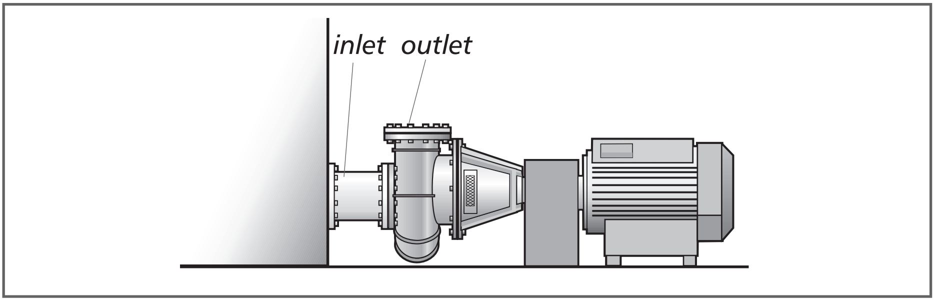
Slurry pump types

Three main types of pumps are used for slurry pumping:

- Horizontal slurry pumps
- Vertical slurry pumps
- Submersible slurry pumps.

Horizontal slurry pumps

These types of pumps are often called *dry mounted* as the hydraulic end and the drive unit are located outside the sump. It is the main group of slurry pumps and they are available for a wide range of head and flow conditions and material options.



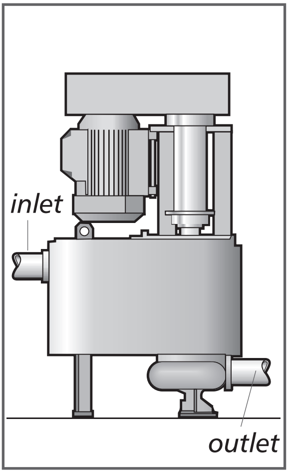
These types of pumps normally use standardized electrical motors and seals.

In plants where there is a risk of flooding, there can be reasons for replacing a horizontal pump by a dry-mounted, submersible, slurry pump.

Vertical slurry pumps

This type of pump can be subdivided into two main groups:

- Tank pumps
- Cantilever/sump pumps



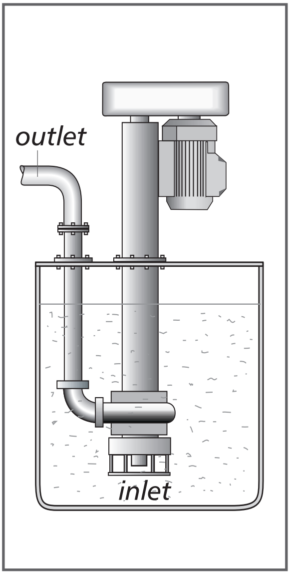
Tank pumps are considered as *dry installed* pumps. The sump is incorporated in the pump. Open sump and vertical inlet prevent air blocking and give smooth operation. There are no submerged bearings or shaft seals, but quite a long shaft overhang from lower bearing to the impeller.

Cantilever/sump pumps are considered as *semi-dry installed*, as the hydraulic end is lowered into the slurry, but the drive unit and support structure are dry installed. Similarly to tank pumps there are no submerged bearings or shaft seals, but a long shaft overhang.

Depending on size the pump is either mounted with a base plate over the sump or hung from the roof.

Cantilever-pumps have a number of disadvantages which make them suitable for replacement with submersible pumps:

- Long distance between motor and volute makes the pump bulky to handle.
- Limited access to the sump. Problems with sediment build-up when used in sumps deeper than 2 m.
- Not water-proof. Flooding will damage the motor.
- High noise level.



Why submersible?

Some slurry pump users may have limited knowledge of submersible slurry pumps. It is therefore important to advance arguments for the submersible concept.

Submersible pumps offer a number of benefits over dry and especially semi-dry mounted pumps:

- Operating directly in the slurry, the submersible slurry pump requires no support structure. It therefore occupies less space.
- The motor and volute are one integrated unit, compact and easy to install.
- Operation underwater means low noise levels or even silent operation.
- Motor cooled by surrounding liquid allows for up to 15 starts/hour, resulting in smaller and more efficient sumps.
- Flexible installation with several installation modes, all of which are either portable or semi-permanent.
- Possibility to practice Clean sump technology (see page 28).

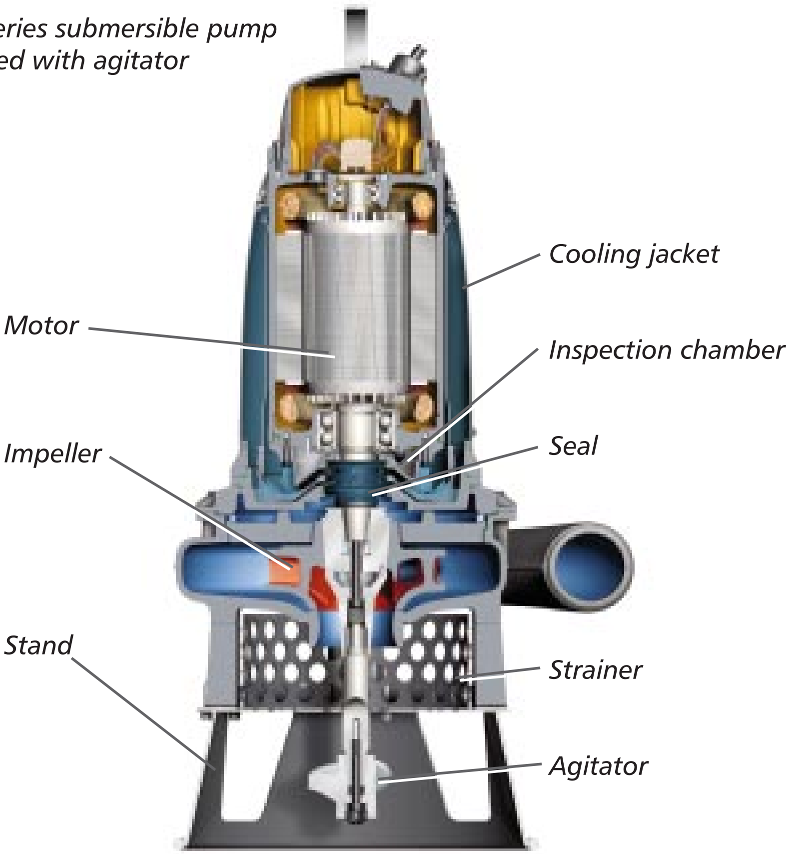
All the information that follows in this book, such as technical descriptions, calculation examples, etc., is applicable to submersible slurry pumps.

2. Flygt slurry pumps

The main difference between slurry and waste water pumps is in the parts that are in direct contact with the slurry and thus subject to wear by the slurry's solid particles.

Important factors for slurry pumps such as cooling, seals and especially the hydraulic design, are described in this chapter.

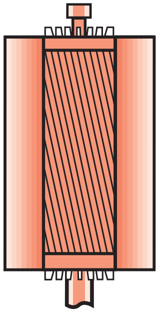
5150-series submersible pump equipped with agitator



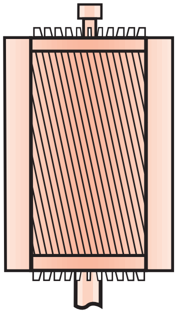
Drive unit

Motor

Important factors for slurry pump motors:
- **Effective cooling**
- **Insulation**



Standard motor design



Flygt motor design

Effective cooling

Water cooling is superior to air cooling and gives the submerged motor a high power density and comparatively low temperature.

In the Flygt motor the rotor diameter is bigger and the stator thinner than in standard motors. This directs more of the losses (heat release) to the stator and to the surrounding, cooling liquid. The short heat transfer distance makes the cooling effective and keeps the working temperature low.

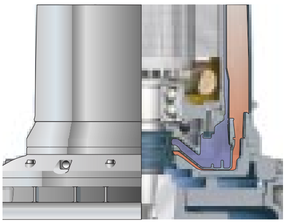
The pump can be cooled in three ways depending on the slurry temperature and other circumstances:

1. Pumps that work fully submerged in slurry, cooled by the ambient liquid. The slurry temperature may not exceed 40°C.

2. Pumps that work at times with the motor partially or totally un-submerged, can be equipped with a cooling jacket for internal cooling, where a cooling medium (glycol mixture) circulates (5100/5150).

3. Pumps that often work in a low level, in hot slurry or are dry installed can be cooled using an external supply of cooling liquid, connected to the cooling jacket.

The ways in which the various cooling methods are used is described on page 27.



Pump with internal cooling system

Insulation
Class H insulation (180°C) is applied to the stator winding by a trickle impregnation system. Flygt limits the motors to Class B rise (140°), which reduces thermal stress resulting in extended lifetime.

Trickle impregnation gives a winding fill much greater than typical dip and bake systems. This gives much higher protection against short circuits in the winding.

Shaft and bearings

Important factors for shafts and bearings:

- **Shaft design and dimensioning**
- **Bearing type and protection**

Shaft design and dimensioning
The shaft and bearings are of sturdy design. The distance between the lower bearing and the impeller is minimal, eliminating shaft deflections. This provides long seal and bearing life, low vibration and silent operation.

Bearing type and protection
All slurry pumps have two row angular contact ball bearings as the main bearing, because they give a high load capability in the radial as well as the axial direction.

Pump shaft and bearings

The bearings are well protected with a lifetime lubrication of high performance grease.

Seals

Important factors for submersible pump seals:

- **Low leakage and wear resistance**

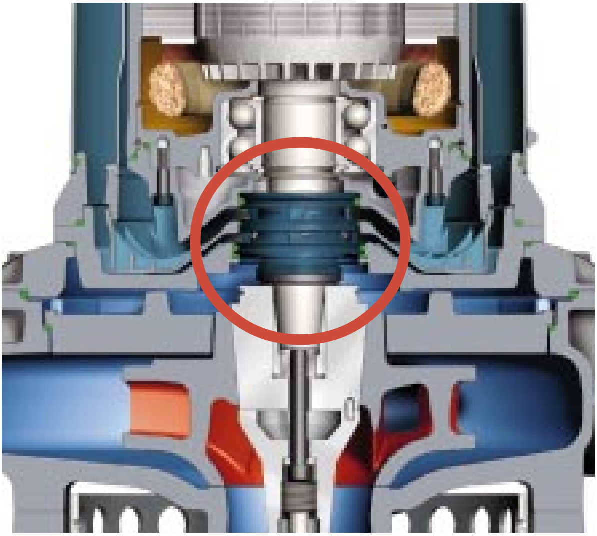
Low leakage and wear resistance

In conjunction with low leakage rate, the most important feature for seals in slurry applications is the ability to resist wear from abrasive particles.

The seals for the slurry pumps are designed to cope with highly abrasive pump media. Only the seal rings are exposed to the media. Other parts of the seal, such as springs and torque locks are protected from wear, clogging and corrosion inside the seal housing.

The pre-mounted Plug-in™ seal unit (5100/5150) is fast and easy to handle. The seal faces are closed and cannot be contaminated or damaged during service. The seal rings are always properly aligned to eliminate run-out.

Plug-in™ seal (5100/5150)



Protection systems

Important factors for submersible pump protection:

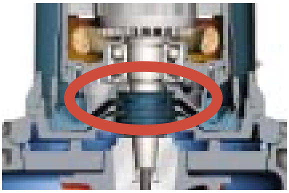
- **The possibility of detecting a leaking seal before any damage occurs**
- **Spin-out™ seal protection**
- **Overheating protection**

Possibility of detecting a leaking seal

5500: In the area that contains cooling oil above the seal, there is a sensor that emits a warning if water enters. In addition, the oil is discoloured by water leakage and this can be seen through an inspection screw on the side of the pump.

Stator housing leakage: A float switch shuts the pump down if water is detected.

5100/5150: The inspection chamber between the seal unit and the bearings has a built-in sensor for early detection of fluid leakage. The space can be inspected and emptied via a screw, which is easily accessible from the outside.



Inspection chamber, 5100/5150

Spin-out™ seal protection

A patented outer seal design that protects the seal by expelling abrasive particles.

Spin-out™ seal protection

Overheat protection

Thermal sensors are embedded in the stator windings to prevent overheating.

Hydraulic design

Important factors for submersible pump hydraulic parts:

- **Efficiency**
- **Wear**
- **Agitator**

Efficiency

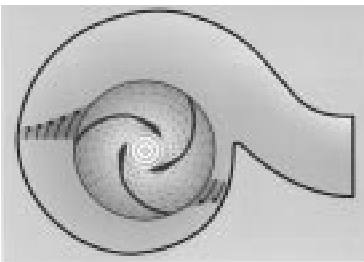
Pumping slurry can cause a severe reduction in the hydraulic efficiency of a pump. The Flygt impeller is designed to minimize this drop. Higher pumping efficiencies also correlate with lower wear rates.

Wear

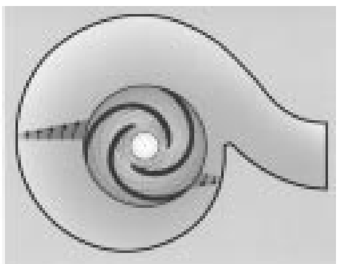
Experience shows that the design of the impeller and volute is as important as the choice of material, in order to minimize the wear rate.

The shape of the impeller used in slurry handling is important in ensuring high wear resistance and hydraulic efficiency. The Flygt impeller has a more sweptback design than conventional impellers, which ensures a more homogenous flow between the vanes. This minimizes the separation of solids from the carrier liquid, resulting in extremely low wear rates and sustained hydraulic efficiency.

Slurry pump impeller



Standard hydraulic design



Flygt hydraulic design

Because of the tangential outflow of particles from the impeller, suspended particles hit the volute wall at an almost parallel angle, thus decreasing line wear. The larger volute size also means a lower internal velocity, which further reduces the amount of wear.

The trimmable impeller (5100/5150)/suction cover (5500) makes it possible to compensate for wear and thus prevent deteriorations in efficiency.

Agitator
The pump can be equipped with an agitator, designed for maximum re-suspension of settled particles. This makes the particles easier to transport and ensures a cleaner sump at the end of the pumping cycle.

The use of the agitator is also described on page 28.

Agitator

3. Slurry properties

Pumping slurry, i.e. a liquid containing solid particles, raises different requirements for a pump compared to pumping just water.

A number of characteristics of the slurry and of the system must be known to be able to select a slurry pump correctly.

When selecting a slurry pump using FLYPS, Flygt’s selection program for pumps, it is necessary to know certain parameters. These are covered in this chapter.

”Slurry Questionnaire”, on page 47 shows the parameters that should be included when making calculations for a slurry pump. The accuracy of the results will be better if more exact and a larger number of these values are available. In cases when assumptions must be made, it is important that the customer is informed of them.

It is always possible to send samples for full rheology tests to the Flygt laboratory in Sweden.

Slurry parameters

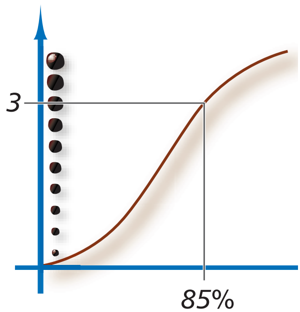
The following parameters must be determined when calculating a slurry pump with FLYPS or manually.

Particle size and distribution

Particle size d_{50} (d_{85}) is a measure of the percentage of particles in the slurry with a certain size or smaller.

The value is determined by sifting the solids through screens with varying mesh and then weighing each fraction. A sieve curve can then be drawn and the percentage of particles of different sizes read.

Ex: d_{85} = 3 mm means that 85% of the particles have a diameter of 3 mm or less.



Sieve curve

Mass fraction of small particles

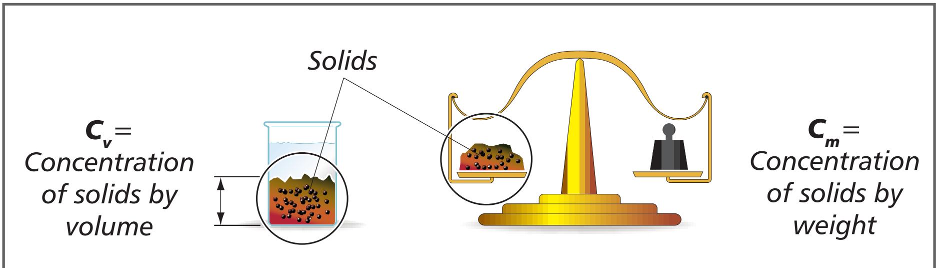
The fraction of particles smaller than 75 µm.

It is important to determine the percentage of small particles in the slurry. Particles smaller than 75 µm can to some extent facilitate the transport of larger particles. However, if the percentage of particles smaller than 75 µm exceeds 50%, the character of the slurry changes towards non-settling and the calculations cannot be done using FLYPS. Contact your Flygt support for advice.

Non-settling slurry, see page 18

Concentration of solids

The concentration of particles in the slurry can be measured as a volume percentage, C_v, and a weight percentage, C_m.



Density/Specific Gravity

Solids

The density of the solids is stated as the Specific Gravity. This value, SG_s, is determined by dividing the density of the solid by the density of water.

Water

The density of water is 1000 kg/m^3. The SG of water is 1,0 at 20°C. The value varies somewhat with temperature.

Slurry

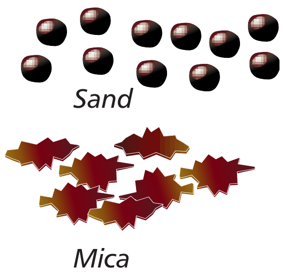
The specific gravity of the slurry can be determined using a nomograph (see page 39) or calculated (see page 38). Two of the values of SG_s, C_v, and C_m, must be known.

SG_{sl} is calculated in FLYPS, based on the values above.

Particle shape

The shape of the particles is very significant for the behaviour of the slurry when pumping and for the wear on the pump and the pipe system.

The form factor denotes the deviation of the slurry particles from a perfect sphere. In FLYPS it is possible to choose between sand (round shape) or mica (flat shape).



Slurry characteristics

Slurries can be divided up into **settling** and **non-settling** types, depending on the parameters mentioned on previous pages.

Non-settling slurry

A slurry in which the solids do not settle to the bottom, but remain in suspension for a long time. A non-settling slurry acts in a homogeneous, viscous manner, but the characteristics are non-Newtonian (see page 20).

Particle size: less than 60-100 μm.

A non-settling slurry can be defined as a homogeneous mixture.

Homogeneous mixture

A mixture of solids and liquid in which the solids are uniformly distributed.

Settling slurry

This type of slurry settles fast during the time relevant to the process, but can be kept in suspension by turbulence. Particle size: greater than 100 μm.

A settling slurry can be defined as a pseudo-homogeneous or heterogeneous mixture and can be completely or partly stratified.

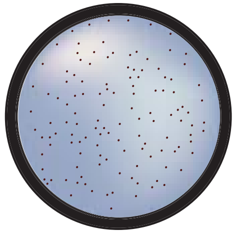
Pseudo-homogeneous mixture

A mixture in which all the particles are in suspension but where the concentration is greater towards the bottom.

Heterogeneous mixture

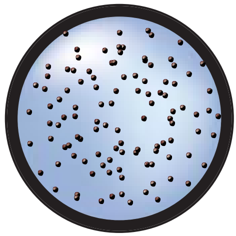
A mixture of solids and liquid in which the solids are not uniformly distributed and tend to be more concentrated in the bottom of the pipe or containment vessel (compare to settling slurry).

Non-settling slurry

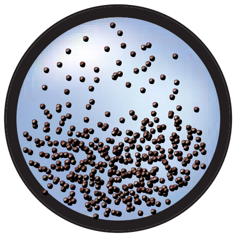


Homogeneous mixture

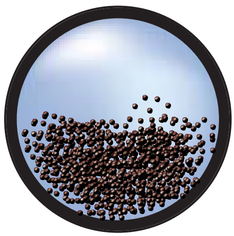
Settling slurry



Pseudo-homogeneous mixture

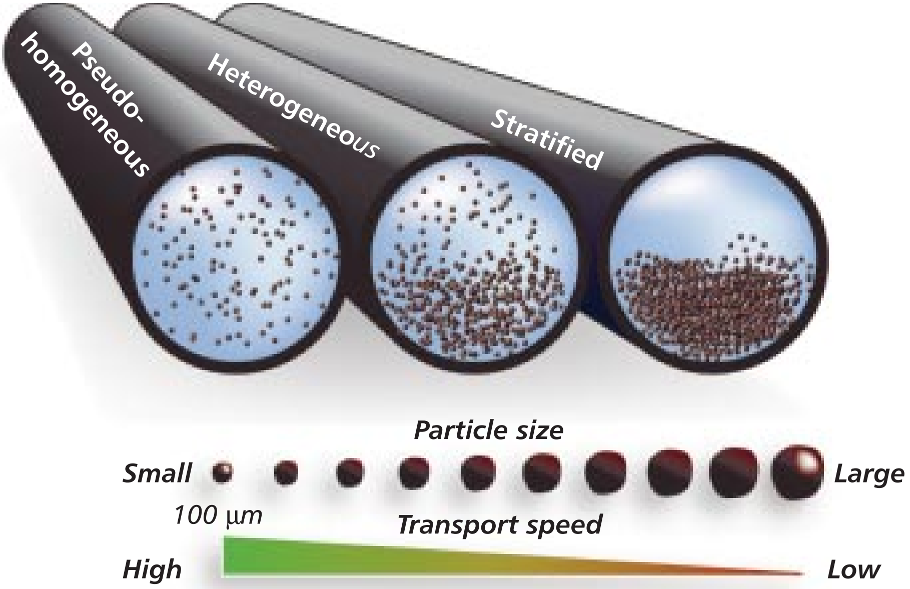


Heterogeneous mixture, partly stratified



Heterogeneous mixture, fully stratified

The diagram shows how different types of slurry behave, depending on particle size, and transport speed.



A high transport speed and/or small particles means that all the particles are in suspension. The slurry behaves pseudohomogeneously.

When the particle size is larger and the transport speed is lower, the particles tend to become more concentrated towards the bottom of the tube or are in mechanical contact with it. The slurry behaves heterogeneously.

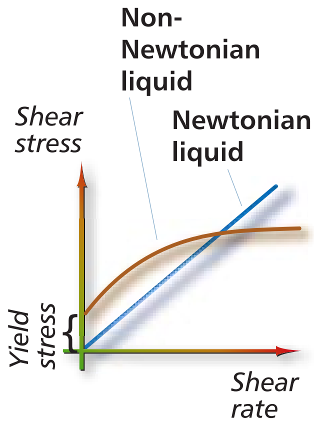
At low transport speeds and/or large particles, the slurry tends to collect/glide. A slurry consisting of large particles can also move like a sliding bed.

Liquid definitions

Except for density (see page 17) the characteristics of a liquid are decided by its viscosity.

Liquids deform continuously as long as a force is applied to them. They are said to flow. When a flow takes place in a liquid, it is opposed by internal friction arising from the cohesion of the molecules. This internal friction is the property of a liquid called viscosity.

The viscosity of liquids decreases rapidly with increasing temperature.



Newtonian liquids

Newtonian liquids give a shearing stress that is linear and proportional to the velocity gradient, or the shearing rate. Water and most liquids are Newtonian.

Non-Newtonian liquids

Some liquids, such as water based slurries with fine particles, do not obey the simple relationship between shearing stress and shearing rate (compare non-settling slurry, page 18). They are referred to as non-Newtonian liquids.

Some non-Newtonian liquids have a unique property of not flowing until a certain minimum shear stress is applied. This minimum shear stress is known as the yield stress.

In applications where the pumped slurry is viscous or non-settling, other methods of calculation are required instead of FLYPS or the manual calculations described in this book. Contact your Flygt support for advice.

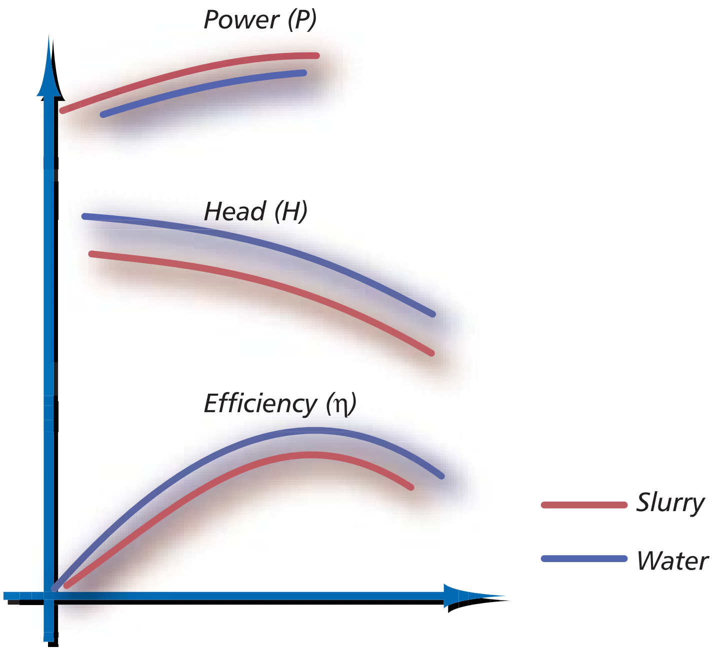
4. Slurry pump systems

Pump performance

The performance of a centrifugal pump pumping slurry differs from the performance with clean water depending on the amount of solid particles in the slurry.

This difference depends on the characteristics of the slurry (particle size, density, and shape, as described in the previous chapter).

The factors that are affected are the power (P), head (H), and efficiency (η). The differences between slurry and water are shown schematically in the curves below.



The diagram illustrates the increased power requirement and the reduction in head and efficiency of a centrifugal pump operating at constant speed and handling slurry.

Calculating with FLYPS

To be able to dimension a pump using FLYPS, that will function correctly with a certain type of slurry in a particular pipe system, data about the slurry is needed (chapter 3) as well as information about the head, required flow, and the design of the pipe system in question.

A correctly dimensioned slurry pump must be capable of overcoming the losses caused by friction in the pipes and valves. It is also important that the flow velocity does not fall below the critical velocity (see page 24) otherwise sedimentation will result.

It is important that all the parameters for the slurry and pipe system, are specified as accurately as possible. In cases when assumptions must be made in the calculations, it is important that the customer is made aware of them.

"Slurry questionnaire", on page 47 is a checklist which shows the parameters that should be included when making calculations for a slurry pump selection.

System design

Static head

Static head is the vertical height difference from the surface of the slurry source to the discharge point.

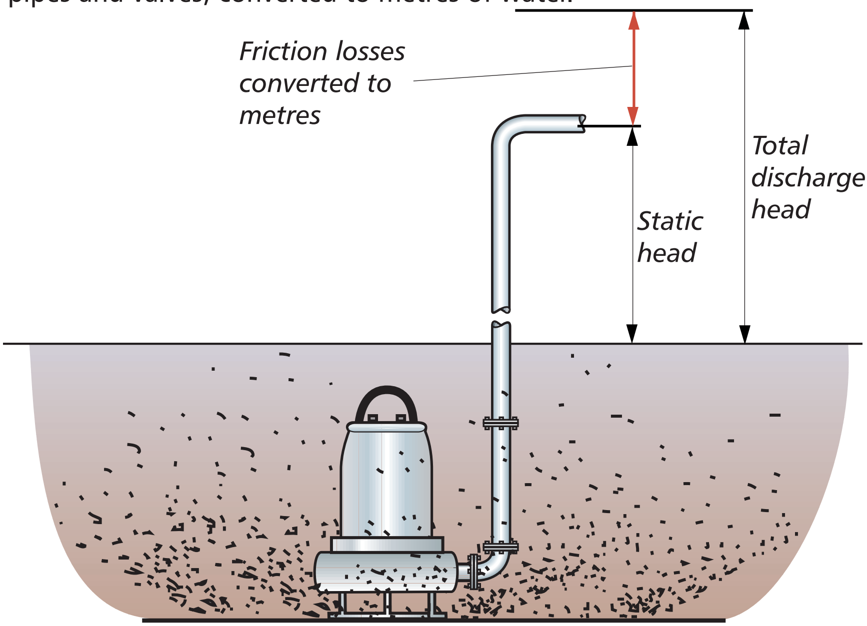
Friction losses

When the liquid starts to flow through the discharge line and valves, friction will arise. When pumping slurry, friction losses caused by pipe roughness, bends and valves, are different compared to the corresponding losses when pumping water. The calculation is done with FLYPS based on the parameters entered.

For manual calculation of the friction losses for slurry, see page 41.

Total discharge head

This value is used for pump calculations and comprises the static head plus friction losses caused by pipes and valves, converted to metres of water.



Critical velocity

In general, the flow velocity in the pipes must be kept above a certain minimum value.

If the flow velocity is too high, friction losses will increase. This may also increase the wear in the pipe system. Flow velocities that are too low will result in sedimentation in the pipes and, thus, increased losses.

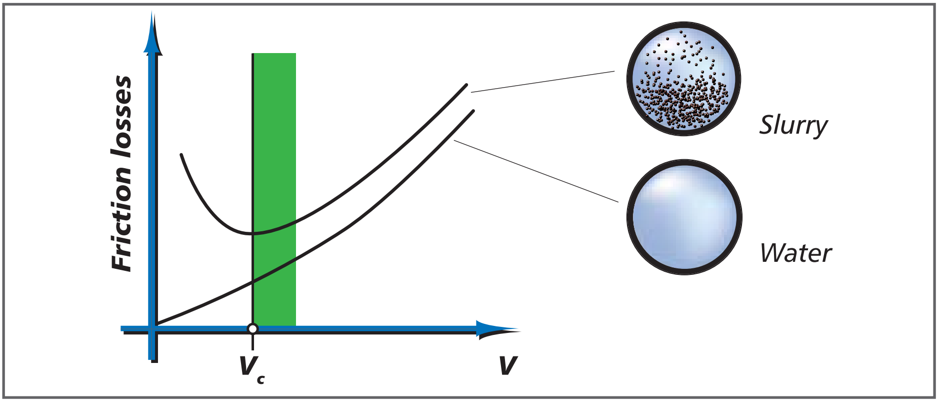
This is illustrated in the diagram below, in which the critical velocity (V_c) indicates the optimum velocity where losses are kept to a minimum.

When making calculations for a slurry pump for a certain flow, the desired flow velocity (V) must be compared to the critical velocity (V_c) for the slurry and the pipe system in question. As the figure below shows, the ideal velocity (marked green) is immediately above the critical velocity but with a margin for the extreme cases that can arise.

To determine the critical velocity, the pipe diameter and the particle size (d_{85}) must be known. The value is then corrected with a factor, which depends on the specific gravity of the solids.

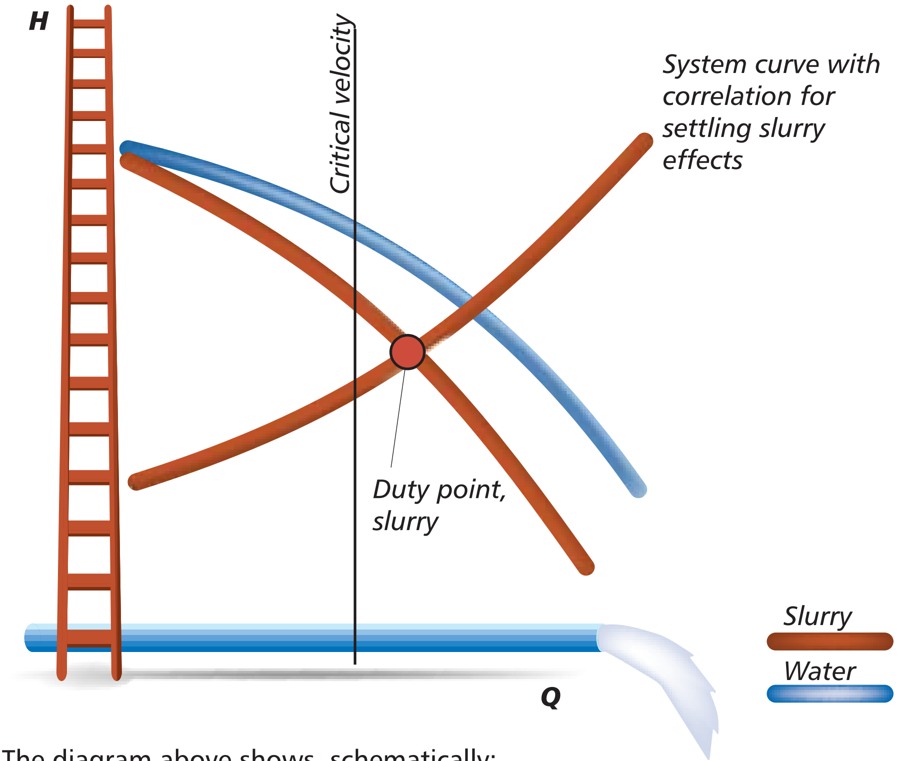
d_{85}, see page 16

When dimensioning with FLYPS, the program calculates the critical velocity based on the parameters entered.



Sizing the pump

FLYPS will show suitable pumps with the correct flow and pressure head, based on the parameters entered for the slurry and pipe system.



The diagram above shows, schematically:
- the pump curve for water
- the reduced curve for slurry
- the duty point for slurry, i.e. the point at which the pump system curve and the performance curve intersect.

In FLYPS the following information can be viewed:

- Slurry performance curve
- Shaft power for slurry and clean water
- Hydraulic efficiency for slurry and clean water
- $NPSH_{req}$
- System curve
- Clean water performance curve

Other considerations

Besides the actual calculation work, a number of practical viewpoints should be taken into consideration when designing systems and selecting pumps.

NPSH

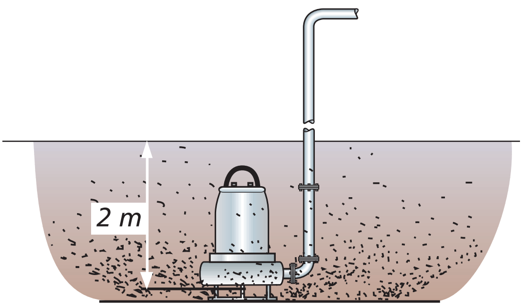
Whenever centrifugal pumps are used, it is important that the pump's inlet pressure exceeds the vapour pressure of the liquid inside the pump. The necessary inlet pressure that is stated for the pump, $NPSH_{req}$* must not be less than the available value in the pump system, $NPSH_a$*.

The available value depends on the ambient air pressure (height above sea level), the vapour pressure of the liquid, the density of the slurry, and the level in the sump.

Example: Pumping a water-based slurry at a height of 1000 m above sea level. Liquid temperature 40°C, liquid level 2 metres above the pump inlet.

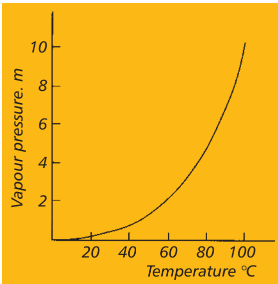
Formula:
$NPSH_a$ = air pressure – vapour pressure + level in sump

$$NPSH_a = 9{,}2 - 0{,}4 + 2 = 10{,}8$$



The value of $NPSH_a$ must exceed the value specified for the pump, $NPSH_{req}$

* $NPSH_{req}$ = NPSH required
$NPSH_a$ = NPSH available



Vapour pressure for water at different temperatures

Air pressure in metres head of water at different heights above the sea level:

m above sea level	*m H_2O*
0	*10,3*
1000	*9,2*
2000	*8,1*
3000	*7.1*

Cavitation

If $NPSH_a$ is lower than $NPSH_{req}$ vapour bubbles will occur in the impeller. When the bubbles reach the area where the pressure is higher, they burst and can cause damage to the impeller and volute.

Besides damage to the pump, cavitation can result in lower efficiency, vibration, and noise.

pH

To prevent damage caused by low pH values, the pumps are painted with epoxy paint (pH-limit 5,5). For high chloride content, zinc anodes are used in addition to the epoxy paint.

Cooling

Submerged slurry pumps of standard type can normally be cooled by the surrounding slurry if the slurry temperature is max. 40°C.

There are however occasions when special measures to cool the pump are required:

1. If the pump works above the liquid surface level, permanently or for periods longer than 10 minutes.
2. If the pump is dry installed.
3. If the temperature of the medium being pumped exceeds 40°C.

In these cases cooling can be arranged using a cooling jacket. Pumps of the type 5100/5150 can in cases 1 and 2 above be cooled by an internal cooling system and in case 3 by an external supply of coolant.

Pumps of type 5500 should in cases 1 - 3 be cooled using an external coolant supply.

See also:
Effective cooling, page 9

Clean sump technology, page 28

Wear

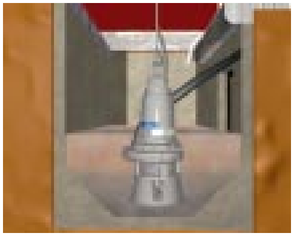
Wear inside a slurry pump varies significantly depending on the velocity, concentration and impact angle of the particles. The wear is typically most severe on the impeller followed by the pump housing and discharge connection.

Wear rate and service intervals depend on the type of application. Ensuring the customer is aware that Flygt service and spare parts are available, is an important part of the sales process.

Over-estimation of system losses

Over-estimation of the losses can lead to over-dimensioning of the pump. This in turn can cause problems such as:

- Too large flow
- Higher power consumption
- Overloading the motor
- Cavitation



Pump with agitator

Clean sump technology

This concept means effective slurry handling without sediment build up. The slurry is kept in suspension by the use of an agitator or mixer. Combined with the pump cooling system and an effective sump design this ensures the sump can be emptied efficiently.

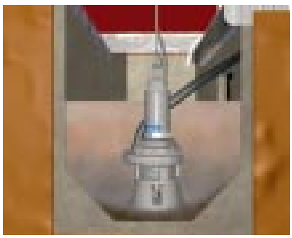
Pump with side-mounted mixer

Agitator

When pumping coarse slurries, an agitator mounted on the pump shaft re-suspends settled particles and makes them easier to transport.

Side-mounted mixer

For large sumps with very coarse and heavy particles, where the agitator is not enough, a side-mounted mixer can be mounted to prevent sediment build- up.



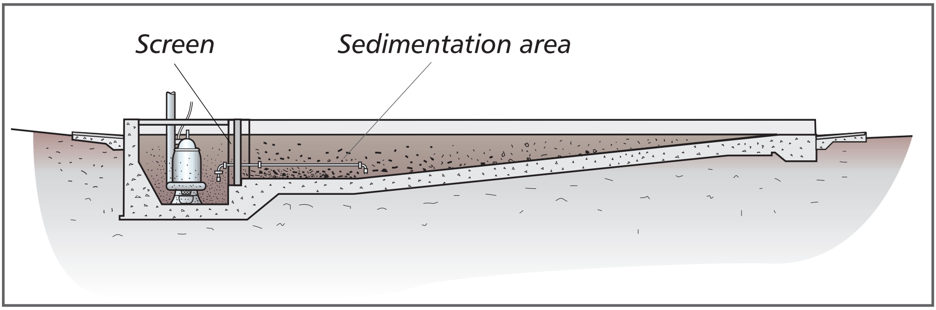
Pump with internal cooling system

Cooling

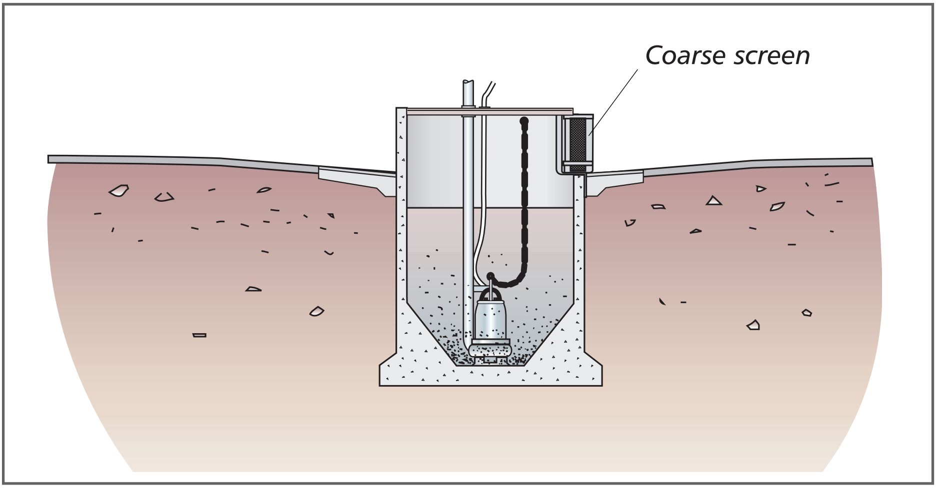
An internal/external cooling system means that the pump can continue pumping down to low slurry levels. See also Cooling on previous page.

Sump design

A bigger so called launder sump has a sedimentation area for solids before the overflow into the smaller part where the pump is installed. The sedimentation area permits an excavator to enter in order to remove the sediment.



Smaller sumps with sloping walls create turbulence and high velocity in the sump, preventing the slurry from settling. Settling solids slide down into the zone directly under the pump inlet.



5. Application guide

Flygt slurry pumps can be used in many different industries and applications. The purpose of this chapter is to give a brief overview of some common industries and applications for slurry pumps.

Types of installation

Flygt submersible slurry pumps can be installed in many ways as mentioned earlier. However there are some general rules regarding installation that should be considered irrespective of application.

- Dry installation: The slurry pump must always be installed with a cooling system. For the 5500 series, water for the cooling jacket must be supplied externally.

Consider the design of the sump in order to feed the pump with the slurry. An agitator and side mounted mixer cannot be used in this installation method.

- Submerged installation: If possible the sump should be equipped with sloping walls to allow the sediment to slide down to the area directly under the pump inlet. Use an agitator when there is a high solids content and when the density of the particles is high. A side mounted mixer is an excellent option to resuspend the solids, when the sump is large or lacks sloping walls.

The mixer can also help the agitator when pumping very high density particles.

- A raft installation is an option to be considered when pumping sediments from dams or lagoons. An agitator is recommended as well as one or more mixers.

The mixer can either be mounted on the pump or directly on the raft.

Application areas

Iron & Steel

Pumps for mill scale transportation

Water from the cooling process is collected in sumps. This water has a high content of mill scale, which is normally very abrasive. These particles are often separated and the water re-used in the cooling process.

Pumps for cooling water

Cooling water may have a high content of abrasive particles from earlier use.

Removal of sediments from tailing dams.
Dust and solids from melting processes is often collected in settling dams. This is suitable for raft installations using an agitator and side mounted mixer.

Pumps for cooling oil in machining processes
Cooling oil containing metallic waste from grinding or similar machining processes.

Power generation (coal-fired power plants)

Pumping bottom ash slurry

Pumping bottom ash and water to settling lagoons.

Run off water

Run-off water from the coal storage, coal cleaning and coal conveyor areas must be collected and pumped to further treatment.

Pulp & paper

Collecting tanks and overflow sumps

Black liquor from recovery boilers containing sand, fly ash, boiler grit, pine knots, etc.

Oil & gas

Pumping drilling mud

Return mud with a high content of abrasive materials. A pump is normally used for transporting the mud from a supply ship to a mud recycling plant. Normally drilling mud must be considered to be homogeneous slurry.

Waste water treatment plant

Grit chamber/sand trap

Pumps installed after primary screening for pumping the sediment solids for disposal.

Mining operations

Sump pumping of thicker slurries

Cleaning main drainage basin from settled solids

Suitable for raft installation with agitator and side mounted mixer.

Mineral processing

Sump pumping at the lowest level in the processing plant

Watch out for larger heavier objects and particles that may end up on the sump floor.

If possible, mount an inlet screen cover on top of the sump or a screen basket.

When recommending our slurry pumps for low pH, for high chloride content (i.e. sea water), and when the slurry contains copper sulphate (used in flotation processes), consider recommendations on page 24 or contact your Flygt support.

If the slurry is frothy, the volume capacity of the pump must at least be doubled.

Specify if possible our clean sump design (to minimize sedimentation).

Recovering material from the plant emergency dam

Suitable for a raft installation with an agitator and side mounted mixer.

Quarries (crushed stone, sand and gravel)

Dredging (lower capacity)
Suitable for a raft installation with an agitator and side mounted mixer.

Quarry sumps
Suitable for raft or permanent installation for pumping solids containing ground water or flood drainage, or for transfer of slurries comprising sand and gravel products.

Sump pumping in a concrete recycling plant
Suitable for pumping slurries of sand and cementious solids for recycling of returned concrete.

Used in combination with a submersible mixer.

6. Appendix

Step by step calculation

See page 37 for values used in the example.

Pages 38, 39

1. Determine SG/density of the liquid. If the density is unknown, it can be determined by using the formula or nomograph.

Page 40

2. Calculate the critical velocity using the table and curve. Choose a pipe diameter so that the pipe velocity is higher than the critical velocity. If the velocity is too low, losses, wear and also the risk of blockage increase.

3. Calculate the total discharge head, which is the sum of the static discharge head, the losses in the pipe system, and the pipe discharge pressure (if required).

Page 41

The losses in the pipe system consist of friction losses and losses caused by fittings like pipe bends and valves etc. The friction losses can be established using the diagram. If the concentration is more than 15% by volume, the value should be adjusted using the correction factor diagram. For slurry pumping, pipe bends with a large radius and valves with free through flow should be selected. In this way, losses in fittings can be neglected when estimating the total losses.

Page 42

4. The required duty point has now been established. If the solid concentration exceeds 15% by volume, the discharge head of the pump must be reduced. By dividing the duty head with the reduction factor, the equivalent clean-water pump head is obtained.

5. The pump can now be selected based on the flow and head values above.

Page 43

The type of installation conditions in question should also be considered. Overall operating expenses, including wear, maintenance and energy consumption are equally important points to be considered.

6. Corresponding power consumption, clean-water versus slurry.

Page 44

The power curves for the pumps are based on clean water and these must then be multiplied by the specific gravity of the slurry to obtain the corresponding value for slurry pumping. Normally variations in the slurry can be expected and the motor should therefore be relatively large. Flygt recommends a motor with a 20% excess power margin for slurry applications.

Example

Calculate the size of a pump in a coal mine, pumping coal slurry from the mine.

Data from customer:

Voltage	**380 V, 50 Hz**
Water temp	**max 40°**
Concentration of solids by volume	**C_v = 30%**
Density of solids: 1800 kg/m^3	**SG_s = 1,8**
Requested flow:	**Q = 50 l/s**
Geodetic head:	**H = 22 m**
Pipe diameter:	**150 mm**
Pipe length:	**L = 50 m**
Size of solids:	**d_{85} = 1**

These values are used in the example on the following pages.

1 Specific gravity (SG) of slurry

Determine the specific gravity of the slurry. Use the formula below or the nomograph on the next page.

Specific gravity is the density of a particular material normalised by the density of water.

Example: Density of sand is normally 2600 kg/m^3. SG of sand is then 2,6.

$$SG_{sl} = 1 + C_v(SG_s - 1)$$

or

$$SG_{sl} = \frac{SG_s}{SG_s - C_m(SG_s - 1)}$$

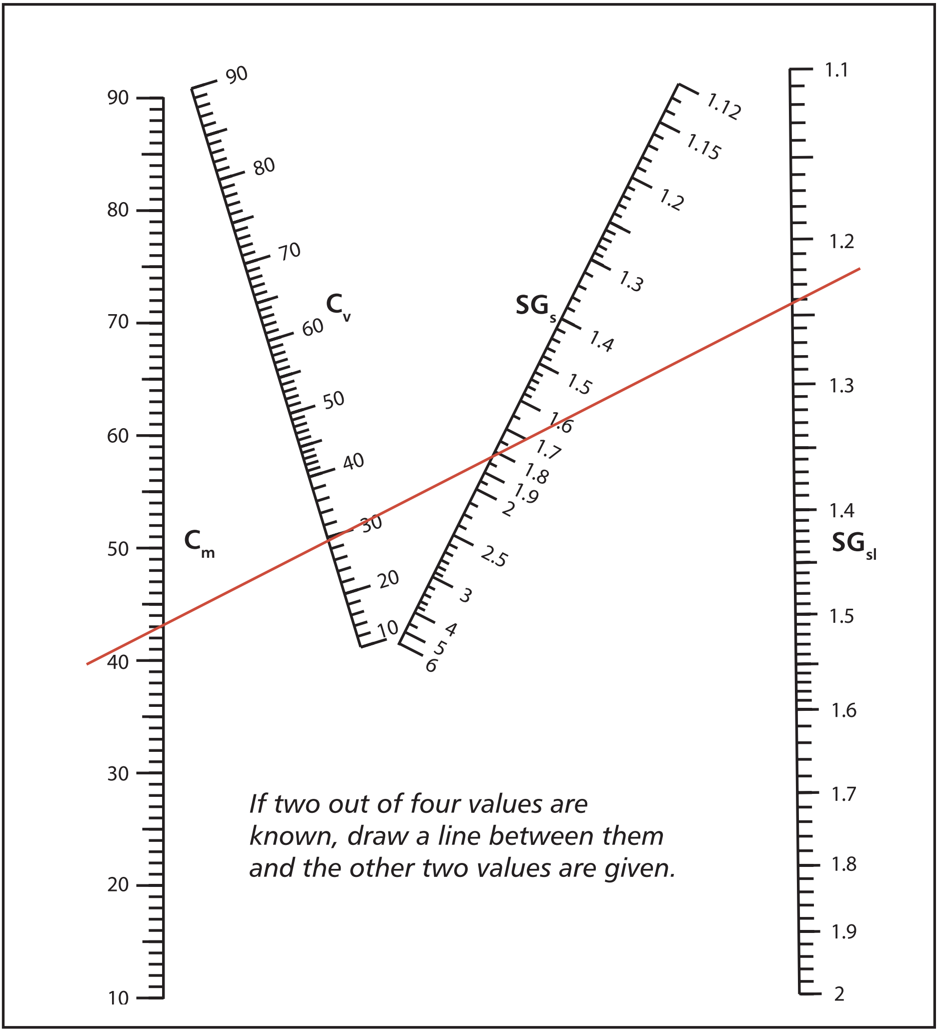
SG_{sl} = Specific gravity of the slurry
SG_s = Specific gravity of the solids
C_v = Concentration of solids by volume
C_m = Concentration of solids by weight

Example

Calculate the specific gravity (SG) of the slurry

$$SG_{sl} = 1 + 0,3(1,8 - 1) = 1,24$$

You can also use the nomograph on the next page.



Nomograph showing the relationship of concentration to specific gravity in aqueous slurries.

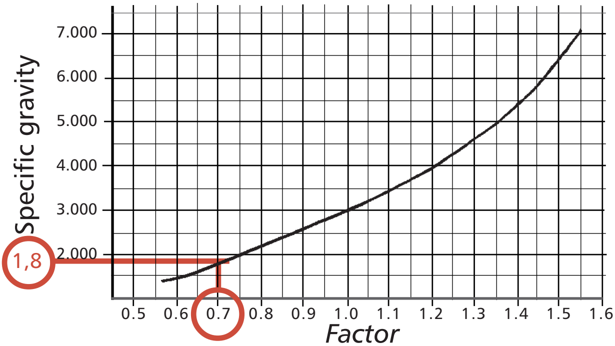
❷ Critical velocity

Calculate the critical velocity using the table and curve below. Choose a pipe diameter so that the pipe velocity is less than the critical velocity. If the velocity is too low, the losses, wear and also the risk of blockage will increase

Critical velocity (V_{cr}) m/s (for d_{85} and SG=3)

Pipe size mm	inch	Mesh 65 mm 0.2	48 0.3	32 0.5	24 0.7	16 1.0	9 2.0	<4 >5
25	1	1.3	1.4	1.4	1.4	1.4	1.4	1.4
50	2	1.3	1.7	1.8	1.8	1.8	1.8	1.8
75	3	1.6	1.8	1.9	1.9	1.9	1.9	1.9
100	4	1.7	1.9	2.0	2.1	2.1	2.1	2.1
150	6	1.7	2.0	2.1	2.4	2.4	2.4	2.4
200	8	1.8	2.0	2.3	2.5	2.5	2.5	2.5
300	12	1.8	2.1	2.4	2.7	2.8	3.0	3.0
400	16	1.8	2.1	2.5	2.8	2.9	3.1	3.6

As the SG of the solids is below 3, a correction of the value must be done according to the diagram below.



Example
Check that the velocity in the pipe is above the critical velocity.
Pipe diameter: 150 mm
Size of solids: $d_{85} = 1$
$V_{cr} = 2{,}4$ m/s

Correction factor
Density of solids: 1800 kg m³ = $SG_s = 1{,}8$ = factor 0,7

Critical velocity
$V_{cr} = 2{,}4 \times 0{,}7 = 1{,}7$ m/s

Actual velocity $V = \dfrac{Q}{A^*} = \dfrac{50 \times 10^{-3}}{3{,}14 \times 0{,}075^2} = 2{,}8$ m/s

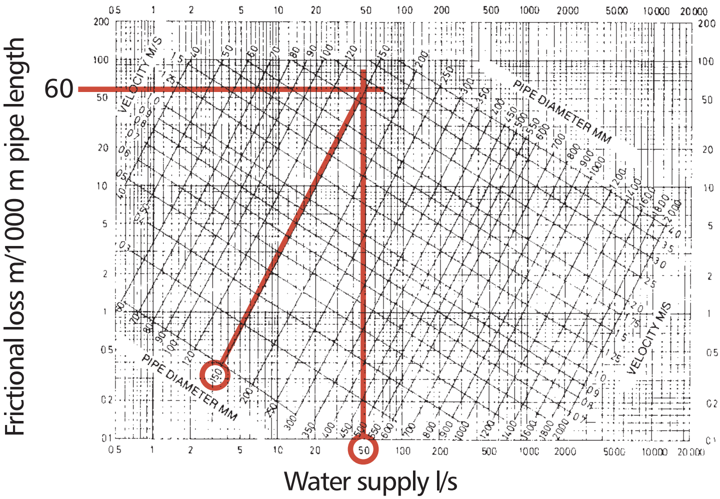
2,8 m/s > 1,7 m/s Well above!

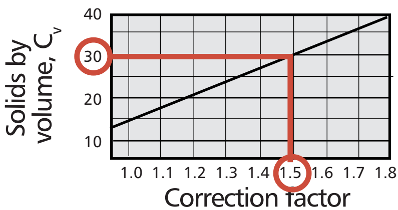
*A is the pipe area

❸ Total discharge head

Determine the total discharge head, by adding the friction losses to the geodetic head.

The table shows the frictional losses for clean water and the value must be multiplied with a correction factor for slurry.





Example

Friction losses

For steel pipe with a roughness factor 0,2, diameter 150 mm and flow rate, Q=50 l/sec, the top diagram gives friction losses for clean water: 60 m/1000m= 0,06 m/m_{pipe}

For pipe length 50 m: 50 x 0,06 = 3m

Correction factor

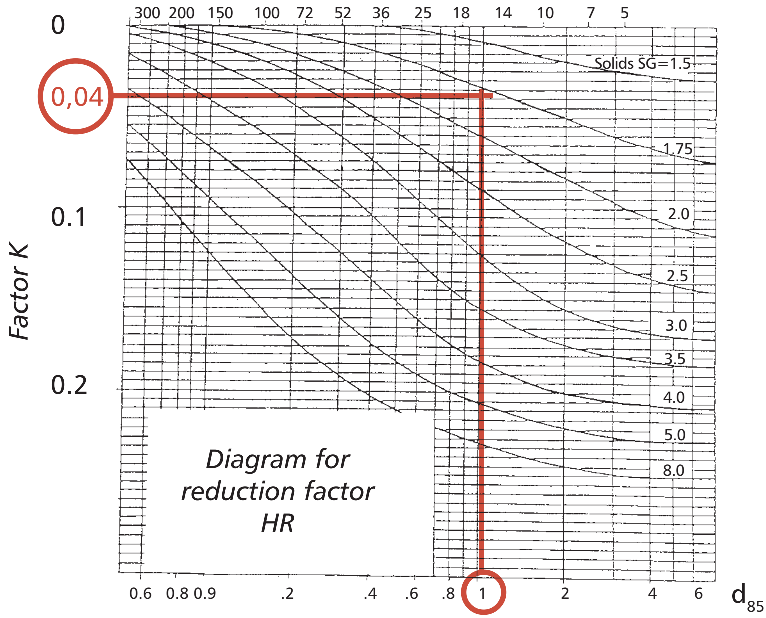
Correction factor for slurry C_v 30% = 1,5

Head

H_{frsl} = 3 x 1,5 = 4,5 m ; H_{totsl} = 4,5 + 22 = 26,5 m

❹ Clean-water pump head

The diagram below gives the reduction factor HR for calculation of the equivalent clean water head, H_{cw}, since the performance curves are for clean water.



Example

Reduction factor HR

With d_{85} = 1 and SG_s = 1,8 the diagram gives K = 0,04

$$HR = 1 - K \times \frac{C_v}{20} = 1 - 0{,}04 \times \frac{30}{20} = 0{,}94$$

$$H_{cw} = \frac{H_{totsl}}{0{,}94} = \frac{26{,}5}{0{,}94} = 28{,}2 \text{ m}$$

Choose a pump with a clean water curve for duty point:
H_{cw}=28,2 m (H_{sl}=26,5) and Q=50 l/s.

❺ Select pump

The pump is selected based on the flow and head values. The type of installation conditions in question should also be considered. Overall operating expenses, including wear, maintenance and energy consumption are equally important points to be considered.

Example

Select pump

Choose 5150.300, curve 53-432. It gives 50 l/s at the requested head.

6 Corresponding power consumption, clean-water vs slurry

The power curves for the pumps are based on clean water and these must then be multiplied by the specific gravity of the slurry to obtain the corresponding value for slurry pumping.

Pump	Poles	Rated shaft power, kW	$P_{shaft\ duty\ point}$	$P_{shaft\ max(432)}$
5150	4	30,0	22,5	25
	4	37,0	22,5	25
	4	45,0	22,5	25

Example

Check motor power

Check that the pump motor has a power margin to handle the higher density.

The table shows that the maximum permitted shaft power for the chosen motor is between 30 and 45 kW and the performance curve shows that we need 22,5 kW shaft power for clean water at the requested duty point.

$$SG_{sl} \times P_{incw} = P_{insl}$$

$$1{,}24 \times 22{,}5 = 27{,}9 \text{ kW}$$

The value is well below the maximum permitted input power at the requested duty point, but check that the value is below the power limit for the whole curve in case there are variations in the pumped head.

$P_{shaft\ max}$ = 25 kW for the chosen curve. $P_{inmaxsl}$ = 25 x 1,24 = 31 kW

There is still a sufficient power margin.

Selected pump: HS 5150.300, curve 53-432 with 37 kW motor.

Index

Designations and formulas

Q	**= Flow rate (l/s)**
V	**= Velocity (m/s)**
V_{cr}	**= Critical velocity**
A	**= Pipe area**
L	**= Pipe length (m)**
H	**= Head (m)**
SG_{sl}	**= Specific gravity of slurry**
SG_s	**= Specific gravity of solids**
C_v	**= Concentration by volume (%)**
C_m	**= Concentration by weight (%)**
d_{85}	**= Concentration by volume**
η	**= Efficiency**

$$SG_w = 1$$

$$SG_s = \frac{\text{Density of solids}}{\text{Density of water}}$$

$$V = \frac{Q}{A}$$

FLYGT

Slurry Questionnaire

Contact information

- Company: ______
- Contact person: ______
- E-mail: ______
- Telephone no: ______

Application information

- Industrial segment: ______
- Pump application: ______

Pump duty

- Required flow [l/s, USgpm, m^3/h]: ______ *
- Required total head [m, ft]: ______ *
  (or preferable)
- Static head + Pipe configuration ______
  - Static head [m, ft]: ______
  - Pipe length [m, ft]: ______
  - Inner diameter [mm, inch]: ______
  - Number of valves: ______
  - Number of bends: ______
  - Pipe material: ______

Information about the slurry

- Particle size [d_{50}]: ______ *
- Particle size [d_{85}]: ______

- SG of particles: ______ **
- SG of liquid: ______ **
- Concentration by weight [%]: ______ **
- Concentration by volume [%]: ______ **
- SG of slurry: ______ **

- Mass fraction [% of particles < 75 µm]: ______
- Particle shape [round or flat]: ______

** must be filled in*
*** three out of five must be filled in*

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