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Basics in Minerals Processing

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Expect results

CONTENT

1. Introduction

2. Minerals in operation

3. Size reduction

5. Enrichment

Metso Mining and Construction Technology

Brand names in rock and minerals processing

Allis Chalmers (AC)
Allis Minerals System
Altairac
Armstrong Holland
Barmac
Bergeaud
Boliden Allis
Cable Belt
Conrad Scholtz
Denver
Dominion
FACO
GFA
Hardinge
Hewitt Robins
Kennedy Van Saun KVS
Kue-ken Seco
Koppers
Lennings
Lokomo
Marcy
Masterscreens
McDowell Wellman
McNally Wellman
Neims
NICO
Nokia
Nolan
Nordberg
MPSI
Orion
PECO
Pyrotherm
Read
REDLER
Sala
Scamp
Skega
Stansteel
Stephens – Adamson
Strachan & Henshaw
Svedala
Thomas
Tidco
Trellex
Tyler

Notes

Notes

"The practice of minerals processing is as old as human civilisation. Minerals and products derived from minerals have formed our development cultures from the flints of the Stone Age man to the uranium ores of Atomic Age".

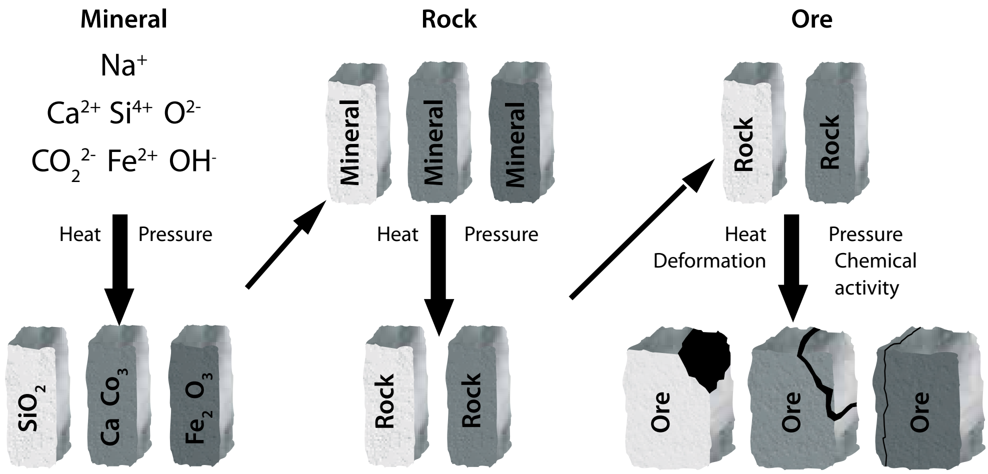
The ambition with this handbook, "Basics in Mineral Processing Equipment", is not to give a full coverage of the subject above.

The intention is to give technicians involved in mineral operations practical and useful information about the process equipment used, their systems and operational environment.

The technical data given are basic, but will increase the understanding of the individual machines, their functions and performances.

Basic definitions

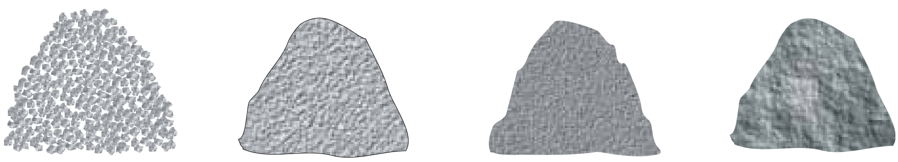
It is important to know the definitions of *mineral, rock* and *ore* as they represent different product values and partly different process systems



"Natural components of chemical elements" "Compounds of minerals" "Rocks containing minerals or metals which can be recovered with profit"

Artificial minerals

"Man made" minerals are not minerals by definitions. But from processing point of view they are similar to virgin minerals and are treated accordingly (mainly in recycling processes).



Slag Concrete Mill scale Glass & Ceramics

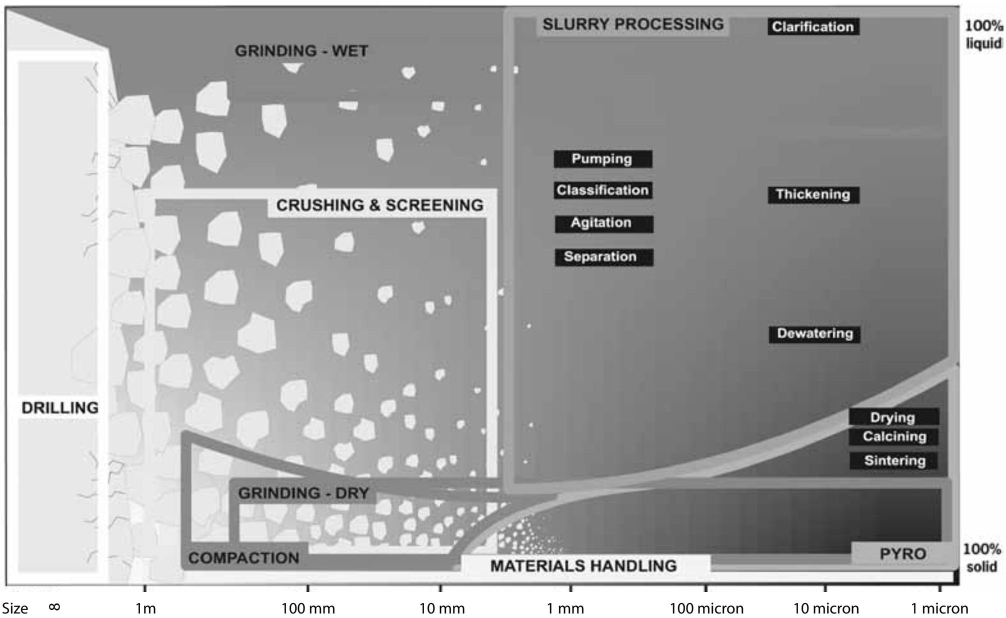
Minerals by value

Minerals

- **Industrial minerals**
  - **Abrasives**: Corundum, Quartz, Diamond a.o.
  - **Glass**: Quartz, Feldspar, Calcite, Dolomite a.o.
  - **Plastic**: Calcite, Kaolin, Talc, Wollastonite, Mica a.o.
  - **Ceramics**: Quartz, Kaolin, Feldspar a.o.
  - **Fertilisers**: Phosphate, Potash, Calcite, Dolomite a.o.
  - **Fillers and pigment**: Barite, Bentonite, Calcite, Dolomite, Feldspar, Talc a.o.
  - **Refractories**: Wollastonite, Calcite, Dolomite, Corundum a.o.
- **Mineral fuels**
  - Coals
  - Oil shale
  - (Oil sand)
- **Rock**
  - **Aggregate, sand & gravel**: Concrete ballast, Asphalt ballast, Rock fill, Industrial sand, a.o.
- **Ores**
  - *Non-ferrous*
    - **Base metals**: Copper, Lead, Zinc a.o.
    - **Light metals**: Aluminium, Magnesium, Titanium
    - **Precious metals**: Gold, Silver, Platinum a.o.
    - **Rare metals**: Uranium, Radium, Beryllium a.o.
  - *Ferrous alloy*
    - **Alloying metals**: Chromium, Vanadium, Molybdenum, Tungsten, a.o.
  - *Ferrous*
    - **Iron**

The process frame of minerals

The goal in mineral processing is to produce maximum value from a given raw material. This goal can be a crushed product with certain size and shape or maximum recovery of metals out of a complex ore.
The technologies to achieve these goals are classical, complementary and well defined.
Below they are presented in the Process Frame of Minerals, classified according to their interrelations in product size and process environment (dry or wet).



Drilling (and blasting) is the technology of achieving primary fragmentation of "in situ" minerals. This is the starting point for most mineral processes with the exception of natural minerals in the form of sand and gravel.

Crushing and screening is the first controlled size reduction stage in the process. This is the main process in aggregate production and a preparation process for further size reduction.

Grinding is the stage of size reduction (wet or dry) where the liberation size for individual minerals can be reached. By further size reduction filler (mineral powder) is produced.

Slurry processing includes the technologies for wet processing of mineral fractions.

Pyro processing includes the technologies for upgrading of the mineral fractions by drying, calcining or sintering.

Materials handling includes the technologies for moving the process flow (dry) forward by loading, transportation, storage and feeding.

Compaction of minerals includes the technologies for moving and densifying minerals by vibration, impaction and pressure, mainly used in construction applications.

Mineral processing and hardness

All deposits of minerals, rock or ores have different hardness depending on the chemical composition and the geological environment.

Mohs numbers are a simple classification:

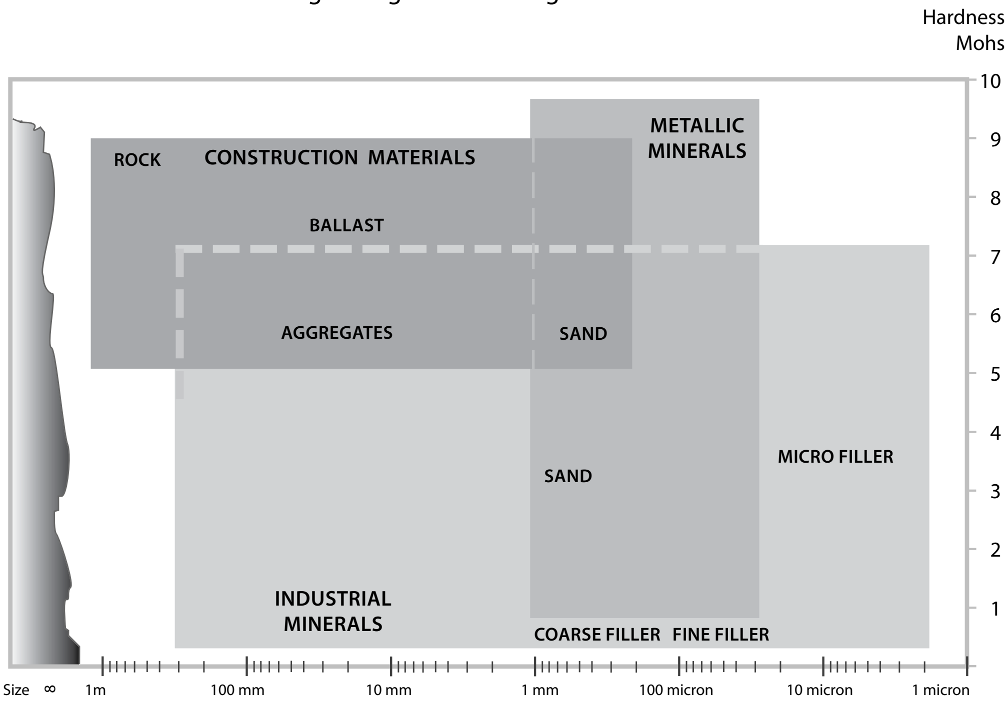
1.	Talc	Crushed by a finger nail	Graphite, Sulphur, Mica, Gold
2.	Gypsum	Scratched by a finger nail	Dolomite
3.	Calcite	Scratched by an iron nail	Magnesite
4.	Fluorite	Easily scratched by a knife	Magnetite
5.	Apatite	Scratched by a knife	Granite, Pyrite
6.	Feldspar	Hardly scratched by a knife	Basalt
7.	Quartz	Scratches glass	Beryl
8.	Topaz	Scratched by quartz	
9.	Corundum	Scratched by a diamond	
10.	Diamond	Cannot be scratched	

In 1813 an Austrian geologist, Mr. Mohs, classified minerals according to their individual hardness.

In operation we naturally need more information about our feed material.
See information on **work index** and **abrasion index**, section 3 page 2.

Size and hardness

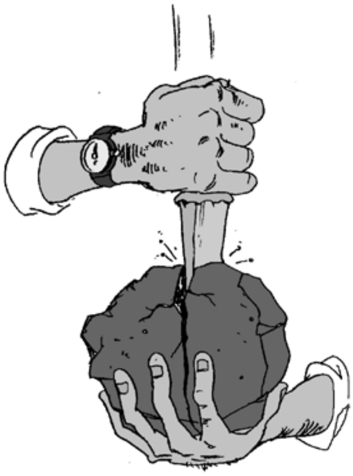
All operations have different process environments due to mineral hardness and size range. It is important to know in which "range" we are operating as this will affect many process parameters, (wear rate, uptime, operation costs etc.).
Size and hardness together give interesting information.



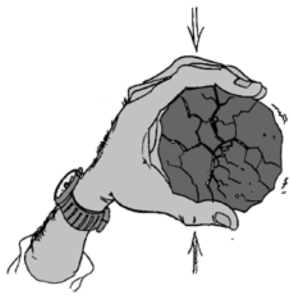
The stress forces of rock mechanics

Beside size and hardness, the classical stress forces of rock mechanics are the fundamentals in most of what we do in mineral processing. They guide us in equipment design, in systems layout, in wear protection etc. They are always around and they always have to be considered.

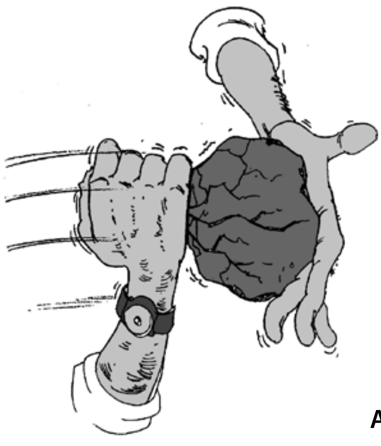
Tensile



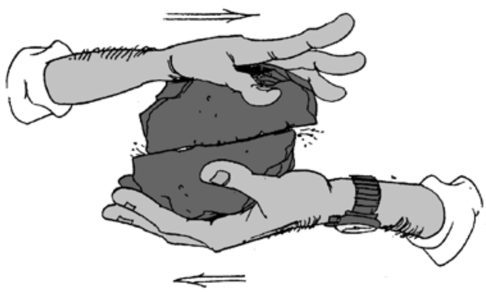
Compression



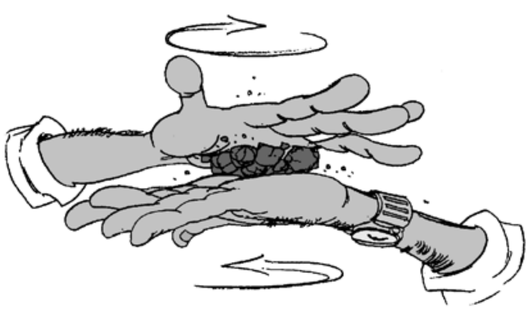
Impaction



Shearing

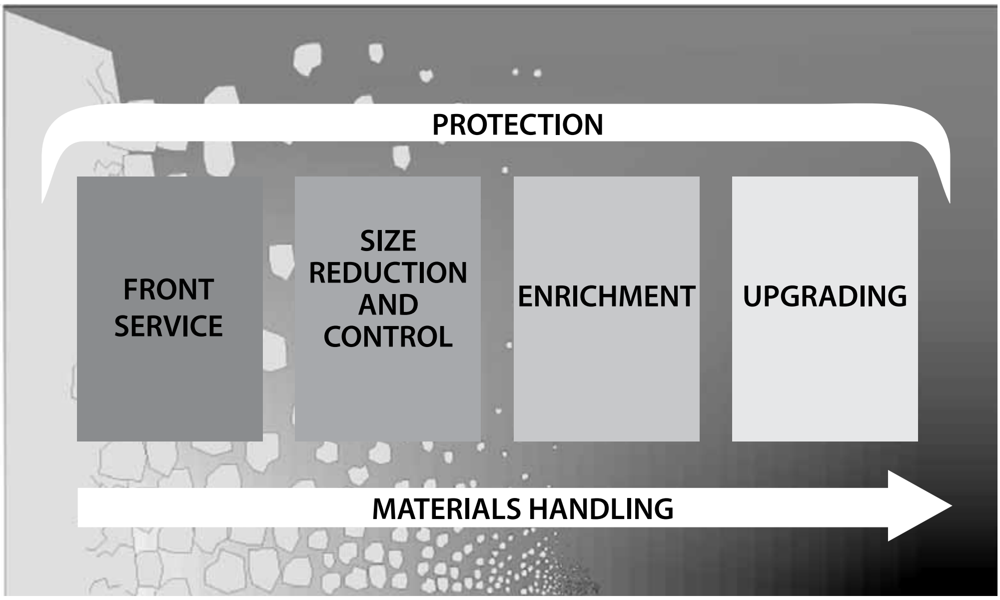


Attrition



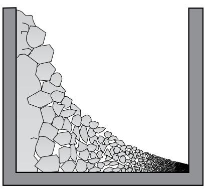
Operation stages

The operating stages in minerals processing have remained the same for thousands of years. Of course we have come far in development of equipment and processes since then, but the hard, abrasive and inhomogeneous mineral crystals have to be treated in special ways in order to extract maximum value out of each size fraction.
The operation pattern below has been used since the days of "mineralis antiqua"

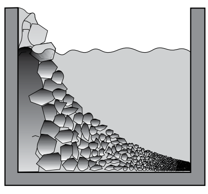


Front service:	Starting point of mineral processing
Size reduction & control:	Processes to produce requested size distributions from feed material
Enrichment:	Processes to improve value of minerals by washing and/or separation
Upgrading:	Processes to produce requested end products from value and waste minerals.
Materials handling:	Operations for moving the processes forward with a minimum of flow disturbances
Protection:	Measures to protect the process environment above from wear and emissions of dust and sound

Operation – Dry or wet ?



Dry processing
- When no water is needed for processing
- When no water is allowed for processing



Wet processing
In all other cases due to:
- Better efficiency
- More compact installation
- No dusting

Note! Wear rate is generally higher in wet processing!

Mining and quarry fronts

The mining and quarry fronts are the starting points for recovery of rock and mineral values from surface and underground deposits.

Operations are drilling (blasting), primary crushing (optional) and materials handling, dry and wet.

Mining and quarrying

Open pit

Underground

Natural fronts

In the glacial, alluvial and marine fronts nature has done most of the primary size reduction work.

Raw material such as gravel, sand and clay are important for processing of construction ballast, metals and industrial mineral fillers.

Operations are materials handling (wet and dry) and front crushing (optional).

Glacial

Glacial sand and gravel occur in areas which are – or have been – covered by ice. The material is rounded and completely unsorted with an heterogeneous size distribution which ranges from boulders larger than 1 m (3 ft) down to silt (2-20 microns). Clay contamination is concentrated in well defined layers.

Alluvial

The size of alluvial sand and gravel depends on the flow velocity of the water, among other things. Normally the maximum size is around 100 mm (4”). Alluvial sand and gravel have a homogeneous size distribution and larger particles often have high silica content. The clay content is often high, normally in the range of 5 to 15 %. Alluvial fronts are in certain areas hosting gold, tin and precious stones.

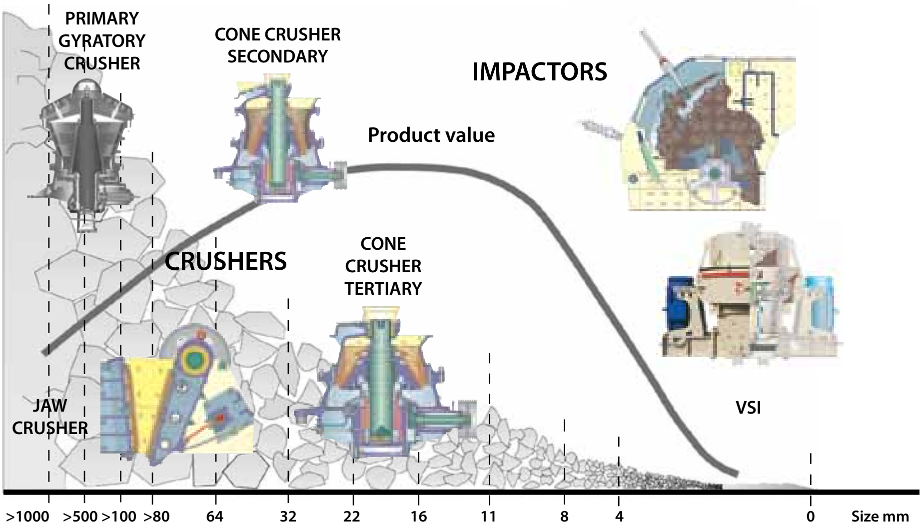
Marine

Marine sand and gravel often have a more limited size distribution than other types of sand and gravel. The minerals in marine sand and gravel have survived thousands – or even millions of years – of natural attrition, from erosion in the mountain ranges and grinding during transport down to the sea. The particles have become well rounded and the clay content is extremely low. Marine fronts are in certain areas hosting heavy minerals like hematite, magnetite, rutile a.o.

Size reduction

Crushing of rock and minerals

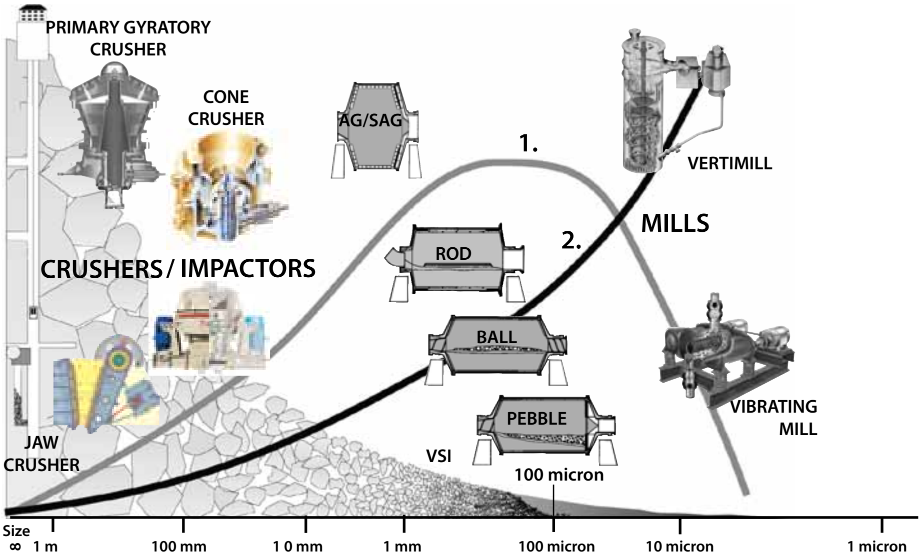
By tonnage this is by far the largest process operation in minerals processing. The goal is to produce rock or (more seldom) mineral fractions to be used as rock fill or ballast material for concrete and asphalt production. Quality parameters are normally strength, size and shape. The size fractions, see below, are priced according to defined size intervals and can be reached by crushing only, see section 3.



Crushing and grinding of ore and minerals

Size reduction of ores is normally done in order to liberate the value minerals from the host rock. This means that we must reach the liberation size, normally in the interval 100 – 10 micron, see value curve 1.
If the raw material is a single mineral (Calcite, Feldspar a.o.) the value normally lays in the production of very fine powder (filler), see value curve 2.

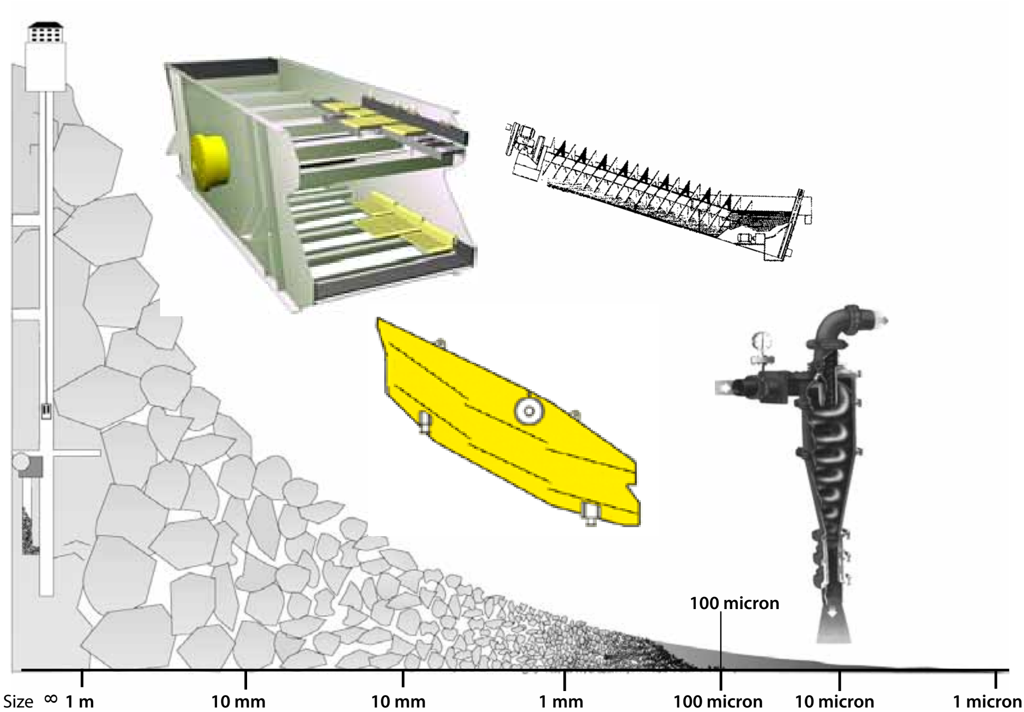
In order to maximise the value in size reduction of rock and minerals, see below, we need both crushing and grinding in various combinations, see section 3.



Size control

Neither crushers nor grinding mills are very precise when it comes to the correct sizing of the end products. The reason is to find partly in the variation of the mineral crystals compounds (hard-soft, abrasive – non abrasive), partly in the design and performance of the equipment.

Size control is the tool for improvement of the size fractions in the process stages and in the final products.
For the coarser part of the process, screens are used (in practise above 1-2mm).
In the finer part we have to use classification with spiral classifiers and/or hydro-cyclones, see section 4.



Enrichment – Washing

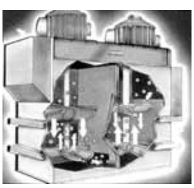
Washing is the simplest method of enrichment used to improve the value of rock and mineral fractions from sand size and upwards. Removing of surface impurities like clay, dust, organics or salts is often a must for a saleable product.
Different techniques are used depending on how hard these impurities are attached to the rock or mineral surface, see section 5.

Washing using

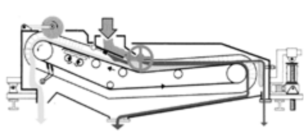
Wet screens

Scrubbers

Attrition cells



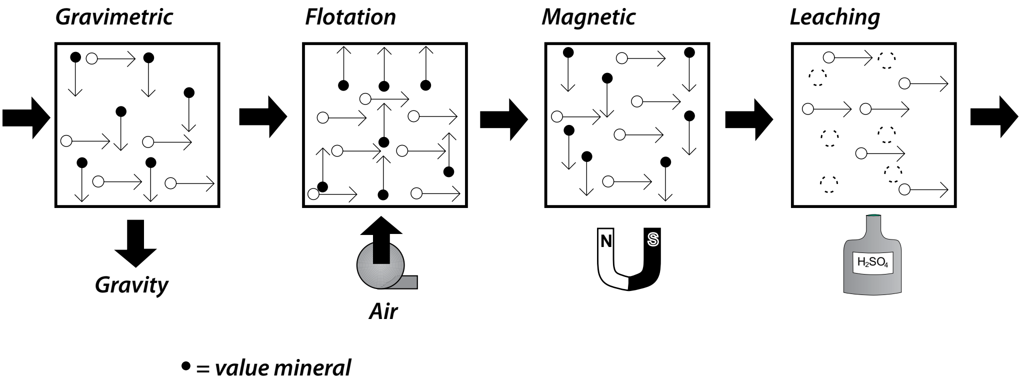
Gravity beds



Enrichment – Separation

Most value minerals (both metallic and industrial) are priced by their purity. After liberation by size reduction and size control all minerals are free to be separated from each other.

Depending on the properties of the individual minerals they can be recovered by different methods of separation, see section 5.



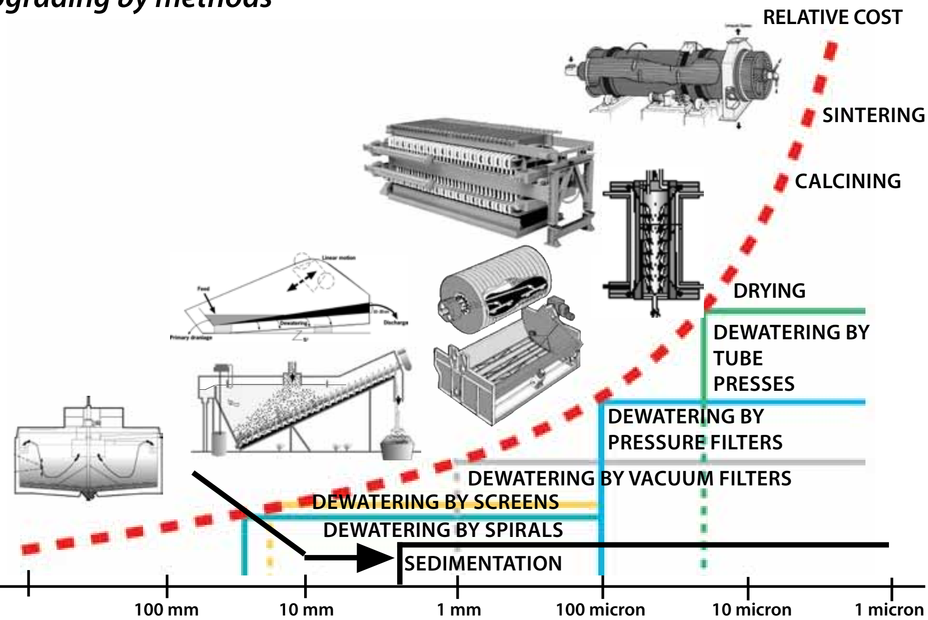
Upgrading

After the enrichment operation we end up with a value product (concentrate) and a non-value product (tailings).

These products are probably not sellable nor disposable due to the content of process water, particle size, or chemical composition.

By upgrading we mean the methods of increasing the value of these products by sedimentation, mechanical dewatering, drying, calcining or sintering and recovering the process water from the tailings, making them disposable, see section 6.

Upgrading by methods



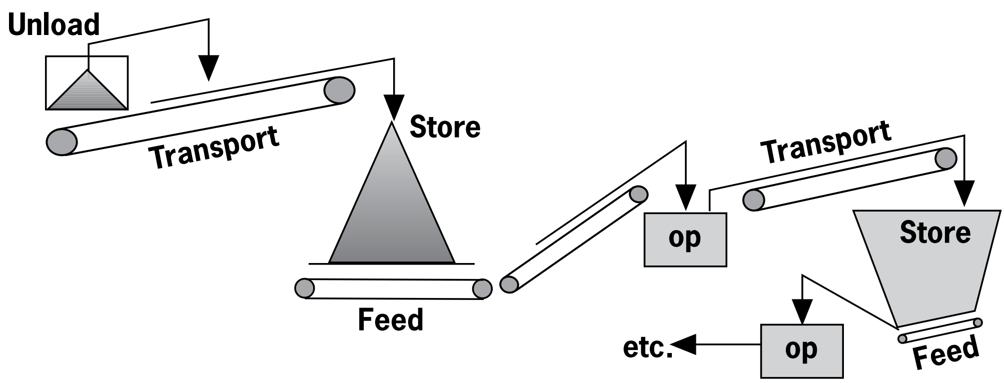
Materials handling

Without a proper set up for materials handling no processing system will perform. Different process stages may be in various locations, may have various feed conditions, are on different shift cycles etc.

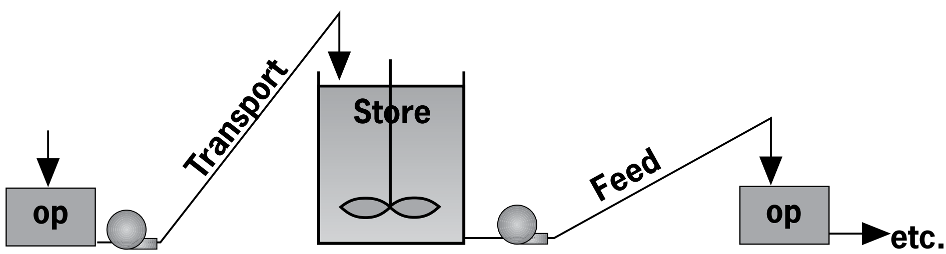
Materials handling of dry material is based on the operations of loadíng, unloading, transportation, storing and feeding, see section 7.

Materials handling of wet material, called **slurry handling** is also based on the operations of transportation (by slurry pumps and hoses), feeding (by slurry pumps) and storage (by slurry agitation), see section 8.

Dry handling



Slurry handling

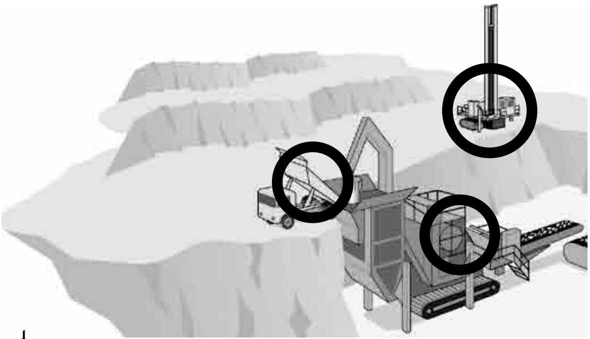


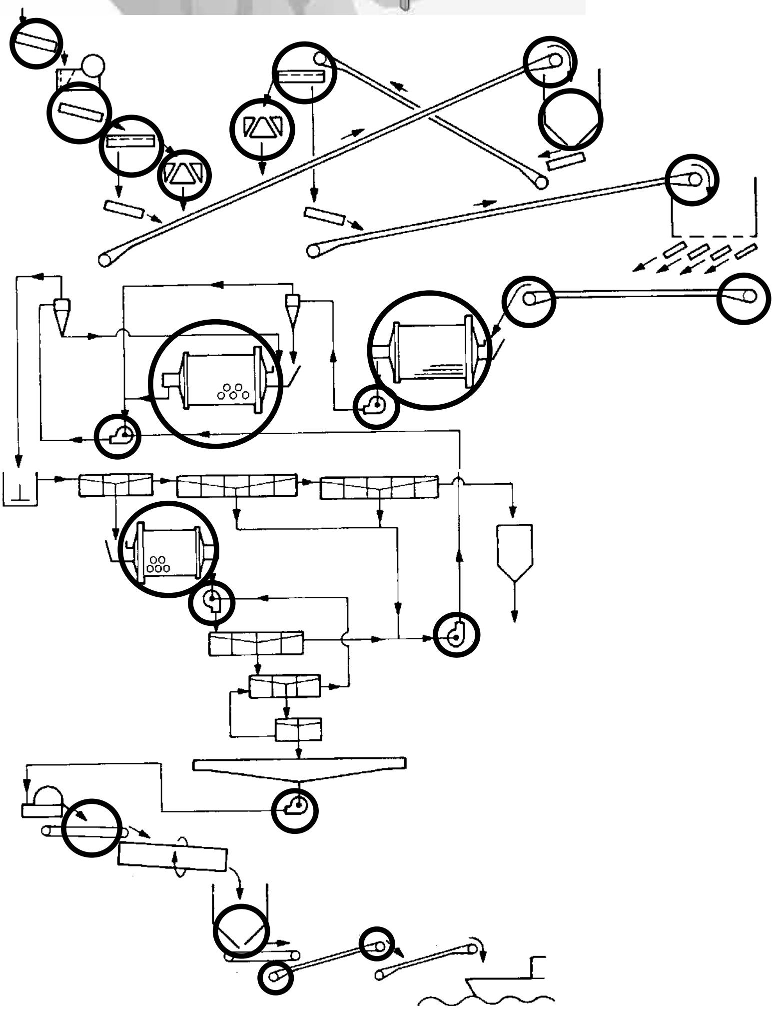
Wear in operation

Whenever energy in any form penetrates rock, ore or mineral, wear will appear.

There is of course a difference whether the minerals are hard or soft, small or large, wet or dry, but wear will always be around. Both machines and structures must be protected from wear using metals, polymers or compound material.

See section 9, wear in operation.





Operation and environment

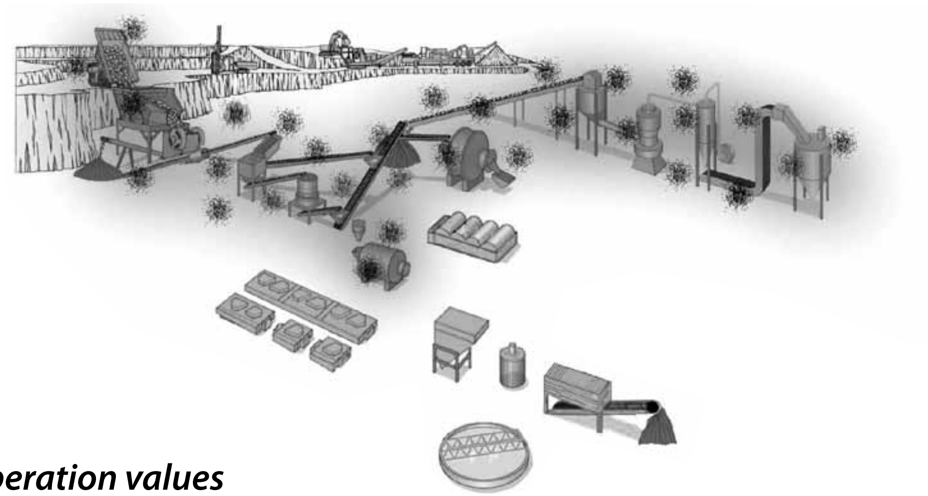
If wear is dangerous for equipment and structures, dust and noise is primarily a danger to the operators.

Dust is a problem to both equipment and operators in dry processing

Noise is a problem to operators both in wet and dry processing.

By tradition, the environment in mineral processing has a bad reputation.

This is now changing fast due to harder restrictions by law and harder demands from the operators, see section 10, Operation and environment.



Operation values

Prices for products from your operation are seldom set by yourself, but by the market buying them. There is always a possibility to increase the income from your operation by **added values** generated by the operation itself.

- **By improving the output we can increase the product volumes**
- **By improving the quality we can increase the price of our products**
- **By improving the cost control we can reduce our costs of operation**
- **By improving the comfort for our operators we can improve motivation and reduce disturbances in operation**

This can be done by small adjustments, by improved service or by reinvestment in more effective equipment, see all sections.

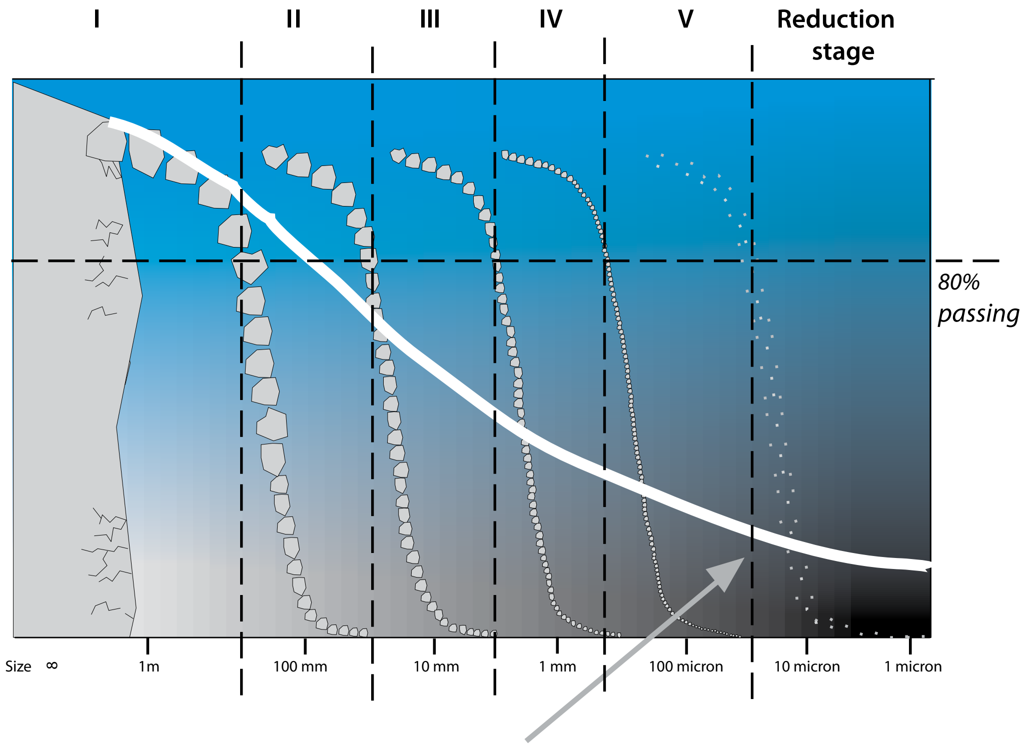
Added value in operation

VOLUME x PRICE − COSTS + MOTIVATION = $

Output	Quality	Cost control	Comfort
AVAILABILITY (up time)	SIZE / SHAPE	CAPITAL	SECURITY
CAPACITY	PURITY / RECOVERY	ENERGY	ENVIRON-MENT
FLEXIBILITY	COMPAC-TION / DENSITY	MATERIAL	RELATIONS

The size reduction process

Minerals being crystals have a tendency to break into endless numbers of sizes and shapes every time they are introduced to energy. The difficulty in size reduction lays in the art of limiting the number of over and under sizes produced during the reduction. If this is not controlled, the mineral will follow its natural crystal behaviour, normally ending up in over-representation of fines.



Size reduction behaviour of minerals - by nature

Note!

So, the trick when producing quality products from rock or minerals (fillers excepted) is to keep the size reduction curves as steep as possible. Normally that is what we get paid for **- the shorter or more narrow fraction - the more value!**

To achieve that goal we need to select the correct equipment out of the repertoire for size reduction in a proper way.

They are all different when it comes to reduction technique, reduction ratio, feed size etc. and have to be combined in the optimum way to reach or come close to the requested size interval for the end product.

Feed material

All operations in size reduction, both crushing and grinding are of course determined by the feed characteristics of the minerals (rock/ore) moving into the circuit. The key parameters we need are the “crushability or grindability”, also called **work index** and the “wear profile”, called **abrasion index.** Values for some typical feed materials from crushing of rocks, minerals and ore are tabulated below.

Impact Work Index W_i

Material	Wi value		
Basalt	20	±	4
Diabase	19	±	4
Dolomite	12	±	3
Iron-ore, Hematite	11	±	3
Iron-ore, Magnetite	8	±	3
Gabbro	20	±	3
Gneiss	16	±	4
Granite	16	±	6
Greywacke	18	±	3
Limestone	12	±	3
Quartzite	16	±	3
Porphyry	18	±	3
Sandstone	10	±	3
Syenite	19	±	4

INFLUENCING

• Size reduction • Energy requirement
• Machine status

Abrasion index = A_i

Material	Ai value		
Basalt	0,200	±	0,20
Diabase	0,300	±	0,10
Dolomite	0,010	±	0,05
Iron-ore, Hematite	0,500	±	0,30
Iron-ore, Magnetite	0,200	±	0,10
Gabbro	0,400	±	0,10
Gneiss	0,500	±	0,10
Granite	0,550	±	0,10
Greywacke	0,300	±	0,10
Limestone	0,001	–	0,03
Quartzite	0,750	±	0,10
Porphyry	0,100	–	0,90
Sandstone	0,600	±	0,20
Syenite	0,400	±	0,10

INFLUENCING

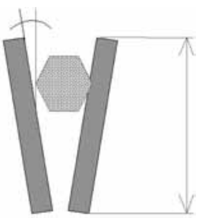
• Wear rate

Regarding Work Index (Bond) for grinding, see 3:24.

Reduction ratio

As seen above all size reduction operations are performed in stages. All equipment involved, crushers or grinding mills have different relation between feed and discharge sizes. This is called **reduction ratio.** Typical values below.

Compression crushers

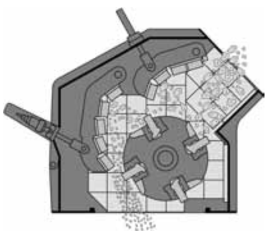


Jaw 3-4

Gyratory 3-4

Cone 4-5

Impactors (horizontal type)

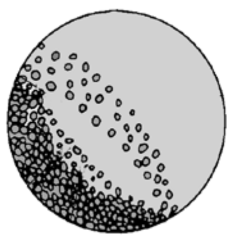


10-15

Impactors (vertical type)

3-8

Grinding mills (tumbling type)



Rod 100

Ball 1000

AG & SAG 5000

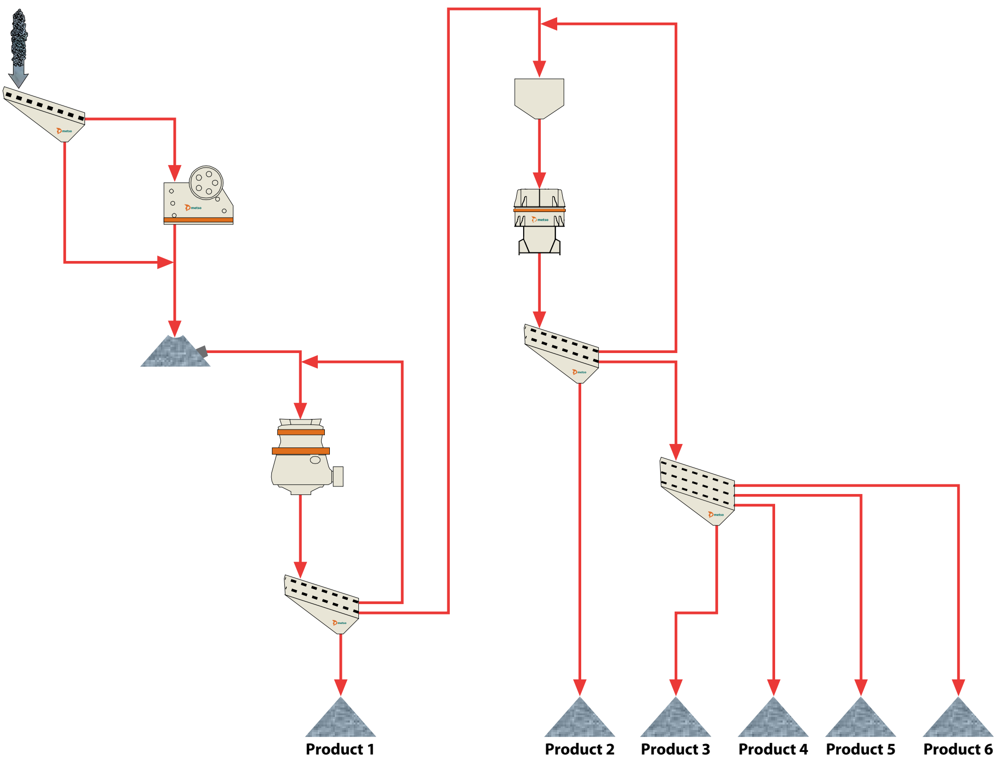
The art of crushing

Crushing means different things for different operations and the production goals are not always equal.

Crushing rock	Crushing gravel	Crushing ore
Limited reduction	Limited reduction	Maximum reduction
Cubical shape	Cubical shape	Shape of no importance
Over and undersize important	Over and undersize important	Over and under size of minor importance
Flexibility	Flexibility	Flexibility of minor importance
Crushing and screening	Less crushing - more screening	More crushing- less screening
		Low production costs High utilisation

Crushing of rock and gravel

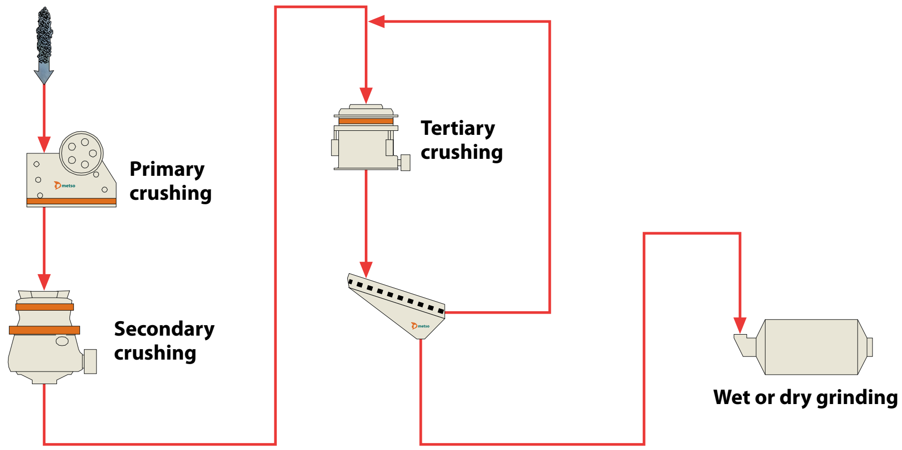
In the ballast business you are normally paid for short fractions of relatively coarse material with the correct size and shape. Most of the ballast for concrete and asphalt is in the 4 - 18 mm ($^{1}/_{5}$ - $^{3}/_{4}$") interval.
In order to ptoduce the correct shape and keep over- and under sizes as low as possible this crushing must be done in several stages (3 - 5).



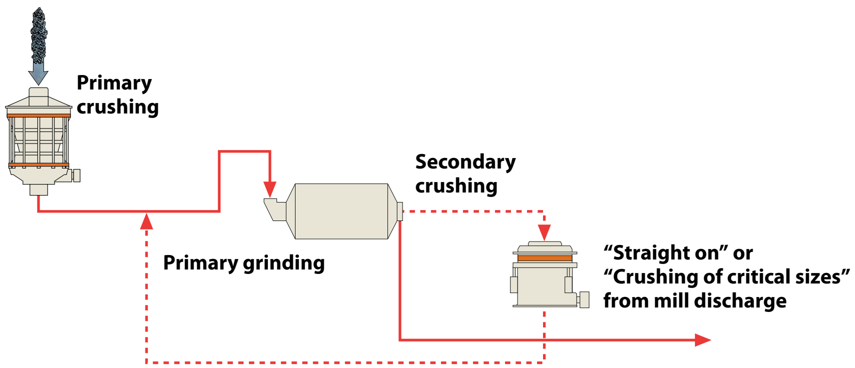
Crushing of ore and minerals

In these operations the value is achieved at the fine end, say below 100 micron (150 mesh).
Normally the size reduction by crushing is of limited importance besides the top size of the product going to grinding.
This means that the number of crushing stages can be reduced depending on the feed size accepted by primary grinding stage.

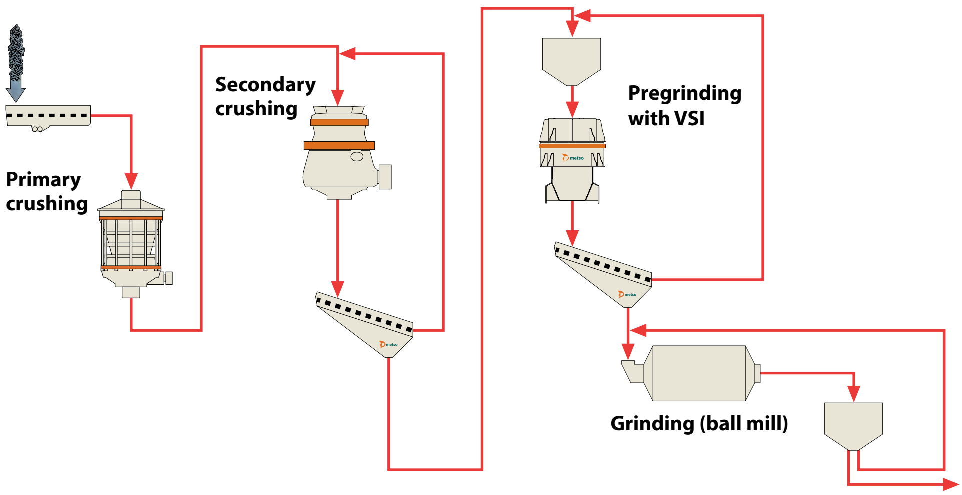
"Classical" 3-stage crushing prior to rod mill



Typical 1-2 stage ore crushing prior to AG-SAG mill



Typical 3- stage pregrinding prior to ball mill



Crushing – Calculation of reduction ratio

All crushers have a limited reduction ratio meaning that size reduction will take place in stages. The number of stages is guided by the size of the feed and the requested product, example see below.

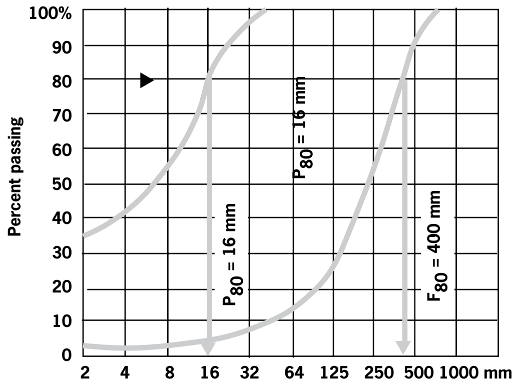
Feed material size: F_{80} = 400 mm
Blasted rock, 80% smaller than 400 mm

Product size: P_{80} = 16 mm
Road aggregates or rod mill feed 80% smaller than 16 mm

Total reduction ratio (R) F_{80}/P_{80} 400/16 = **25**

Reduction ratio in the primary crushing stage
R1 = **3**
Reduction ratio in the secondary crushing stage
R2 = **4**

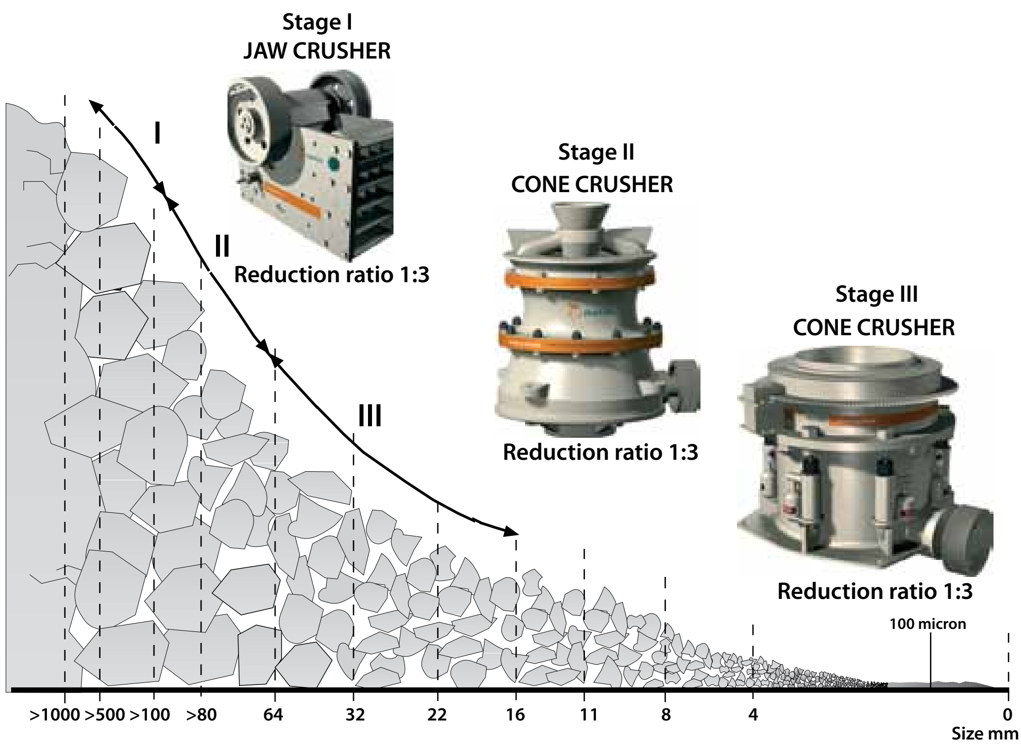
Total in 2 crushing stages gives
R1xR2 = 3x4 = **12**
This is not sufficient. We need a third crushing stage.*



**As we have to use three stages, we can reduce the reduction ratio a bit in every stage, giving more flexibility to the circuit!*

For example:	Reduction first stage	R1 = 3
	Reduction second stage	R2 = 3
	Reduction third stage	R3 = 3

Together these three stages give R1xR2xR3 = 3x3x3 = **27** = sufficient reduction



The same size reduction with soft feed (below mohs 5) is done with two stages of HSI (horizontal shaft impactors) as they can easily reduce 1:10 in each stage giving max reduction possibility of 1:100.

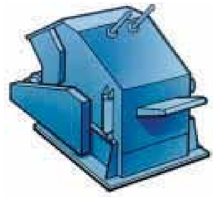
Selection of crushers

Knowing the number of crushing stages we can now start to select the correct crusher for each reduction stage. Depending on operating conditions, feed size, capacity, hardness etc, there are always some options. For primary crushers, see below.

Stationary crushers - surface and underground

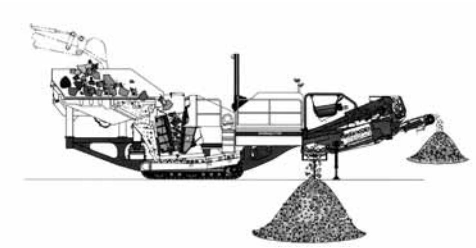
Primary Gyratory

Jaw

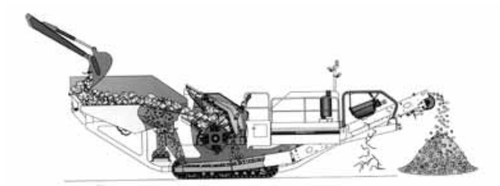


Impact

Mobile Crushers



Jaw + grizzly



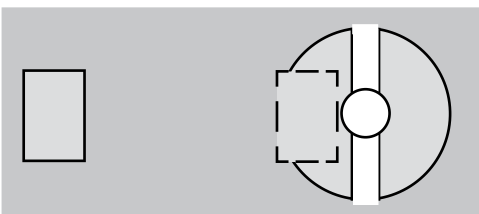
Impact + grizzly

For mobile crushers see further section 11:9

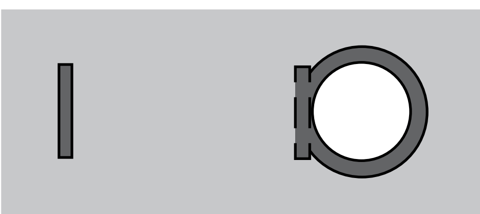
Primary crusher – Type

For **soft feed** (below Mohs5) a horizontal Impactor (HSI) is normally the first option if capacity is not too high.

For **harder feed** there is a choice between a gyratory or a jaw crusher, see below.



Feed opening Jaw crusher *Feed opening Gyratory crusher*



Discharge opening Jaw crusher *Discharge opening Gyratory crusher*

Rule 1: *Always use a jaw crusher if you can, being the most cost effective alternative.*

Rule 2: *For low capacity use jaw crusher and hydraulic hammer for oversize*

Rule 3: *For high capacities use jaw crusher with big intake opening*

Rule 4: *For very high capacities use gyratory crusher*

Primary crusher – Sizing

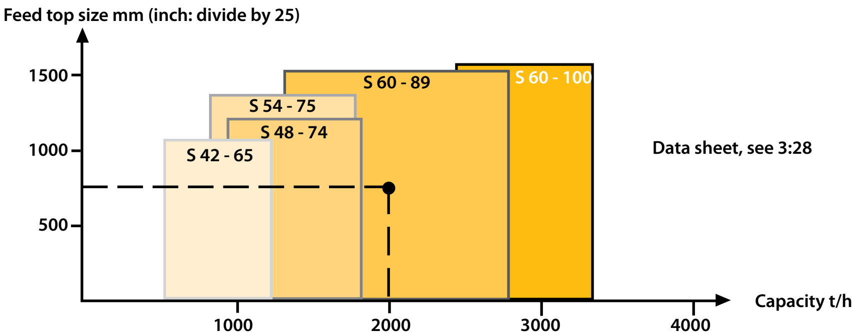
Crushers are normally sized from top size of feed. At a certain feed size, knowing the capacity, we can select the correct machine, see below.

A correct sizing of any crusher is not easy and the charts below can only be used for guidance.

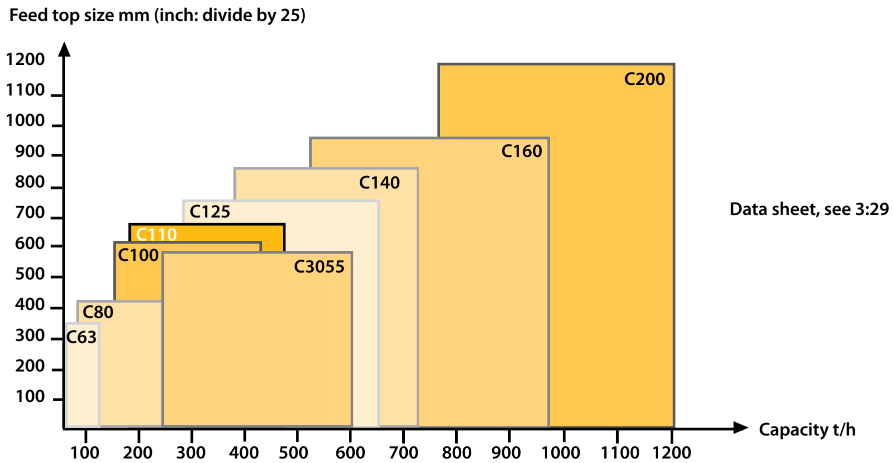
Ex. Feed is a blasted hard rock ore with top size 750 mm. Capacity is 2000 t/h.

- *Which primary crusher can do the job?*
- *Check on the two compression machines below and take out the sizing point!*
- *Correct selection is Superior® MK-II Primary Gyratory Crusher type S60-89*

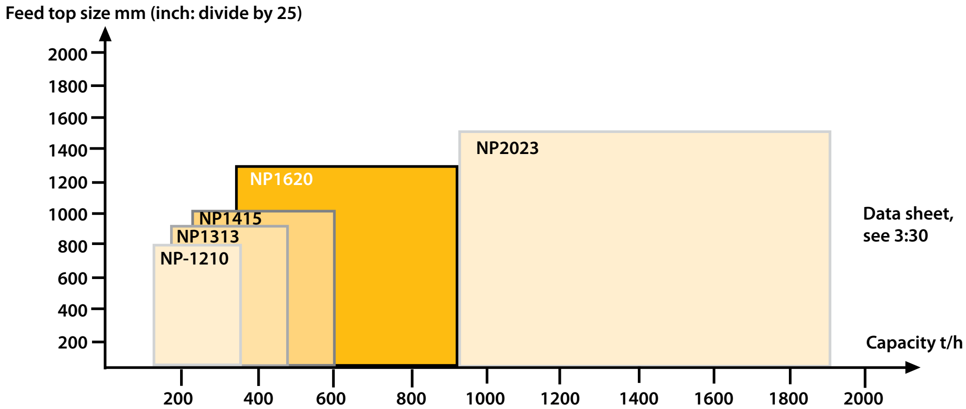
Primary gyratory – Feed size vs capacity



Primary jaw crusher – Feed size vs capacity



Primary impactor – Feed size vs capacity



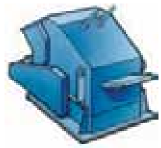
Secondary crusher – Type

In a **rock crushing circuit,** the second stage normally starts to be of importance for control of size and shape.
Because of this the jaw crusher, in most cases, is disqualified as secondary crusher. Instead the cone crusher is used more frequently.
Also in comminution (crushing and grinding) circuits for ore and minerals the cone crusher is frequently used as the secondary stage, see 3:4.

Using a secondary HSI means as always a restriction in feed hardness.

Yesterday | **Today** | **Demands**

Jaw Crusher



HSI

Limitations in W_i and A_i

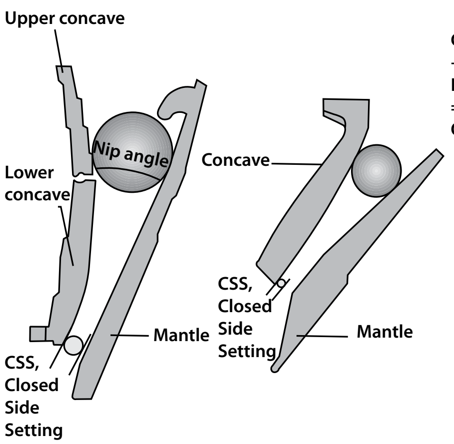
Cone Crusher

- **Big feed opening**
- **High capacity**
- **Controlled feed**
- **Shape**

Cone crusher – A powerful concept

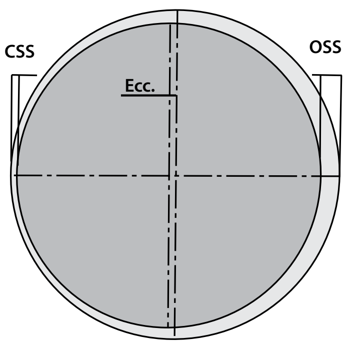
Compared to other crushers the cone crusher has some advantages making them very suitable for size reduction and shaping downstream a crushing circuit. Reason is the crushing chamber and the possibilities to change feed and discharge openings during operation.

Chamber geometry



Chamber settings

Closed side setting (CSS)
+
Eccentric setting (Ecc.)
=
Open side setting (OSS)



- *Chamber intake to match feed size*
- *Each machine size has different chamber options (other crusher types have not)*
- *Each chamber has a certain feed size vs capacity relation*
- *Increased Ecc. (at the same CSS) will give higher capacity, but also coarser discharge*
- *Decreased CSS will improve cubicity but will also reduce capacity and increase risk for packing*

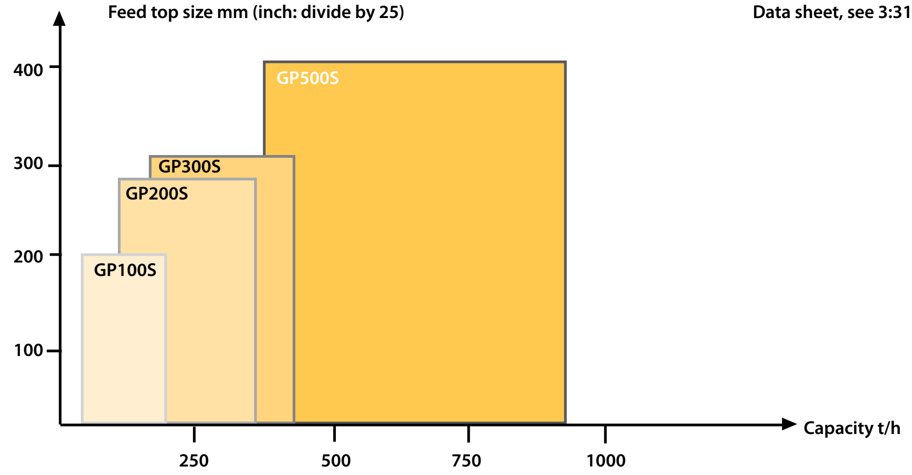
Approx. size of discharge:

From Cone	*70-80%<CSS*
From Gyratory	*55-60%<CSS*

Secondary crushers – Sizing

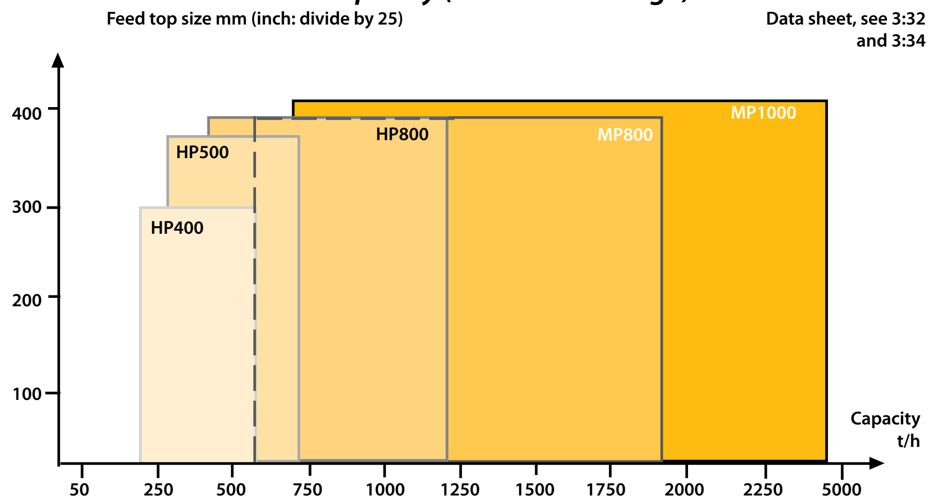
Secondary crushers – Feed size vs capacity (GPS range)

Data sheet, see 3:31



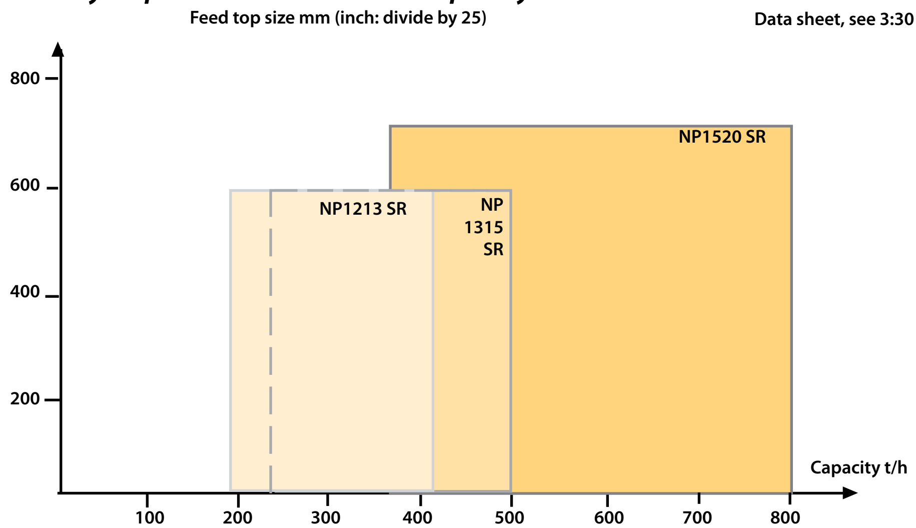
Cone crusher – Feed size vs capacity (HP and MP range)

Data sheet, see 3:32 and 3:34



Secondary impactor – Feed size vs capacity

Data sheet, see 3:30



Final crushing stage – More than just crushing

For many rock and gravel crushing circuits the final crushing stage is of special interest.

The final sizing and shaping will take place in this stage influencing the value of the final product.

For hard rock circuits there are only two options, cone crushers or Vertical Shaft Impactors (VSI).

Most common

Cone crusher

VSI

Demands		Variables
• Max feed size	→	Crushing chamber
• Capacity	→	Size of crusher
• Product shape	→	Setting / speed

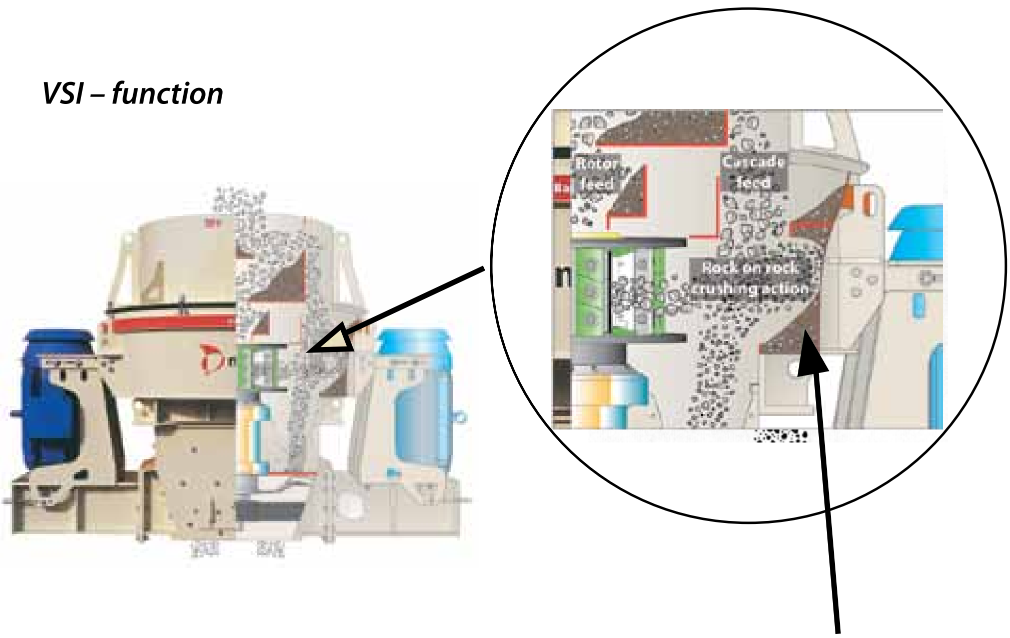
VSI – A rock on rock autogeneous crushing impactor

Horizontal impactors normally use rock to metal impaction. This means a restriction in crushing circuits with hard feed material, when wear can be dramatically high.

The VSI Impactor of Barmac type is using a **rock-to-rock** impaction technology where most of the design is protected by rock, see below. This means that we can use the advantages of the impaction techniques also in hard rock operations.

The crushing action takes place in the "rock cloud" in the crushing chamber, not against the rock protection.

VSI – function

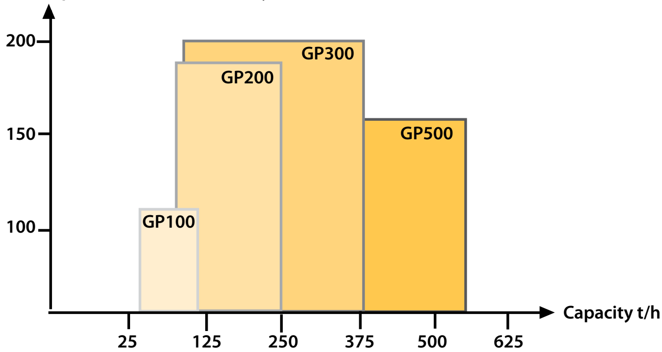


Rock protection

Final crusher – Sizing

Tertiary Cone Crushers – GP series – Feed size vs capacity*

Feed top size mm (inch: Divide by 25)

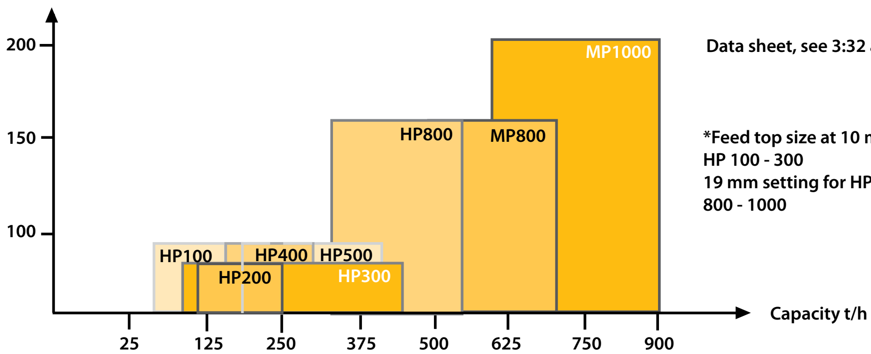


Data sheet, see 3:33

*Feed top size at minimum setting 10 mm and coarse liner profile

Tertiary cone crushers – HP and MP* series – Feed size vs capacity*

Feed top size mm (inch: Divide by 25)

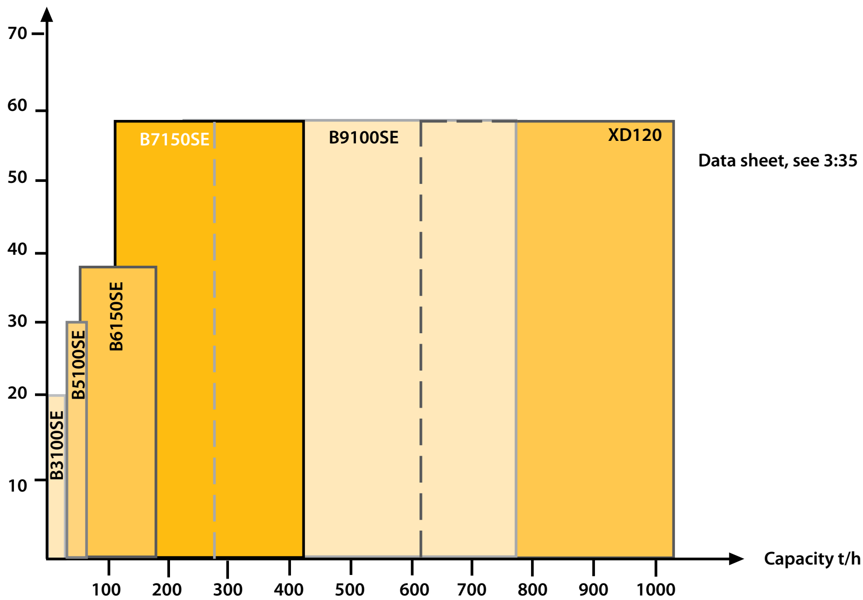


Data sheet, see 3:32 and 3:34

*Feed top size at 10 mm setting for HP 100 - 300
19 mm setting for HP 400 - 800, MP 800 - 1000

VSI crusher – Feed size vs capacity

Feed top size mm (inch: Divide by 25)



Data sheet, see 3:35

Wet crushing prior to grinding

WaterFlush is a patented wet crushing process for producing a flakier finer product from specially designed cone crushers. The method is intended for mining applications comprising secondary crushing, sand manufacturing and fine crushing of ore prior to leaching. The typically crusher discharge is a slurry of 30 to 70% solids. The flakier feed brakes easily in the following grinding mill. WaterFlush can be an alternative to conventional crushing prior to grinding in applications with critical-size-build-up problems in the grinding circuits of type AG/SAG and Pebble mill, see grinding next page.

Performance range:

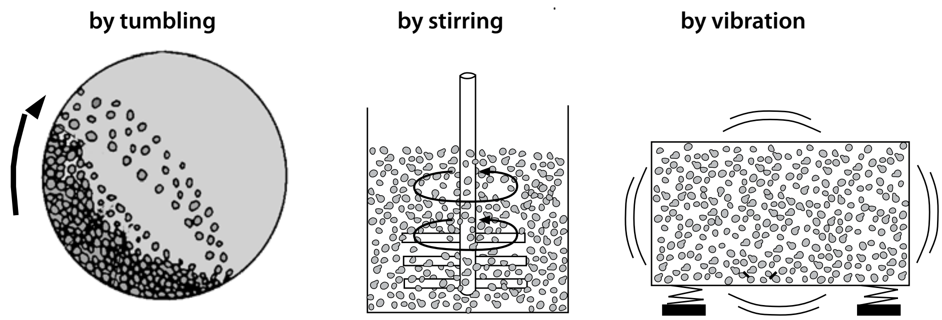
Model	TPH	kW/hp installed	Red. ratio (max)
WF 200	20-60	125/168	7.0
WF 300	60-100	200/268	7.0
WF 400	90-120	300/400	8.5
WF 500	120-150	350/470	8.5
WF 800	300-350	500/670	8.5
WF 900	400-500	650/872	8.5

Grinding – Introduction

Size reduction by crushing has a size limitation for the final products. If we require further reduction, say below 5-20mm, we have to use the processes of grinding Grinding is a **powdering or pulverizing** process using the rock mechanical forces of impaction, compression, shearing and attrition.
The two main purposes for a grinding process are:

- *To liberate individual minerals trapped in rock crystals (ores) and thereby open up for a subsequent enrichment in the form of separation.*
- *To produce fines (or filler) from mineral fractions by increasing the specific surface.*

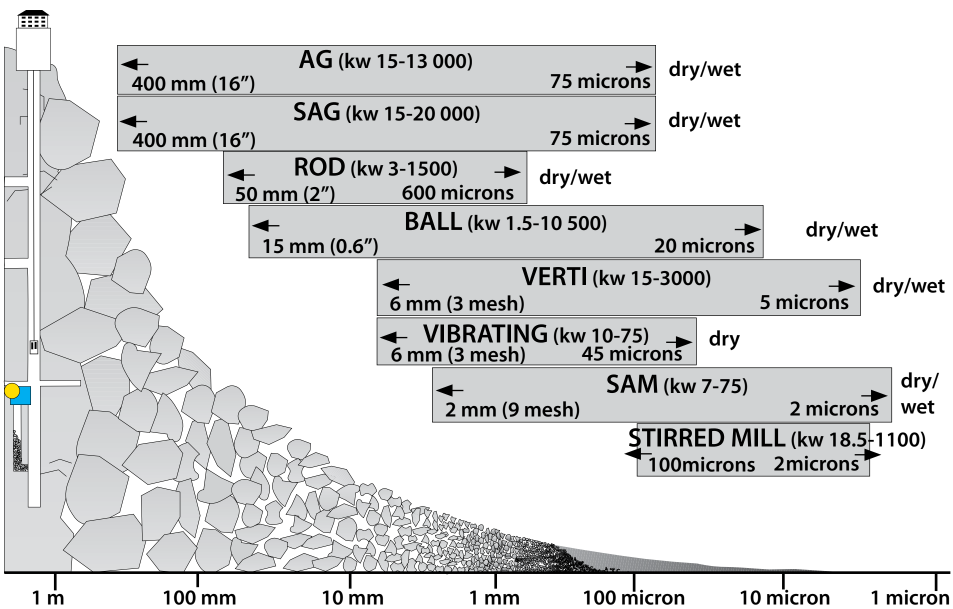
Grinding methods



Grinding mills – Reduction ratios

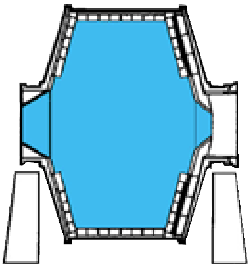
All crushers including impactors have limited reduction ratios. Due to the design there is a restricting in retention time for the material passing.

In grinding as it takes place in more "open" space, the retention time is longer and can easily be adjusted during operation.
Below the theoretical size reduction and power ranges for different grinding mills are shown. In practise also size reduction by grinding is done in optimised stages.

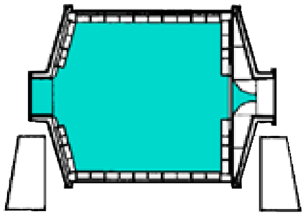


Grinding – Tumbling mills

Autogenous (AG) mill



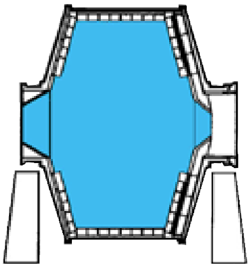
Cascade type US



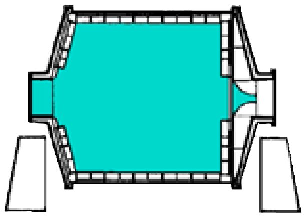
European type

- Wet or dry
- Primary, coarse grinding (up to 400 mm feed size)
- Grinding media is grinding feed
- High capacity (short retention time)
- Sensitive to feed composition (critical size material), Data sheet 3:36

Semi – Autogenous (SAG) mill



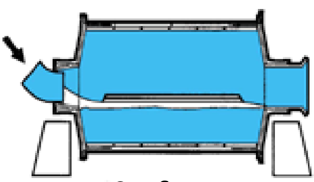
Cascade type US



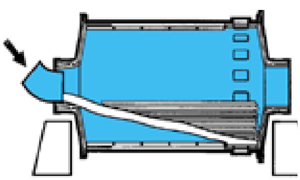
European type

- Wet or dry
- Higher capacity than A-G mill grinding
- Primary, coarse grinding (up to 400 mm feed size)
- Grinding media is grinding feed plus 4-12% ball charge (ball dia.100-125 mm)
- High capacity (short retention time)
- Less sensitive to feed composition (critical size material), see data sheet 3:36

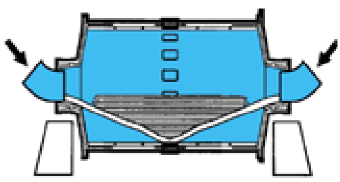
Rod mill



Overflow



End peripheral discharge



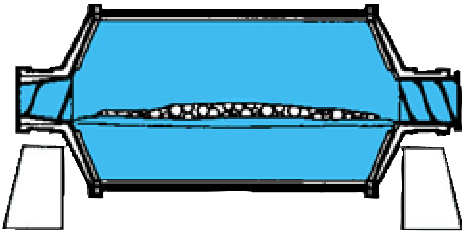
Center peripheral discharge

- Wet only
- Coarse grind
- Primary mill at plant capacities of less than 200t/h
- Coarse grinding with top size control without classification
- Narrow particle size distribution

- Mostly dry
- Coarse grind and high capacity
- Special applications
- End discharge: finer product
- Centre discharge: rapid flow, less fines
- Narrow particle distribution

Note! No grate discharge

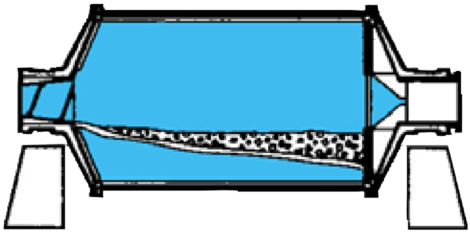
Ball mill



Overflow

- Wet only
- Robust and simple
- Mostly in closed circuit (secondary)
- Finer grind (longer retention time)
- Higher risk for over grinding
- Ball charge 35-45%

Data sheet, see 3:37

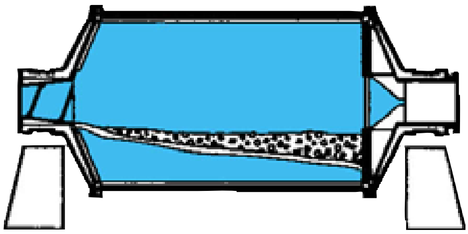


Grate discharge

- Dry or wet
- Discharge end more complicated
- Mostly in closed circuit (secondary)
- Coarser grind (shorter retention time)
- Lower risk for over grinding
- Can take about 5-10% more ball with correspondingly higher through put

Pebble mill

- Wet or dry
- Always grate discharge
- Secondary grinding
- Grinding media:
  - A fraction screened out from feed
  - Flint pebbles
  - Porcelain balls
  - Al_2O_3 balls
- Larger than Ball mills at same power draw

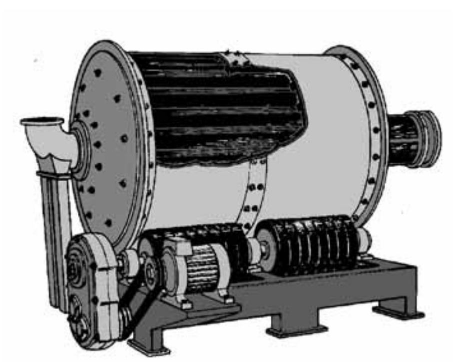


Special tumbling mills

Conical ball mill

- Wet or dry (air swept)
- Overflow or partial grate
- Conical shell for ”graded” ball charge
  and optimal size reduction
- Only available in small and intermediate sizes
- Efficient ”high reduction ratio” grinding

Data sheet, see 3:38



SRR (Rubber roller mill)

- Wet or dry
- Overflow and grate discharge
- Light and fabricated construction
- Ready assembled on steel frame
- Easy to move
- Limited in size (max. dia. 2.4 m)

Data sheet, see 3:39

Grinding – Stirred mills

VERTIMILL®

- Wet grinding only
- Top or bottom feed
- Grinding by attrition/abrasion
- Primary-, regrinding- or lime slaking mill
- Ideal for ”precision” grinding on finer products
- Restriction in feed size (6mm)
- Restriction in size (1119 kW / 3000 hp)
- Ball size max 30mm

Comparison with conventional tumbling mills

- Lower installation cost
- Lower operation cost
- Higher efficiency
- Less floor space
- Simple foundation
- Less noise
- Few moving parts
- Less overgrinding
- Better operation safety

Data sheet, see 3:40 and 3:41

Stirred media grinding mills

Wet Grinding Only

- Open or closed circuit
- Feed size 100 micron and below
- Product size down to 2 micron
- Grinding media:

Silica pebbles and sand, 1 to 9 mm, for coarser grinds down to 10 micron

Silica sand, 0.5 to 1 mm, for finer grinds below 10 micron

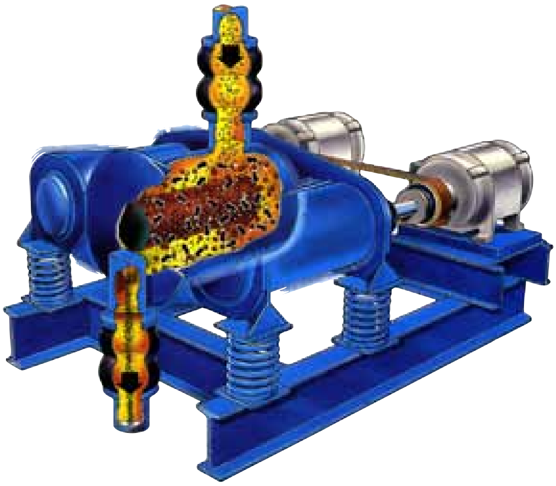
Synthetic media with above size ranges can be used in place of silica sand

Three machine sizes available, with installed powers of 185 kW, 355 kW, and 1100 kW

Data sheet, see 3:42

Grinding – Vibrating mills

Vibrating ball mill



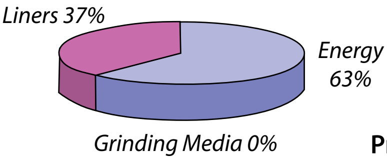
- Wet or dry
- Impact, shearing and attrition
- Open or closed circuit
- Short retention time - less overgrinding
- Feed size, minus 5 mm
- Limited in size (2x37 kW, 2x50 hp)
- High noise level
- Low cost, simple installations

Data sheet, see 3:43

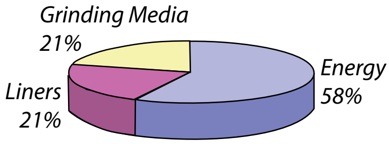
Cost of grinding – Typical

The main costs for grinding are **energy, liners and grinding media**. They are different for different mill types. Below some figures for tumbling mills

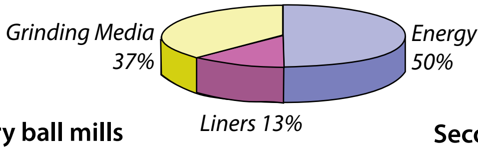
AG mills



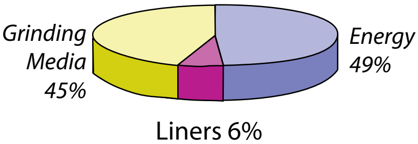
SAG mills



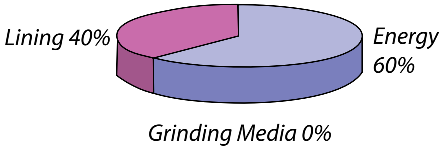
Primary Ball Mills



Secondary ball mills



Secondary pebble mills



Mill linings – Basic

Use **rubber** linings wherever possible due to lifetime, low weight, easy to install and noise dampening.
When application is getting tougher use **steel-capped rubber**, still easier to handle than steel.

When these both options are overruled (by temperature, feed size or chemicals) use **steel.**
Ore-bed is a lining with rubber covered permanent magnets used for special applications like lining of Verti mills, grinding of magnetite a.o, see also Wear in operation, section 9.

Lining components

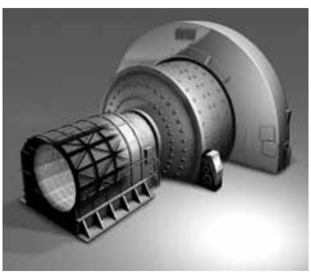
Rubber linings

Poly-Met® linings

Metallic linings

Orebed® linings

Trommel screens



Discharge systems

Grinding mills – Sizing

Even today this is more of an art than a science. Therefore it should be left to the application offices of your supplier for any valid statements or quotes.

Below will be described some basics of how mills are sized, only.

Fundamental to all mill sizing is determining the necessary specific power consumption for the grinding stage (primary, secondary, tertiary etc.) in question.

It can be established (in falling scale of accuracy) in one of the following ways:

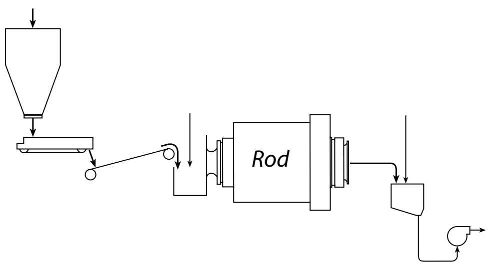
1. Operating data from existing mill circuit (direct proportioning).
2. Grinding tests in pilot scale, where the specific power consumption is determined (kWh/t dry solids).
3. Laboratory tests in small batch mills to determine the specific energy consumption.
4. Energy and power calculations based on Bonds Work Index (called Wi and normally expressed in **kWh/short ton**), see 3:23.
5. Other established methods, for instance Hardgrove Index, population balance.

Scale-up criterion is the net specific power consumption, i.e. the power consumed by the mill rotor itself minus all mechanical and electrical losses divided by the feed rate of solids. For the full scale mill this is then to be multiplied by the feed rate to get the net mill power. This must then be increased by the anticipated mechanical inefficiencies (trunnion and pinion bearing friction, ring gear/pinion friction and possible speed reducer losses) as well as electrical losses, in order to arrive at the gross mill power.

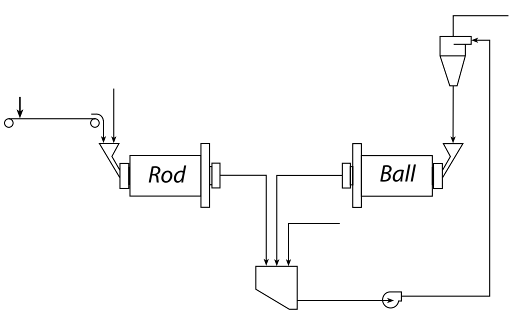
In our labs we can run tests batchwise (in kg scale), or for more critical applications in pilot scale (200-1000 kg/h). The pilot tests are more accurate, but also more expensive.

For all AG or SAG installations such tests are mandatory, since they will tell whether this type of grinding is possible at all, as well as establishing the necessary specific power consumption.

Grinding circuits



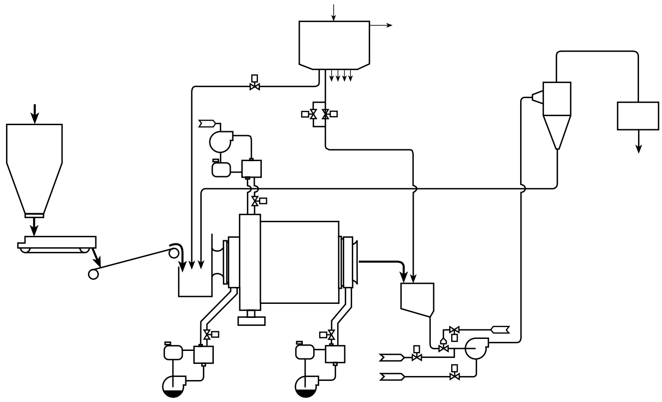
Wet grinding of feed k_{80} 25 - 30 mm (1″ - 1 $^1/_4$″) to product size k_{80} 0.3 mm to 2 mm (8 Mesh - 48 Mesh) in open circuit.



One of the most common flow-sheets for concentrating plants to wet grind - 25 mm (1″) feeds (or finer) to desired product size. Rod mill discharge ab. 1 mm (16 Mesh).

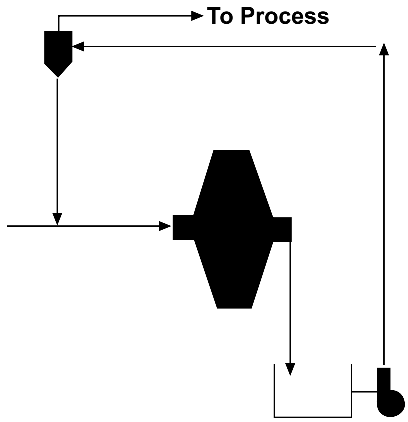
Typical duties: (Single stage ball grinding and single classification circuit)

The most simple and common (although not the most efficient) circuit to wet grind from max. feed sizes of k80 15 mm (5/8") and finer to required product sizes. Tend to produce more slimes than multistage grinds and classifying.



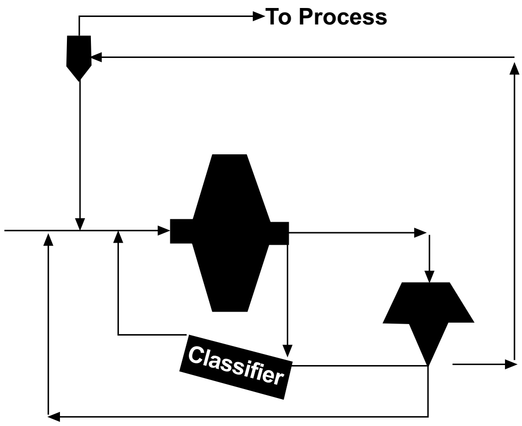
Typical duties: 1. Autogenous-Single stage

For the rare cases where primary AG milling will inherently produce the required product size. (Wet or dry)



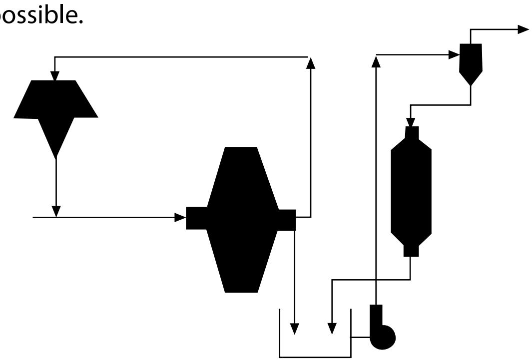
Typical duties: 2. Autogenous + Crusher

For the also not too common cases where critical size pebbles are created and thus inefficient grinding results. With pebble ports in the mill grate and separate crushing of the critical sizes this can be remedied. However, resulting product size must match product requirements. (Wet or dry)



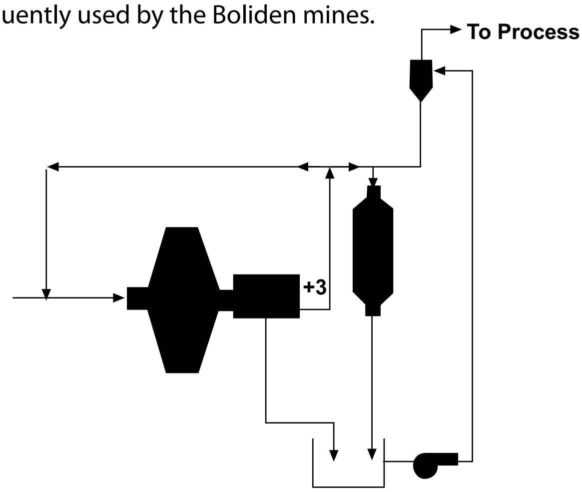
Typical duties: 3. Autogenous + Ball mill + Crusher

This is also called "ABC-circuit" and has a ball mill added in comparision with the above circuit No 2. This can be used to correct a too coarse product from the primary mill, and in this way be more useful and common. Mostly operated wet, but also dry possible.



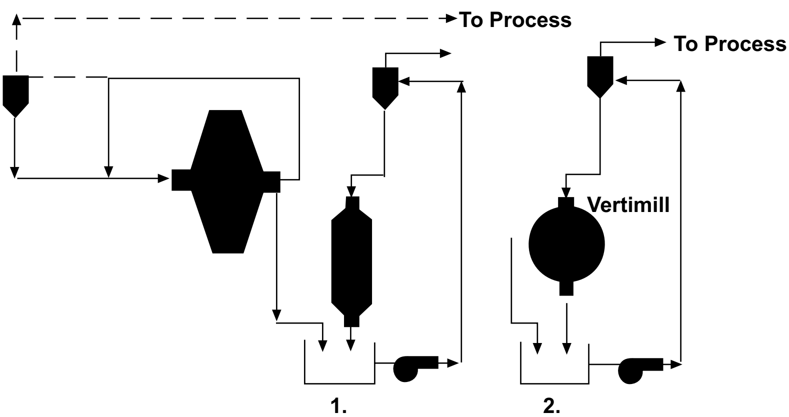
Typical duties: 4. Autogenous + Pebble mill

Two stage AG-grinding with the primary mill in open circuit and the secondary pebble mill in closed circuit. The pebble mill gets competent pebbles screened out from the primary mill discharge as needed (or otherwise recirculated to the primary mill). Frequently used by the Boliden mines.



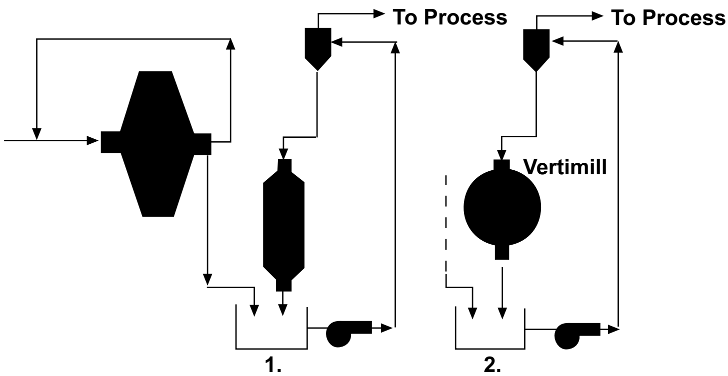
Typical duties: 5. Autogenous + Ball mill / VertiMill

Same as the above, but with the pebble mill replaced by a ball mill or a Vertimill. This is used when there is not enough pebbles available in the circuit, or all-autogenous grinding produces too much fines.



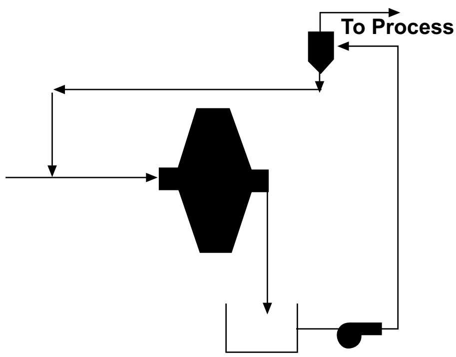
Typical duties: 6. Semi-Autogenous + Ball mill / VertiMill

Same as the above No. 5, but with the primary mill as semi-autogenous, which in most cases means higher capacity for the circuit. Many circuits type No. 5 in the US / Canada have been converted to this circuit.



Typical duties: 7. Semi-autogenous-Single stage

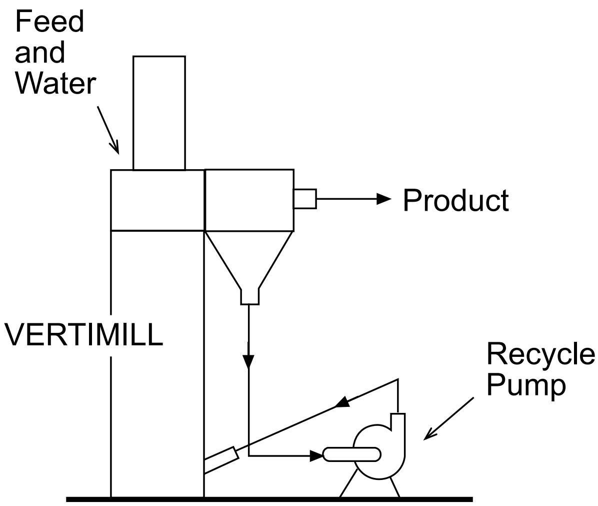
Same as No.1 above, but with the mill as semi-autogenous. This will increase capacity as well as application range, but will also increase wear costs (balls and lining) and still be dependent on "natural" product size being close to the desired. Common circuit in the US and Canada.



VERTIMILL® Circuits

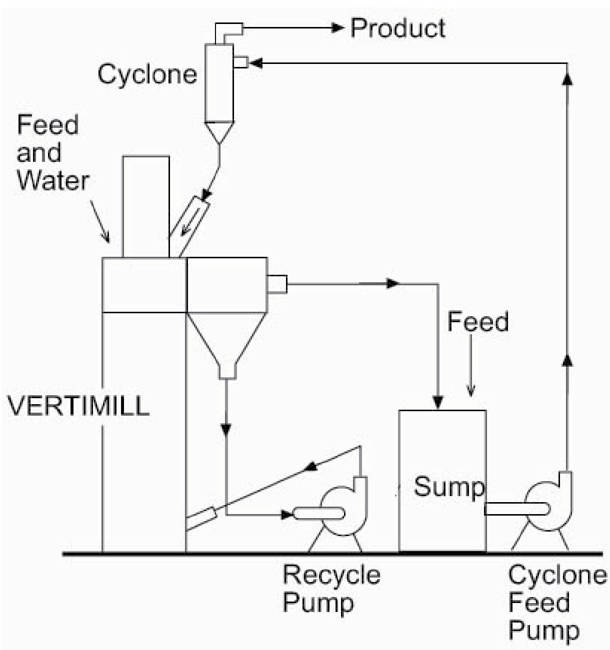
Typical duties: 8. Closed circuit with integral cassifier

For wet circuits with not too fine desired product and/or not stringent limits on coarse end oversize of the product. Max. feed size - 6 mm (1/4")



Typical duties: 9. Closed circuit with cyclone

For wet circuits with fine or very fine product size and more stringent limits for product top size.



Grinding – Power calculation

The basic formula for this is the Bond* formula

W (specific power consumption) = 10 x Wi $(\frac{1}{\sqrt{P}} - \frac{1}{\sqrt{F}})$

with P and F the 80% passing sizes of product and feed in microns and Wi expressed as kWh/sh.t.

Then for P = 100 and F very large, Wi is roughly the same as W, or in other words equal to the specific power consumption to comminute a material from infinite size to k_{80} = 100 microns see below.

* Fred Bond, Allis Chalmers Corp.

Grinding - Bonds Work Index*

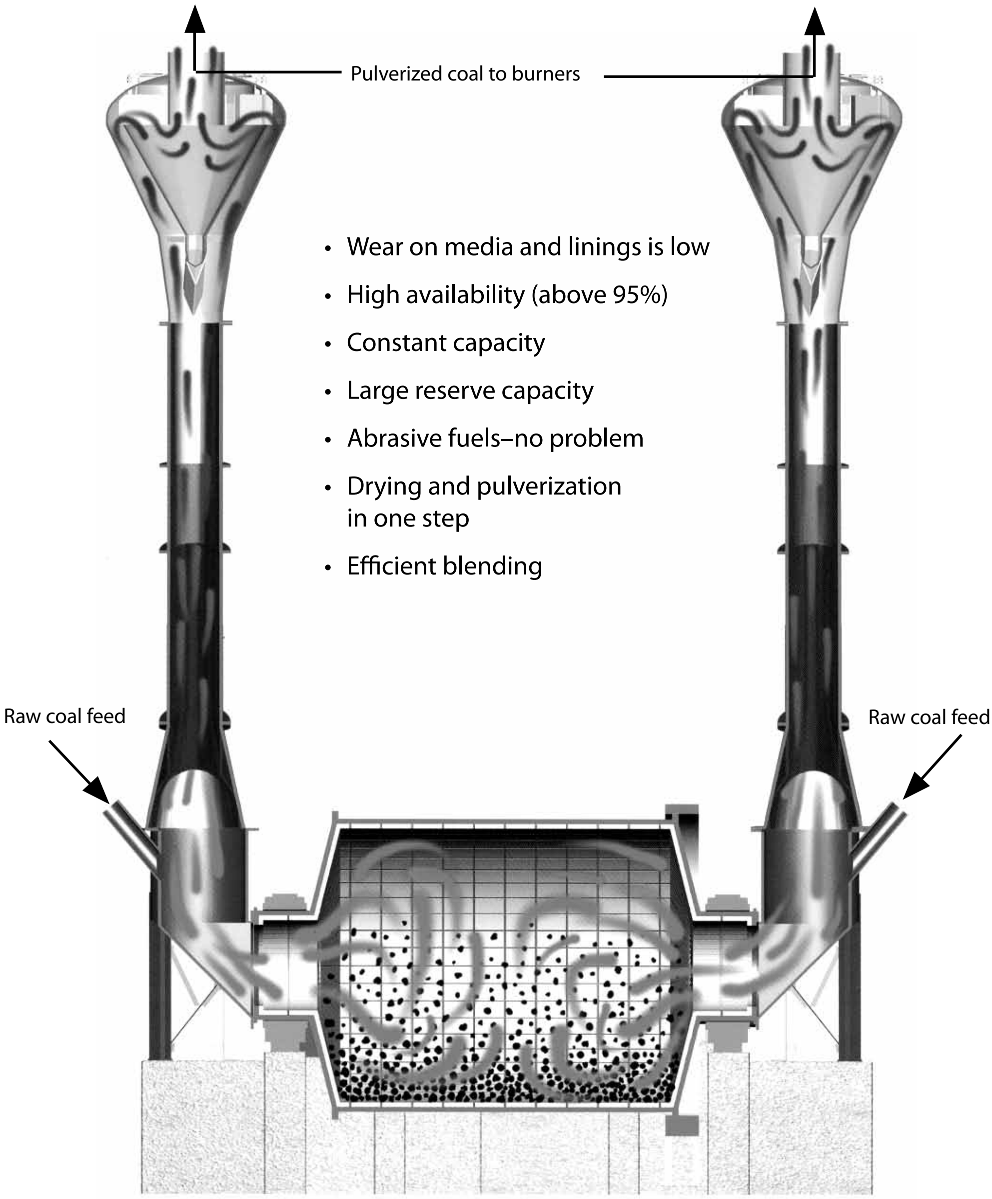
Solids [kWh/sh.ton]	Wi
Andesite	18.25
Barite	4.73
Basalt	17.10
Bauxite	8.78
Cement clinker	13.45
Cement raw material	10.51
Clay	6.30
Coal	13.00
Coke	15.13
Copper ore	12.72
Diorite	20.90
Dolomite	11.27
Emery	56.70
Feldspar	10.80
Ferro-chrome	7.64
Ferro-manganese	8.30
Ferro-silicon	10.01
Flint	26.16
Fluorspar	8.91
Gabbro	18.45
Glass	12.31
Gneiss	20.13
Gold ore	14.93
Granite	15.13
Graphite	43.56
Gravel	16.06
Gypsum rock	6.73
Hematite	12.84

These values are not constant and must be used accordingly!

Solids [kWh/sh.ton]	Wi
Magnetite	9.97
Taconite	14.61
Lead ore	11.90
Lead-zinc ore	10.93
Limestone	12.74
Manganese ore	12.20
Magnesite	11.13
Molybdenum	12.80
Nickel ore	13.65
Oil shale	15.84
Phosphate rock	9.92
Potash ore	8.05
Pyrite ore	8.93
Pyrrhotite ore	9.57
Quartzite	9.58
Quartz	13.57
Rutile ore	12.68
Shale	15.87
Silica sand	14.10
Silicon carbide	25.87
Slag	10.24
Slate	14.30
Sodium silicate	13.40
Spodumene ore	10.37
Syenite	13.13
Tin ore	10.90
Titanium ore	12.33
Trap rock	19.32
Zinc ore	11.56

Pulverizing of coal

Coal pulverizing is an important application for grinding mills (ball mill type) and the advantages of using tumbling grinding are many.



- Wear on media and linings is low
- High availability (above 95%)
- Constant capacity
- Large reserve capacity
- Abrasive fuels–no problem
- Drying and pulverization in one step
- Efficient blending

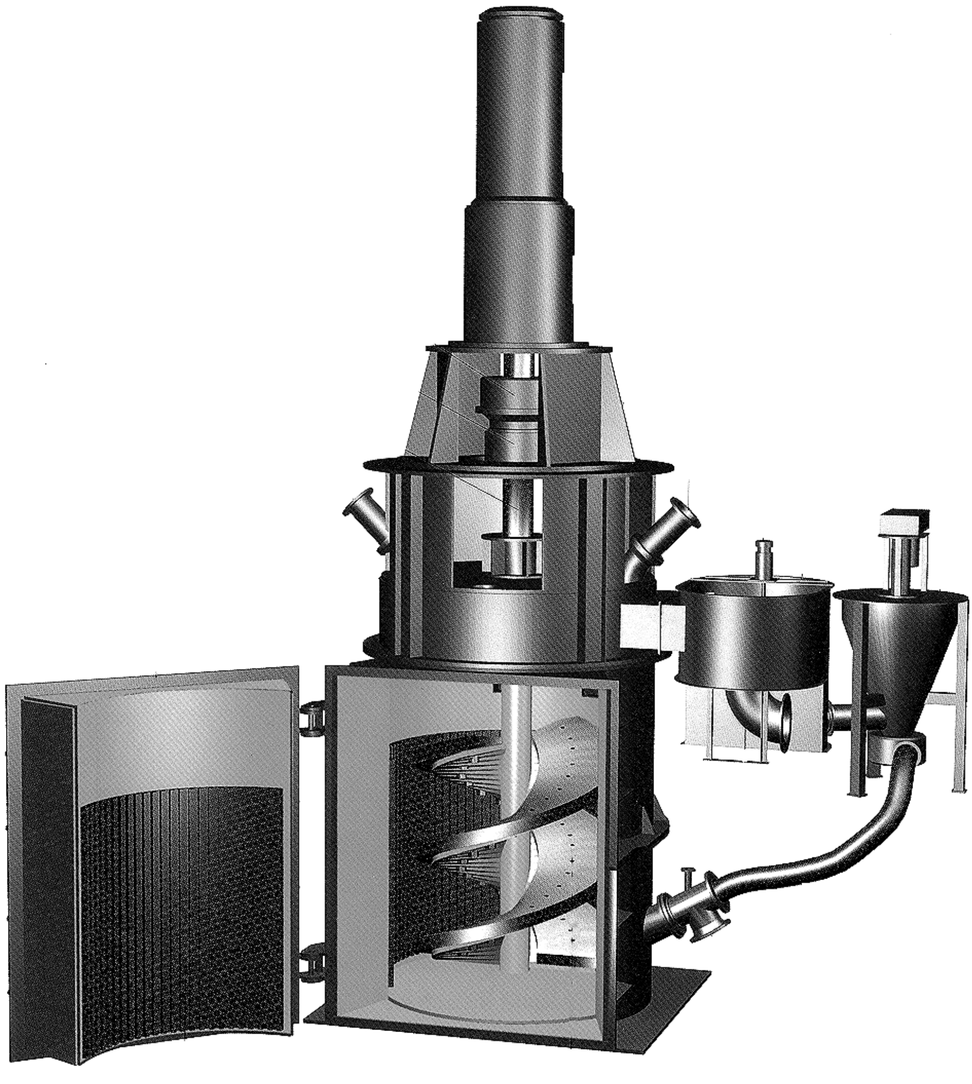
Double Ended, Air-Swept Ball Mill System

Typical capacities (feed moisture 8%)

Mill size m	ft	Coal flow (mtph)	Motor power kW/hp
3.8x5.8	12.5x19	42	820/1 100
4.0x6.1	13x20	50	969/1 300
4.3x6.4	14x21	62	1193/1 600
4.7x7.0	15.5x23	82	1640/2 200
5.0x7.7	16.5x25	110	2237/3 000
5.5x8.2	18x27	141	2760/3 700

VERTIMILL® – More than a grinding mill

The VERTIMILL® grinding mill is considered to be an "intelligent" grinding concept giving an energy saving and controlled process of size reduction. For comparison with tumbling mills, see 3:15.



Mineral applications

- Fine / Ultra fine grinding
- Primary grinding
- Secondary grinding
- "In circuit" regrinding of concentrates

FGD applications

- Fine grinding of lime stone
- Lime slaking, see next page

Fuel preparation

- Clean coal
- Coal / water
- Coal / oil

VERTIMILL® as lime slaker

The VERTIMILL® is an excellent lime slaker producing an optimal product in a simple one-step operation.

Typical operation conditions:

Material	Pebble lime with approximately 5 % grit
Feed size	minus 25mm (1”)
Product size	90-95% passing 45 micron (325 Mesh)
Percent solids (product)	20-26%
Temperature inside mill (product)	50-70 °C (130-160°F)

Capacities vs mill sizes

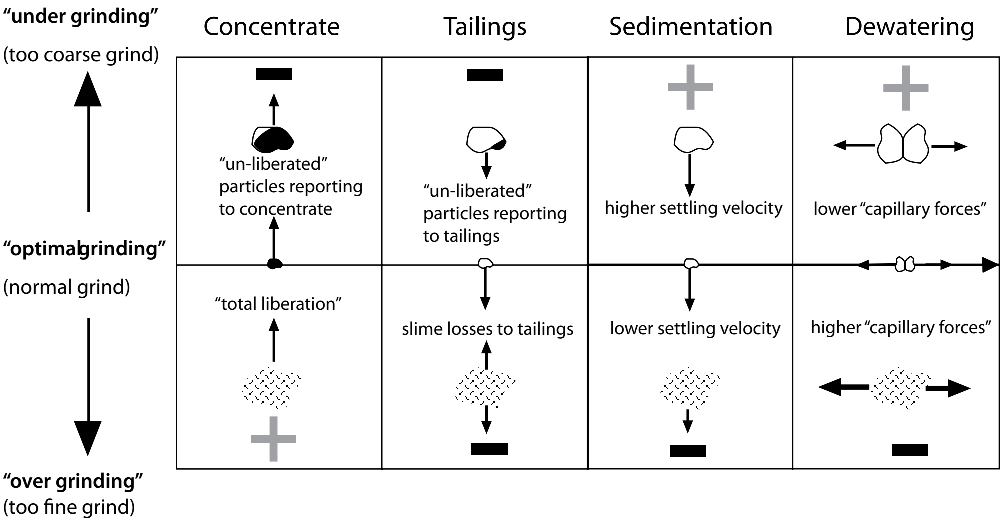
Mtph CaO	Stph CaO	Mill unit	Motor kW	Motorhp
1.4	1.5	VTM-10-LS	7.5	10
2.7	3.0	VTM-20-LS	14.9	20
3.7	4.1	VTM-30-LS	22.4	30
5.3	5.8	VTM-50-LS	37.3	50
6.6	7.3	VTM-100-LS	44.7	60
12.0	13.2	VTM-150-LS	74.6	100
13.9	15.3	VTM-200-LS	111.9	150
18.7	20.6	VTM-300-LS	149.1	200
30.0	33.0	VTM-400-LS	223.7	300

Grinding vs enrichment and upgrading

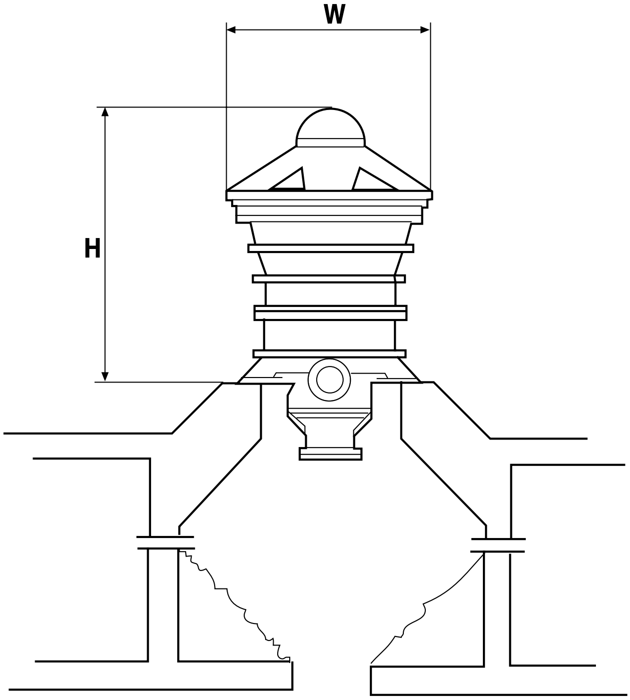
In the size reduction stages of grinding we are also creating the conditions for the following process stages of enrichment and upgrading.

From the picture below we can see the effect of “under- and over grinding”.

The lost performance in separation, sedimentation and dewatering due to “mis-grinding” represents a major problem for many operations, eroding the process economy.

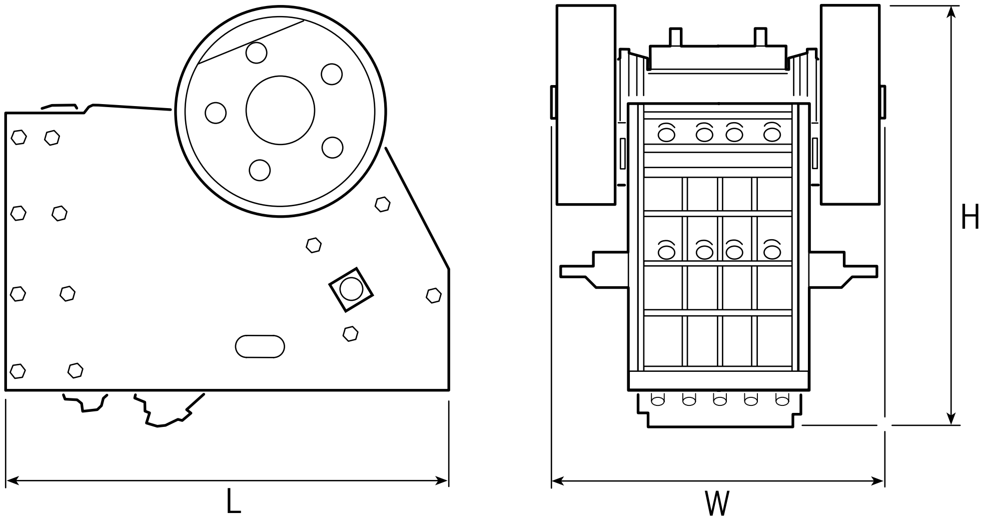


Gyratory crusher - SUPERIOR® MK-II Primary



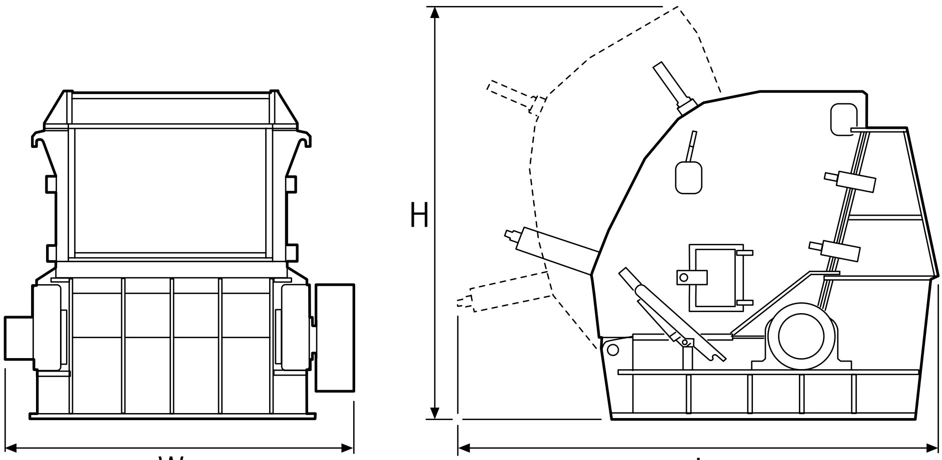
Type	H mm (inch)	W mm (inch) mt (U.S. t)	Weight kW (Hp)	Max. power
42-65	4 807 (189)	3 937 (155)	119.4 (131.7)	375 (500)
50-65	5 513 (217)	4 458 (176)	145.4 (160.2)	375 (500)
54-75	5 693 (224)	4 928 (194)	242.2 (267.0)	450 (600)
62-75	6 633 (261)	5 574 (219)	302.5 (333.4)	450 (600)
60-89	7 169 (282)	5 588 (220)	387.4 (427.0)	600 (800)
60-110	7 906 (311)	6 299 (248)	588.1 (648.3)	1 000 (1 400)

Jaw crusher – C series



Type	H mm (inch)	L mm (inch)	W mm (inch)	Weight US (ton)	kW/Hp Max. power
C 63	1 600 (63)	1 950 (77)	1 390 (55)	6.05	45/60
C 80	1 700 (67)	2 020 (80)	1 565 (62)	7.52	75/100
C 100	2 400 (95)	2 880 (113)	2 250 (89)	20.10	110/150
C 105	2 050 (81)	2 630 (104)	1 920 (76)	13.50	110/150
C 110	2 670 (105)	2 830 (112)	2 385 (94)	25.06	160/200
C 125	2 900 (114)	3 370 (133)	2 690 (106)	36.70	160/200
C 140	3 060 (121)	3 645 (144)	2 890 (114)	45.30	200/250
C 145	3 330 (131)	3 855 (152)	2 870 (113)	53.80	200/250
C 160	3 550 (140)	4 200 (165)	3 180 (125)	68.60	250/300
C 200	4 220 (166)	4 870 (192)	3 890 (153)	118.40	400/500
C 3055	2 400 (95)	2 920 (115)	2 550 (100)	25.50	160/200

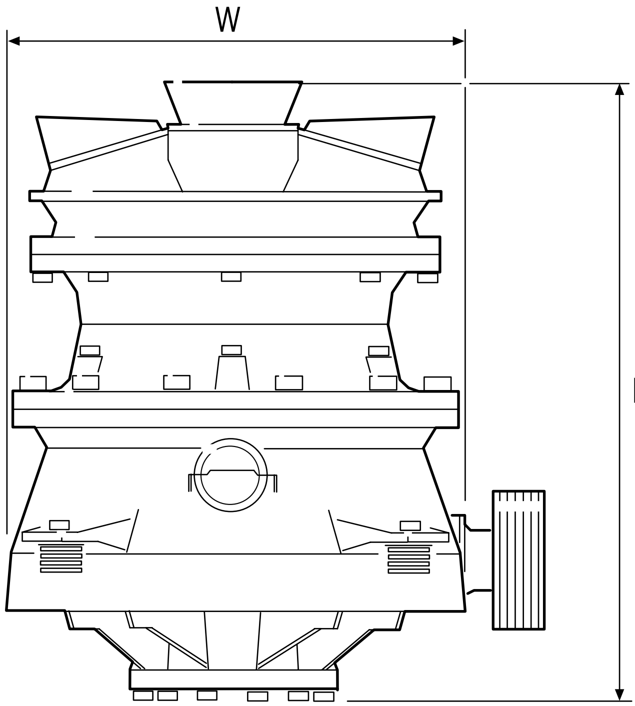
Impact crusher – NP series



Type	H mm (inch)	L mm (inch)	W mm (inch)	Weight US ton	kW/Hp Max. power
NP* 1007	2 647 (104)	3 473 (137	1 804 (71)	7.24	90/125
NP 1110	2 716 (107)	3 487 (137)	2 106 (83)	9.25	160/200
NP1213	2 882 (114)	3 875 (153)	2 529 (100)	12.60	200/300
NP1315	3 055 (120)	4 030 (159)	2 750 (108)	16.13	250/350
NP1520	3 540 (139)	4 703 (186)	3 400 (134)	27.10	400/500
NP 1210	3 167 (125)	3 058 (120)	2 126 (88)	12.8	160/220
NP 1313	3 405 (134)	3 396 (134)	2 560 (101)	17.8	200/250
NP 1415	3 600 (142)	3 395 (134)	2 790 (110)	21.8	250/350
NP 1620	4 400 (173)	3 935 (155)	3 600 (142)	40.5	400/600
NP 2023	5 700 (224)	5 040 (198)	4 330 (171)	74.2	1 000/1 200

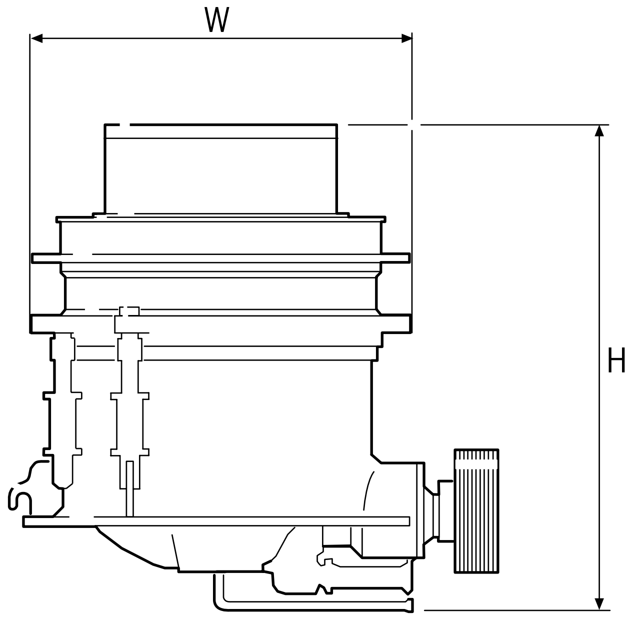
*NP 1007 = Rotor size 1000 x 700 mm (40 x 28″)
All rotors with 4 hammers

Cone crusher – GPS series



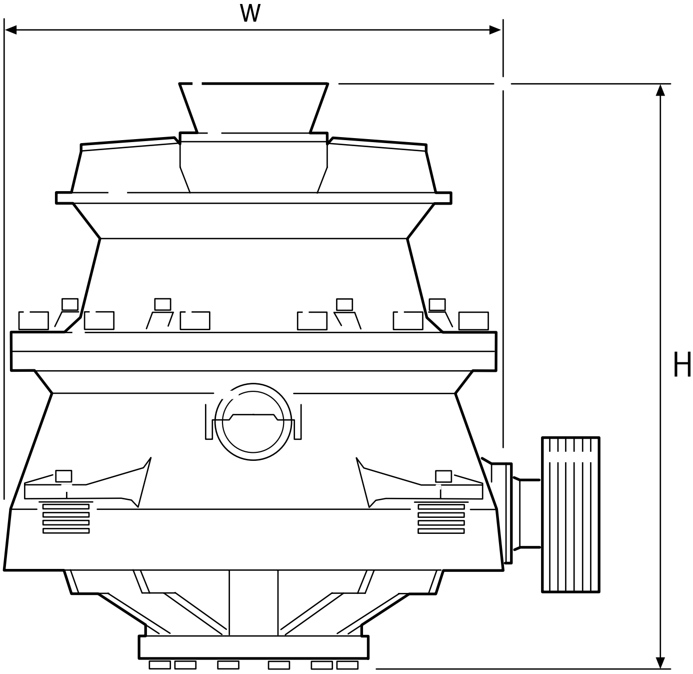
Type	H mm (inch)	W/L mm (inch)	Weight US ton	kW/Hp Max. power
GP100S	2 328 (92)	1 300 (51)	7.5	90/125
GP200S	2 461 (97)	1 745 (69)	10.6	160/250
GP300S	2 546 (100)	1 858 (73)	16.0	250/350
GP500S	3 227 (127)	2 300 (91)	32.0	315/400

Cone crusher – HP series



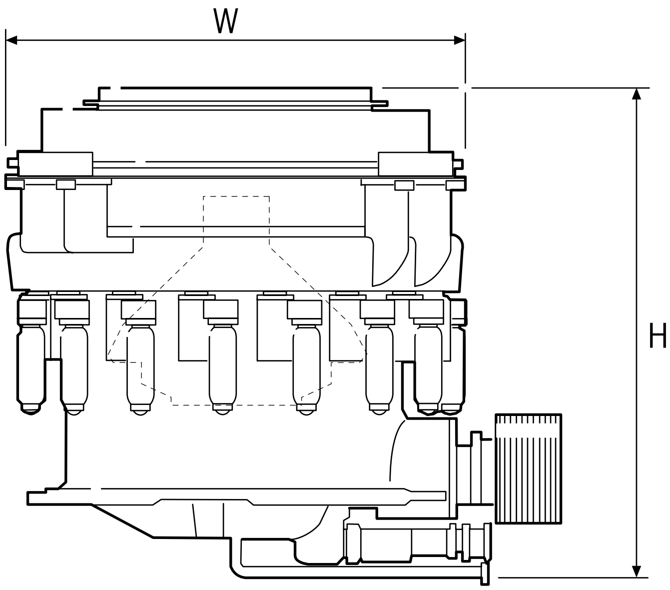
Type	H mm (inch)	W mm (inch)	Weight mt (U.S. t)	Max. power kW (Hp)
HP 100	1 583 (62)	1 505 (59)	4.9 (5.4)	90 (125)
HP 200	1 927 (76)	1 952 (77)	9.4 (10.4)	132 (200)
HP 300	2 193 (86)	2 207 (87)	14.3 (15.8)	220 (300)
HP 400	2 295 (90)	2 370 (93)	20.8 (23.0)	315 (400)
HP 500	2 715 (107)	2 730 (108)	30.1 (33.2)	355 (500)
HP 800	4 057 (160)	3 490 (137)	68.7 (75.7)	600 (800)

Cone crusher – GP series



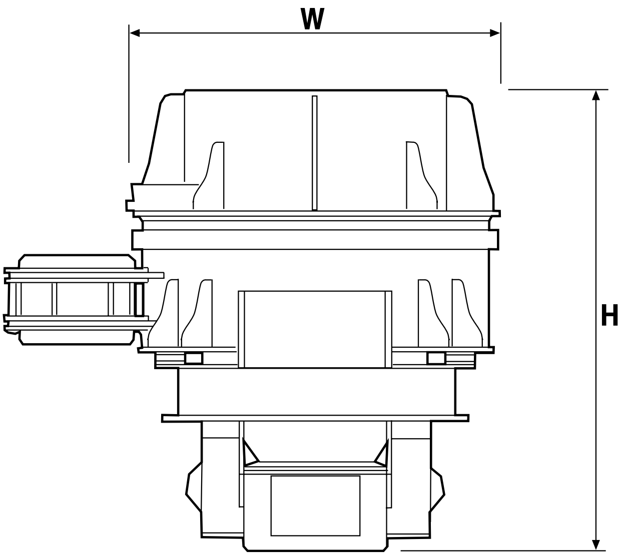
Type	H mm (inch)	W/L mm (inch)	Weight US ton	kW/Hp Max. power
GP100	2 038 (80)	1 300 (51)	5.7	90/124
GP200	2 230 (84)	1 735 (68)	9.1	110/160
GP300	2 181 (86)	1 860 (73)	13.1	250/300
GP500	2 573 (101)	2 240 (88)	23.3	300/400

Cone crusher – MP series



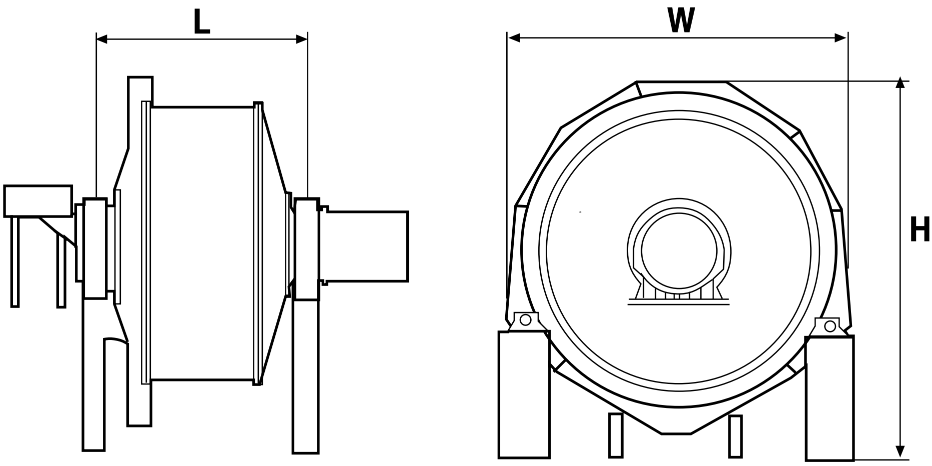
Type	H mm (inch)	W mm (inch)	Weight mt (U.S. t)	Max. power kW (Hp)
MP800	4 622 (182)	4 550 (179)	120.6 (132.9)	600 (800)
MP1000	4 540 (179)	5 360 (211)	153.1 (168.8)	750 (1 000)

Vertical shaft impactor (VSI)



Type	H mm (inch)	W mm (inch)	Weight US ton	kW/Hp Max. power
B3100SE	1 171 (46)	940 (37)	1.0	15/20
B5100SE	1 705 (67)	1 435 (56)	2.8	55/75
B6150SE	2 189 (86)	1 870 (74)	5.0	150/20
B7150SE	2 464 (97)	2 220 (87)	10.6	300/400
B9100SE	2 813 (111)	2 434 (96)	13.2	600/800
XD120	4 211 (166)	3 110 (122)	23.4	800/1075

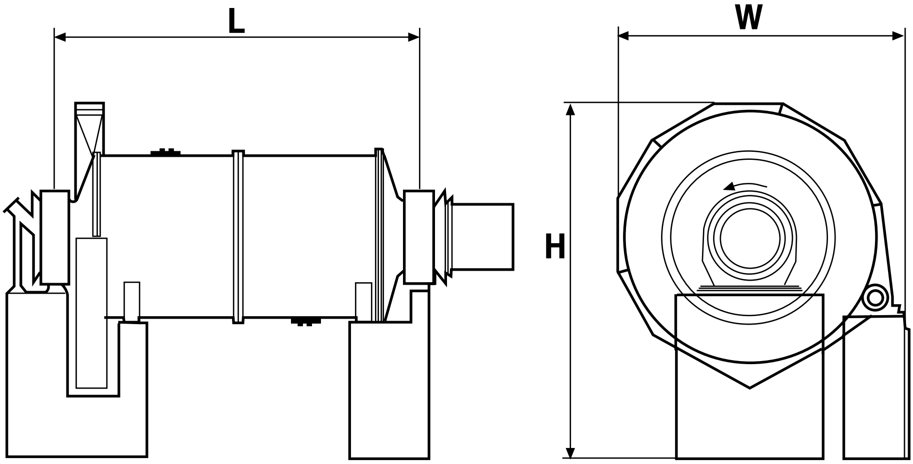
AG and SAG mills



Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power (motor) kW/Hp
Single drive				
5.5x2.4 (18x8)	9 000 (354)	4 445 (175)	7 670 (302)	650 - 900/900 - 1 250
6.1x2.4 (20x8)	9 880 (389)	4 620 (182)	8 400 (331)	930 - 1 300/1 250 - 1750
6.4x3.0 (21x10)	10 600 (416)	5 600 (222)	9 000 (354)	1 300 - 1 800/1 750 - 2 500
6.7x3.0 (22x10)	10 500 (414)	5 500 (217)	9 150 (360)	1 490 - 2 200/2 000 - 3 000
7.3x3.0 (24x10)	11 500 (452)	5 900 (232)	10 100 (398)	1 800 - 2 600/2 500 - 3 500
7.9x3.0 (26x10)	11 800 (466)	5 900 (232)	drive dep.	2 200 - 3 400/3 000 - 4 500
8.5x3.0 (28x10)	12 400 (488)	6 050 (238)	drive dep.	2 600 - 4 100/3 500 - 5 500
8.5x4.3 (28x14)	13 300 (525)	7 400 (292)	drive dep.	3 700 - 5 600/5 000 - 7 500
9.0x3.7 (30x12)	13 600 (536)	7 010 (276)	drive dep.	3 700 - 5 600/5 000 - 7 500
Dual drive				
9.8x4.3 (32x14)	13 650 (538)	7 800 (308)	12 700 (500)	7 400 - 8 200/10 000 - 11 000
9.8x4.9 (32x16)	13 650 (538)	8 450 (333	12 700 (500)	6 700 - 9 700/9 000 - 13 000
10.4x4.6 (34x15)	13 900 (548)	8 200 (323)	13 000 (512)	6 700 - 10 440/9 000 - 14 000
10.4x5.2 (34x17)	13 970 (550)	8 790 (346)	13 200 (520)	7 400 - 11 900/10 000 - 16 000
10.4x5.8 (34x19)	14 700 (580)	9 400 (371)	13 900 (550)	8 900 - 13 400/12 000 - 18 000
11.0x4.6 (36x15)	15 060 (593)	8 350 (329)	13 900 (550)	7 400 - 11 900/10 000 - 16 000
11.0x5.2 (36x17)	15 060 (593)	9 060 (357)	13 900 (550)	8 900 - 13 400/12 000 - 18 000
11.0 - 5.8 (36x19)	15 060 (593)	9 700 (382)	13 900 (550)	10 400 - 14 900/14 000 - 20 000
Ring motor drive (SAG only)				
11.0x5.2 (36x17)	17 400 (686)*	9 340 (368)	11 000 (432)	11 900/16 000
11.6x6.1 (38x20)	18 400 (724)*	10 400 (410)	11 600 (456)	14 900/20 000
12.2x6.7 (40x22)	19 400 (763)*	10 700 (420)	12 200 (480)	18 600/25 000
12.8x7.3 (42x24)	20 300 (800)*	11 700 (460)	12 800 (50)	23 000/31 000

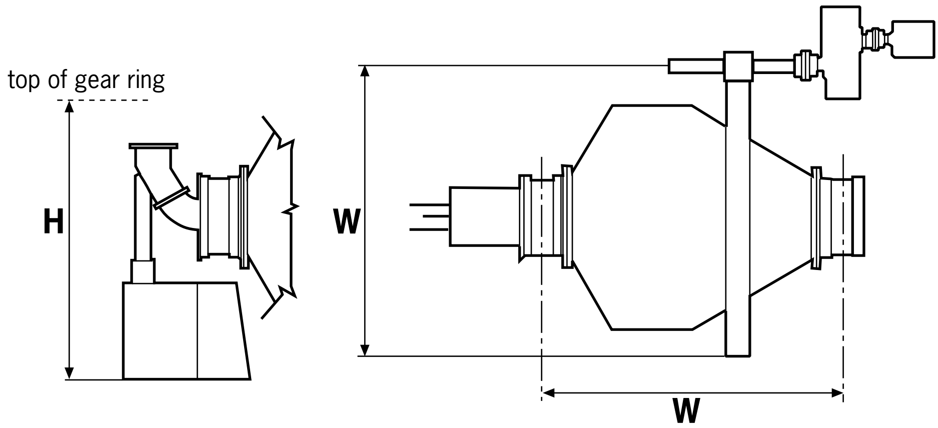
* From floor to top of motor housing

Ball mill



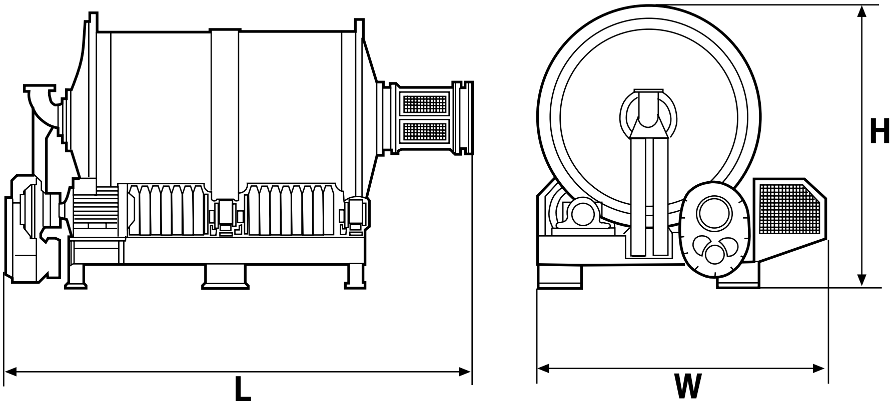
Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp
2.4x3.0 (8x10)	4 670 (184)	4 480 (176)	3 860 (152)	224/300
2.4x 3.7 (8x12)	4 670 (184)	5 050 (199)	3 860 (152)	260/350
2.4x4.3 (8x14)	4 670 (184)	5 660 (223)	3 960 (156)	298/400
2.7x3.7 (9x12)	5 180 (204)	5 050 (199)	3 960 (156)	336/450
2.7x 4.3 (9x14)	5 330 (210)	5 660 (223)	4 270 (168)	373/500
2.9x4.6 (9.5x15)	5 530 (218)	6 170 (243)	4 370 (172)	447/600
3.0x4.6 (10x15)	6 170 (243)	6 240 (246)	5 020 (198)	522/700
3.2x4.6 (10.5x15)	6 500 (256)	6 320 (249)	5 390 (212)	597/800
3.2x 5.2 (10.5x17)	6 500 (256)	6 930 (273)	5 390 (212)	671/900
3.4x5.2 (11x17)	6 190 (244)	6 830 (269)	5 200 (205)	746/1 000
3.5x5.5 (11.5x1)	6 380 (251)	7 140 (281)	5 360 (211)	983/1 250
4.0x5.2 (13x17)	7 160 (282)	7 030 (277)	6 200 (244)	1 119/1 500
4.0x5.8 (13x19)	7 160 (282)	7 600 (299)	6 200 (244)	1 305/1 750
4.3x5.5 (14x18)	7 620 (300)	7 510 (296)	6 600 (260)	1 491/2 000
4.3x 6.0 (14x20)	7 620 (300)	8 120 (320)	6 600 (260)	1 529/2 250
4.6x5.8 (15x19)	8 180 (322)	7 950 (313)	7 110 (280)	1 864/2 500
4.6x6.4 (15.5x21)	8 690 (342)	8 560 (337)	7 650 (301)	2 237/3 000
5.0x6.4 (16.5x21)	8 840 (348)	8 890 (350)	7 820 (308)	2 610/3 500
5.0x7.3 (16.5x24)	8 840 (348)	9 800 (386)	7 820 (308)	2 983/4 000
5.0x8.2 (16.5x27)	9 530 (375)	10 500(414)	8 480 (334)	3 356/4 500
5.0x9.1 (16.5x30)	9 600 (378)	11 650(459)	8 560 (337)	3 728/5 000
5.0x10.0 (16.5x33)	9 600 (378)	12 570(495)	8 560 (337)	4 101/5 500
5.5x8.8 (18x29)	10 010 (398)	11 600(457)	9 040 (356)	4 474/6 000
5.5x9.6 (18x31.5)	10 090 (430)	12 570(495)	9 980 (389)	4 847/6 500
5.5x10.2 (18x33)	11 600 (456)	13 180(519)	10 440(411)	5 220/7 000
6.0x9.6 (20x31.5)	12 300 (484)	12 700(500)	10 800(425)	5 966/8 000
6.0x10.2 (20x33.5)	12 300 (484)	13 300(524)	10 800(425)	6 711/9 000

Conical ball mill



Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp
1.5x0.5 (5x1.8)	2 430 (96)	2 160 (85)	1 900 (75)	22/30
1.5x0.9 (5x3)	2 430 (96)	2 510 (99)	1 900 (75)	30/40
1.8x0.5 (6x1.8)	2 740 (108)	2 510 (99)	2 570 (101)	37/50
1.8x0.9 (6x3)	2 740 (108)	2 870 (113)	2 570 (101)	45/60
1.8x1.2 (6x4)	2 740 (108)	3 120 (123)	2 570 (101)	56/75
2.1x0.9 (7x3)	3 250 (128)	3 200 (126)	2 950 (116)	75/100
2.1x1.2 (7x4)	3 250 (128)	3 500 (138)	2 950 (116)	93/125
2.1x1.5 (7x5)	3 250 (128)	3 810 (150)	2 950 (116)	112/150
2.4x0.9 (8x3)	3 350 (132)	3 430 (135)	3 200 (126)	112/150
2.4x1.2 (8x4)	3 350 (132)	3 730 (147)	3 200 (126)	130/175
2.4x1.5 (8x5)	3 350 (132)	4 040 (159)	3 200 (126)	150/200
2.4x1.8 (8x6)	3 350 (132)	4 340 (171)	3 200 (126)	186/250
2.7x1.5 (9x5)	3 960 (156)	4 270 (168)	3 660 (144)	224/300
3.0x1.2 (10x4)	4 360 (168)	3 810 (150)	3 660 (144)	260/350
3.0x 1.7 (10x5.5)	4 360 (168)	4 110 (162)	3 860 (152)	300/400
3.0x1.8 (10x6)	4 360 (168)	4 420 (174)	3 860 (152)	336/450
3.0x2.1 (10x7)	4 360 (168)	4 720 (186)	3 860 (152)	373/500

SRR mill



SRR Ball mill Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
0.6x0.9 (2x3)	1 110 (44)	1 830 (72)	1 220 (48)	2.2/3	0.9
1.0x1.5 (3.3x5)	1 635 (64)	2 700 (106)	1 850 (73)	11/15	2.4
1.2x2.4 (4x8)	1 970 (78)	3 670 (144)	2 740 (108)	30/40	5.6
1.5x3.0 (3.3x6.6)	2 255 (89)	4 550 (179)	3 150 (124)	75/100	9.2
1.8x3.6 (6x12)	2 660 (105)	5 560 (219)	3 500 (138)	132/177	12.8
2.1x3.6 (7x12)	3 150 (124)	5 830 (230)	4 400 (173)	132+75/	22.0
				177+100 *	

SRR Rod mill Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
0.6x0.9 (2x3)	1 110 (44)	1 830 (72)	1 220 (48)	2.2/3	1.0
1.0x1.5 (3.3x5)	1 635 (64)	2 700 (106)	1 850 (73)	11/15	3.0
1.2x2.4 (4x 8)	1 970 (78)	3 670 (144)	2 740 (108)	30/40	6.2
1.5x3.0 (3.3x6.6)	2 255 (89)	4 550 (179)	3 150 (124)	75/100	10.0
1.8x3.6 (6x12)	2 790 (110)	5 600 (220)	3 900 (154)	55+55/	14.5
			74+74*		

**Dual drive*

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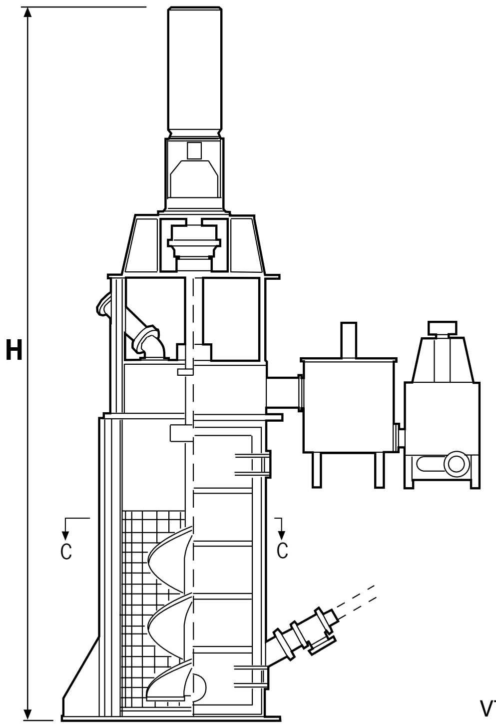
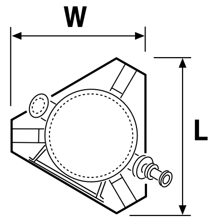
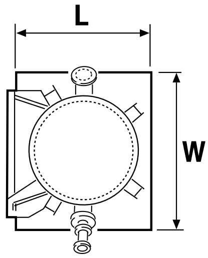
Type WB (**W**et grinding – **B** design) is larger in diameter, but also have larger diameter, screw turning at lower speed and shorter overall height compared with the LS type. They are designed to operate at full motor power. Orebed lining.

Regarding type LS (Lime Slaking) for size reduction and slaking of lime, see 3:41





SECTION C-C
VTM-15-WB – VTM-500-WB



SECTION C-C
VTM-650-WB – VTM-1250-WB

Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
VTM-15-WB	7 060 (278)	1 520 (60)	1 320 (52)	11/15	5.5
VTM-20-WB	7 180 (283)	1 520 (60)	1 320 (52)	15/20	5.9
VTM-40-WB	7 460 (294)	1 780 (70)	1 520 (60)	3040	8.2
VTM-60-WB	7 600 (299)	1 780 (70)	1 520 (60)	45/60	8.8
VTM-75-WB	7 900 (311)	1 960 (77)	1 700 (67)	56/75	12.5
VTM-125-WB	9 270 (365)	2 670 (105)	2 310 (91)	93/125	17.9
VTM-150-WB	9 780 (385)	2 670 (105)	2 310 (91)	112/150	19.6
VTM-200-WB	9 780 (385)	2 670 (105)	2 310 (91)	150/200	20.5
VTM-250-WB	9 650 (380)	3 660 (144)	3 180 (125)	186/250	33.8
VTM-300-WB	9 650 (380)	3 660 (144)	3 180 (125)	224/300	35.7
VTM-400-WB	11 320 (446)	3 910 (154)	3 380 (133)	298/400	52.7
VTM-500-WB	12 070 (475)	3 860 (152)	3 780 (149)	373/500	66.1
VTM-650-WB	12 270 (483)	3 250 (128)	3 860 (152)	485/650	82.6
VTM-800-WB	13 460 (530)	3 560 (140)	4 060 (160)	597/800	100.4
VTM-1000-WB	13 460 (530)	3 660 (144)	4 270 (168)	746/1 000	116.1
VTM-1250-WB	13 460 (530)	4 090 (161)	4 520 (178)	932/1 250	125.4
VTM-1500-WB	14220(560)	4370(172)	4570(180)	1118/1 500	167.0
VTM-3000-WB	17590(692)	6820(268)	6880(271)	2237/3000	343.0

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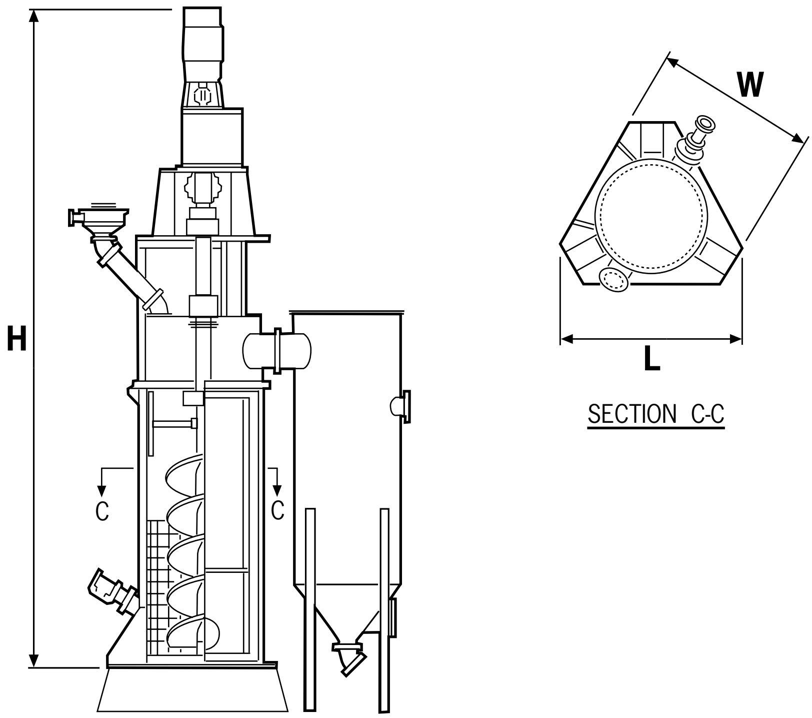
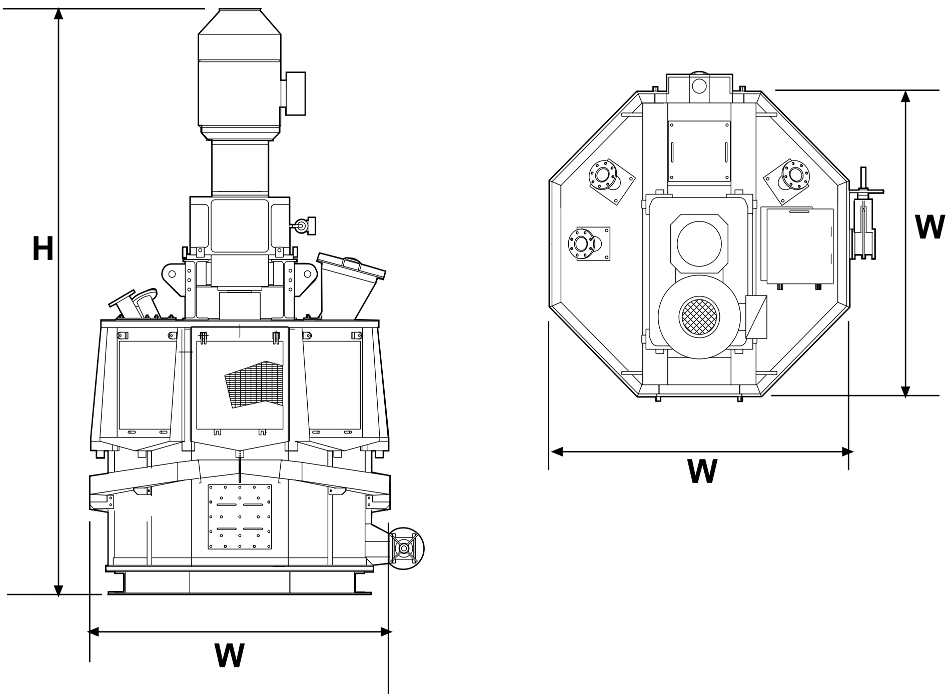
Type LS (Lime Slaking) for size reduction and slaking of lime

Regarding type WB (Wide body) for grinding operations only, see: 3:40



Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
VTM-20-LS	7 060 (278)	1 520 (60)	1 320 (52)	15/20	5.5
VTM-30-LS	7 180 (283)	1 520 (60)	1 320 (52)	22/30	5.9
VTM-50-LS	7 460 (294)	1 780 (70)	1 520 (60)	37/50	8.2
VTM-100-LS	7 900 (311)	1 960 (77)	1 700 (67)	45/60	8.8
VTM-150-LS	8 740 (344)	2 670 (105)	2 310 (91)	75/100	12.5
VTM-200-LS	9 780 (385)	2 670 (105)	2 310 (91)	112/150	17.9
VTM-300-LS	10 160 (400)	3 660 (144)	3 180 (125)	150/200	19.6
VTM-400-LS	11 320 (446)	3 910 (154)	3 380 (133)	224/300	50.0

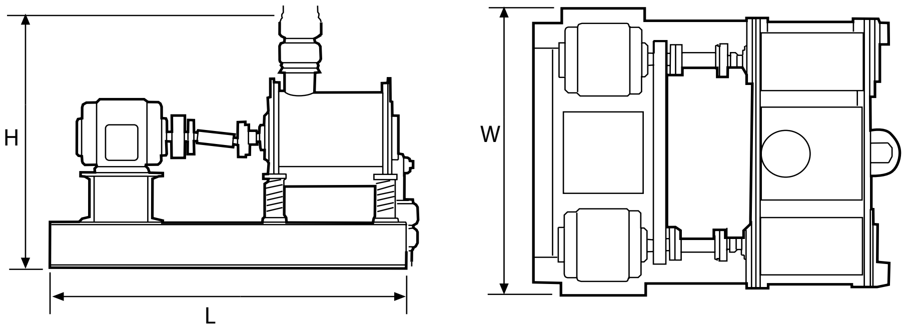
Stirred media grinding mIll



Model	Power motor kW (HP)	H mm (in.)	W mm (in.)	Weight (empty) kg (lb.)
SMD 185	185 (250)	4 350 (171)	2 275 (90)	7 200 (15 875)
SMD 355	355 (475)	5 990 (236)	2 800 (110)	13 450 (29 650)
SMD 1100*	1 100 (1475)	4 825 (190)	4 220 (166)	27 500 (60 630)

* The SMD 1100 utilizes an independently supported, horizontal foot-mounted motor and a right-angle (bevel-helical) gear reducer.

Vibrating ball mill



Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
VBM 1518*	1 120 (44)	1 780 (70)	1 350 (53)	2x5.6/2x7.5	1.2
VBM 3034**	1 680 (66)	2 790 (110)	2 130 (84)	2x37/2x50	6.2

* Grinding chamber diameter15”(380mm), length 18”(460mm)

** Grinding chamber diameter30”(760mm), length 34”(860mm)

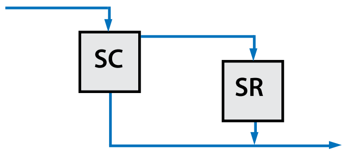
Size control – Introduction

With size control we understand the process of separating solids into two or more products on basis of their size. This can be done dry or wet.

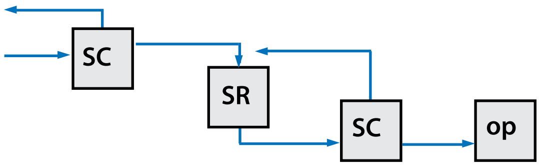
As mentioned earlier neither crushers nor grinding mills are too precise in their size reduction job and a lot of size fractions are misplaced. By using optimum size control the result can be improved both regarding capacity, size and particle shape.

Size control by duties

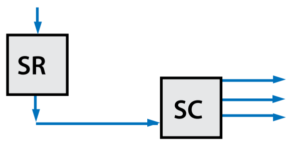
To prevent undersize in the feed from blocking the next size reduction stage (scalping)



To prevent oversize from moving into the next size reduction or operation stage (circuit sizing)



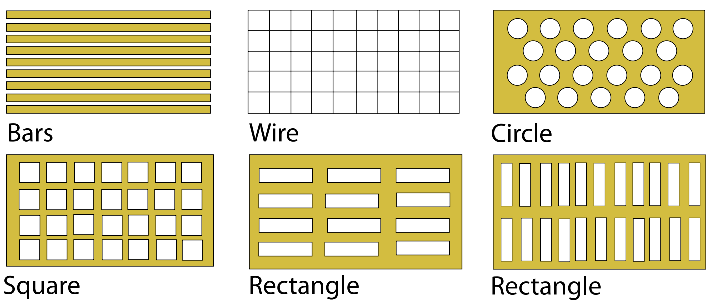
To prepare a sized product (product sizing)



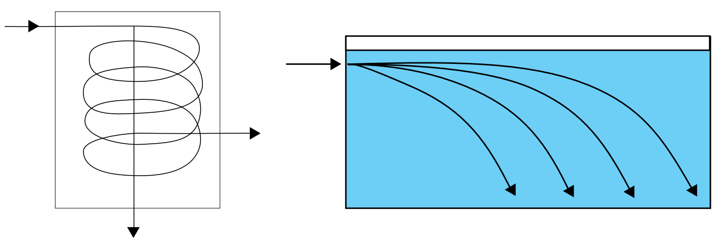
Size control by methods

In mineral processing practices we have two methods dominating size control processes:

- **Screening** using a geometrical pattern for size control.



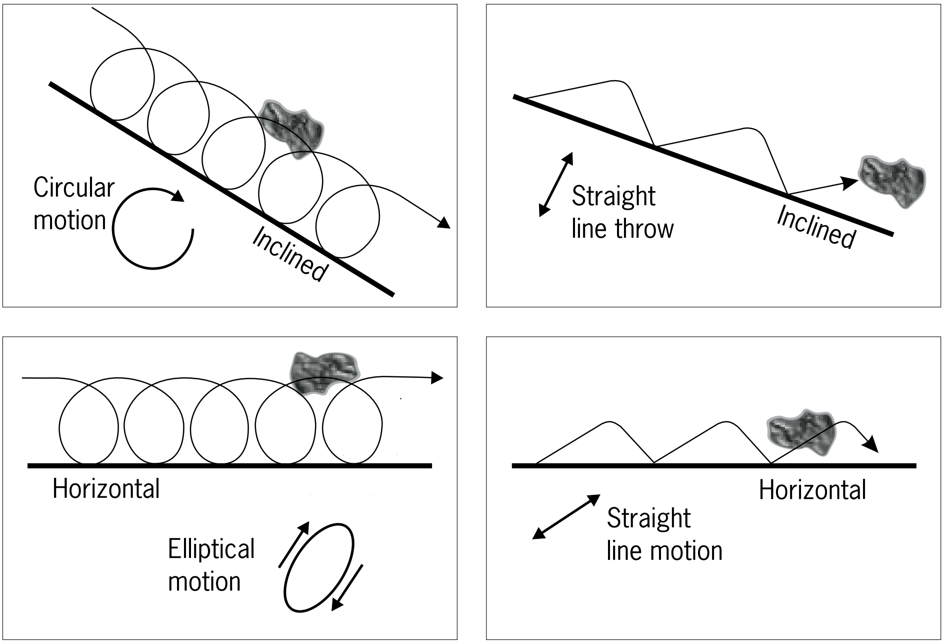
- **Classification** using particle motion for size control.



Screens

Performance of screens will fall back on three main parameters:
Motion – Inclination – Screening Media

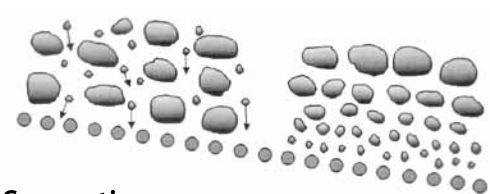
Screen motions



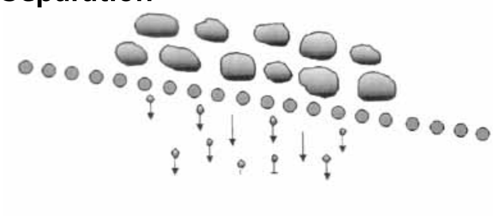
Screening by stratification

By building up a material bed on a screen deck the material will stratify when the motion of the screen will reduce the internal friction in the material. This means that the finer particles can pass between the larger ones giving a sharp separation.

Stratification

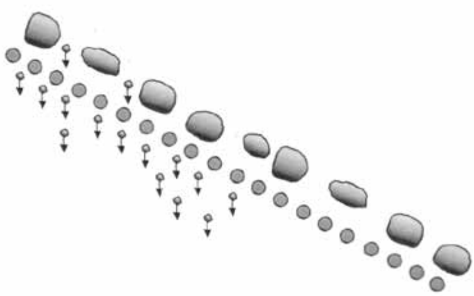


Separation



Screening by free fall

If we use the double inclination used for stratification (from 10-15 up to 20-30 degrees) we are in free fall, meaning that no particle layer can build up on the screen deck. The particles will now be sized directly via the screening media, giving a higher capacity, (or a more compact installation), but also less sharpness in separation. Optimal use when a large amount of fines shall be removed fastly.



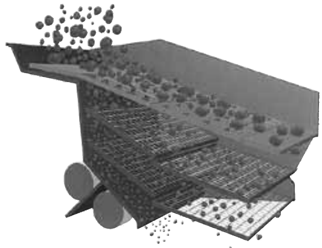
Screen types

There are many types of screens, but they can be reduced to the four types shown below. Of these types approx.80 % used worldwide are of type **single inclination**, stratification screens. The other are of type **double, triple** or **multiple** inclination, where screening by stratification and free fall are combined for different applications.

Single inclination

- Stratification screen
- Circular (15 deg.)
- Linear 0-5 (deg.)
- Still the leader in selective screening

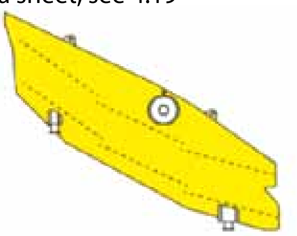
Data sheet, see 4:19



Double inclination

- Free fall
- Compact - high capacity paid for by lower selectivity
- Typical in circuit screening

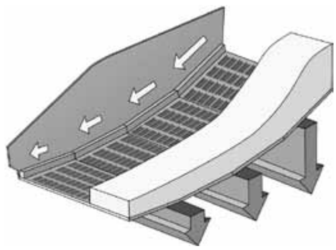
Data sheet, see 4:20



Triple inclination

- Combine capacity and selectivity
- Typical control screen for advanced product fractions

Data sheets see 4:21



Multiple inclination (”banana screen”)

- Effective ”Thin-layer” screen
- Popular in coal and metallic mining

Data sheets, see 4:21

Screen capacities

Sizing of screens is a time consuming process to be done by specialists. To get an idea about capacities we can use the figures below. They refer to screening by stratification using wire mesh as screening media.

Feed through screen deck (t/h)				
Separation	**3.6 x 1.5 m**	**4.2 x 1.8 m**	**4.8 x 2.1 m**	**6.0 x 2.4 m**
(mm)5.4 m²	**7.6 m²**	**10.0 m²**	**14.4 m²**	
2 20	30	45	65	
5 50	70	95	135	
8 75	105	140	180	
12 100	145	200	230	
16 125	180	230	270	
25 175	250	300	350	
32 200	290	350	400	
50 270	370	430	500	
90 370	460	550	640	

Example:

Single deck screen. Feed size 50% - 2 mm. Feed capacity 90 t/h, cut 2 mm

select: a 10 m² screen deck.

Selection of screening media

Selection of the correct size and type of screen is important. Equally important is the selection of the screening media. This refers not only to a correct aperture related to the "cut size ", but also to the wear in operation of these screens. Below a short selection guide to screening media can be found.

Rubber or polyurethane?

Feed size	Select	Because
>35 mm dry	Rubber 60 sh	Absorbes impact Resistant to sliding abrasion
<0-50 mm wet	Polyurethane	Very good against sliding abrasion Accurate separation
<40 mm dry/moist	Rubber 40 sh (soft)	Very flexible Prevents blinding
Look out for:	Oil in rubber applications Hot water or acids in PU-applications	

What thickness?

General rule for min. thickness

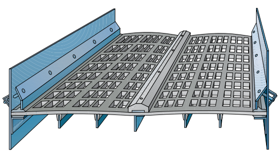
$$\frac{\text{Max Feed size}}{4} = \text{Panel thickness}$$

What happens if we go...?

THINNER		THICKER
+	Capacity	–
+	Accuracy	–
–	Service life	+
–	Blinding/Pegging Tendency	+

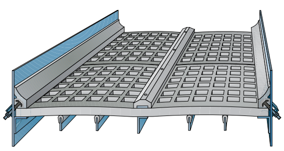
N.B.: Thickness should not exceed required product size

What type of panel

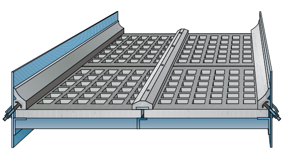


***Tension mats with hooks** fits all screens designed with cambered decks and tensioning rails.*

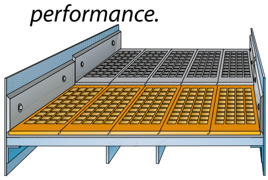
***Wire mesh panels** offer superior open area and are quickly available.*



***Bolt down panels**, pre-tensioned for easy installation and guaranteed screening performance.*



***Self supporting panels**, for screens of open frame design for tough applications .*

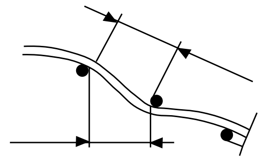


***Modular systems** provide flexibility in wear material/hole configuration combinations.*

What hole size? (Inclined deck)

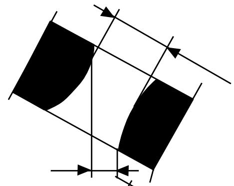
General guideline for wire mesh:

"Required product size plus 5 – 10%"



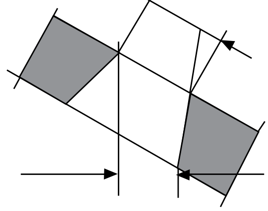
General guideline for rubber panels:

"Required product size plus 25 – 30%"



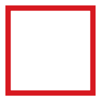
General guideline for PU panels:

"Required product size plus 15 – 20%"

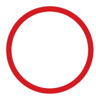


What type of hole?

The standard choice

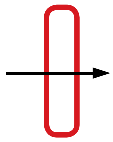


For improved service life (coarse screening)



For improved capacity

For improved accuracy and dewatering

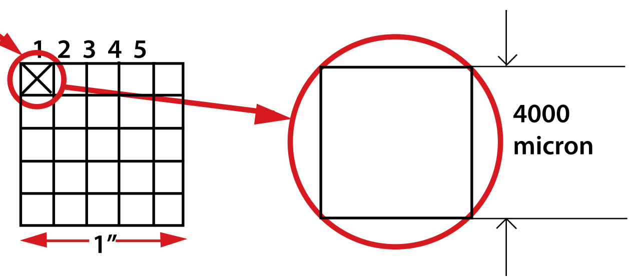


Particle size – Mesh or Micron?

mesh*	micron	mesh	micron	mesh	micron
2½	8000	14	1180	80	180
3	6700	16	1000	100	150
3½	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

*Taylor serie (US)

Mesh number = the number of wires per inch or the number of square apertures per inch



Classification – Introduction

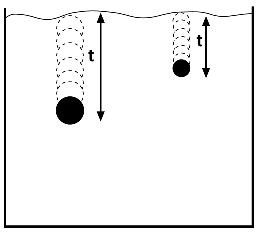
For size control of particles finer than 1 mm, we are moving out of the practical range of conventional screens.

Classification is the process of separating particles by size into two or more products according to their behaviour in air or water (liquids).

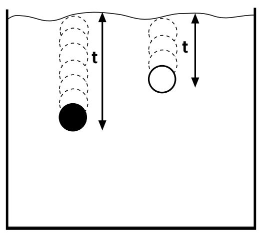
Classification methods

- **Wet** classification with **Hydrocyclones** using separation by centrifugal force covering the size range of 100 –10 micron (typical)
- **Wet** classification with **Spiral classifiers** using separation by gravity covering the size range of 100- 1000 micron (typical)
- **Dry** classification using separation by centrifugal force covering the range of 150 –5 micron (typical).

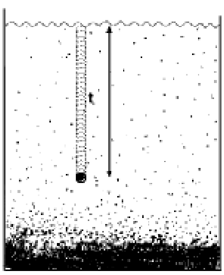
Wet classification – fundamentals



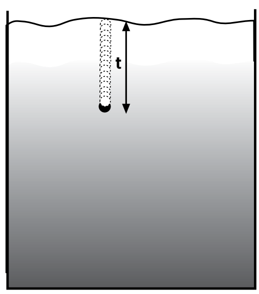
Coarse particles move faster than fine particles at equal density



High density particles move faster than low density particles at equal size



Free movement

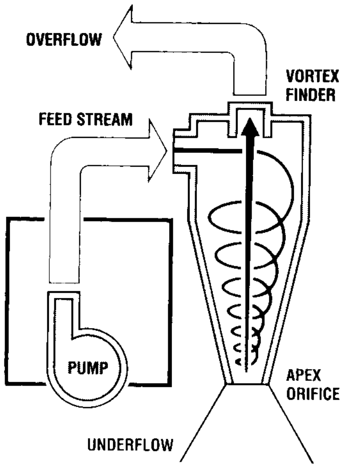


Hindered movement

If a particle has no interference from other particles it moves faster than a particle surrounded by other particles due to increased density and viscosity of the slurry. This is called **free** and **hindered** movement and is valid both for gravity and centrifugal classification.

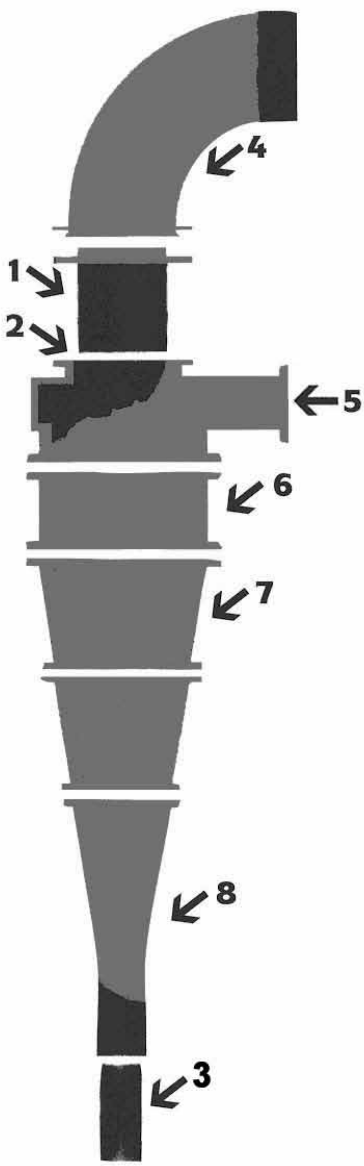
Hydrocyclone

Centrifugal forces classify solids by size (mass).
High mass particles closer to outer wall reporting to underflow.
Low mass particles closer to the centre reporting to overflow.



Hydrocyclone design

1. Vortex finder
2. Inlet head
3. Spigots (apex)
4. Overflow elbow
5. Feed inlet
6. Barrel
7. Cones
8. Cone extension



Hydrocyclone applications – more than size control

Although the hydrocyclone by nature is a size controlling machine the number of applications in mineral are many

- Classification in grinding circuits
- Dewatering and thickening
- Desliming and washing
- Enrichment of heavy minerals (DMS)
- a.o.

See also data sheet 4:22

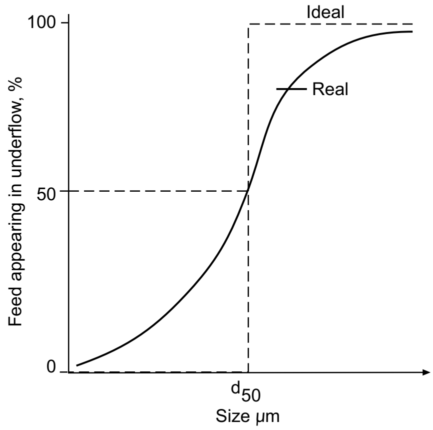
Hydrocyclone – Sizing

Accurate Hydrocyclone selection depends upon a number of interrelating factors and is best achieved by computer simulation done by your supplier.
Below you will find a condensed procedure helping you to get a preliminary selection

What is the d_{50} value?

Any Hydrocyclone is inefficient. Coarse particles will report to overflow and fine particles to underflow.

The **nominal cut point** for a cyclone is therefore defined as d_{50}, i.e. the size of particle that has 50% chance of reporting either to underflow or overflow. This cut point is used in selecting the correct cyclone diameter, see below.



Define cut point

An end user of cyclones normally doesn't use the value d_{50}. In practice the selection is based on required size analysis of the overflow i.e. 95 % minus 100 micron.

(K_{95} = 100 micron)

Conversion to cut point d_{50}

% passing in overflow	Factor
99	0.49
95	0.65
90	0.79
80	1.06
70	1.36
60	1.77
50	2.34

Example: A flotation circuit needs a 95% minus 75 micron feed.This corresponds to a nominal cut point d_{50} =75 x 0.65 = 48.75 micron

Once d_{50} is defined the cyclone diameter can be selected from table on next page!

Feed density

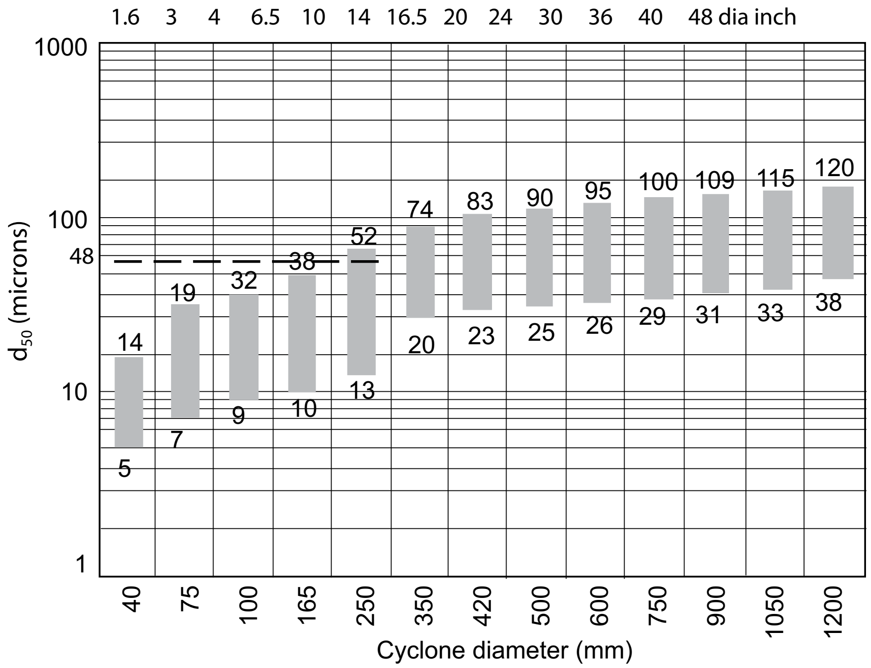
For efficient classification it is important that the feed density is as low as possible (free moving particles).

10-15 % solids by volume	Good efficiency
15-30% solids by volume	Deteriorating efficiency
> 30 % solids by volume	Inefficient

Feed pressure will influence the cut point, higher pressure – lower cut point (look out for wear).

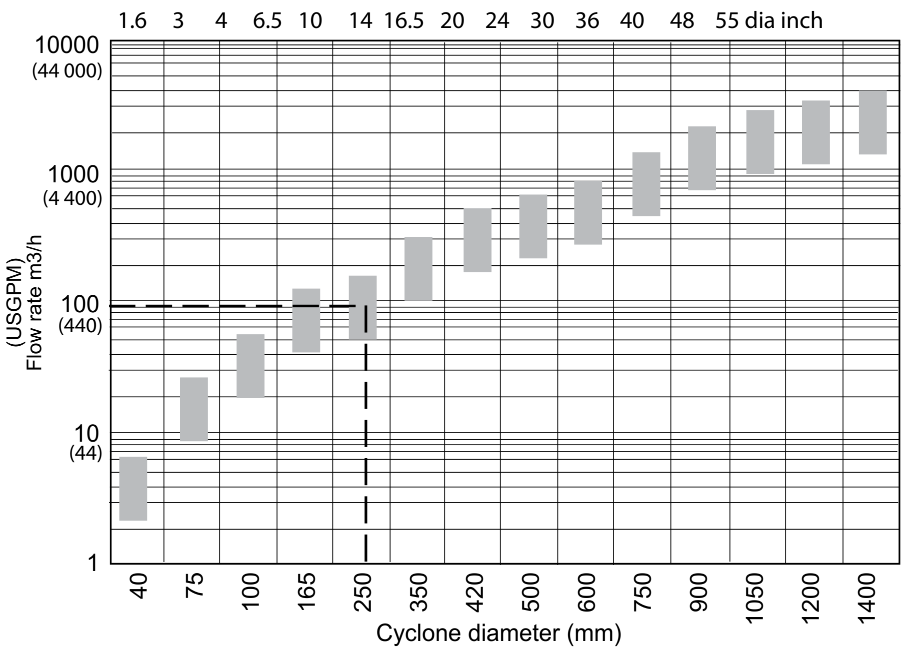
Select hydrocyclone diameter

Once d_{50} is defined the hydrocyclone diameter can be selected from the following table: Example above = 48 micron = cyclone dia 250 mm (10").



Select quantity of hydrocyclones

The volumetric capacity of a cyclone depends upon its diameter. A larger cyclone will handle a larger capacity. Once the required diameter has been defined then the number of units needed to handle the given feed flow can be determined from the following table. Example above: 250 mm dia. cyclone = flow rate 100 m3/h/unit.



Spiral classifier

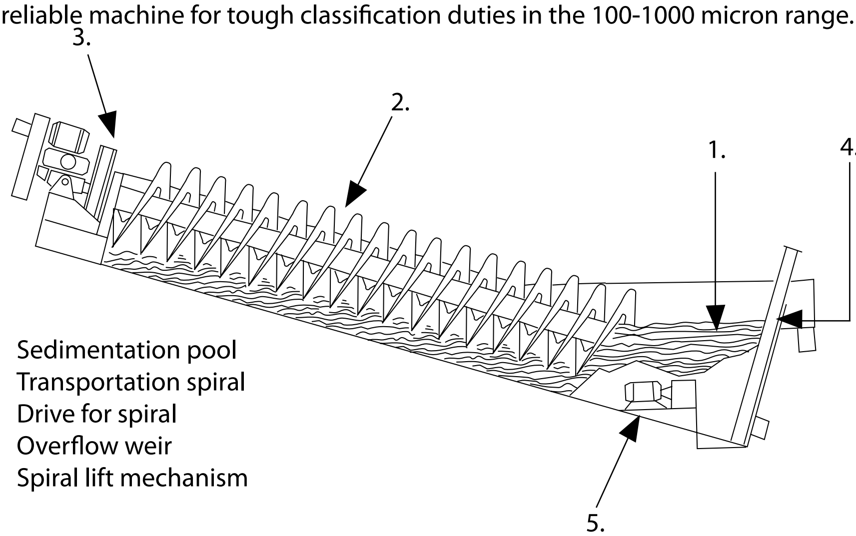
By combining a gravity settler of rectangular section with a sloped transport spiral for the sediment - we have got a spiral classifier.

Spiral classifier – Nomenclature

SC 90 ST-2 means 90 cm spiral diameter, straight tank, two pitches.

Spiral classifier – Design

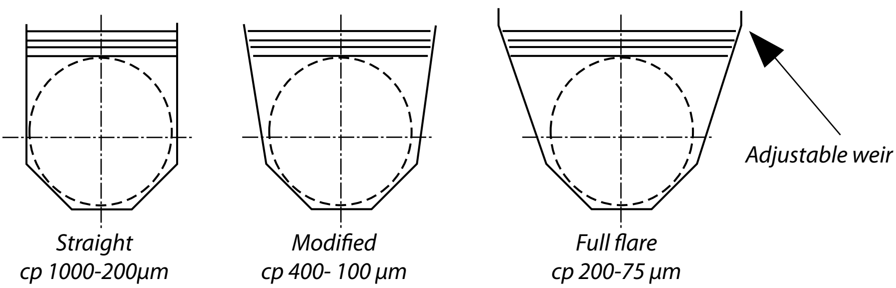
The design of a spiral classifier is simple and robust with few moving parts.
A reliable machine for tough classification duties in the 100-1000 micron range.



1. Sedimentation pool
2. Transportation spiral
3. Drive for spiral
4. Overflow weir
5. Spiral lift mechanism

Spiral classifier design features:

- Replaceable wear shoes,
- Submerged bearing for spiral
- Tank options and adjustable weir for full flexibility in pool area and classification cut point (cp)



Spiral classifier-applications

As for the hydrocyclone this size control machine has many practical applications in mineral processing

- Closed circuit grinding (primary classification with cyclone as secondary)
- Dewatering
- Sand recovery
- De-sliming
- Heavy media densifying

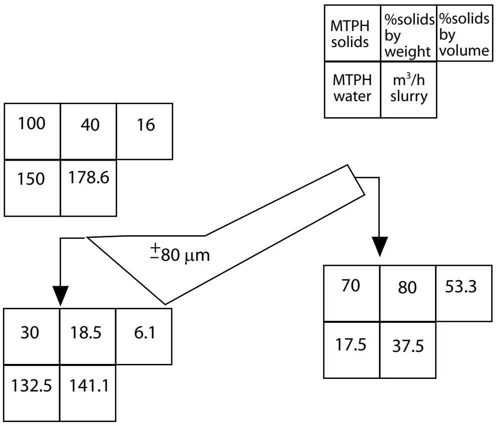
Spiral classifier – Sizing, metric

Please refer to your Support Centre for detailed Spiral Classifier selection. A preliminary sizing can be made by using the following method.

Spiral Classifier selection is a **three** part process. First the **spiral diameter**, the number of pitches and the rotational speed are selected to handle the predicted quantity of coarse (raked) product. Then the **overflow pool area** is selected to achieve the correct cut-point at the predicted overflow rate and pulp density. Finally the **coarse fraction (=sand) compression pool area** has to be checked.

1. Establish mass balance

Use metric system! 1 metric tonne = 1.1 short ton



2. Select spiral peripheral speed and sand raking efficiency

Peripheral speed is chosen to avoid the spiral running too fast causing excessive turbulence in the separation zone or reducing the drainage time for the coarse fraction.

The **sand raking efficiency** reflects the fact that a spiral is not a 100% efficient transport device and some particles will tend to slide back along the screw particularly when handling wet or fine materials.

Selection is made from Table 1 below:

*Table 1 Sand raking efficiency and spiral speed**

Particle size	Specific gravity 2.0		3.0		4.0		5.0	
mm	M/s	Eff. %	M/s	Eff. %	M/s	Eff. %	M/s	Eff. %
0.300 - 12.7	0.40	75	0.45	80	0.55	90	0.55	95
0.100 - 12.7	0.35	70	0.40	75	0.45	75	0.55	80
0.100 - 0.6	0.35	67	0.35	70	0.35	75	0.40	80
0.075 - 0.6	0.35	60	0.35	67	0.35	70	0.35	70
0.075 - 0.3	0.35	50	0.35	60	0.35	67	0.35	70
0.045 - 0.2	0.30	50	0.30	60	0.35	60	0.30	50

**As flight tip speed*

3. Calculate 'corrected' Rake Capacity

$$\text{Corrected rake Capacity} = \frac{\text{Rake Capacity (m}^3\text{/h)}}{\text{Spiral Efficiency}}$$

4. Select correct diameter, pitch and speed

Selection is made from Table 2 and Table 3 below using the corrected volumetric rake capacity. Pitch refers to the number of spirals on a single shaft (1 or 2). Select peripheral speed to match selected diameter and pitch.

Table 2. Rake capacity (m^3/h)

	PITCH	Spiral speed, rpm													
Ø cm		**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**20**
30	SP												0.6		0.6
	DP		SP=Single Pitch										1.2		1.9
40	SP		DP= Double Pitch						0.6				1.2		
	DP								1.2				1.9		
60	SP						4.3	5.0	5.6	5.6	6.8	7.4	8.1	8.7	
	DP						8.3	9.4	10.6	10.6	13.0	14.1	15.5	16.7	
75	SP				5.6	6.8	7.4	8.1	8.7	9.3	9.9	10.5			
	DP				10.6	13.0	14.1	15.3	16.5	17.7	18.9	20.0			
90	SP			9.3	11.2	13.0	14.9	15.5	17.4	19.2					
	DP			17.7	21.2	24.8	28.3	29.5	33.0	36.5					
120	SP		18.6	22.3	27.3	31.0	34.1								
	DP		35.4	42.4	51.9	58.9	64.8								
150	SP	27.3	35.4	43.4	50.9										
	DP	51.9	67.2	82.5	96.7										
200	SP	52.1	68.9	81.9											
	DP	99.0	130.8	156.6											

Table 3. Peripheral speed (m/s)

	Spiral speed. RPM														
Ø cm	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**20**
0													0.24		0.32
40									0.21				0.32		
60							0.25	0.28	0.32	0.35	0.38	0.42	0.48	0.51	
75					0.24	0.28	0.32	0.36	0.40	0.44	0.48	0.52	0.24		
90				0.24	0.28	0.34	0.38	0.43	0.48	0.53					
120			0.25	0.32	0.38	0.45	0.51								
150	0.24	0.32	0.40	0.48											
200	0.31	0.43	0.53												

5. Equivalent particle size

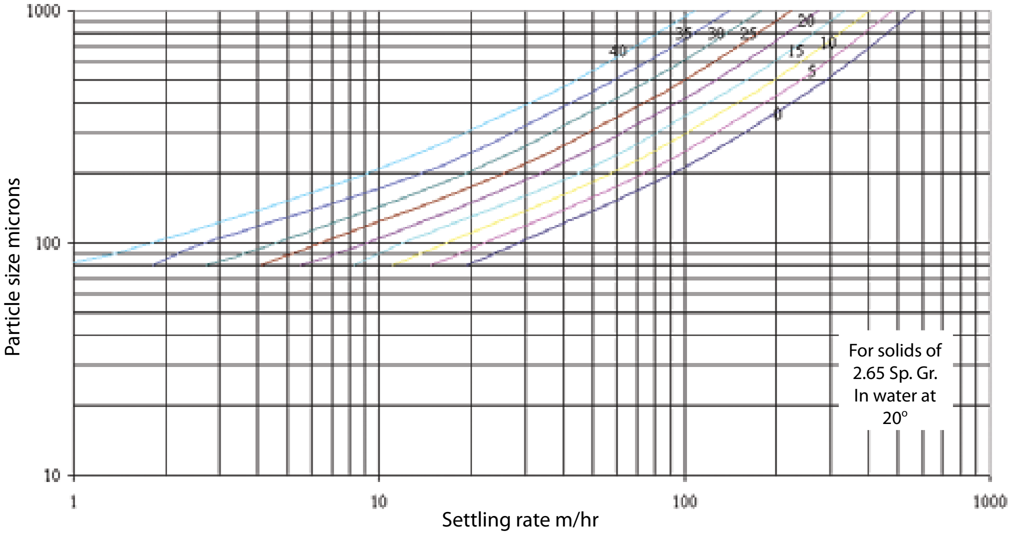
Pool areas are calculated assuming a particle SG of 2.65. If the actual figure is something different a correction has to be made. Multiply with the factor $\sqrt{(SG - 1 / 1.65}$ (Stokes Law).

For example an 80 µm particle of SG 3.2 has a correction factor of $\sqrt{(3.2 - 1) / 1.65} = 1.15$ so the equivalent particle size is 80 x 1.15=92 µm.

6. Particle settling rate

Read **particle settling rate** from the diagram below according to equivalent particle size and **percent solids by volume** in the overflow (from the mass balance).

Diagram 1. Settling rate vs. particle size at various volume percent solids.



7. Calculate overflow pool area

The **overflow pool area** is calculated as $A_{overflow} = \dfrac{\text{Overflow Rate } (m^3/h)}{0.7 \text{ x Particle Settling Rate } (m/h)}$

0.7 is a factor due to disturbance by the spiral.

Select a classifier from Table 4 so that the calculated area falls within the design range.

8. Calculate compression pool area

As particles settle in the classifier tank they sink at an ever decreasing rate (hindered settling theory). In order to avoid build-up of particles that are too small to sink to the bottom and too large to overflow the weir, the **compression pool area** must be checked.

- From Diagram 1 read the settling rate for the equivalent cut-size at 40 %solids by volume.
- Calculate coarse sand compression volume at 40 % v/v by dividing the dry tonnes with (SGx0.4).

Calculate **compression pool area as** $A_{compr} = \dfrac{40\%v / v\text{Flow Rate } (m^3/h)}{0.7 \text{ x } 0.8 \text{ x Settling Rate } (m/h)}$

The 0.7 factor is the same as above, and 0.8 refers to the smaller pool area available at compression level.

Select a classifier from Table 4.

9. Selection

Select the smallest unit that satisfies the requirements of both spiral diameter, overflow pool area and compression pool area. Machine dimensions and motor power are taken from the Technical data sheet.

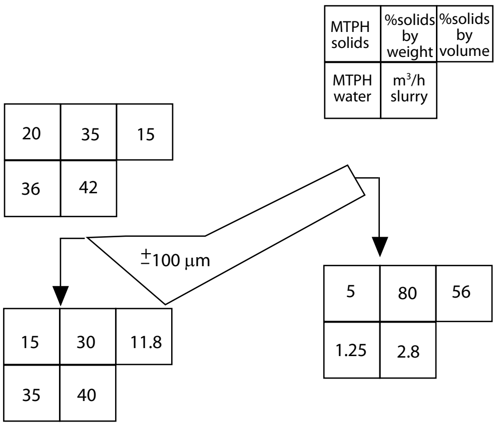
Table 4. Pool area for standard classifiers

Spiral diameter	Configuration	Max pool area m^2	Min pool area m^2
30 (12")	Straight Tank	0.15	-
	Mod.Flare	0.21	-
	Full Flare	0.30	-
40 (16")	Straight Tank	0.29	-
	Mod.Flare	0.37	-
	Full Flare	0.47	-
60 (24")	Straight Tank	1.5	1.1
	Mod.Flare	2.3	1.8
	Full Flare	3.2	2.4
75 (30")	Straight Tank	2.2	1.7
	Mod.Flare	3.4	2.6
	Full Flare	4.9	3.7
90 (36")	Straight Tank	3.3	2.4
	Mod.Flare	5.1	3.8
	Full Flare	7.2	5.4
120 (48")	Straight Tank	5.7	4.3
	Mod.Flare	8.9	6.7
	Full Flare	12.5	9.3
150 (60")	Straight Tank	12.4	9.3
	Mod.Flare	19.8	14.9
	Full Flare	27.8	20.8
200 (78")	Straight Tank	14.7	11.0
	Mod.Flare	24.1	18.0
	Full Flare	32.6	24.4

Selection example data

Mineral:	Sulphide ore
Capacity:	20 mtph (or t/h)
Percent Solids:	35 w/w
SG Solids:	3.2
Feed Size:	80 % -250 µm
Duty:	De-sliming at 100 µm

1. Mass Balance



2. Peripheral speed and sand raking efficiency

   From Table 1 interpolate a peripheral speed of 0.35 m/s and efficiency of 68 % for the stated SG solids 3.2 and size 80 % -250 µm.

3. "Corrected" rake capacity = $\frac{2.8}{0.68}$ = 4.1 corrected m^3/h

4. From Table 2 the smallest spiral with enough transport capacity:

   60 cm diameter, single pitch and 8 r/min

5. Calculate the Equivalent Particle Size = 100 x $\sqrt{(3.2 - 1) / 1.65}$ = 115 µm

6. Read the settling rate in Diagram 1 of a 115 µm particle at 12 % solids v/v. The settling rate is about 19 m/h.

7. Calculate Overflow Pool Area = 39.7/(0.7x19) = 3.0 m^2

8. Read settling rate in Diagram 1 of a 115 µm particle at 40 %v/v: 2.2 m/h

9. Calculate Compression Pool Area [5 /(3.2 x 0.4)] / (0.7 x 0.8 x 2.2)= 3.2 m^2

10. The smallest classifier with large enough pool area (3.2 m^2 required) is SC 60 FF-1 (Table 4). With single pitch and 8 r/min (Table 2) required raking capacity is obtained.

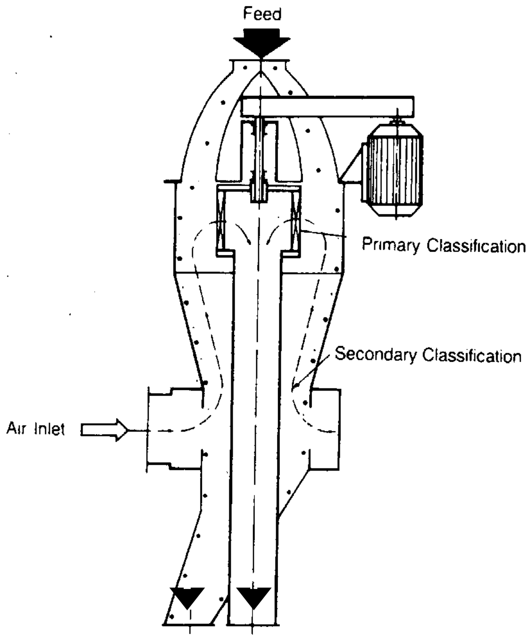
Dry classification

General

Classification by using air instead of liquid has many similarities. In both cases we are using the drag forces of the media to affect particles of different size.

Dry classifiers

The picture shows the main principles for an air classifier system (Delta Sizer).



The upward airflow and the turbulence around the rotor ensures dispersion of the material.

Aerodynamic drag force pulls the fine particles through the rotor, whilst the centrifugal force rejects the oversize particles. A secondary classification takes place when the oversize particles fall through the uprising air stream, liberating any fines that adhere to the oversize particles.

Size control in crushing and grinding circuits

Crushing circuits - open screening

- Screening ahead of a crusher avoids packing
- Less wear in the crusher
- Higher total capacity
- The screening media is "controlling" the product in two dimensions. No "flaky shortcuts".

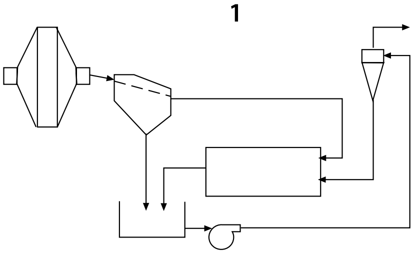
Crushing circuits - closed screening

- The screens are lowering the capacity
- Calibration of the product is improved
- Better cubical shape
- Higher reduction ratio

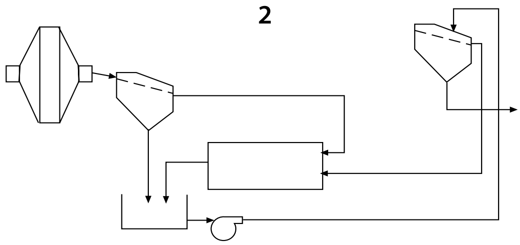
Grinding circuits – screening

- Used for "trapping critical sizes" in AG - SAG circuits (1)
- Used for taking out size fractions from AG circuits for pebble grinding (1)
- Used in circuits with heavy minerals – avoiding over grinding (fine screening) (2)
- Screens being static (fixed cut point) are not too tolerant to changes in product size, causing variations in circulating loads.
- Mechanical damage or clogging of screening media can disturb operation.

1



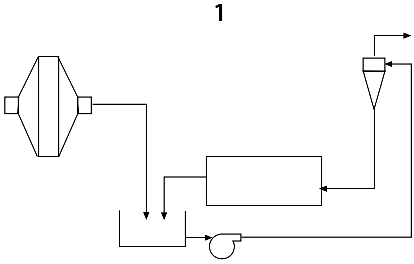
2



Grinding circuits – classification

- Classifiers being dynamic (floating cut point) are more tolerant to changes in product size as the cut point is moving with the changes
- Cyclones, being most common, are effective as classifiers at cut points below 200 microns (1)
- Spiral classifiers are effective as classifiers at cut points up to 800 microns. For the coarse fraction solids up to 50mm (2") can be removed by the spiral.
- Spiral classifiers and cyclones can be used complementary if cut point is coarser than 200 microns. (2)

1



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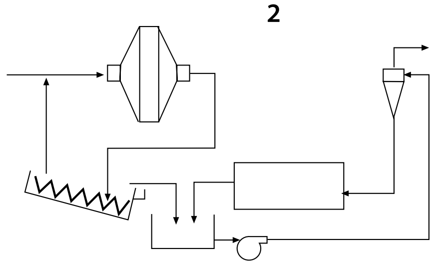
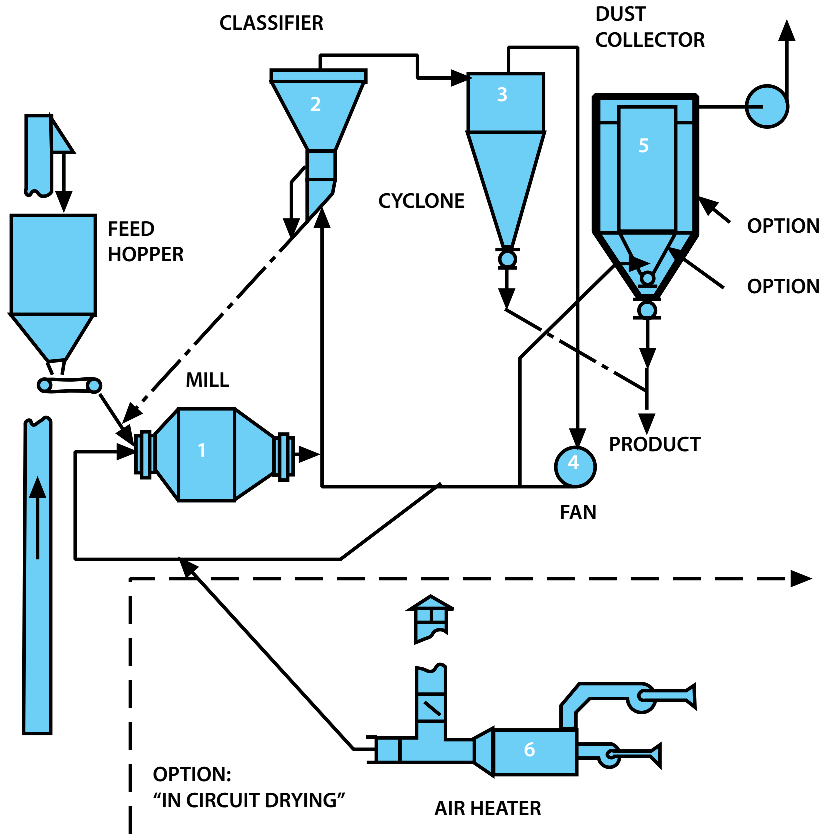


Size control

Dry classifier system

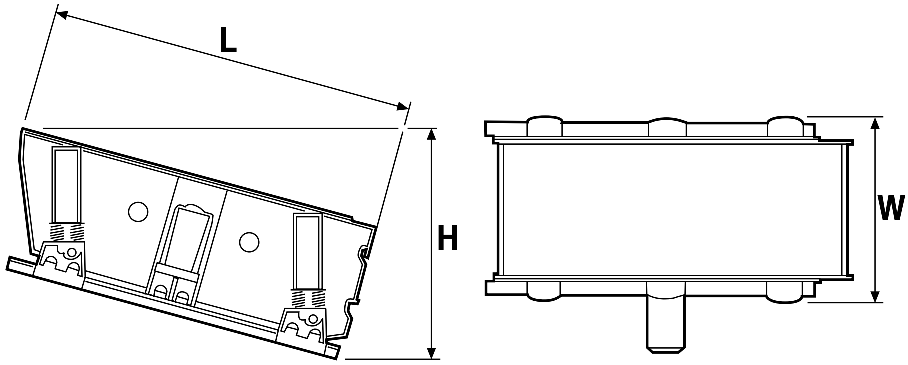
A typical dry classifier system is shown below. Due to the difference in viscosity between water and air the installation volume is quite different, see page 4:25.



1. Grinding mill
2. Classifier
3. Cyclone for product recovery
4. Main fan for circuit air flow
5. Dust collector for cleaning of exhaust air
6. "In circuit heater" for moistures feed

- Normally used for mineral filler production
- Voluminous installation due to low solids content per m^3 of air
- Dust collector needed for bleed -off air
- Sensitive to moisture
- Low wear rate
- Products down to 99% below 10 micron

Single inclination screen – Circular motion



Dimensions at 15° inclination

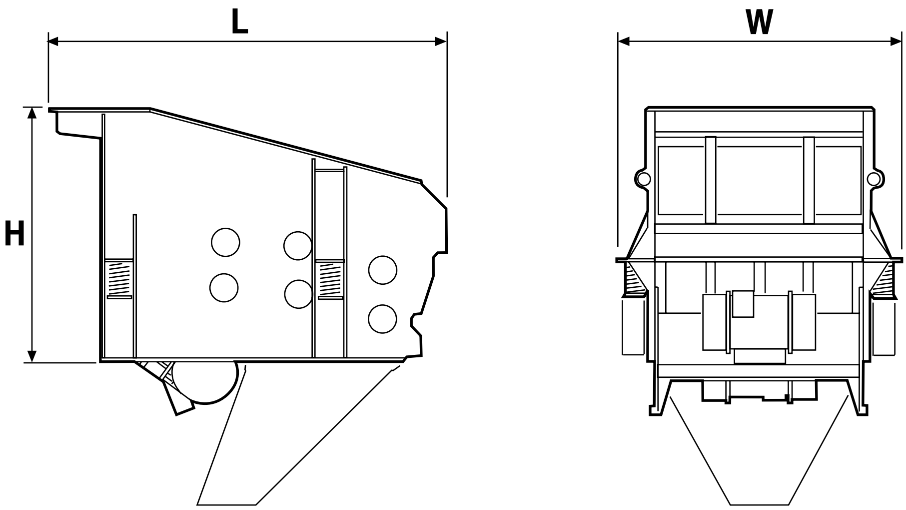
Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/hp	Weight ton
VFS 36/15 2d	2 700 (106)	4 465 (176)	2 230 (88)	11/15	3.7
VFS 42/18 2d*	2 965 (117)	5 065 (199)	2 530 (100)	15/20	4.5
VFS 48/21 2d	3 100 (122)	5 665 (223)	2 830 (111)	18.5/25	5.5
VFS 36/15 3d	3 065 (121)	4 465 (176)	2 230 (88)	15/20	4.7
VFS 42/18 3d	3 220 (127)	5 065 (199)	2 530 (100)	18.5/25	5.8
VFS 48/21 3d	3 530 (139)	5 665 (223)	2 830 (88)	22/30	7.5
VFSM 42/18 2d**	2 900 (114)	5 200 (205)	2 530 (100)	18.5/25	5.6
VFSM 48/21 2d	3 050 (120)	5 800 (228)	2 830 (111)	22/33	7.0
VFSM 60/24 2d	3 550 (140)	7 000 (276)	3 340 (131)	2x18.5/2x25	10.8
VFSM 48/21 3d	3 425 (135)	5 800 (228)	2 830 (88)	2x18.5/2x25	8.5
VFSM 60/24 3d	4 305 (170)	7 000 (276)	3 340 (131)	2x22/2x33	14.2

* VFS 42/18 2d = screen deck dimension 4.2m x1.8m (165“x70“), double deck

**VFSM 42/18 2d = same as above but heavy duty version

Screening area calculated from screen type ex. VFS 42/18; 4.2x1.8= **7.6 m²** x11= **82ft²**

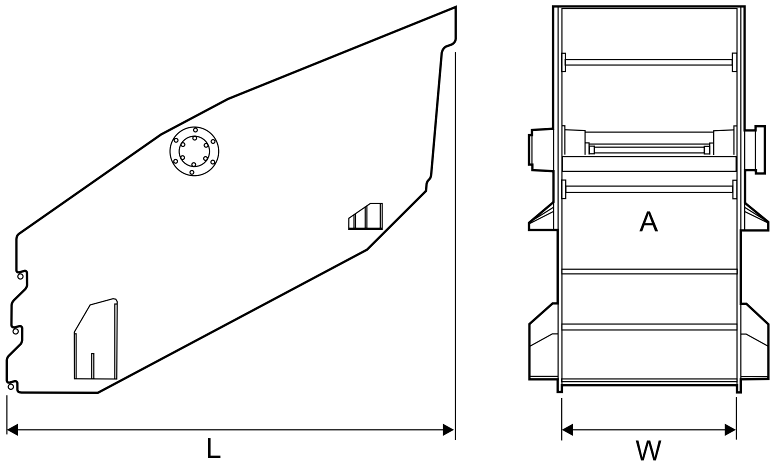
Double inclination screen – Linear motion



Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/hp	Weight ton	Max feed mm/inch
VFO 12/10 2d	1 450 (57)	1 330 (52)	435 (17)	2x1.3/2x1.7	1.0	120/5
VFO 20/12 2d	1 515 (60)	2 380 (94)	1 700 (67)	2x2.3/2x3.1	1.6	150/6
VFO 20/12 3d	1 515 (60)	2 380 (94)	1 700 (67)	2x2.3/2x3.1	1.7	150/6
VFOM 12/10 3d*	1 390 (55)	1 460 (579	1 426 (56)	2x2.3/2x3.1	1.3	300/12
VFOM 20/12 3d	1 915 (75)	2 980 (117)	1 720 (68)	2x4.0/2x5.4	2.7	300/12

* VFOM, heavy-duty version with dual springs at feed and discharge ends

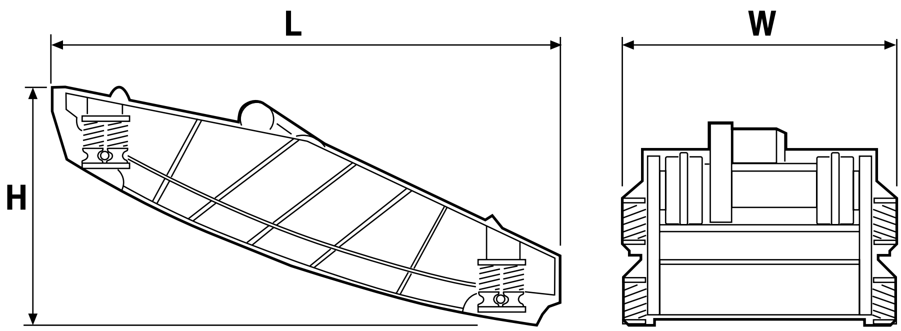
Triple inclination screen – Linear motion



Model	L mm (ft)	W mm (ft)	A m^2 (Sq. ft.)	Power motor kW /HP	Weight ton
TS*202	4 900 (16)	1 530 (5)	7.4 (80)	15/20	4.8
TS*203	4 900 (16)	1 530 (5)	7.4 (80)	15/20	6.1
TS 302	6 100 (20)	1 835 (6)	11 (120)	15/20	6.2
TS 303	6 100 (20)	1 835 (6)	11 (120)	22/30	8.2
TS 402	6 100 (20)	2 445 (8)	15 (160)	22/30	8.4
TS 403	6 100 (20)	2 445 (8)	15 (160)	30/40	11.2
TS 502	8 250 (27)	2 445 (8)	20 (216)	30/40	11.2
TS 503	8 250 (27)	3 055 (10)	25 (270)	2x22/2x30	15.0

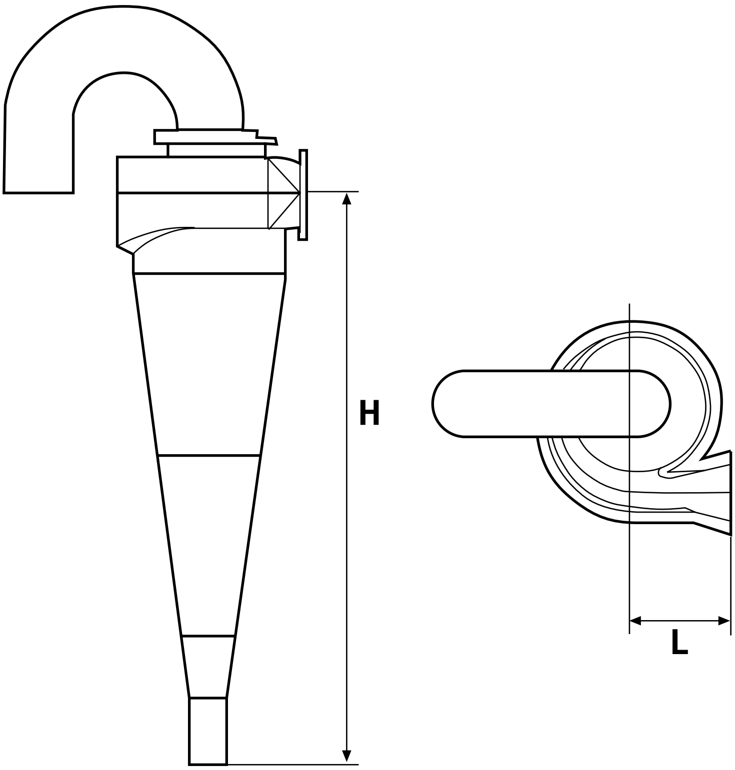
* TS 202 = 2 decks and TS 203 = 3 decks screen

Multiple inclination screen – Linear motion (Banana screen)



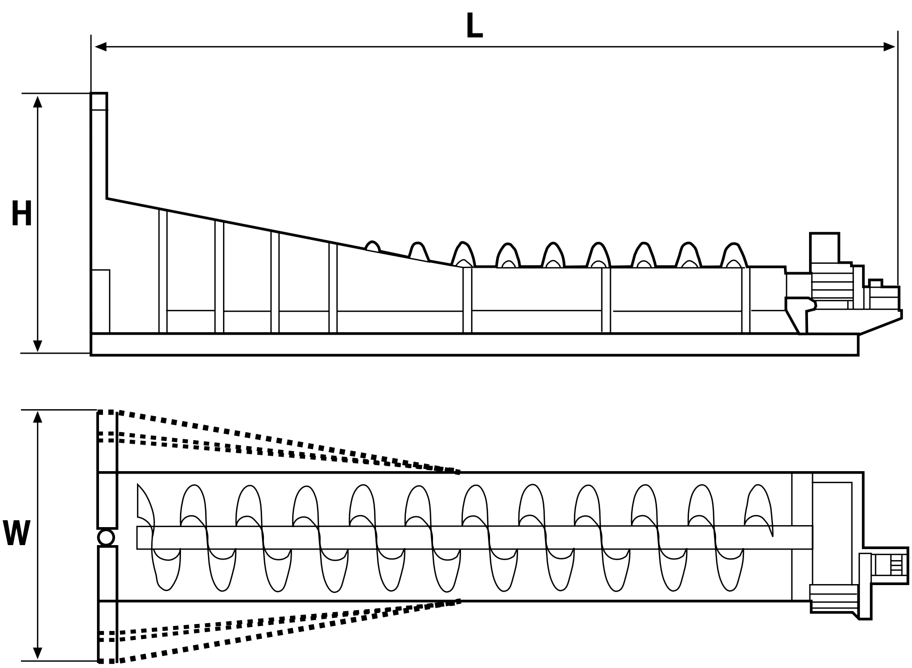
Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/hp	Weight ton
MF 1800x6100 1d	2 703 (107)	6 430 (253)	2 555 (101)	22/30	6.7
MF 2400x6100 1d	2 691 (106)	6 431 (253)	3 166 (125)	30/40	8.5
MF 3000x6100 1d	2 897 (114)	6 614 (260)	3 774 (149)	45/60	11.5
MF 3000x6100 2d	4 347 (171)	6 759 (266)	3 774 (149)	45/60	17.0

Hydrocyclone



Diameter mm (inch)	H mm (inch)	L mm (inch)	Weight kg (lbs)
40 (1.6)	610 (24)	150 (6)	2 (4.4)
65 (2.6)	1 130 (45)	150 (6)	9 (20)
100 (4)	1 220 (48)	278 (11)	14 (30)
165 (6.5)	1 690 (67)	240 (9)	31 (68)
250 (10)	1 512 (60)	390 (15)	77 (170)
350 (14)	1 990 (78)	500 (20)	140 (309)
420 (17)	2 140 (84)	400 (16)	-
500 (20)	2 280 (90)	435 (17)	-
600 (24)	2 420 (95)	432 (17)	-
750 (30)	3 060 (120)	500 (20)	-

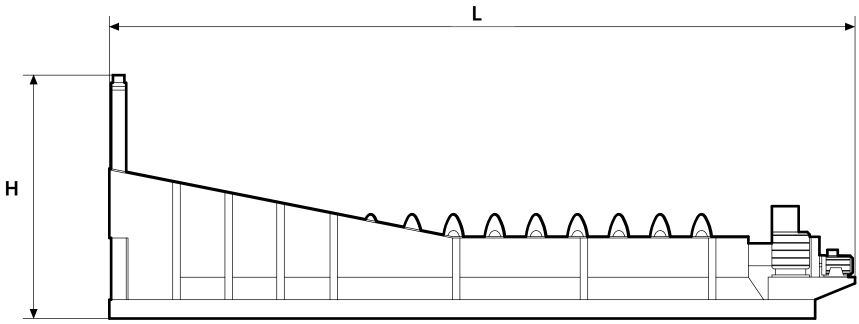
Spiral classifier simplex

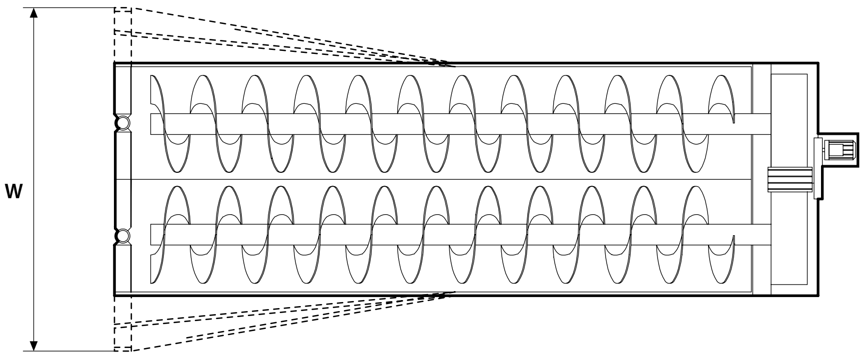


Model*	H mm (inch)	L mm (inch)	W mm (inch) ST	W mm (inch) MF	W mm (inch) FF	Weight ton	Power (max) kW/hp
60	1 557 (61)	6 111 (241)	711 (28)	1 092 (43)	1 534 (60)	2.2	2.2/3
75	1 862 (73)	7 203 (284)	864 (34)	1 340 (53)	1 890 (74)	2.9	2.2/3
90	2 172 (86)	8 799 (346)	1 042 (41)	1 613 (64)	2 273 (90)	4.1	4.0/5
120	2 431 (96)	10 904 (429)	1 347 (53)	2 093 (82)	3 004 (118)	7.8	7.5/10
150	2 888 (114)	12 758 (502)	1 677 (66)	2 540 (100)	3 744 (147)	15.0	15/30
200	4 082 (161)	14 599 (575)	2 135 (84)	3 470 (137)	5 052 (199)	24.4	22/30
220	4 643 (183)	16 398 (646)	2 287 (90)	3 533 (139)	5 159 (203)	32.4	22/30

ST = Straight ; MF = Modified Flare ; FF = Full Flare

Spiral classifier duplex

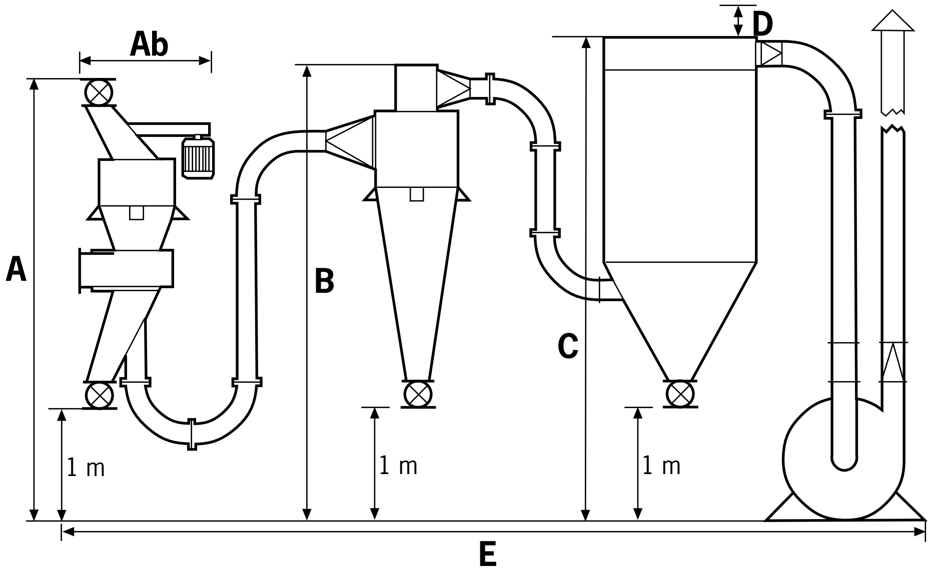




Model	L mm (inch)	W mm (inch) ST	W mm (inch) MF	W mm (inch) FF	H mm (inch)	Weight ton	Power (max) kW/hp
1800	12567 (399)	3962 (156)	5121 (201)	6455 (254)	3909 (154)	33	22/3
1800	13583 (535)	3962 (156)	5121 (201)	6455 (254)	3909 (154)	36	22/3
1800	14599 (575)	3962 (156)	5121 (201)	6455 (254)	3909 (154)	39	22/3
2000	13627 (537)	4267 (168)	5623 (221)	7185 (283)	4137 (163)	37	30/3
2000	14643 (577)	4267 (168)	5623 (221)	7185 (283)	4137 (163)	41	30/3
2000	15659 (617)	4267 (168)	5623 (221)	7185 (283)	4137 (163)	44	30/3

ST = Straight ; MF = Modified Flare ; FF = Full Flare

Dry classification system – Delta sizer

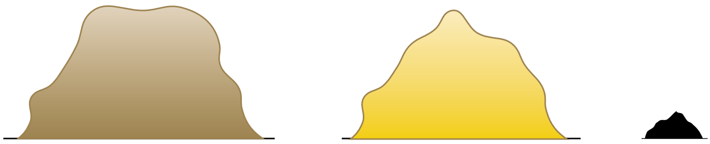


Model	A mm (inch)	Ab mm (inch)	B mm (inch)	C mm (inch)	D mm (inch) (bag removal)	E mm (inch)	Width overall
DS 2	1 700 (67)	850 (33)	3 000 (118)	4 500 (177)	2 100 (83)	5 000 (197)	1 600/63
DS 4	2 600 (102)	1 010 (40)	3 400 (134)	5 500 (217)	2 700 (106)	7 000 (276)	1 800/71
DS 8	3 400 (134)	1 430 (56)	4 000 (157)	6 500 (256)	3 100 (122)	8 500 (335)	2 700/106
DS 16	4 500 (177)	2 030 (80)	4 500 (177)	7 000 (276)	3 200 (126)	11 000 (433)	2 600/103
DS 32	5 900 (232)	2 620 (103)	6 000 (236)	8 400 (331)	3 200 (126)	13 000 (512)	3 500/138

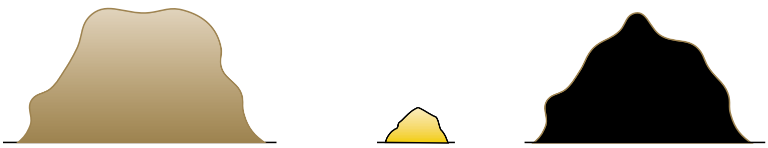
Enrichment – Introduction

With Enrichment we understand the process of improving the mineral or rock value by removing impurities by

- **Washing**, mainly used in the enrichment process of industrial minerals, coal, aggregates, sand and gravel, normally with the products in solid form. (size = 1 mm and coarser)



- **Separation,** mainly used in the enrichment processes of metallic minerals and high value industrial minerals, normally with the products in liberated particle form (size = 1mm and smaller)



Enrichment – Processes

Washing by using

Log washers
Wet screens
Aquamator separators
Tumbling scrubbers
Attrition scrubbers
(all wet processes)

Separation by

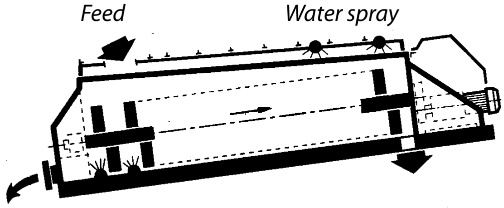
Gravity separation (wet)
Magnetic separation (dry & wet)
Flotation (wet)
Leaching (wet)

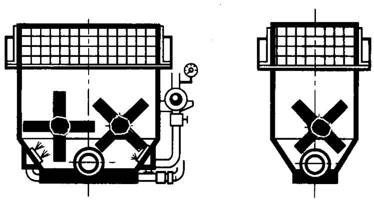
Washing

Log washers

Single or double shaft log washers are used for washing of gravel. Contaminated material is fed at the trough bottom and is transported upwards by blades in a screw pattern due to friction between the material. Effluent in slurry form leaves via an overflow weir.

Typical capacities 40 – 350 t/hour (for double shaft version), see further page 5:45 and 5:46.





Wet screens

Water spraying can be used to wash materials on a screen regardless of hole size in the screening media. If the hole size is 20 mm or less, water spraying increases the capacity (inversely proportional to the hole size).

Water requirements (typical) m^3/h at low (3-6 bar) and high (above 70 bar) pressure:

	Low	High
Sand and gravel	1.0	0.8
Aggregates - hard rock	0.5	0.4
Mining - raw ore	0.5	0.4
Recycling (concrete)	0.2	0.15

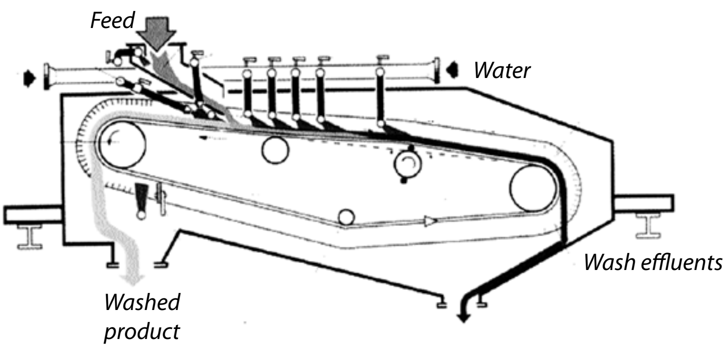
Capacities typical, see 4:3.

Aquamator separator

The Aquamator is developed for efficient washing of waste material of lower densities like coal, wood etc. Used mainly for gravel, chippings and demolition rubble. The water and feed form a bed with a density high enough (SG range1.2-1.6) enabling light material to float off.

Typical feed size is plus 2 mm up to 32 mm. (9 mesh – 1.3")

Typical capacity 10-180 t/h (solids), see further page 5:47.



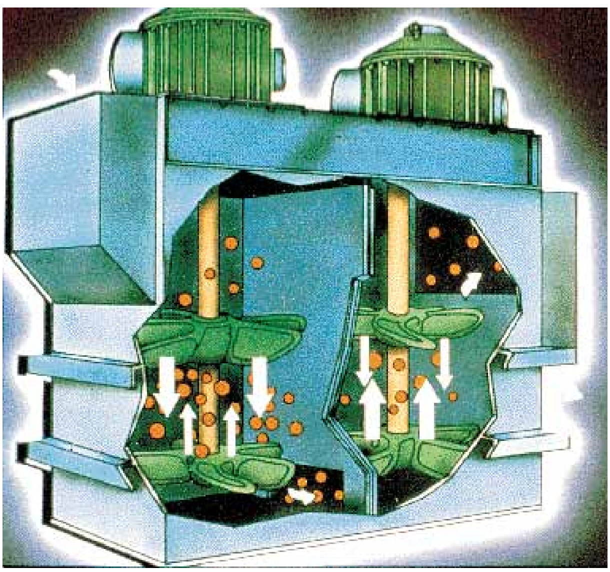
The **Hydrobelt** separator operates according to the same principles as the Aquamator, however designed to handle sand down to micron size. Typical capacities are 80-225 t/h, see further page 5:48.

Tumbling scrubber

If solids of rock, gravel or minerals contain a high and sticky content of clay and dirt that has to be removed, wet screening is normally not effective enough. A medium speed washing drum for scrubbing solids against solids is then the option. The drum is relatively short in relation to its diameter. Water requirements per ton is the same as for wet screening. Typical capacities 8-120 t/h.

Attrition scrubber

These scrubbers are mainly used for washing of material below 10 mm in size. Very high energy inputs are possibly used for washing of silica sand for glass making and cleaning of foundry sand. The machine is also suitable for clay blunging and lime slacking, see further page 8:27-28 and 8:40.



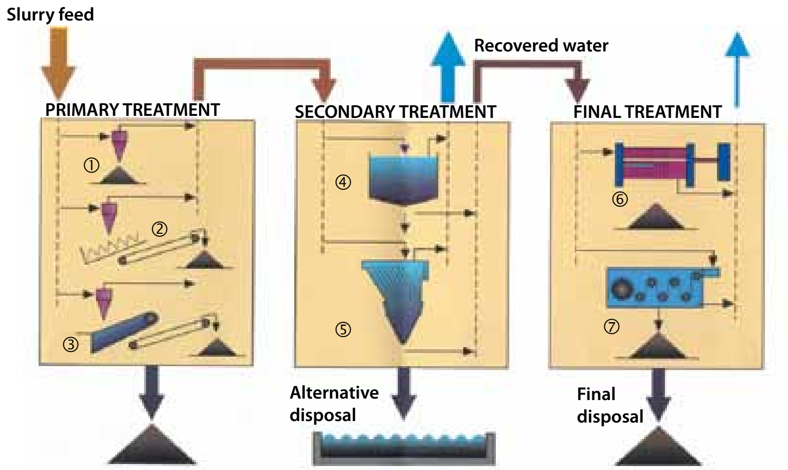
Wash water treatment

General

All washing operations are normally consuming a lot of expensive water. Not only costly, but also containing a lot of washing effluents both coarse and fine. Water and effluents that have to be processed partly to recover some value (coarse material and water), partly to protect the environment from damage (sludge fractions).
Most washing operations today must have systems for this treatment.

Wash water treatment stages

Depending on local conditions and restrictions, one, two or three treatment stages may be required, see below.

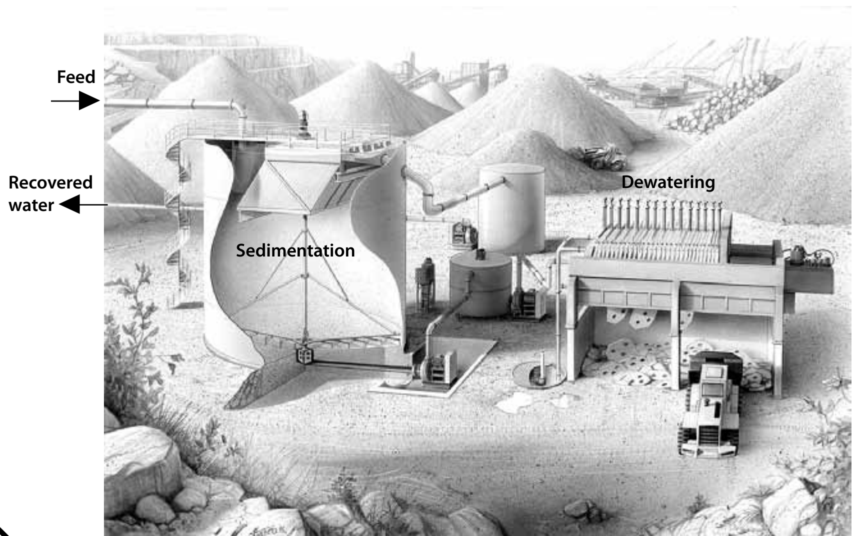


1. Hydrocyclone
2. Dewatering spiral
3. Dewatering screen
4. Conventional clarifier
5. Compact clarifier
6. Simple Pressure filter*
7. Belt press*

*Not covered in this handbook

Wash water treatment – closed system

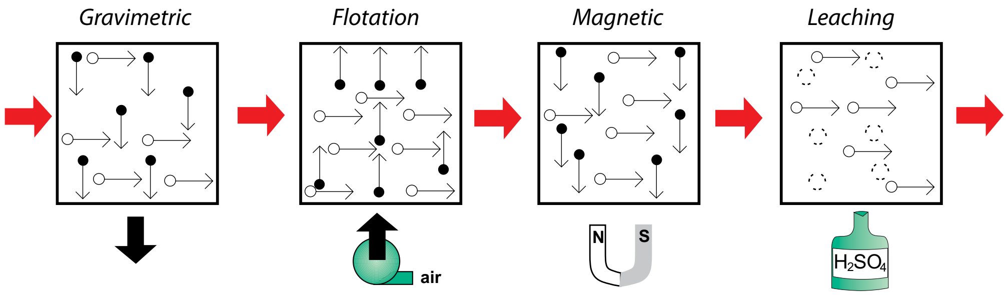
After recovery of coarser material the fines can be treated in a closed system recovering all process water and bringing the fine solids into a transportable form.



For more information see section 6!

Separation – Introduction

After liberation of all individual minerals in a rock or an ore feed, either by grinding or by natural size reduction (beach sands a.o.) they can be separated individually. Depending on their behaviour, different technologies are applied. We will cover the classical methods of separation as per below.



Separation by gravity

If there is a certain difference in density between two minerals or rock fractions they can be separated by using this difference. Separation by gravity covers two different methods.

- Separation in water (Gravity concentration)
- Separation in a heavy medium (Dense Media Separation, DMS)

The formula for Separation in water is:

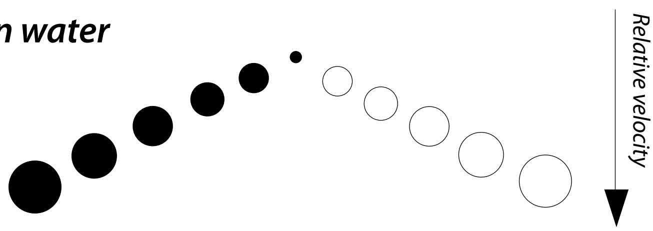
Density difference (Dd) = (D(heavy mineral)-1) / (D(light mineral)-1)

The formula for Dense Media Separation is:

Dd= D (heavy mineral)- D (heavy media) / D (light mineral) - D (heavy media)

Value of Dd	Separation	Comments
+ 2.50	easy	applicable down to 100 micron and lower
1.75 – 2.50	possible	applicable down to 150 micron
1.50 – 1.75	difficult	applicable down to 1700 micron
1.25 – 1.50	very difficult	applicable only for sand & gravel. see washing 5:2
< 1.25	not possible	

Separation in water



Equipment	Particle size range	Typical applications
Coal Jigs	40 – 200 mm (1.6 - 8″)	Coal
Mineral Jigs	75 µm - 6 mm ($3^1/_2$ mesh)	Gold, Chromite, Galena
Spirals	75 µm - 1.0 mm light, (16 mesh)	Coal, Beach sands, Iron
75 µm - 0.5 mm heavy, (32 mesh)		Cassiterit
Shaking tables	50 µm - 2 mm (9 mesh)	Tin, Copper, Gold, Lead,
	Zinc, Tungsten	

Separation by jigs

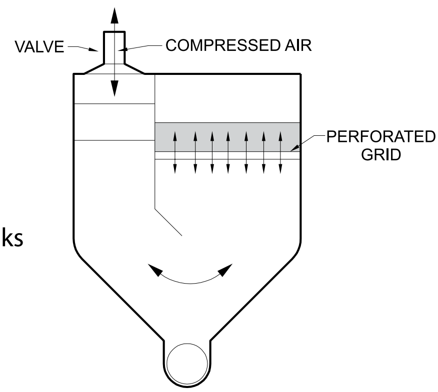
The jig operation consists of two actions. One is the effect of **hindered settling** meaning that a heavier particle will settle faster than a light particle. The other one is the separation process in an **upward flow of water** which will separate the particles by their density.

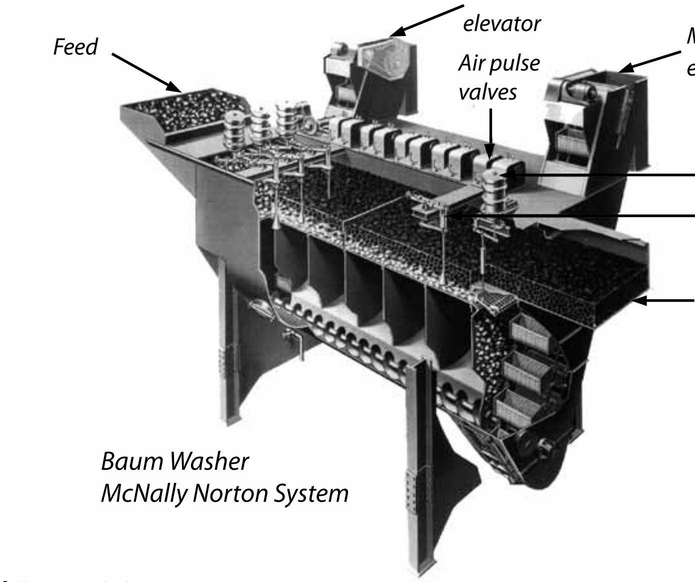
These two actions are combined in a Jig by slurry pulses generated mechanically or by air.

Coal jigs (Baum type)

Suitable for coarse load, feed size range maximum 175 - 200 mm (7 - 8 inch), minimum 40 - 60 mm (1.5 - 2.5 inch).

- Air pulsation type
- Two or three products
- Automatic discharge
- Modular design, bed area and elevators designed to suit duty.
- Designed to handle high portions of sinks compared to the mineral jig.





Baum Washer
McNally Norton System

Coal jigs – sizing

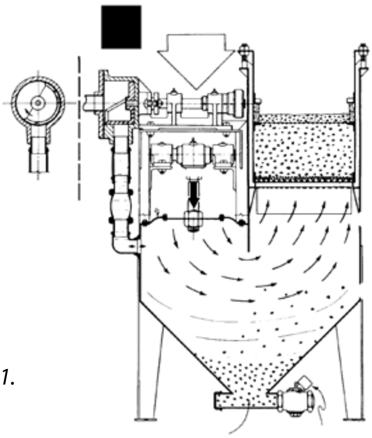
Type*		Compartments	Jig area		Feed capacity
(m)	(ft)	(No.)	(m^2)	(ft^2)	(t/h)
2.0	6.7	3 - 9	6.1 - 18.3	66 - 197	260
2.4	7.9	4 - 9	8.4 - 20.4	90 - 219	315
3.0	9.8	6 - 11	16.5 - 31.5	178 - 339	390
3.6	11.8	6 - 11	19.8 - 37.8	213 - 407	470
4.2	13.8	7 - 11	27.3 - 44.1	294 - 474	550

**Type refers to width of jig bed.*

Mineral jig (Denver type)

Suitable for minus 6 mm (3 mesh) feed, primarily a "through the bed" jig.

- Simplex or duplex versions
- Heavy-duty - long life diaphragm
- Synchronized water valve
- Variable stroke
- Right or left hand arrangement



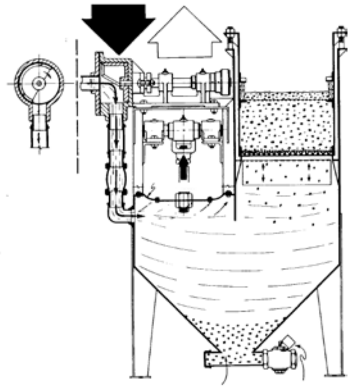
1.

Operation

1. On the "forward stroke" the fluidized particle bed re-organizes and

- lighter particles move to a higher bed position
- heavier particles move to a lower bed position

2. On the "back stroke" the separation bed is resting (closed) and the heavy particles are drawn down through the particle bed into the concentrate zone.



2.

Sizing

Type*	Bed area		Media flow (water)	
	(m^2)	(ft^2)	(m^3/h)	(USGPM)
Simplex 4x6	0.02	0.17	0.1-0.3	0.4 - 1.3
Simplex 8x12	0.06	0.67	0.5-0.8	2.2 - 3.5
Simplex 12x18	0.14	1.50	1.3-2	5.7 - 8.7
Simplex 16x24	0.25	2.67	1.5-3	6.6 - 13.2
Simplex 24x36	0.56	6.00	5-7	22 - 31
Duplex 8x12	0.12	1.33	1-1.5	4.4 - 6.6
Duplex 12x18	0.28	3.00	2-4	8.8 - 17.6
Duplex 16x24	0.80	5.33	3-5	13.2 - 22
Duplex 24x36	1.12	12.00	9-14	40 - 61

* type no. refers to width and length of particle bed area (in inches).

Jig capacity based on bed area, tph solids per m^2 typical capacities.

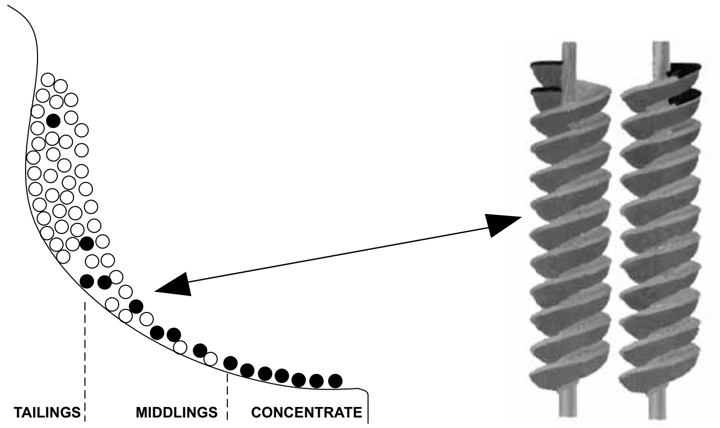
Heavy mineral

Capacity	(tph/m^2)	(stpd/ft^2)
Sphalerite	1.8 - 3.6	4 - 8
Pyrite	2.7 - 5.4	6 - 12
Galena	3.6 - 7.2	8 - 16
Gold (open circuit)	13.4 - 20.2	30 - 45
Gold (closed circuit)	15.7 - 21.4	35 - 70

Separation by spiral concentrators

A spiral concentrator uses gravity to separate particles of different densities. It should not be confused with a Spiral Classifier which usually separates particles of different size, see section 4.

A Spiral concentrator consists of one or more helical profiled troughs supported on a central column. As slurry travels down the spiral high and low density particles are stratified and separated with adjustable splitters at the end of the spiral.



Cross section through spiral concentrator

Design

Single, twin or triple start assemblies. Three, five or seven turn (18″ or 21″ pitch angle)

Separation

Dd - values, see 5:4
2.0 Excellent separation, e.g. mineral sands
1.5 Good separation, e.g. Coal
1.1 Poor separation, e.g. Diamonds

Sizing – Heavy minerals
Typical: 1 300 kg/h per start. 30%solids w/w. Pulp volume 3,5 m^3/h (15.4 USGPM)
Select spiral from the percentage of heavy mineral (density above 2.9) in the feed.

% Heavy mineral	**Suggested spiral selction**
0 - 20	7 turn 18° pitch
10 - 30	5 turn 18° pitch
20 - 80	5 turn 21° pitch
60 - 100	3 turn 21° pitch

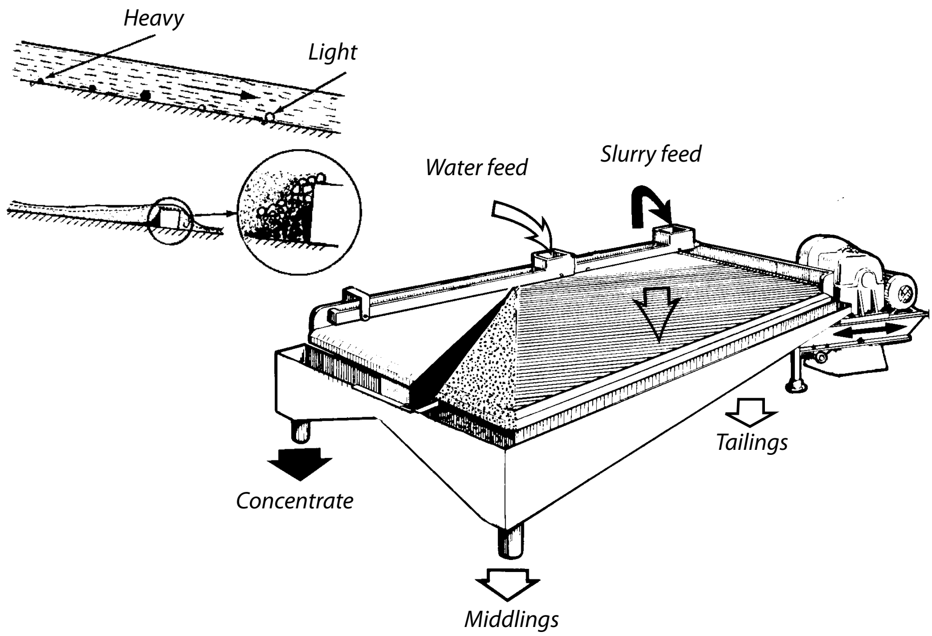
Sizing – Coal
Spiral diameter 1000 mm Particle size range: 1.0mm – 0.1mm
Typical: 3 200 kg/h per start, 35% solids w/w. Pulp volume 8 m3/h (35 USGPM)

Spiral – applications

Anthracite	Coke Breeze	Iron ore
Beach sand	Ferro chrome	Phosphates
Carbon/grit	Gold/carbon	Retile
Cassiterite	Gold sand (re-treatment)	Soil washing
Coal	Graphite	Zirconium

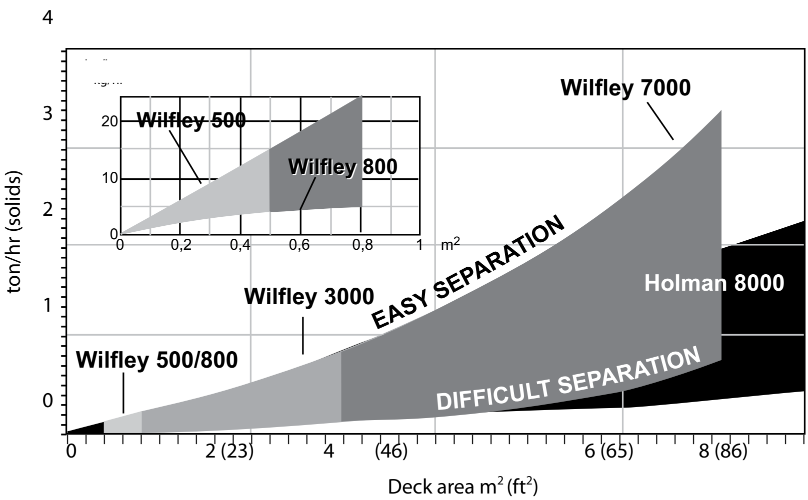
Separation by shaking tables

A cross stream of water transports material over the table to riffles running perpendicular to the direction of feed. Particles build up behind each riffle and stratification occurs with heavier particles sinking to the bottom. The light particles are carried over each riffle to the tailings zone. The shaking action of the tables carries the heavy particles along the back of each riffle to the concentrate discharge.



Sizing (Wilfey, Holman)

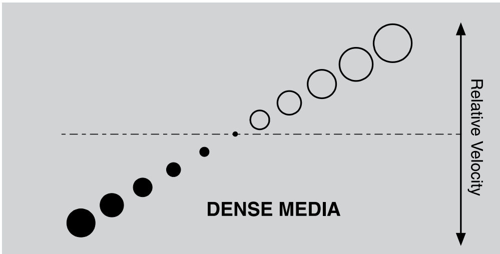
Table	Area	Application
H8000	7.9m^2 (85ft^2)	Cleaning duties, difficult separations
W7000	7.0m^2 (75 ft^2)	Rougher duties, high capacity separation
W3000	3.3m^2 (34 ft^2)	Pilot plants
W800/500	0.8/0.5m^2 (9/5 ft^2)	Lab- and on site testing



Separation in dense media

Gravity separation utilises the settling rate of different particles in water to make a separation. Particle size, shape and density all affect the efficiency of the separation.

Dense Media Separation (DMS) takes place in fluid media with a density between that of the light and heavy fractions that are to be separated. The separation is dependent upon density only



DMS – fluid media

Media	Density
Sand in water	1.2 - 1.6
Fine (- 50 micron or 270 mesh) Magnetite in water	1.6 – 2.5
Atomised Ferrosilicon in water	2.4 – 3.5
"Heavy Liquids" for lab testing	1.5 – 3.5

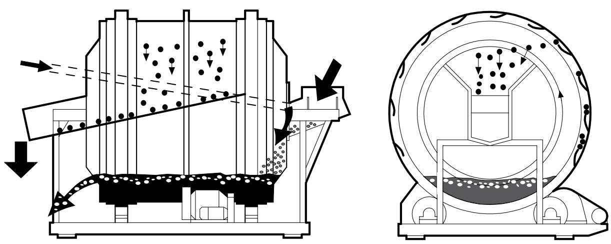
Typical vessels for DMS

- Static Drum separator
- Drewboy Separator
- Dynamic, "Dyna Whirlpool" or "Tri-Flow" separators
- Dense Media Cyclone

Dense media separators

Drum separator

Mainly mineral applications
Particle size range
6-200 mm (1/4" – 8")
Simple and robust
Low medium input
Max. media density =3.5
Data sheet, see 5:50.



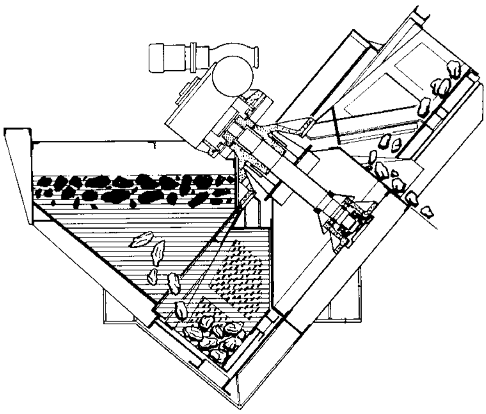
Sizing

Drum size (m)	Size (ft)	Feed capacity t/h
1.8 x 1.8	6 x 6	15 - 30
2.4 x 2.4	8 x 8	30 - 70
3.0 x 3.0	10 x 10	70 - 140
3.6 x 3.6	12 x 12	140 - 250

Drewboy

- Mainly coal applications
- Particle size range 6 - 1200 mm ($^{1}/_{4}$"-48")
- High sinks capacity up to 300 t/h
- Low medium input
- Max media S.G. 3.5

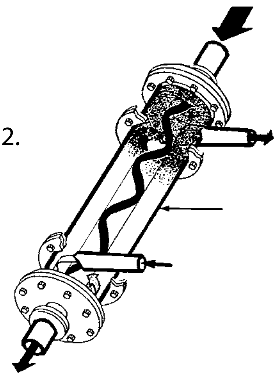
Data sheet, see 5:51.



Dyna Whirlpool

- For all types of DMS
- Slope angle for mineral separation 25 degrees
- Slope angle for coal separation 15 degrees
- Particle size range 0.3 - 30 mm (50 mesh - 1$^{1}/_{4}$")
- Capacities 10 - 75 t/h and unit
- Can be built in series with different separation densities
- Max media S.G. 3.5
- Feed pressure 100-150 kPa (14 - 22 PSI)

Data sheet, see 5:52.



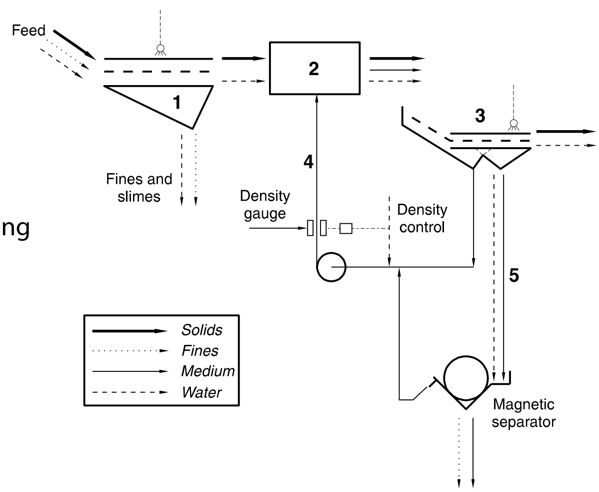
Sizing

Drewboy		Dyna Whirlpool	
Size*m (ft)	Feed capacity t/h	Model **	Feed capacity t/h
1.2 (4.0)	200 - 350	DWP9	10 - 20
1.6 (5.0)	210 - 385	DWP12	20 - 35
2.0 (6.5)	225 - 425	DWP15	35 - 55
2.6 (8.5)	305 - 565	DWP18	55 - 75
3.2 (10.5)	405 - 665		
4.0 (13.0)	500 - 820		

*Refers to inside width of bath **Refers inside diameter in inch

Dense media circuit

1. Feed preparation screens (removal of fines)
2. DMS separator (see below)
3. DMS screen (drain and washing stages)
4. Dense media circuit
5. Dilute media circuit



DMS – Applications

Coal	Tin
Diamonds	Manganese
Iron Ore	Phosphate
Chromite	Scrap metals
Fluorspar	

In many cases Dense Media Separation is used for "Pre- concentration" e.g. rejecting waste material prior to further processing (typical between crushing and grinding).

Dense media circuits – Sizing

These systems have to be adapted to each particular case. For rough estimations the following figures can be used.

1. Feed preparation screens

Screens to be of horizontal vibrating type ("Low Head") with width determined by particle size, solids density and amount of fines.

Use the following guide-lines for *screens.*

Particle size mm (inch)	Capacity/Screen width t/h x m	t/h x ft
6 - 100 ($^1/_4$ - 4)	90	30
6 - 30 ($^1/_4$ - 1$^1/_4$)	50	17
0.5 - 10 (35 mesh - $^3/_8$")	20	7

Screen lengths should be approx. 4 m (13 ft) for coarse feeds (> 6 mm) ($^1/_4$"), and 4.5 - 6 m (15 - 20 ft) for finer feeds (< 6 mm) ($^1/_4$") all related to smaller plants (capacity 15-35 t/h).

2. Medium feed rate

1.7 m^3/t (450 USG/t) dry solids for drum separator systems

4.0 m^3/t (1050 USG/t) dry solids for DWP system

3. Medium loss

For coarse feeds (> 6 mm, $^1/_4$") 100 g/ton solids

For fine feeds (< 6 mm, $^1/_4$") 150-300 g/ton solids depending on material porosity.

4. Magnetic separator

Magnetic separator can be roughly sized from a figure of 3.5 m^3 (900 USG) diluted medium per ton feed solids. For magnetic separator capacities see Magnetic Separation, 5:25-26.

5. Spray screens

The width of the screens depends on the amount of spray water used (= feed to the magnetic separator) and the sink/float distribution.

For capacity 15-35 t/h use 4,5 m. (15 ft)

For capacity 35-100 t/h use 6,0 m. (20 ft)

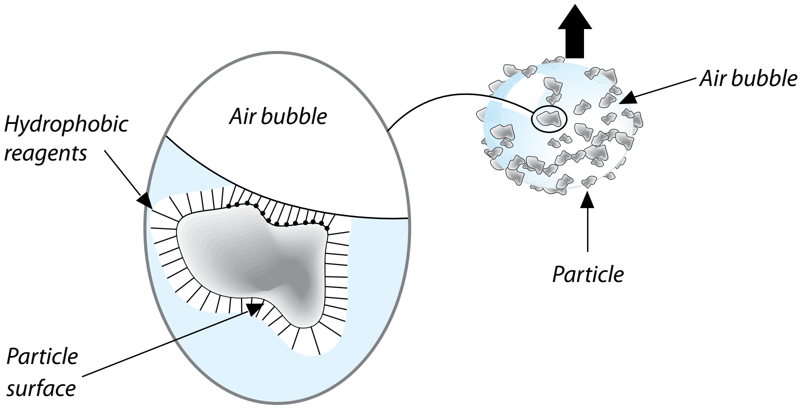
Screen length varies with capacity and particle size.

Use 4,8 m for particle size + 6 mm (16 ft for +$^1/_4$")

Use 6,0 m for particle size + 1 mm (20 ft for + 15 mesh)

Separation by flotation

Flotation is a mineral separation process, which takes place in a water-mineral slurry.
The surfaces of selected minerals are made hydrophobic (water-repellent) by conditioning with selective reagents. The hydrophobic particles become attached to air bubbles that are introduced into the pulp and are carried to a froth layer above the slurry thereby being separated from the hydrophilic (wetted) particles.



In addition to the reagents added, the flotation process depends on two main parameters.

- **Retention time** needed for the separation process to occur determines the volume and number of flotation cells required.
- **Agitation** and **aeration** needed for optimum flotation conditions, determine the type of flotation mechanism and the power input required.

Size of cells – lengths of banks

As flotation is based on retention time we have two alternative approaches:

- **Small cells and longer banks**
- **Fewer large cells and shorter banks**

The first alternative is a more conservative approach and is applicable to small and medium tonnage operations. Using more smaller cells in flotation means

- **Reduced short circuiting**
- **Better metallurgical control**
- **Higher recovery**

The second alternative is becoming more accepted for high tonnage operations using large unit volume flotation machines. Modern flotation equipment gives opportunities to use larger cells and shorter circuits.

- **Effective flow pattern minimizes shortcircuiting**
- **Improved on line analyzers will maintain good metallurgical control**
- **Less mechanical maintenance**
- **Less energy input per volume pulp**
- **Lower total cost**

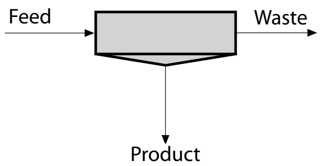
Selection of cell size is made on the basis of the largest individual cell volume that will give the required total flotation volume with an acceptable number of cells per bank. Typical figures for different minerals are given later in this section.

Flotation circuit layout

Flotation circuit designs vary in complexity depending primarily on the type of mineral, degree of liberation of valuble minerals, grade (purity) of the product and the value of the product.

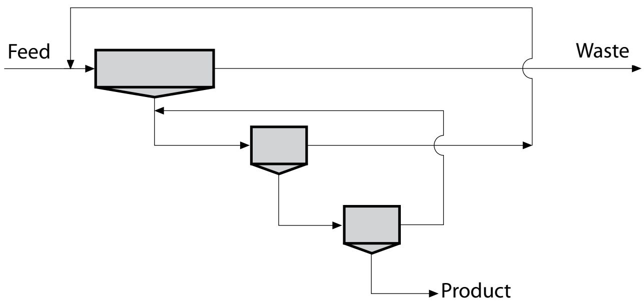
Simple circuit (e.g. coal)

Single stage flotation, with no cleaning of the froth.



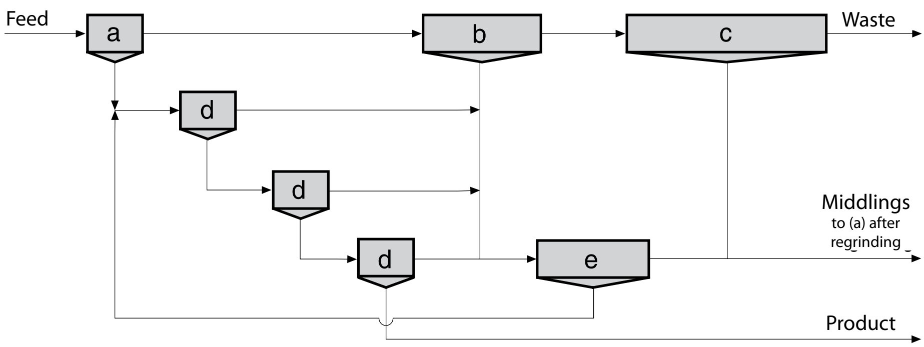
Commonly used circuit (e.g. lead)

Single stage rougher, two stages of cleaning, no regrind.



Complex circuit (e.g. copper)

Two stages roughing (a,b), one stage scavenging (c), three stages cleaning (d), cleaner scavenger (e), regrind.



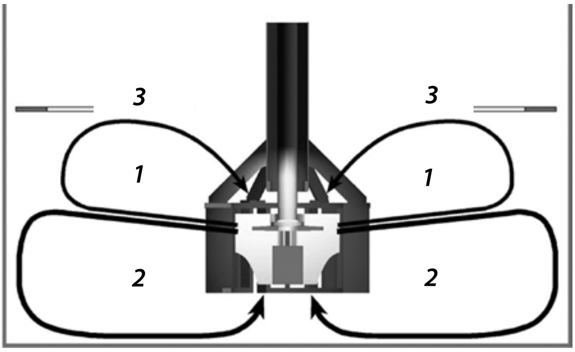
Typically the **first rougher stage** would comprise 10-40 % of the total rougher volume and will produce a good grade concentrate with but only medium recovery. **The second rougher stage** comprises 60-90 % of the total rougher volume and is designed to maximise recovery.

The scavenger cells would have a cell volume equal to the total rougher stage and are included when particularly valuable minerals are being treated or a very high recovery is needed. **Cleaner cells** are used to maximise the grade of the final concentrate. Typical cleaner retention time is 65-75% of that for rougher flotation and will be at a lower percent solids. Less cells per bank than for rougher duties can be used.

Reactor cell flotation system (RCS)

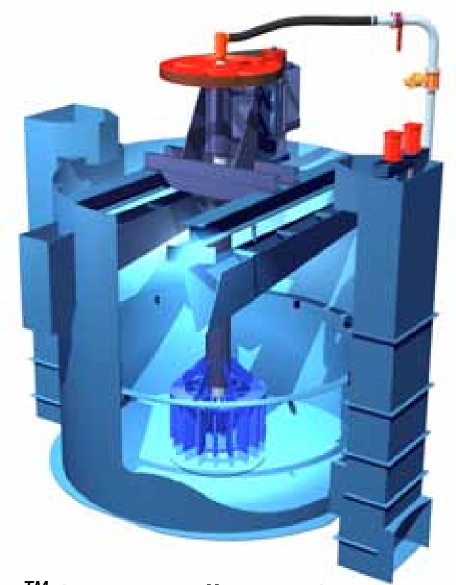
The RCS™ (Reactor Cell System) flotation machine utilises the patent protected DV™ (Deep Vane) Mechanism. Flow pattern characteristics are:

- Powerful radial slurry flow patterns to tank wall (1).
- Primary return flow to underside of impeller (2).
- Secondary top recirculation (3).



Flotation enhanced due to:

- Maximum particle-bubble contacts within the mechanism and tank.
- Effective solids suspension during operation and re-suspension after shutdown.
- Effective air dispersion throughout the complete cell volume.



Features of the RCS™ (Reactor cell system):

- Active lower zone for optimum solid suspension and particle – bubble contact.
- Upper zone with reduced turbulence to prevent particle – bubble separation.
- Quiescent cell surface to minimise particle re-entrainment.
- Circular tank with low level slurry entry and exit to minimise slurry short circuiting.
- Cell size 3 – 200 m^3 (105 - 7060 ft^3)
- V-V drive up to 70 m^3. Gearbox drive for 100 m^3 and above. (V-V drive for larger volume cells optional)
- Automatic level control by dart valves.
- Separate source of low pressure air.
- Double internal cross-flow froth launders or internal peripheral launders with central crowder.
- Application : The majority of mineral flotation duties.

See data sheet 5:53.

Reactor cell system (RCS) – Sizing, metric

Selection of the size and number of cells for each stage of the flotation circuit (roughing, cleaning etc) is made by a three step calculation.

1. Determination of total flotation cell volume

Total flotation cell volume required can be calculated from the formula:

$$Vf = \frac{Q \times Tr \times S}{60 \times Ca}$$

Vf = Total flotation volume required (m^3)

Q = Feed flow rate m^3/hr

Tr = Flotation retention time (minutes). Typical figures for different minerals are given overleaf, alternatively the retention time may be specified by the customer or be determined from testwork.

S = Scale up factor dependent upon source of flotation retention time date (above)

Tr specified by customer S = 1.0

Tr taken from typical industrial data S = 1.0

Tr taken from continuous Pilot Plant test S = 1.0

Tr taken from laboratory scale test work S = 1.6 – 2.6

Ca = Aeration factor to account for air in pulp. 0,85 unless otherwise specified.

2. Select the number of cells per bank

The table overleaf shows typical amount of cells per bank for common mineral flotation duties. Divide Vf calculated above by number of cells selected to calculate volume (m^3) per cell. Check that Q is in flow rate range for cell size selected. Reselect if necessary.

3. Select the bank arrangement

To ensure necessary hydraulic head to allow slurry to flow along the bank intermediate boxes may be required. Maximum numbers of cells in a section between intermediate or discharge boxes are given overleaf. Each bank will also need a feed box and a discharge box.

Typical bank designation is F-4-I-3-D, i.e. Feed box, four cells, intermediate box, three cells, discharge box.

Reactor cell system flotation sizing

Selection data for rougher flotation duties are as follows:

Mineral	% solids in feed	Retention time min (normal)	No. of cells/bank
Barite	30 - 40	8 - 10	6 - 8
Copper	32 - 42	13 - 16	8 - 12
Fluorspar	25 - 32	8 - 10	6 - 8
Feldspar	25 - 35	8 - 10	6 - 8
Lead	25 - 35	6 - 8	6 - 8
Molybdenum	35 - 45	14 - 20	10 - 14
Nickel	28 - 32	10 - 14	8 - 14
Phosphate	30 - 35	4 - 6	4 - 5
Potash	25 - 35	4 - 6	4 - 6
Tungsten	25 - 32	8 - 12	7 - 10
Zinc	25 - 32	8 - 12	6 - 8
Silica (iron ore)	40 - 50	8 - 10	8 - 10
Silica (phosphate)	30 - 35	4 - 6	4 - 6
Sand (impurity)	30 - 40	7 - 9	6 - 8
Coal	4 - 12	4 - 6	4 - 5
Effluents	as received	6 - 12	4 - 6

For cleaning applications use 60% of the rougher percent solids. Required retention time for cleaning is approx. 65% of rougher retention time.

Selection data for Reactor Cell System (metric) are as follows:

	Volume (m^3)	Maximum bank feed rate (m^3/h)	Maximum cells per section (1)
RCS 0,8	0,8	25	4
RCS 3	3	240	4/5
RCS 5	5	320	4/5
RCS 10	10	540	4
RCS 15	15	730	4
RCS 20	20	870	4
RCS 30	30	1120	3
RCS 40	40	1360	3
RCS 50	50	1650	3
RCS 70	70	2040	2
RCS 100	100	2550	2
RCS 130	130	3050	2
RCS 160	160	3450	1
RCS 200	200	3990	1

(1)Number of cells on same level between connecting boxes

Reactor cell system flotation – Example calculation

Requirement:

Single rougher bank. Copper flotation.

Feed pulp flow rate 1400 m^3/h (6160 USGPM).

Retention time 16 minutes, determined by continuous pilot plant test.

1. Determination of total flotation cell volume

$$Vf = \frac{Q \times Tr \times S}{60 \times Ca} = \frac{1400 \times 16 \times 1}{60 \times 0.85} = 439 \text{ m}^3 \text{ total bank volume}$$

2. Select the number of cells in bank

Minimum cell size to handle 1400 m^3/hr is RCS 50 (Maximum 1650 m^3/hr).

439 / 50 = 8.78 cells. Normal range for copper is 8 - 12 cells, so this is a valid selection. If this was not the case choose the next cell size up or down as appropriate.

9 x RCS 50 cells required. Total volume 9 x 50 = 450 m^3.

3. Select the bank arrangement

For RCS 50 the maximum amount of cells in one section is 3. So to have 9 cells choose bank arrangement.

RCS 50 F-3-I-3-I-3-D

RCS specifications

	Standard Drive (1)	Cell volume (2)		Connected motor (3)		Air requirements (4)			
		m^3	ft^3	kW	HP	Am^3/min	kPag	Acfm	psig
RCS 3	VB	3	105	11	15	2	17	70	2,5
RCS 5	VB	5	175	15	20	3	19	110	2,8
RCS 10	VB	10	355	22	30	4	22	140	3,2
RCS 15	VB	15	530	30	40	6	25	210	3,6
RCS 20	VB	20	705	37	50	7	27	250	3,9
RCS 30	VB	30	1060	45	60	9	31	320	4,5
RCS 40	VB	40	1410	55	75	10	34	350	4,9
RCS 50	VB	50	1765	75	100	12	38	420	5,5
RCS 70	VB	70	2470	90	125	15	41	530	5,9
RCS 100	VB/GB	100	3530	110	150	19	47	670	6,8
RCS 130	VB/GB	130	4590	132	200	23	51	810	7,4
RCS 160	GB	160	5650	160	200/250	25	55	880	8,0
RCS 200	GB	200	7060	200	250	30	59	1060	8,6

(1) VB - spindle bearing with v-belt drive GB - gearbox with v-belt drive

(2) Active flotation volume

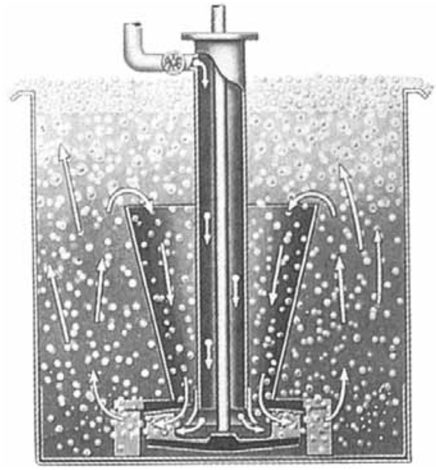
(3) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso

(4) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso Air requirement is at flotation mechanism, pressure losses from blower to flotation bank should be considered when specifying blower

DR Flotation cell system

The Reactor Cell System Flotation Machine is the preferred choice for many mineral flotation applications. The DR design may be specified for certain appli-cations, particularly where de-slimed coarse particles have to be handled such as in glass and potash processing. Features of the DR design are as follows:

Flotation system DR – Design



- Open flow tank with intermediate and discharge boxes
- Near bottom located impeller/ diffuser
- Separate source of low pressure air
- Level control by weir or dart valves (automatic as option)
- Recirculation well
- Reversible impeller direction of rotation
- Max cell size 14 m^3

See data sheet 5:54.

DR – Specifications

	Cell volume (1)		Connected motor (2)		Air requirements (3)			
	m^3	ft^3	kW	HP	Am^3/min	kPag	Acfm	psig
DR 15	0,34	12	2,2	3	0,4	7	15	1,0
DR 18Sp	0,71	25	4	5	0,7	9	25	1,3
DR 24	1,42	50	5,5	7,5	1,3	10	45	1,6
DR 100	2,83	100	11	15	2,3	10	80	1,6
DR 180	5,10	180	15	20	3,1	14	110	2,0
DR 300	8,50	300	22	30	4,5	18	160	2,6
DR 500	14,16	500	30	40	6,5	18	230	2,6

(1) Active flotation volume
(2) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso
(3) Per cell and applicable up to 1.35 slurry sg. If higher slurry sg, consult Metso
Air requirement is at flotation bank air header, pressure losses from blower to flotation bank should be considered when specifying blower

DR – Cell volumes and hydraulic capacities

Size	Maximum Bank Feed Rate		Maximum cells
	m^3/h	USGPM	per bank section (1)
DR15	25	110	15
DR18 sp	55	240	12
DR24	110	485	9
DR100	215	945	7
DR180	415	1 825	6
DR300	580	2 550	5
DR500	760	3 345	4

(1) Number of cells on same level between connecting boxes

Column flotation cell system

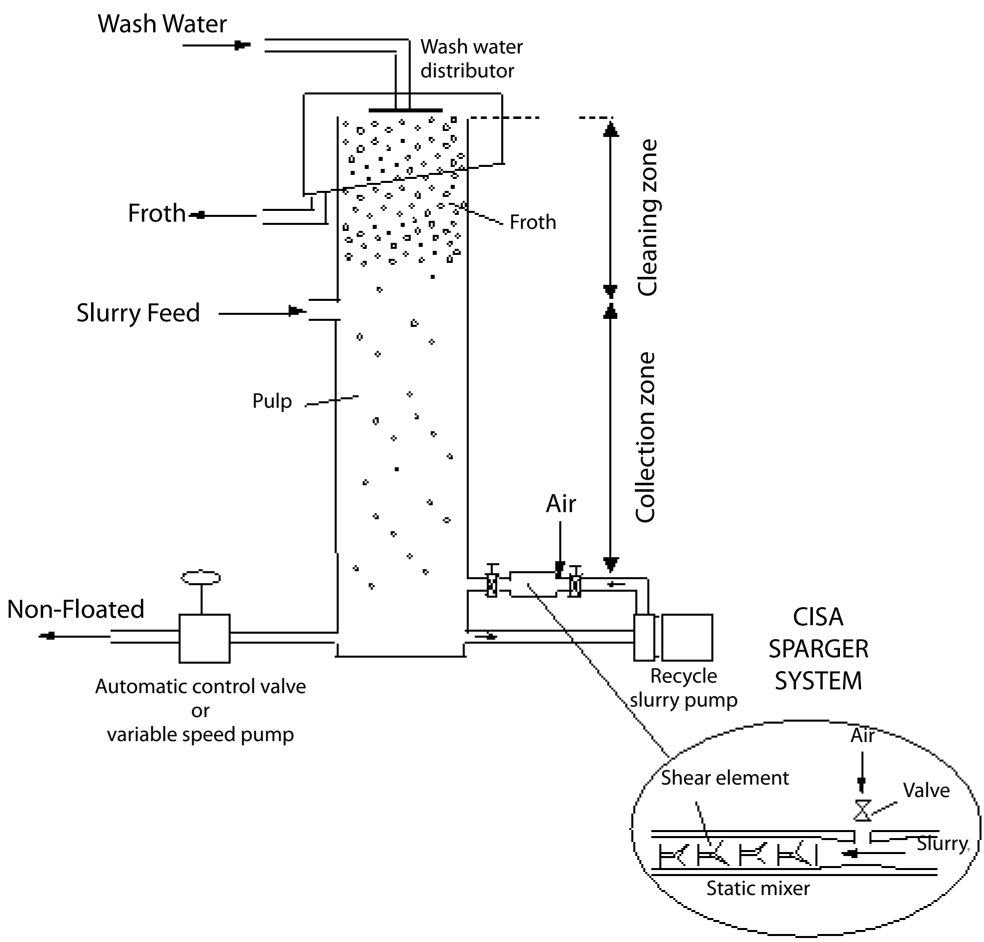
Flotation column work on the same basic principle as mechanical machines such as RCS™. However, in column flotation there is no mechanical mechanism.

Separation takes place in a vessel of high aspect ratio and air is introduced into the slurry through spargers.

In certain cases such as cleaning duties or handling of very fine particles column flotation will offer the following advantages:

- Improved metallurgical performance
- Low energy consumption
- Less floor area
- Less maintenance
- Improved control

Schematic of flotation column (CISA)

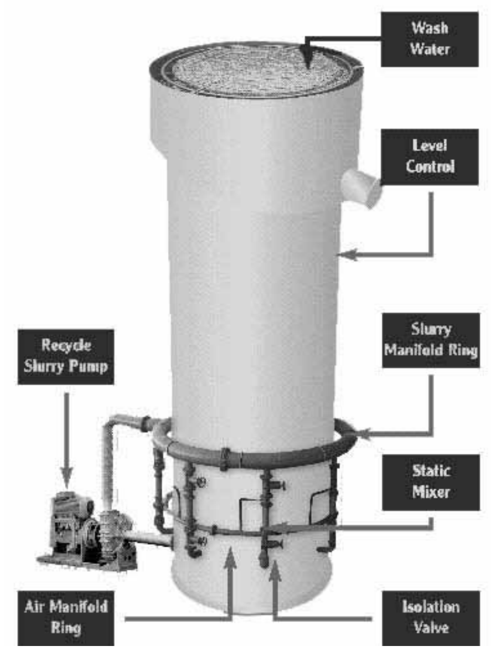


Column flotation – Features

The CISA Sparger consists of inline **Static Mixers** and **a Recycle Slurry Pump**. Tailings Slurry is pumped from the base of the column through the static mixers where air and slurry are mixed together under high shear conditions to create the bubble dispersion. As the air/slurry mixture passes through the stationary blades located inside the mixer the air is sheared into very small bubbles by the intense agitation. The bubble suspension is introduced near the column base.

Slurry **Level Control** is achieved by using Dp or ultrasonic sensors to automatically adjust the Tailings Control Valve.

Wash Water addition improves grade by removing mechanically entrained particles.



Selection

For detailed column design - contact your support center supplier. A preliminary indication of design parameters can be derived from the following notes.

- Column designs available up to 4 metre (39”) diameter
- Typical slurry velocity in column 10 - 48 m/h (33 - 157 ft/h)
- Typical froth capacity 2-4 g/min/ cm^2
- Typical free air velocity in column 54 - 79 m/h (177 - 259 f/h)
- Height of column selected to give slurry retention time in range 10-20 min.
- Washwater approx. 7 m^3/h per m^2 (2740 ft^3/h per ft^2) of column area.

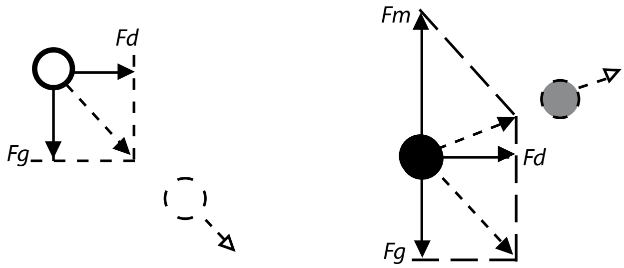
Applications

Applications for flotation columns include:

- Copper
- Graphite
- Lead
- Phosphate
- Zinc
- Coal
- Iron
- Fluorspar

Magnetic separation – Introduction

By creating an environment comprimising a **magnetic force** (Fm), a **gravitional force** (Fg) and a **drag force** (Fd) magnetic particles can be separated from non-magnetic particles by **Magnetic Separation.**



Magnetic separation - Magnetic attraction force (Fm)

Fm = V x X x H x grad H

V = **particle volume** (determined by process)

X = **magnetic susceptibility** (see table below)

H = **magnetic field** (created by the magnet system design) in mT (milliTesla) or kGauss (kiloGauss) 1 kGauss = 100 mT = 0.1 T

grade H = **Magnetic field gradient** (created by the magnet system design) in mT/m

Magnetic field and magnetic gradient are equally important factors for creating the magnet attraction force.

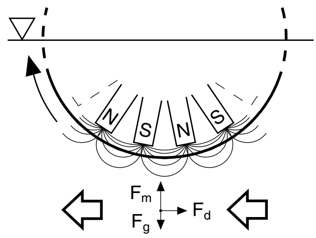
Mineral	Magnetic susceptibility (X_m x 10^6 emu/g)	
Magnetite	20 000 - 80 000	Ferromagnetic (strong magnetic)
Pyrrhotite	1 500 - 6 100	
Hematite	172 - 290	Paramagnetic (weakly magnetic)
Ilmenite	113 - 271	
Siderite	56 - 64	
Chromite	53 - 125	
Biotite	23 - 80	
Goethite	21 - 25	
Monazite	18.9	
Malachite	8.5 - 15.0	
Bornite	8.0 - 14.0	
Rutile	2.0	
Pyrite	0.21	
Cassiterite	- 0.08	Diamagnetic (repelling)
Fluorite	- 0.285	
Galena	- 0.35	
Calcite	- 0.377	
Quartz	- 0.46	
Gypsum	- 1.0	
Sphalerite	- 1.2	
Apatite	- 2.64	

Magnetic separation – Competing forces

- **Gravitational force** (Fg) determined by particle size and particle density.
- **Hydraulic force** (Fd) for wet magnetic separators, determined by particle diameter, shape, liquid viscosity and velocity (see wet LIMS and wet HGMS below.)
- **Centrifugal force** (Fc) for rotating dry magnetic separators, determined by particle size, density and drum speed. (see dry LIMS below.)
- **Air drag force** (Fa) for dry magnetic separators, determined by particle size, density and air velocity. (see dry HGMS below).

Magnetic separation – Separator types

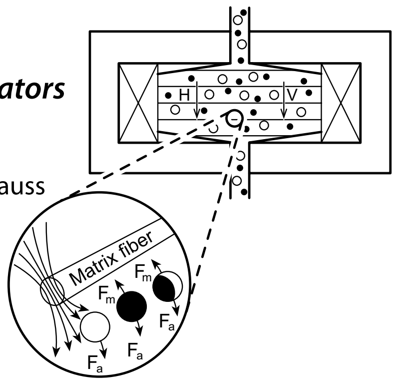
Wet LIMS = Low intensity magnetic separators



- Wet separation of ferromagnetic particles
- Magnetic field in separation zone * = 1-3 kGauss

* approx. 50 mm (2 inches) from drum surface

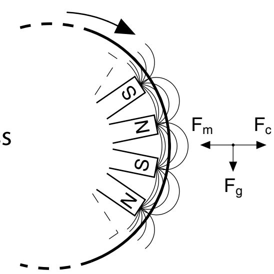
Wet HGMS = High gradient magnetic separators



- Wet separation of paramagnetic particles
- Magnetic field in separation zone* = 2-20 kGauss

* on matrix surface

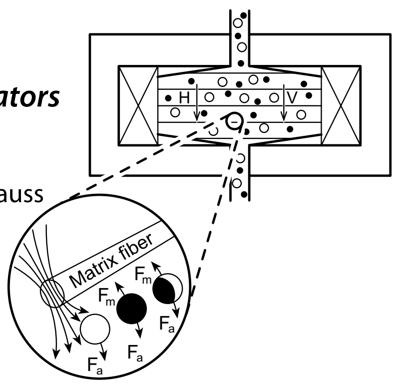
Dry LIMS = Low intensity magnetic separators



- Dry separation of ferromagnetic particles
- Magnetic field gradient in* separation zone = 1-3 kGauss

* approx. 50 mm (2 inches) from drum surface

Dry HGMS = High gradient magnetic separators



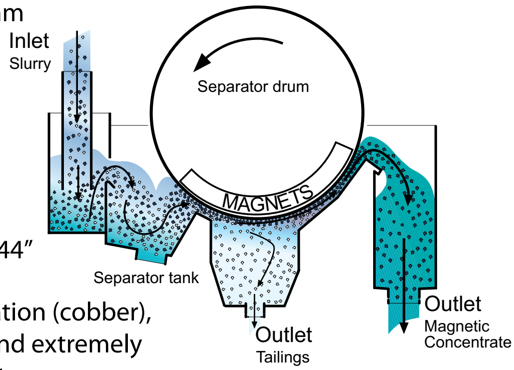
- Dry separation of paramagnetic particles
- Magnetic field in separation zone* = 2-20 kGauss

* on matrix surface

Wet LIMS – Concurrent (CC)

Please always check with Metso for final selection!

- Short pickup zone
- Coarse particle tolerant up to 8 mm - 0.2 inch (up to 15 mm - 0.8 inch with special tank)
- Dia 1200 mm (48")
- Length 600, 1200, 1800, 2400, 3000 and 3600 mm.
- Length 24", 48", 72", 96",120" and 144"

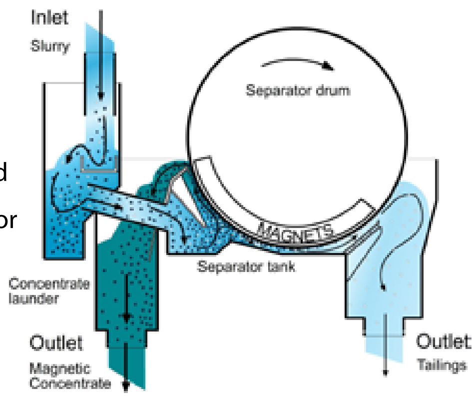


CC is basically used as primary separation (cobber), "working horse" for large capacities and extremely coarse feeds, mainly in iron ore industry.

See data sheet 5:55.

Wet LIMS – Counter rotation (CR) (CRHG)

- Very long pickup zone
- Good separation with high recoveries
- For both low and high grade feeds
- Unsensitive for sedimentation, particles up to 3 mm can be separated
- HG (high gradient) version available for Dense media
- Self adjusting level control
- Dia 1200 mm (48")
- Length 600, 1200, 1800, 2400, 3000 and 3600 mm
- Length 24", 48", 72", 96", 120" and 144"



CR used as: 1. Cobber and rougher mainly in the iron ore industry.
2. Dense media separator, accepting higher flow-rates than DM/DMHG.

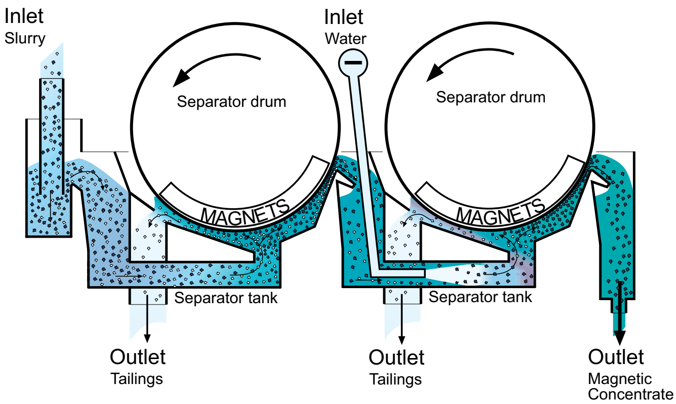
See data sheet 5:56.

Wet LIMS – Countercurrent (CTC)

- Long pickup zone = improved recovery
- Many pole passages = improved grade
- Self adjusting level control
- Coarse particle intolerant max 0.8 mm, due to sedimentation risk.
- Dia 1200 mm (48")
- Length 600, 1200, 1800, 2400, 3000 and 3600 mm.
- Length 24", 48", 72", 96", 120" and 144"

CTC used as: Cleaner and finisher for multistage concentration of magnetic iron ore

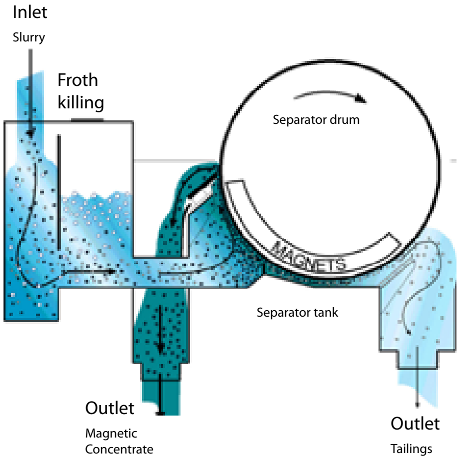
See data sheet 5:57.



Wet LIMS – Froth separator (DWHG)

- Very long pickup zone
- For extremely high recoveries of very fine particles
- Large feedbox for "froth killing"
- Elevated concentrate discharge improves drainage of silica slimes.
- HG yoke, with extended magnetic beam angle
- Dia 1200 mm (48")
- Length 600, 1200, 1800, 2400, 3000 and 3600 mm.
- Length 24", 48", 72", 96", 120"and 144"

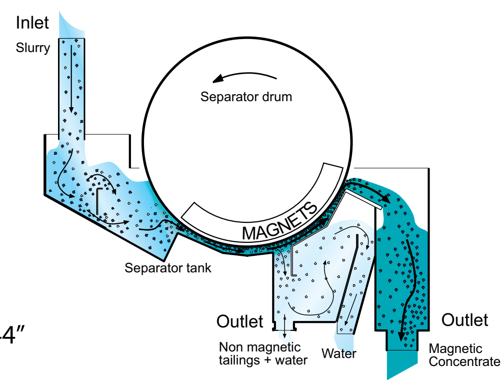
See data sheet 5:58.



Wet LIMS – Dense media recovery (DM) (DMHG)

- Very long pickup zone
- For extremely high recoveries of very fine particles
- HG (high gradient) version available for high recovery from very dilute pulps
- Dia 1200 mm (48")
- Length 600, 1200, 1800, 2400, 3000 and 3600 mm.
- Length 24", 48", 72", 96", 120"and 144"

See data sheet 5:59.



Wet LIMS – Feed densities

Con-current (CC) 35-45 percent solids by weight

Counter-current (CTC) 25-40 percent solids by weight

Counter-rotation (CR) 25-40 percent solids by weight

Dense-Media (DM) 25-300 grams per liter

Dense-Media (DMHG) 5-100 grams per liter

Wet LIMS – Capacities Guidelines only!

Iron ore applications

Fineness	% minus 0.074 mm	Type of tank	Dry solids feed rate ton / h x m drum length 1200 mm	Volumetric feed rate m^3/ h x m drum length 1200 mm
Coarse	15 - 25	Concurrent / Counter rotation	80 - 140	240 - 350
Medium	50	Counter rotation	60 - 100	130 - 220
Fine	75 - 95	Countercurrent	40 - 80	150 - 250

Fineness	% minus 200 mesh	Type of tank	Dry solids feed rate ton / h x ft drum length 48"	Volumetric feed rate US GPM / ft drum length 48"
Coarse	15 - 25	Concurrent / Counter rotation	25 - 50	320 - 470
Medium	50	Counter rotation	20 - 30	175 - 300
Fine	75 - 95	Countercurrent	10 - 25	200 - 335

Froth applications

Model series	Drum diameter mm	Volume capacity m^3/ h x m drum length	Volumetric feed rate US GPM / ft drum length
WS 1200 DWHG	1200	80 - 120	110 -160

Dense media applications

Model series	Drum diameter mm	Volume capacity m^3/ h x m drum length
WS 1200 DM	1200	100 - 150
WS 1200 DMHG	1200	80 - 120
WS 1200 CR	1200	125 - 200

Model series	Drum diameter inch	Volume capacity US GPM / ft width
WS 1200 DM	48	135 - 200
WS 1200 DMHG	48	110 - 160
WS 1200 CR	48	170 - 270

Wet LIMS – Sizing

For sizing, use dry solids feed rate normally at high solids content (>25% solids by weight) and volumetric feed rate at low solids content (<25% solids by weight)

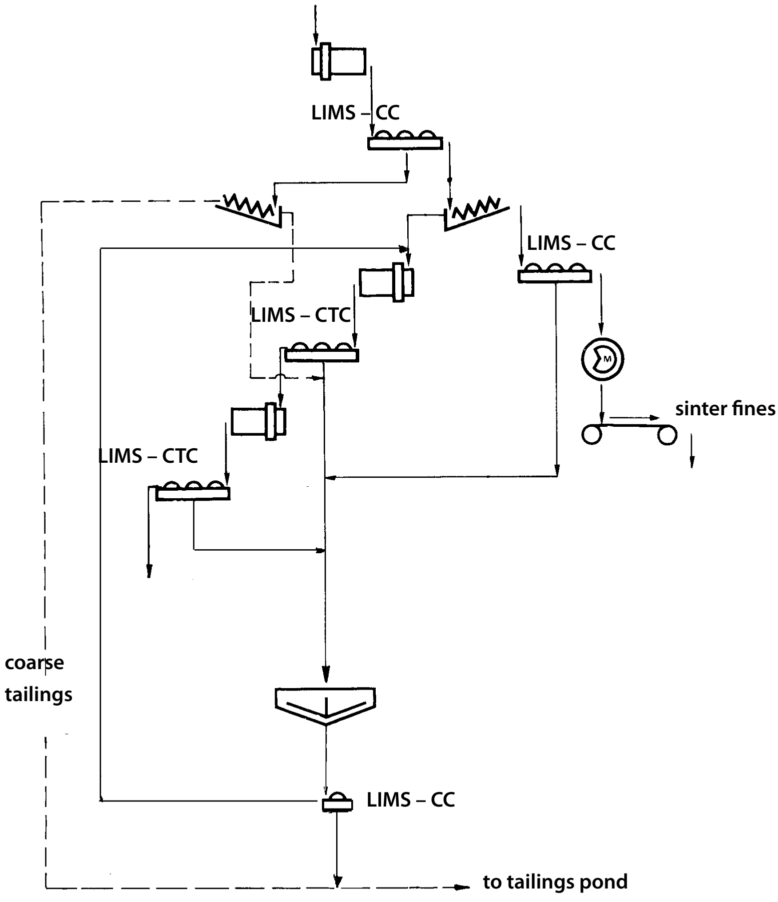
ex: Magnetite rougher, coarse particles 20% minus 200 mesh, capacity 500 t/h. (555 stph)

Sizing: select concurrent separator.
Capacity (see table above) is say 140 t/h (155 stph) and m drum (dia 1200 mm, 48") 500/140 gives 3,6 m (144") drum length. Max length is 3m (120").
2 x drum length 1800 mm (72") gives 504 t/h (556 stph).

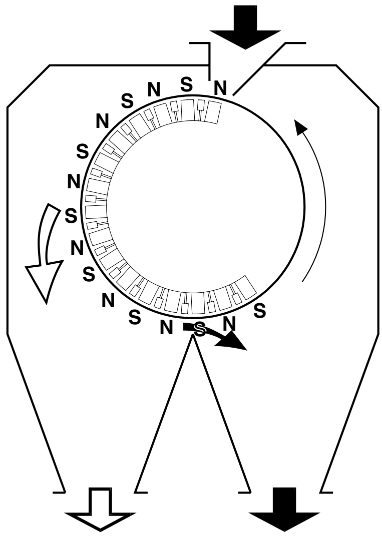
Select: 2 x WS 1218 CC.

Note: There are "magnetite" deposits where the ore is various stages of transformation (e.g. martitisation). These ores will exhibit different magnetic properties and must be tested before separation equipment can be correctly sized.

Wet LIMS – Flowsheet (typical)



Dry LIMS – Drum separator (DS)



- Alternating polarity with different pole pitches giving good recovery and grade
- Variation of drum speed 1-8 m/s (3 - 26 ft/s) gives metallurgical flexibility
- Not sensitive to particle size 0.01 - 20 mm (150 mesh - $^3/_4$")
- Dia 916 mm (36"), 1200 mm (48")
- Length 300 (dia 916 only), 600, 1200, 1800, 2400, 3000, and 3600 mm.
- Length 12" (dia 36" only), 24", 48", 72", 96", 120", and 142"
- For high speed (+5 m/s) separation maximum length is 2400 mm (95")

DS can be used for separation of all types of dry ferromagnetic separation processes:

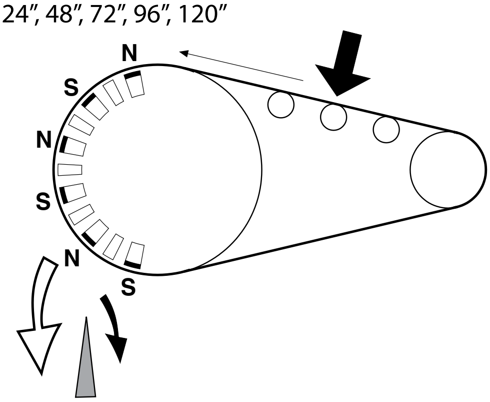
- Iron and steel slag treatment
- Reduced pyrite ash separation
- Calcined ilmenite production
- Iron metal powder production
- Magnetite or supergrade magnetite production

See data sheet 5:60.

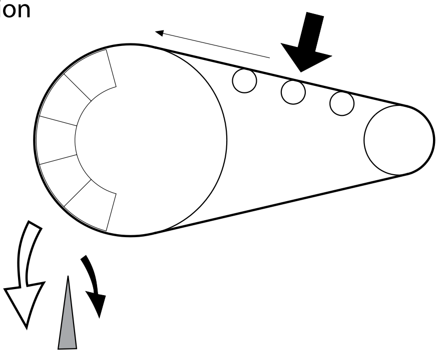
* Max lenght - hight speed plastic drum

Dry LIMS – Belt separator (BSA)

- For coarse particles minus 200 mm
- Alternating polarity with different pole pitches giving good selectivity
- Rubber belt for protection of separator drum and even distribution of the feed
- Variable speed for optimal separation
- Diameter 1200 mm (48")
- Length 600, 1200, 1800, 2400, and 3000 mm.
- Length 24", 48", 72", 96", 120"



Dry LIMS – Belt separator (BSS)



- Extremely strong separation force for - 300 mm lump sizes
- Disc type magnets with no particle rotation giving lower selectivity
- Rubber belt protection
- Variable speed
- Dia 1200 mm (48”)
- Length 600, 1200, 1800 and 2400 mm.
- Length 24”, 48”, 72”, 96”

BSA and BSS mainly used for separation of coarse ferromagnetic ores and slags

See data sheet 5:61.

Dry LIMS – Particle size in feed

DS 0-20 mm (0 - $^3/_4$”) Selectivity drops under 30 microns

BSA 5-200 mm ($^3/_{16}$” - 8”) Selectivity drops under 5 mm ($^3/_{16}$”)

BSS 5-300 mm ($^3/_{16}$” - 12”) Selectivity drops under 5 mm ($^3/_{16}$”)

Dry LIMS – Max. moisture in feed

	Feed size	max % H_2O in feed
DS	- 6 mm ($^1/_4$”)	5
	- 1 mm (16 mesh)	0,5
	- 0,1 mm (150 mesh)	0,1

Dry LIMS – Recommended pole pitch (pole distance)

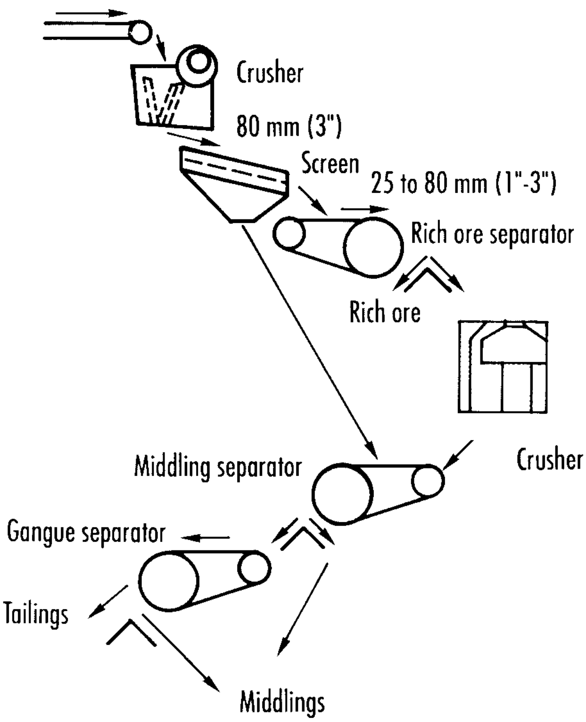
	Feed size (mm)	Pole pitch (mm)	Feed size (inch)	Pole pitch (inch)
DS	0 - 5	25	0 - $^3/_{16}$”	1”
	0 - 10	45	0 - $^3/_8$”	$1^3/_4$”
	0 - 15	65	0 - $^9/_{16}$”	$2^5/_8$”
	0 - 20	100	0 - $^3/_4$”	4”
BSA	5-75	105	$^3/_{16}$” - 3”	4”
	5-100	165	$^3/_{16}$” - 4”	$6^5/_8$”
	5-200	250	$^3/_{16}$” - 8”	10”

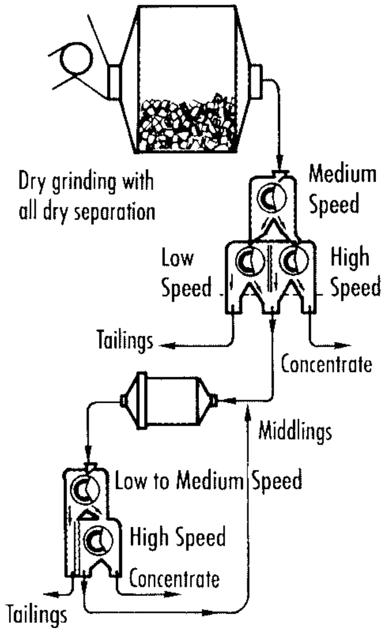
Dry LIMS – Capacities

Type	Dia (mm)	t/h and m drum length[x)]	Dia (inch)	st / h / ft length
DS	916	100 - 150	36″	35 - 50
	1 200	100 - 200	48″	35 - 70
BSA	1 200	150 - 200	48	50 - 70
BSS	1 200	250 - 400	48	85 - 135

x) Typical capacities. Individual ores subject to larger variations.

Dry LIMS – Flowsheets (typical)

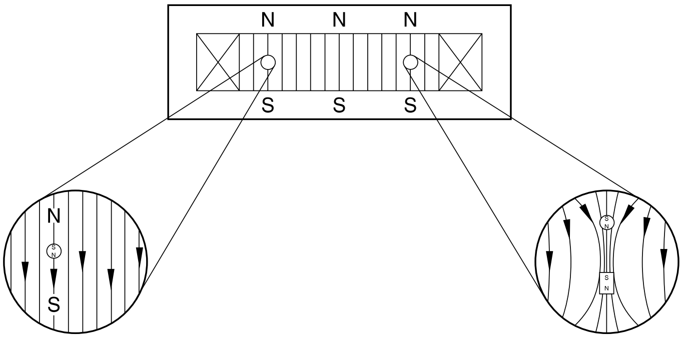




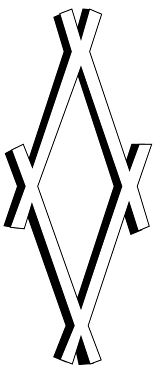
Wet HGMS – Matrix design

By **disturbing** the electromagnetic field by introducing a ferromagnetic material with sharp edges high magnetic field gradients are created at all **disturbing points,** see Magnetic Separation Principle - page 5:22 - 23.

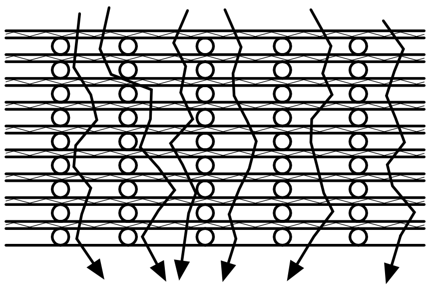
These disturbing elements (**filaments**) are spaced apart to allow pulp flow around them.



Homogeneous field (Fm=0) *Inhomogeneous field (Fm>0)*



Filament



Filament matrix

Facts about filaments:

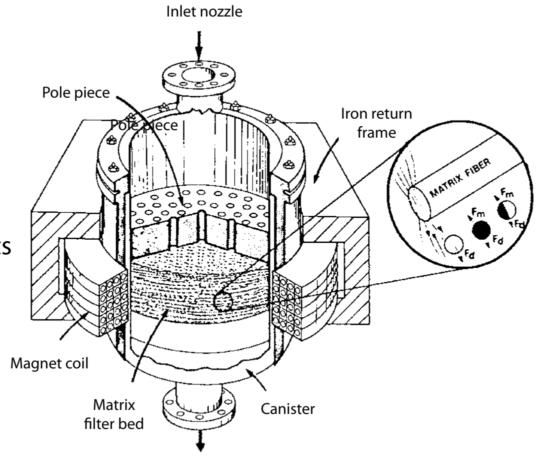
- Made of ferromagnetic material in format expanded metal (x) or steel wool (w)
- Filament thickness is related to the particle size
- Spacing can be approx. 10 times the filament thickness
- The matrix can contain filaments of various thickness, ”sandwich matrix”

Wet HGMS – Separator types

Cyclic Separators: **(< 4% weight)**	For applications with low magnetic content in the feed
Continuous Separators: (Carousels):	For applications with higher magnetic content in the feed **(> 4% by weight)**

Wet cyclic HGMS

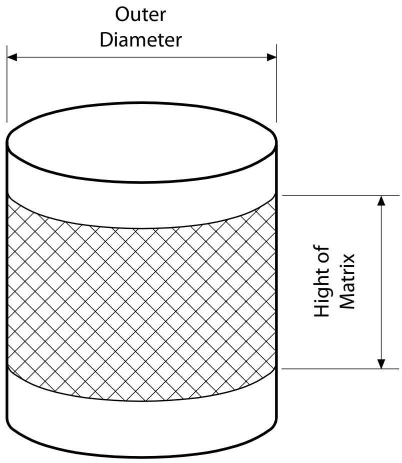
- Robust and simple design (few moving parts)
- Magnetic field from 3-20 kGauss
- Canister dia. up to 305 cm (120")
- High magnetic fields and field gradients giving a good "polishing" of contaminated products



Wet cyclic HGMS
– Sizes and nomenclature

Sizes referring to

- **Outer diameter** of canister (cm): 10, 22, 38, 56, 76, 107, 152,
  214 and 305 (4", 9", 15", 22", 30", 42", 60", 84" and 120")
- **Magnetic field**: 3, 5, 10, 15 and 20 kGauss
- **Height of matrix**: 15, 30 and 50 cm 6", 12", 20")



Nomenclature

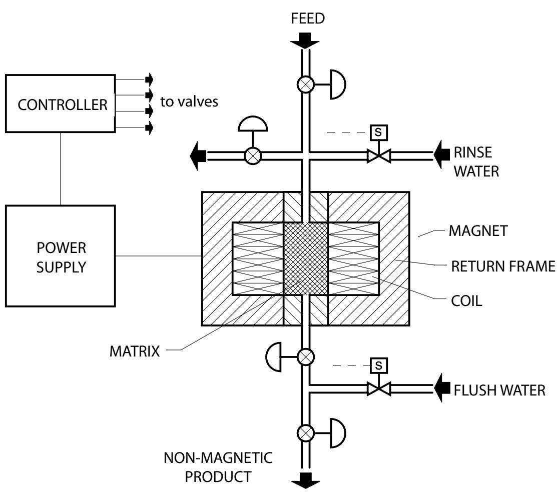
HGMS 107-30-20 = Cyclic separator with canister (or matrix)
diameter 107 cm, matrix height 30 cm and magnetic field of 20 kGauss.

Our laboratory unit is Model 10-15-20 (dia 10 cm, matrix height 15 cm and magnetic field of 20 kGauss)

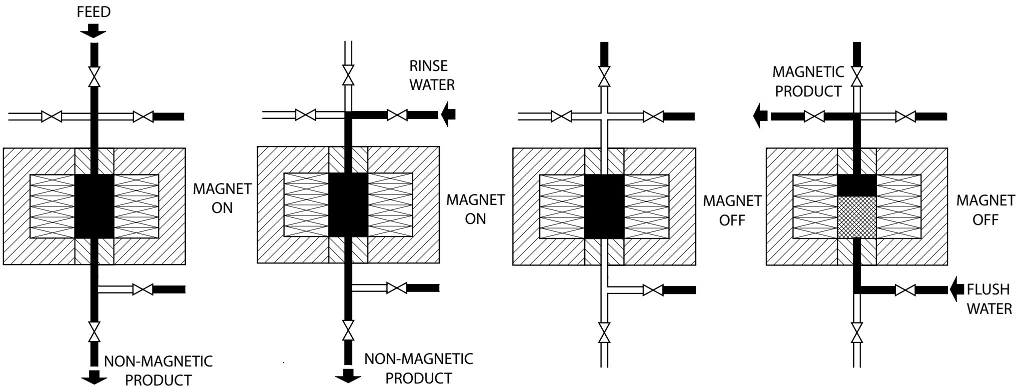
See data sheet 5:62.

Wet cyclic HGMS
– Process system

- Compact system design
- Fail-safe protection (thermal)
- Customer built power supply
- Completely automatic process control



Wet cyclic HGMS – Operation



Cycle 1 Separation	Cycle 2 Rinse	Cycle 3 Demagnetizing	Cycle 4 Flushing
• magnet activated	• magnet activated	• magnet off	• magnet off
• feed on	• feed off	• feed off	• feed off
	• washing on	• washing off	• washing on

Typical cycle times (Kaolin separation):

Separation	(4 min.)
Rinse	(1.5 min.)
Magnetising / Demagnetising	(< 1 min.)
Flush	(< 1 min.)

Wet cyclic HGMS – Applications

- Kaolin Beneficiation (brightening)
- Fe_2O_3 reduction in glass sand, feldspar, barite
- Cu-reduction in Mo Cu concentrates
- De-ashing and desulphurisation of coal
- Phosphates upgrading

Wet cyclic HGMS – Process data

Solids in feed - as high as possible. For clays limited to about 30% solids by weight due to viscosity problems.

Particle size in feed - restricted by matrix type.

Matrix type XR 1.1 for particles <1000 microns (15 mesh)

Matrix type XR for particles <800 microns (20 mesh)

Matrix type XM 1.1 for particles <450 microns (34 mesh)

Matrix type XM for particles <350 microns (42 mesh)

Matrix type XF 1.1 for particles <150 microns (100 mesh)

Matrix type XF for particles <100 microns (150 mesh)

Matrix type WC for particles <20 microns

Matrix type WM for particles <10 microns

Matrix type WF for particles <7 microns

*** Above particle sizes are approximative only.
Particle shape can change selection of matrix!**

Oversize particles will block the matrix!

Matrix areas

Separator Size	Matrix area (m^2)	Matrix area (sq ft)
22	0.04	0.43
38	0.11	1.98
56	0.24	2.58
76	0.45	4.48
107	0.90	9.7
152	1.81	19.5
214	3.60	38.8
305	7.30	78.6

Wet cyclic HGMS – Sizing (indicative)

Ex: Cleaning of kaolin clay, 4 t/h. Select the separator size.

1. Calculate the cycle time:

- Feed 4 min.
- Rinse 1.5 min.
- Magnet on/off 1 min.
- Flushing 1 min.

Total cycle time 7.5 min.

2. Calculate the actual separation time (feed) from 1. above

4 / (4 + 1,5 + 1 + 1) = 4 / 7,5 = 0,53 (53%)

3. Calculate the volume flow of 4.0 t/h (at say 25% solids and S.G. 2.5) which gives 13.6 m^3/h (0.75 ft / min)

   As actual separation time is 53% of total time, separator volumetric capacity must be = 13,6/0,53 = 25,7 m^3/h (15.1 cuft / min)

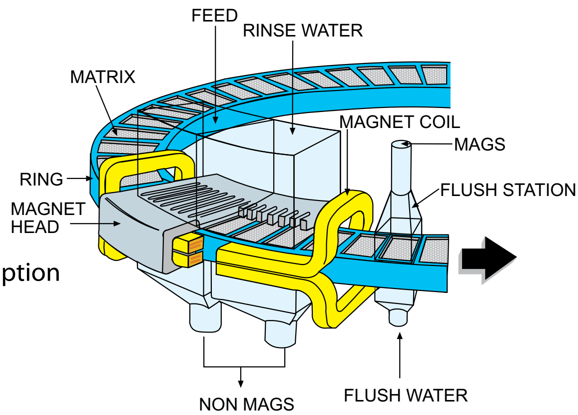
4. Kaolin (very fine particles) means matrix of W-type. Typical flow velocity for kaolin processing is 8 mm/s or 28,8 m/h (19.0 inch / min)

5. Calculate separator size
   matrix area (m^2) = volume capacity (m^3/h) / flow velocity (m/h) = 25,7 / 28,8 = 0,89 m^2 (9.6 sqft)

   Machine size, see above, is HGMS 107-30-20

Wet carousel HGMS

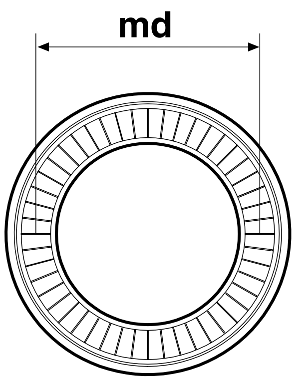
- Broad range of applications
- Fine particle processing
- High separation efficiency
- Simple, reliable design
- Easy flushing of magnetics (patented back flush)
- Low specific power consumption
- Low maintenance
- Long component life
- Large process capacity



Wet carousel HGMS – Sizes and nomenclature

Sizes referring to

- **Mean diameter (md)** of matrix ring (cm): 120, 185, 250, 350 cm. (48", 73", 96", 138", (250")
- **Magnetic field** (intensity): 5, 10, 15 and (20) kGauss
- **Possible number of magnet heads**: One to two for sizes 120, 180 and 240. One to three for size 350.



Nomenclature

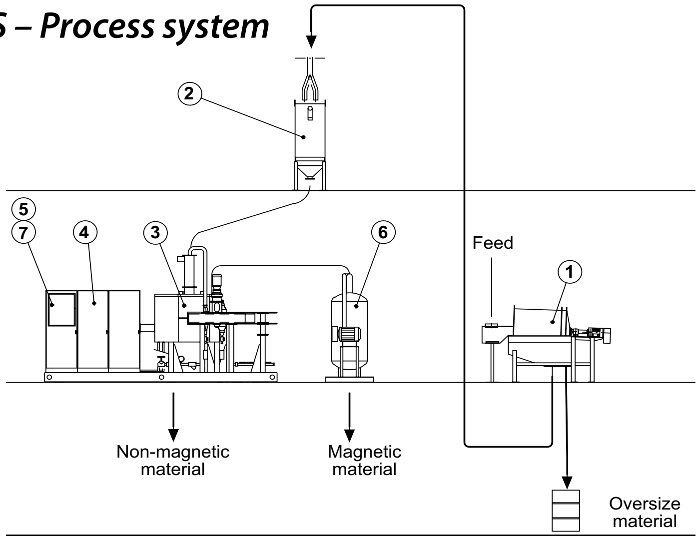
HGMS 120-10 = Carousel separator with matrix ring md 120 cm and one 10 kGauss magnet head

HGMS 185-15-15 = Carousel separator with matrix ring of md 185 cm (73”) and two magnet heads, each 15 kGauss.

See data sheet 5:63.

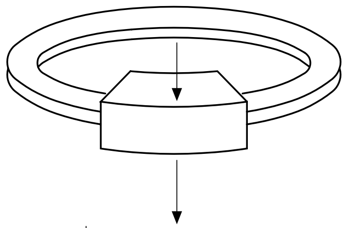
Wet carousel HGMS – Process system

1. Oversize - screen
2. Passive matrix
3. Carousel
4. Power supply
5. Cooling system
6. Vacuum system
7. Control system

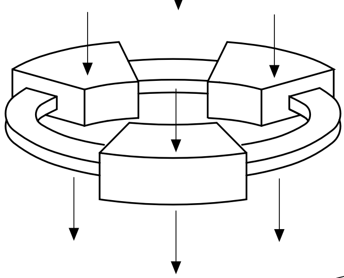


Wet carousel HGMS – Operation

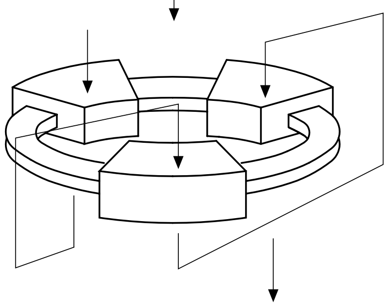
One head single pass



Two or three heads single pass



Two or three heads double or triple passes



Wet carousel HGMS – Applications

1. Concentration of paramagnetic oxide minerals such as:
   - chromite
   - hematite
   - ilmenite
   - manganite
   - volframite

2. Rare earth minerals
3. Industrial minerals (reduction of paramagnetic contaminations)
4. Coal (desulphurisation and de-ashing)
5. Separation of base metal minerals such as:
   - Cu-Mo
   - Cu-Pb
   - Zn-Pb

Wet carousel HGMS – Process data

Solids in feed

- normally 25% solids by weight
- maximum 35% solids by weight

Particle size in feed - restricted by matrix type.
Matrix type XR 1.1 for particles <1000 microns (15 mesh)
Matrix type XR for particles <800 microns (20 mesh)
Matrix type XM 1.1 for particles <450 microns (34 mesh)
Matrix type XM for particles <350 microns (42 mesh)
Matrix type XF 1.1 for particles <150 microns (100 mesh)
Matrix type XF for particles <100 microns (150 mesh)
Matrix type WC for particles <20 microns
Matrix type WM for particles <10 microns
Matrix type WF for particles <7 microns
*** Above particle sizes are approximative only.**
Particle shape can change selection of matrix!

Matrix height (cm)

Model (mm) (inch)	Height
120	14.4 (5.67)
185	18.9 (7.44)
250	18.5 (7.28)
350	21.0 (8.27)

Wet carousel HGMS – Approximate water consumption

Size	Rinse/mag head (m^3/h)	Flush/mag head (m^3/h)	Seal water/unit (m^3/h)	Cooling water* (m^3/h)
120	15	20	8	3
185	70	90	12	4
240	200	250	27	6
350	350	450	40	9

* One magnet head 7 kGauss

Size	Rinse/mag head (USGPM)	Flush/mag head (USGPM)	Seal water/unit (USGPM)	Cooling water* (USGPM)
120	65	90	35	15
185	310	395	50	20
240	880	1 095	120	25
350	1 535	1 975	175	40

* One magnet head 7 kGauss

Wet carousel HGMS – Sizing

Sizing must be done by authorized process engineers!

Sizing parameters are:

Matrix loading = Solids in feed / Matrix volume g/cm^3

Pulp flow velocity

Application	Mag. Field (Tesla) 1 Tesla(T) = 10 kGauss(kG)	Matrix loading (g/cm^3)	Feed flow velocity (mm/s)	(inch/s)
Hematite	0.3 - 0.7	0.3 - 0.65	180 - 250	7 - 10
Ilmenite	0.5 - 0.7	0.3 - 0.45	180 - 200	7 - 8
Chromite	0.5 - 0.7	0.3 - 0.5	150 - 200	6 - 8
Managenese ore	1.0 - 1.5	0.3 - 0.5	100 - 200	4 - 8
Apatite	0.7 - 1.5	0.3	100 - 150	4 - 6
Kyanite	1.5	0.3	100 - 150	4 - 6
Wolframite	1.0	0.3	100 - 150	4 - 6
Nepheline Syenite	1.2 - 1.5	0.3	60 - 90	2 $^1/_2$ - 3 $^1/_2$
Glass sand	1.5	0.3 - 1.0	60 - 90	2 $^1/_2$ - 3 $^1/_2$
Mica	0.8 - 1.0	0.3 - 0.8	60 - 90	2 $^1/_2$ - 3 $^1/_2$

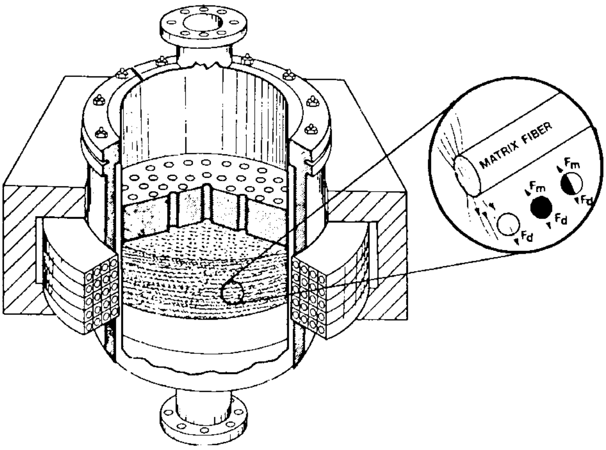
High gradient magnetic filter – HGMF

A special version of the cyclic HGMS technique, is used to remove magnetic or weakly magnetic particles from liquids.

HGMF – design

The design is very similar to the cyclic HGMS machine however with some special features

- Robust and compact design
- Magnetic gradients up to 20 kG
- Canister dia up to 2140 mm (84")
- Maximum pressure drop 100 bar (1450 psi)
- Allowing high pressure and high temperatures
- Large holding capacity in matrix



HGMF – Sizes and nomenclature

Sizes

7 sizes (industrial units) named from outer diameter (cm) of canister:

Type: 38, 46, 56, 76, 107, 152, 214

Magnetic field intensity available for each size: 3, 5, 10 and 15 kG.

Matrix height: 15, 30 and 50 cm. (0.6", 1.2" and 2") (for water clarification)

Nomenclature

HGMF 56-15-3 = magnetic filter with canister diameter 56 cm, matrix height 15 cm and magnetic field intensity 3 kG. See data sheet 5:64.

HGMF - Applications

Generally: For high pressure, high temperature and "lack of space" applications

- Removal of iron and copper particles from boiler circuits
- Cleaning of district heating systems
- Removal of weakly magnetic particles from process water (mill scale, metallurgical dust etc.)

HGMF – Process data

Solids in feed Normally very low ppm levels

Particle size in feed Restricted by matrix type
Matrix type KF will allow particles - 100 microns

Size	Matrix area ft^2	Matrix area m^2
38	0.8	0.07
56	2.0	0.19
76	4.6	0.43
107	9.1	0.85
152	18.8	1.75
214	36.8	3.42

HGMF – Sizing

Sizing similar to conventional clarification sizing, see section 6:3.

Surface load (m^3/h and m^2) is the flow velocity through the matrix for optimal clarification.

Application *	Surface load (m^3/ m^2, h)	Surface load (ft^3/ft^2, min)	Flush interval
Condensate polishing	500 - 1 500	27 - 81	7 - 21 days
District heating systems	500 - 1 500	27 - 81	24 hours
Steel mill cooling water	200 - 800	11 - 44	0.3 - 1 hours

* Magnetic field 3 kg

Ex 1:

Steel mill cooling water can be treated with a surface load of

500 m^3/m^2 x h at 3 kG. The flow is 800 m^3/h.

Required area 800 / 500 = 1.6 m^2

Select HGMF 152 - 15 - 3

Ex 2:

Paper mill Condensate water can be treated with a surface load of approx. 500 GPMPSF (Gallon per minute per squarefoot)

Flow is 3000 GPM

HGMF model 107 has an area = 9.1 ft2

3000 / 9.1 = 330 GPMPSF (OK!)

Separation by leaching

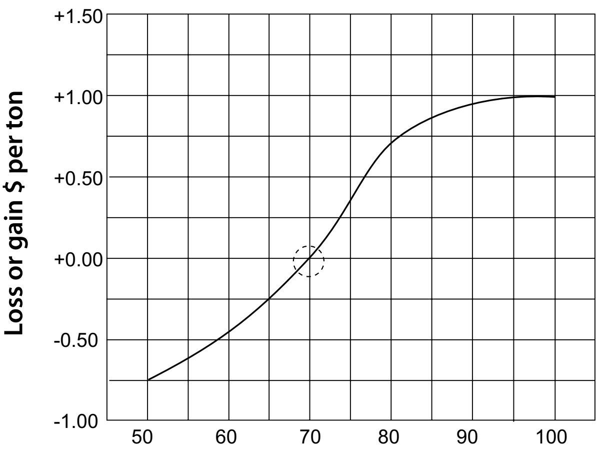
When mechanical methods of separation cannot secure optimal metal value of an ore, leaching is an alternative, either as a complement or as an overall process.
Most of the leaching process is feed preparation by crushing, grinding and in some cases pre-concentration and roasting.
The separation is normally done by creating retention time for the chemicals to penetrate the feed.

Leaching by methods	Typical feed size	Typical retention time
Waste dumps leaching	-1500 mm (60 inch)	10 years
Heaps leaching	-150 mm (6 inch)	1 year
Agitation leaching (coarse)	-200 micron (65 mesh)	2–24 hours
Agitation leaching (fine)	- 10 micron	5–10 min

The waste and heap leaching operations are typically low in investment but high in cost of chemicals. Recovery is normally low (below 60%).
The agitation methods (con current or counter current) are high in investment but are paid back in higher recovery.

Leaching by size

In leaching there is always an optimum in the relation feed size versus recovery. This balance between cost for size reduction and value recovery is important to establish for high value ores, see below.



-75 micron (200mesh) in feed %

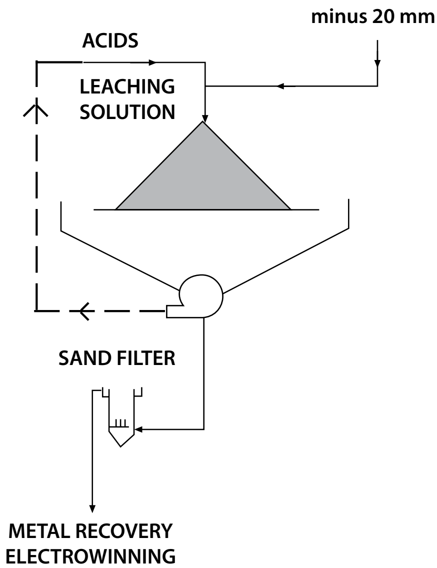
Leachants

Type of ore	Leachant		Typical particle size		Typical retention time
Cu ore (oxide)	H_2SO_4	(5.00%)	- 9 mm,	(3/8 inch)	5 days
Au ore	NaCN	(0.05%)	- 200 micron,	65 mesh	4-24 h
Au conc. (sulphide)	NaCN	(0.10%)	-45 micron,	325 mesh	10-72h
Ilmenite	H_2SO_4	(90.0%)	-75 micron,	200 mesh	0.5h
Ni ore (laterite)	H_2SO_4	(3.00%)	-150 micron,	100 mesh	2h
Ag ore	NaCN	(0.20%)	-200 micron,	65 mesh	72h
Uranium ore	H_2SO_4	(0.5-5%)	-150 micron,	100 mesh	16-48 h
Uranium ore	Na_2CO_3	(5.00%)	-150 micron,	100 mesh	90h

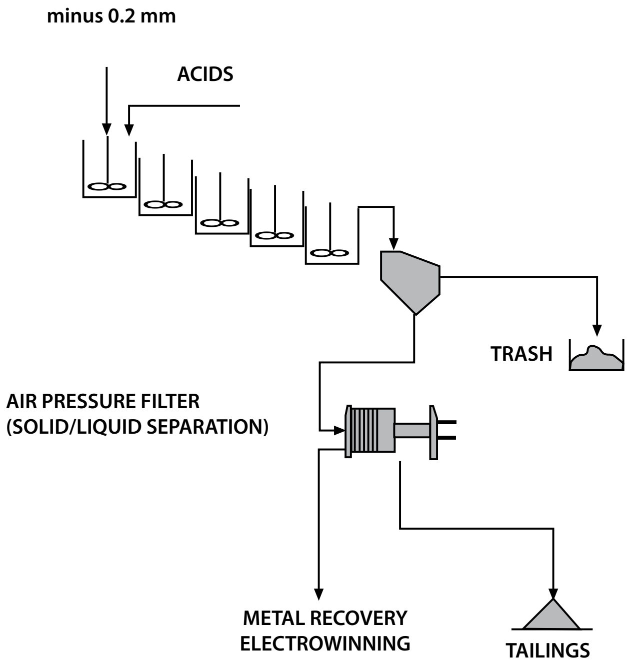
Leaching of metals

Below find the flow sheets for classical leaching circuits, heap leaching for coarse fractions (crushing only) of low grade ores and agitation leaching for finer fraction of high value ores.

In the **heap leaching** process the ground is protected by a sealed surface, collecting the leaching chemicals, re- circulated by pumping. When the solution is "pregnant" its clarified by sedimentation or sand filtration and taken to metal recovery by electrowinning.



In the **agitation leaching** circuit the feed is finer (typical –200 microns) and the slurry moves in the same direction as the chemicals (con current flow). In this case, the pregnant solution has to be recovered from the solids by mechanical dewatering due to particle size, see section 6.



Gold leaching

Enrichment by leaching is mainly used for recovery of gold often in combination with pre separation by gravity. If free coarse gold is released during size reduction, this fraction (typical – 1mm) is recovered in gravity spirals, see 5:8. If finer fractions of free gold are present centrifuge technology can be applied (not covered here). Alternatively, when processing an ore containing gold metal only, leaching with carbon adsorption are frequently used.

Gold leaching – Carbon adsorption

Leaching reaction

$2\ Au + 4\ CN^- + O_2\ (air) + 2H_2O \longrightarrow 2\ Au\ (CN)_2^- + OH^-$ pH>8 (lime)

Process stages

1. ***Leaching*** by agitation to dissolve Au by reaction above. Agitators are arranged in con current flow.
   CIL (Carbon in leach) is a method where the gold adsorption by carbon is done in the leaching circuit. The method, seldom used due to high operating costs, is not covered here.

2. ***CIP (Carbon in pulp) adsorption*** by slow agitation using active carbon granules to adsorb the Au solution from the pulp. Agitators are arranged in counter current flow (carbon travelling towards the pulp flow).
   See flowsheet on next page.

   Carbon granules must be:

   a. Hard to resist abrasion (made from coconut shells)

   b. Coarse to be separated from slurry by sizing (1-3 mm, 16-6 Mesh)

   c. High in specific surface

3. **Carbon recovery** is done by sizing over a screen (cut at 0,7 mm, 24 Mesh) bringing the loaded carbon out of the pulp system

4. **Au stripping** is the process of removing the gold solution by "washing" the carbon granules in a solution (cyanide + Na OH) at 135°C. (retention time 6-8 hours).

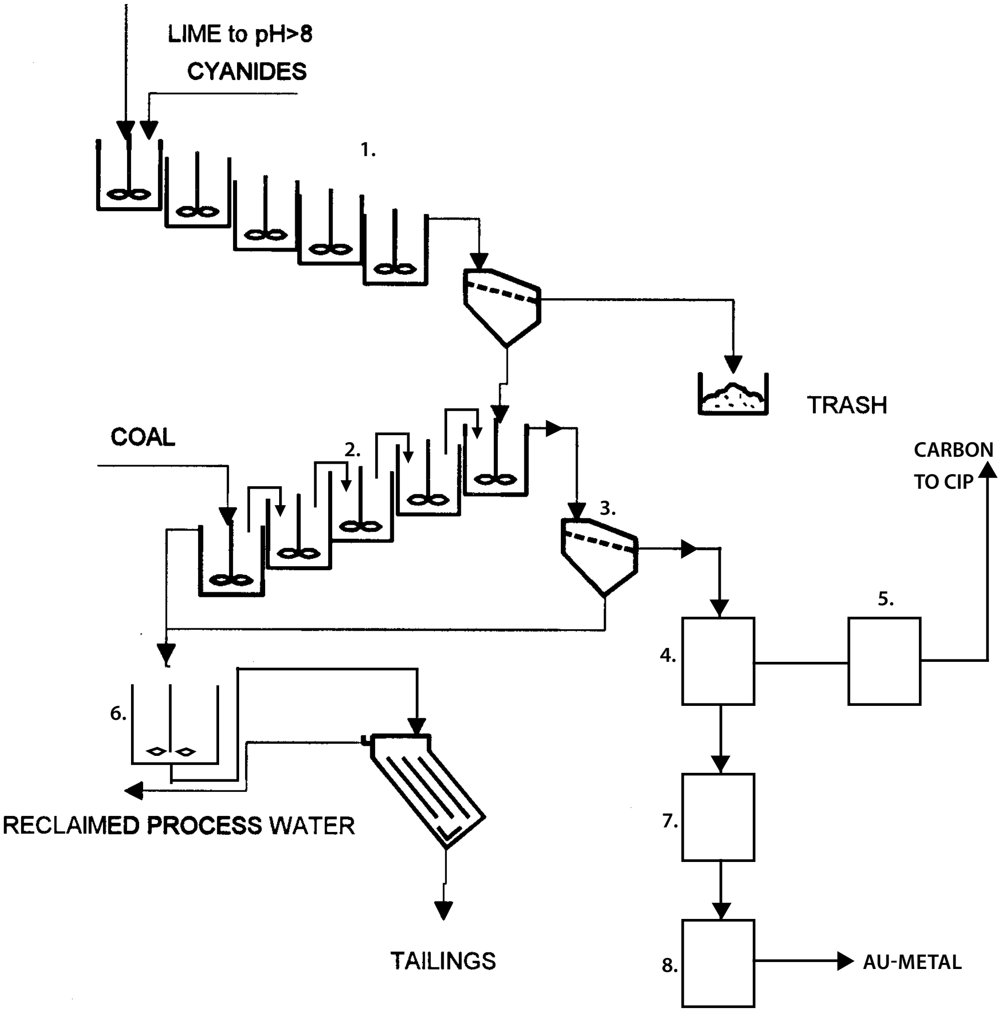
5. **Carbon reactivation** is needed after the washing to restore the active surface of the granules. This is done in a kiln at 125° C

6. **Cyanide destruction** of the pulp leaving the CIP circuit is done in an agitator adding an oxidant (typical hypocloride) bringing remaining cyanide to a harmless state.

7. **Au electrowinning** by plating out the gold metal is done with steel wool cathodes. These cathodes are sent to fluxing and smelting (8).

Gold leaching – CIP

From grinding circuit, typical – 75 micron (200 mesh)

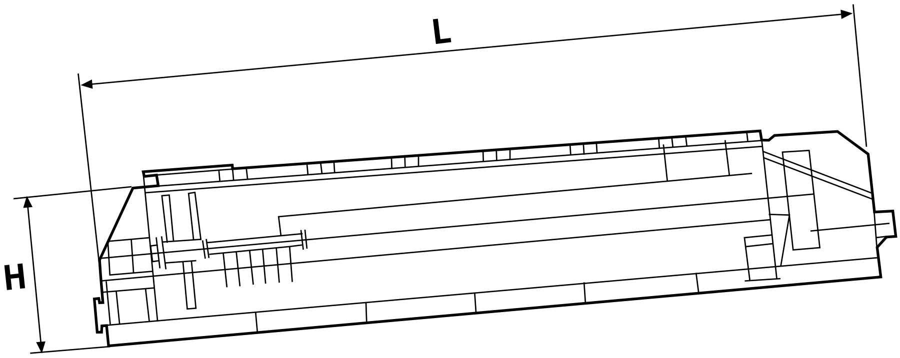


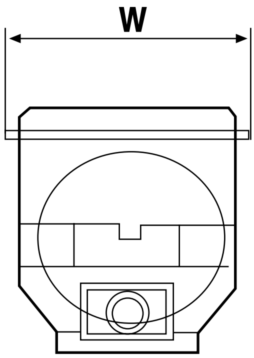
Agitation, see 8:22.

Sedimentation, see 6:2.

Mechanical dewatering, see 6:20.

Log washer – Single shaft



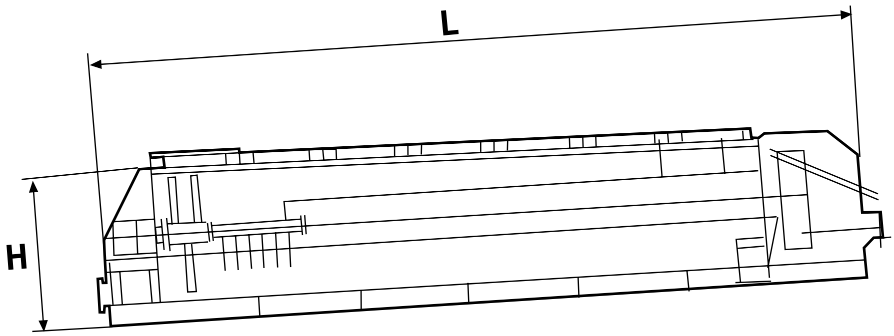


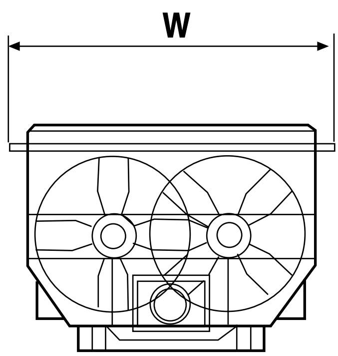
Model	H mm (inch)	L mm (inch)	W mm (inch)	Capacity t/h	Power kW/hp	Weight ton
SW 520/1	870 (32)	3 144 (124)	750 (30)	8 - 10	3/4	1.4
SW 830/1	1 102 (43)	4 598 (181)	1 110 (44)	18 - 20	5.5/7.4	2.2
SW1140/1	1 430 (56)	5 940 (234)	1 410 (56)	35 - 45	11/15	3.5
SW1350/1	1 726 (68)	7 250 (285)	1 700 (67)	100 - 120	30/40	7.0

Max feed size 32 mm (1.3 inch)

Inclination 6-8° upwards in material flow direction

Log washer – Twin shaft



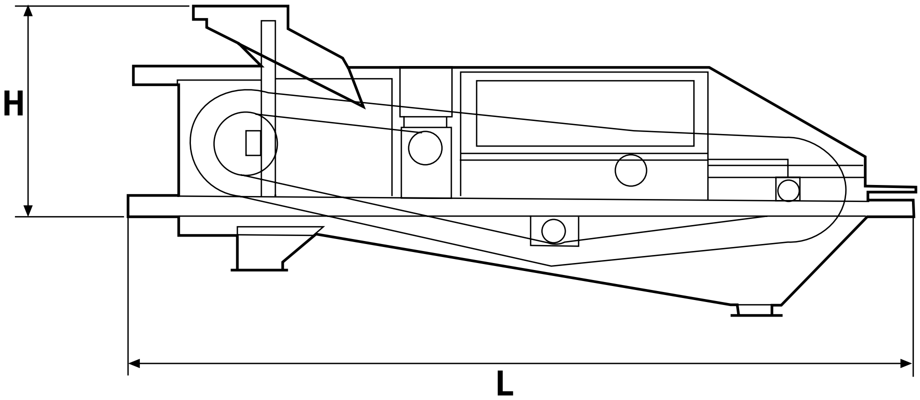


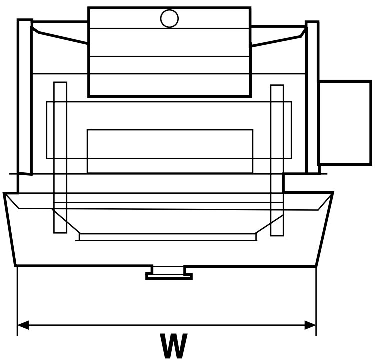
Model	H mm (inch)	L mm (inch)	W mm (inch)	Capacity t/h	Power kW/hp	Weight ton
SW 830	1 096 (43)	4 500 (177)	1 640 (65)	40 - 50	2 x 7.5/2 x 10	3.8
SW 840	1 196 (47)	4 500 (177)	1 640 (65)	40 - 50	2 x 7.5/2 x 10	4.5
SW 952	1 300 (51)	6 500 (256)	1 900 (75)	60 - 70	2 x 11/2 x 15	6.2
SW 960	1 320 (52)	7 290 (287)	1 900 (75)	60 - 70	2 x 15/2 x 20	7.0
SW1140	1 426 (56)	5 500 (217)	2 110 (83)	110 - 120	2 x 11/2 x 15	5.9
SW1150	1 426 (56)	6 500 (256)	2 190 (86)	110 - 120	2 x 15/2 x 20	7.2
SW1160	1 426 (56)	7 290 (287)	2 190 (86)	110 - 120	2 x 18/2 x 24	8.5
SW1155	1 496 (59)	6 500 (256)	2 330 (92)	140 - 150	2 x 18/2 x 24	8.3
SW1165	1 496 (59)	7 350 (289)	2 330 (92)	140 - 150	2 x 22/2 x 30	9.5
SW1175	1 496 (59)	8 400 (331)	2 330 (92)	140 - 150	2 x 30/2 x 40	12.0
SW1250	1 720 (68)	6 680 (263)	2 500 (98)	180 - 200	2 x 22/2 x 30	9.6
SW1260	1 720 (68)	7 680 (302)	2 500 (98)	180 - 200	2 x 22/2 x 30	12.0
SW1270	1 720 (68)	8 680 (342)	2 500 (98)	180 - 200	2 x 30/2 x 40	14.0
SW1360	1 896 (75)	7 780 (306)	2 990 (118)	220 - 350	2 x 37/2 x 50	16.0
SW1370	1 896 (75)	8 780 (346)	2 990 (118)	220 - 350	2 x 45/2 x 60	18.5
SW1380	1 896 (75)	9 780 (385)	2 990 (118)	220 - 350	2 x 45/2 x 60	21.0

Max feed size 32 mm (1,3 inch)

Inclination 6 - 8° upwards in material flow direction

Aquamator

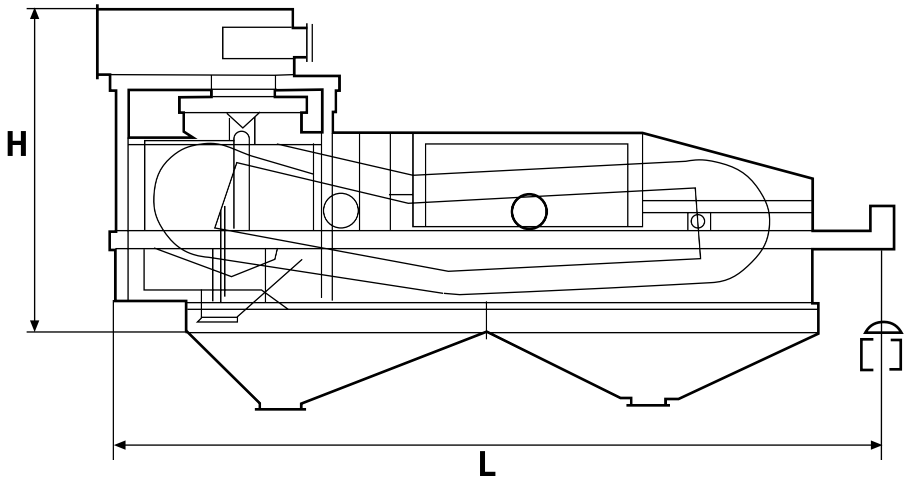


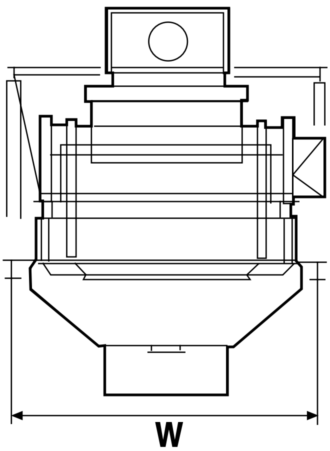


Model	H mm/inch	L mm (inch)	W mm (inch)	Capacity t/h	Water m^3/h (USGPM)	Power kW/hp	Weight ton
AK 3.5/0.8*	2 100 (83)	5 040 (198)	1 100 (43)	10 - 30	80 (352)	3/4	3.1
AK 3.5/1.2	2 100 (83)	5 040 (198)	1 500 (59)	30 - 60	100 (440)	3/4	3.5
AK 3.5/1.6	2 100 (83)	5 040 (198)	1 900 (75)	60 - 100	120 (528)	3/4	4.5
AK 3.5/2.0	2 100 (83)	5 040 (198)	2 300 (91)	90 - 140	140 (616)	4/5	5.8
AK 4.0/2.4	2 480 (83)	5 540 (218)	2 700 (106)	120 - 180	180 (793)	5.5/7	8.0

*AK 3.5/0.8. belt length=3.5m (12ft). belt width=0.8m (3ft).1.2m (4ft). 1.6m (5.2ft).2.0m (7ft).2.4m (8ft)
AK 4.0. belt length 4.0 (13ft)

Hydrobelt

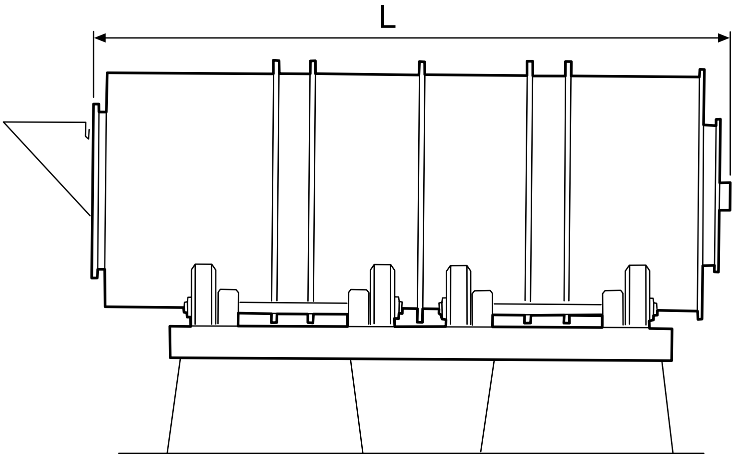


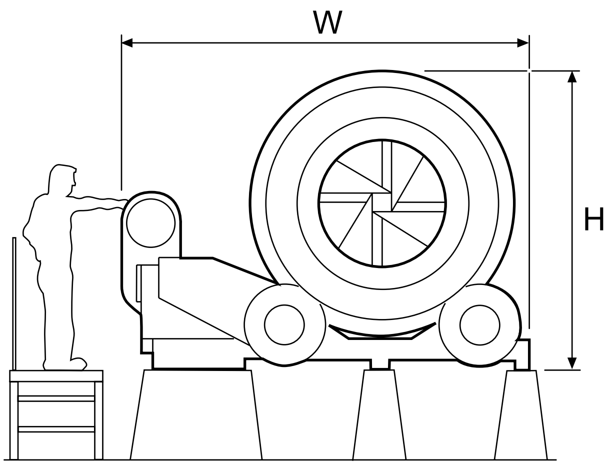


Model	H mm (inch)	L mm (inch)	W mm (inch)	Capacity t/h	Water m^3/h (USGPM)	Power kW/hp	Weight ton
AS 4.0/1.2*	2 230 (88)	5 540 (218)	1 700 (67)	40 - 80	160 (705)	4/5	3.9
AS 4.0/1.6	2 230 (88)	5 540 (218)	2 100 (83)	80 - 120	220 (970)	4/5	5.4
AS 4.0/2.0	2 230 (88)	5 540 (218)	2 500 (98)	120 - 150	300 (1 320)	4/5	6.9
AS 5.0/2.4	3 250 (1289	6 540 (257)	2 900 (114)	150 - 180	450 (1 981)	7.5/10	11.9

*AS 4.0/1.2, belt length =4.0m(13ft), belt width=1.2m (4ft), 1.6m (5.2ft), 2.0m (7ft), 2.4m (8ft)
AS 5.0, belt length= 5.0m (16ft)

Washing barrel – LD

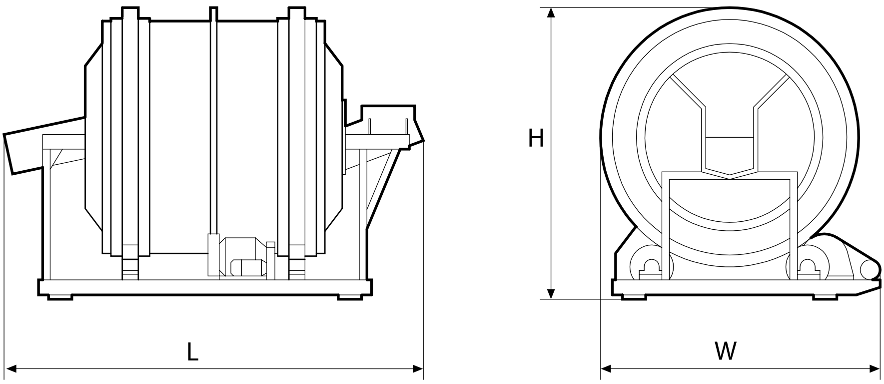




Nominal speed 20 rpm

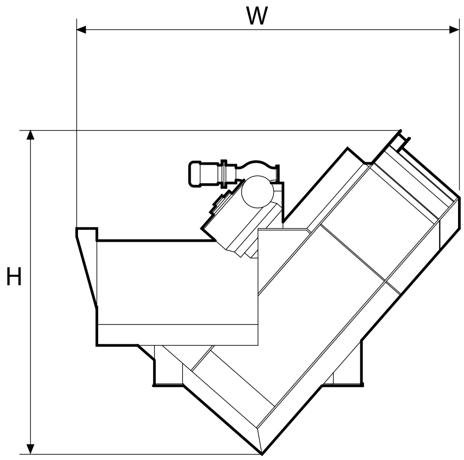
Size DxL m (ft)	H mm (inch)	L mm (inch)	W mm (inch)	Capacity t/h	Wash water m^3/h (USG*)	Power kW/hp	Weight ton
1,3x3,5 (4.2x11.5)	2 000 (79)	3 750 (148)	2 450 (96)	35	35 (154)	3.7/5	4.3
1,6x4,0 (5.2x13.0)	2 250 (89)	4250 (167)	2 650 (104)	50	60 (264)	5.5/7	5.0
1,9x5,0 (6.2x16.4)	2 500 (98)	5 300 (209)	3 450 (136)	110	110 (484)	15/20	10.5
2,2x5,0 (7.2x16.4)	2 750 (108)	5 300 (209)	3 650 (144)	160	150 (660)	18.5/25	12.4
2,5x6,0 (8.2x19.6)	3 000 (118)	6 300 (248)	4 100 (161)	220	220 (969)	30/40	17.4

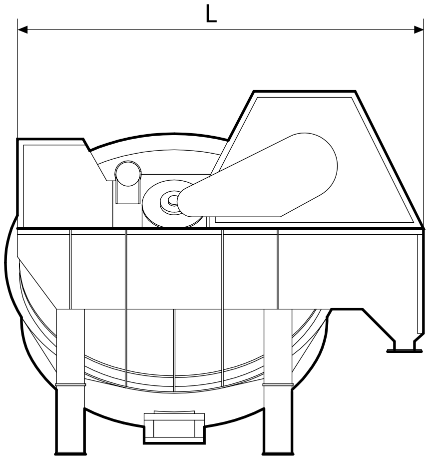
DMS separator – Drum



Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight, ton
RD 1.8x1.8	2 700 (106)	3 900 (154)	2 700 (102)	4.0
RD 2.4x2.4	3 200 (126)	5 200 (205)	3 000 (126)	8.0
RD 3.0x3.0	3 800 (150)	6 000 (236)	3 600 (142)	15.0
RD 3.6x3.6	4 400 (173)	7 000 (276)	4 200 (165)	23.0

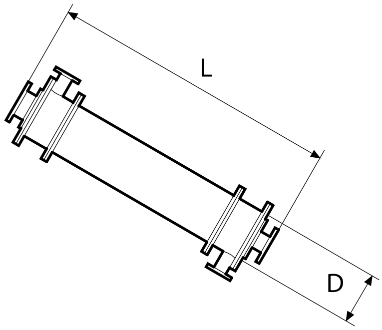
DMS separator – Drewboy





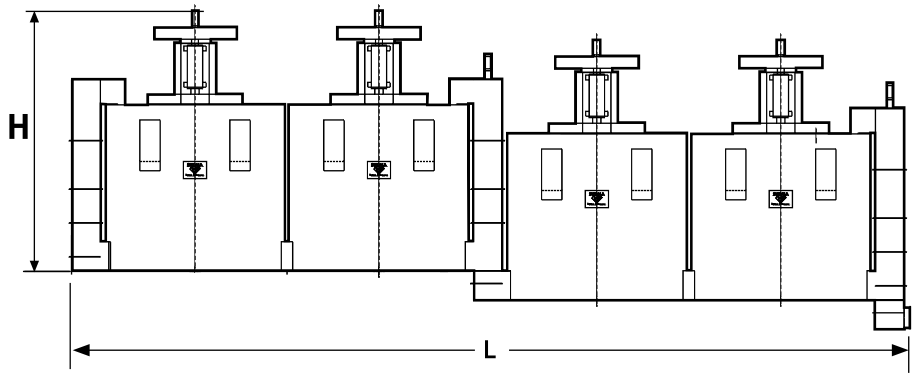
Model	H mm (inch)	L mm (inch)	W mm (inch)
1.2	3 960 (156)	4 940 (194)	3 530 (139)
1.6	3 960 (156)	4 940 (194)	4 030 (159)
2.0	3 960 (156)	4 940 (194)	4 430 (174)
2.6	5 020 (198)	5 170 (204)	4 490 (177)
3.2	5 620 (233)	5 930 (233)	6 240 (246)

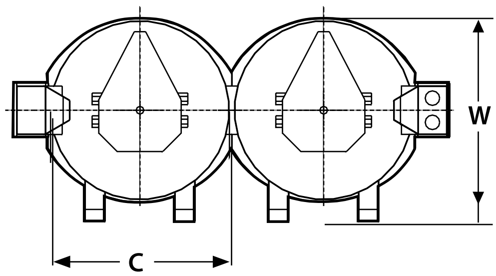
DMS separator – Dyna Whirlpool



Model	D mm (inch)	L mm (inch)	Weight kg (lbs)
DWP 9	290 (11)	1 575 (62)	410 (904)
DWP 12	366 (14)	1 800 (71)	614 (1 353)
DWP 15	458 (18)	1 955 (77)	860 (1 895)
DWP 18	521 (21)	2 075 (82)	1 410 (3 108)

Flotation machine – RCS



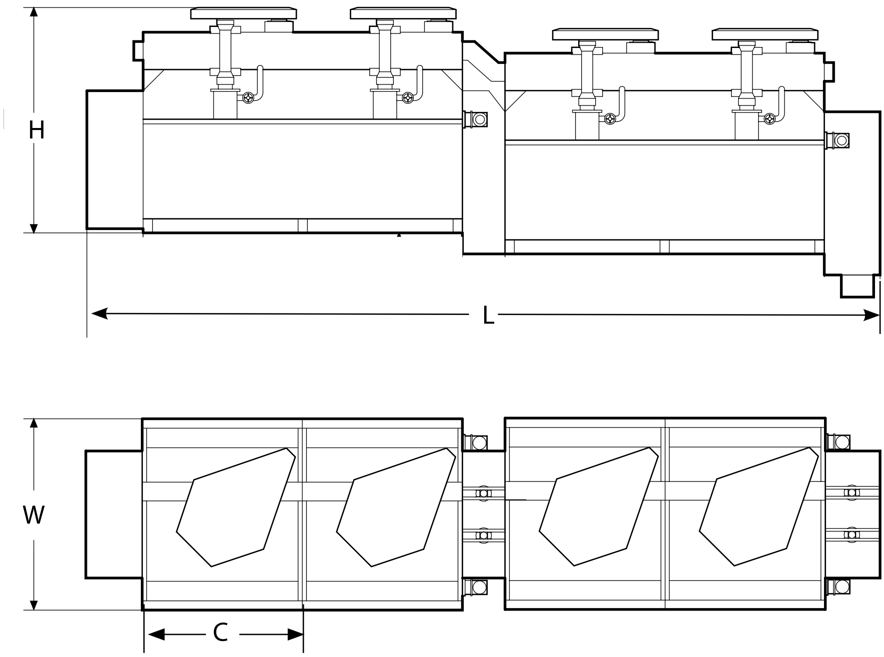


Model	H (1) mm (inch)	L (2) mm (inch)	W mm (inch)	C mm (inch)	Bank weight (2) tonnes (s tons)
RCS 0,8	1 790 (70)	5 550 (219)	1 320 (52)	1 100 (43)	2,73 (3,01)
RCS 3	2 790 (110)	8 250 (325)	1 900 (75)	1 700 (67)	8,4 (9,26)
RCS 5	3020 (119)	9850 (388)	2230 (88)	2000 (79)	10.53 (11.58)
RCS 10	3610 (142)	12250 (482)	2850 (112)	2600 (102)	17.38 (19.12)
RCS 15	3990 (157)	14250 (561)	3320 (131)	3000 (118)	22.97 (25.27)
RCS 20	4610 (181)	15250 (600)	3680 (145)	3250 (128)	26.25 (28.88)
RCS 30	5375 (212)	17350 (683)	4150 (163)	3700 (146)	36.50 (40.15)
RCS 40	5780 (226)	19200 (756)	4410 (174)	4100 (161)	51.04 (56.14)
RCS 50	6100 (240)	20900 (823)	4870 (192)	4500 (177)	56.95 (62.65)
RCS 70	6690 (263)	23600 (929)	5450 (215)	5000 (197)	71.00 (78.10)
RCS 100	6510 (256)	26400 (1039)	6100 (240)	5600 (220)	92.28 (101.51)
RCS 130	6875 (271)	29050 (1144)	6650 (262)	6100 (240)	123.82 (136.2)
RCS 160	7495 (295)	30650 (1207)	7100 (280)	6500 (256)	145.49 (160.00)
RCS 200	8050 (317)	33050 (1301)	7600 (299)	7000 (276)	174.10 (191.40)

(1) RCS 3 to RCS 70 v-drive, RCS 100 to RCS 200 gearbox drive

(2) 4-cell bank arranged F-2-I-2-D, empty

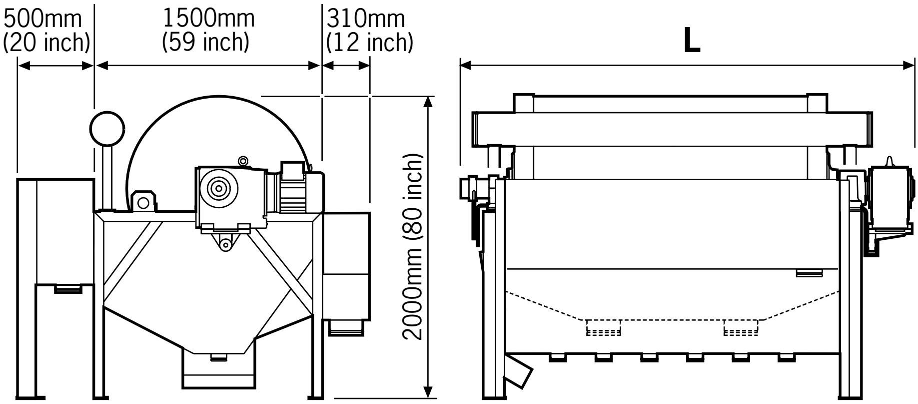
Flotation machine – DR



Model	H mm (inch)	L [1] mm (inch)	W [2] mm (inch)	C mm (inch)	Bank weight [1] tonnes (s tons)
DR 15	1625 (64)	3810 (150)	610 (24)	710 (28)	1.95 (2.14)
DR 18Sp	1830 (72)	4875 (192)	815 (32)	915 (36)	3.35 (3.69)
DR 24	2365 (93)	6100 (240)	1090 (43)	1220 (48)	4.64 (5.10)
DR 100	2720 (107)	7670 (302)	1575 (62)	1575 (62)	7.17 (7.89)
DR 180	2945 (116)	9195 (362)	1830 (72)	1830 (72)	11.87 (13.06)
DR300	3250 (128)	11225 (442)	2235 (88)	2235 (88)	18.83 (20.71)
DR 500	3405 (134)	13360 (526)	2690 (106)	2690 (106)	24.04 (26.44)

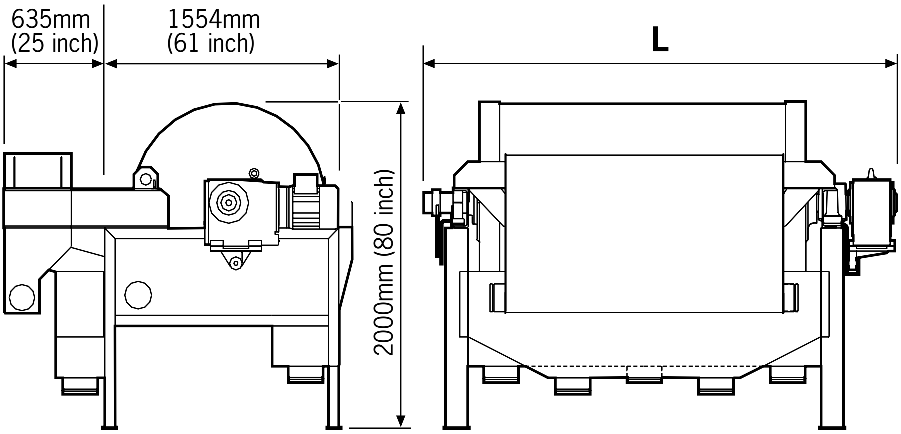
(1) 4-cell bank arranged F-2-I-2-D, empty
(2) Cell width excluding launders
DR15 to DR 24 single side overflow, DR 100 to DR 500 double side overflow

Wet LIMS – Concurrent (CC)



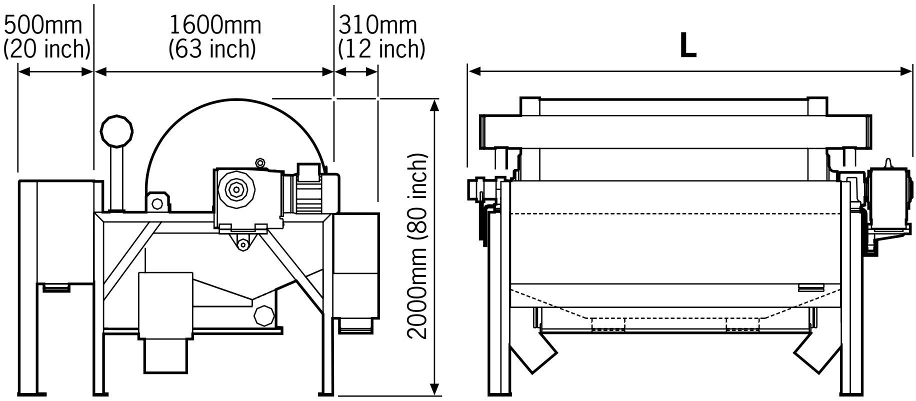
Model	Drum mm (ft) DxL	L mm (inch)	Power kW/HP	Weight (empty) ton
WS 1206 CC	1 200 x 600 (4 x 2)	1 770 (7)	4/5	1.9
WS 1212 CC	1 200 x 1 200 (4 x 4)	2 370 (93)	5.5/7.5	2.8
WS 1218 CC	1 200 x 1 800 (4 x 6)	2 970 (117)	7.5/10	3.6
WS 1224 CC	1 200 x 2 400 (4 x 8)	3 570 (141)	7.5/10	4.7
WS 1230 CC	1 200 x 3 000 (4 x 10)	4 218 (166)	7.5/10	5.6
WS 1236 CC	1 200 x 3 600 (4 x 12)	4 818 (190)	11/15	6.6

Wet LIMS – Counterrotation (CR) (CRHG)



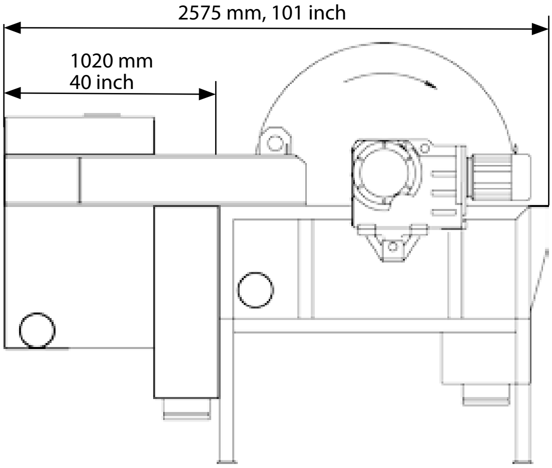
Model	Drum mm (ft) DxL	L mm (inch)	Power kW/hp	Weight (empty) ton
WS 1206 CR	1 200 x 600 (4 x 2)	1 810 (71)	4/5	1.9
WS 1212 CR	1 200 x 1 200 (4 x 4)	2 410 (95)	5.5/7.5	2.8
WS 1218 CR	1 200 x 1 800 (4 x 6)	3 010 (119)	7.5/10	3.6
WS 1224 CR	1 200 x 2 400 (4 x 8)	3 610 (142)	7.5/10	4.7
WS 1230 CR	1 200 x 3 000 (4 x 10)	4 218 (166)	7.5/10	5.6
WS 1236 CR	1 200 x 3 600 (4 x 12)	4 818 (190)	11/15	6.6

Wet LIMS – Countercurrent (CTC)



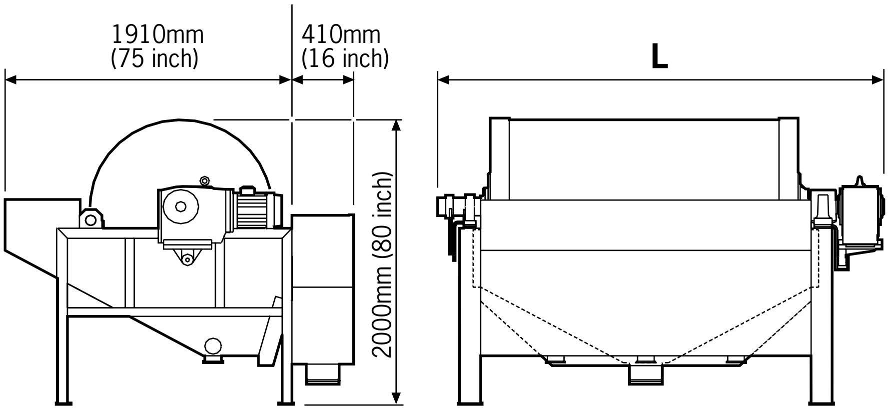
Model	Drum mm (ft) DxL	L mm (inch)	Power kW/hp	Weight (empty) ton
WS 1206 CTC	1 200 x 600 (4 x 2)	1 810 (71)	4/5	1.9
WS 1212 CTC	1 200 x 1 200 (4 x 4)	2 410 (95)	5.5/7.5	2.8
WS 1218 CTC	1 200 x 1 800 (4 x 6)	3 010 (119)	7.5/10	3.6
WS 1224 CTC	1 200 x 2 400 (4 x 8)	3 610 (142)	7.5/10	4.7
WS 1230 CTC	1 200 x 3 000 (4 x 10)	4 218 (166)	7.5/10	5.6
WS 1236 CTC	1 200 x 3 600 (4 x 12)	4 818 (190)	11/15	6.6

Wet LIMS – Froth separator (DWHG)



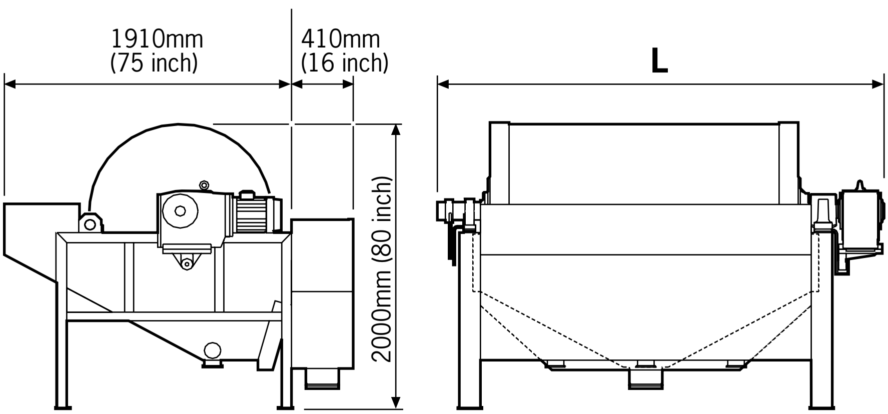
Model	Drum mm (ft) DxL	L mm (inch)	Power kW/hp	Weight (empty) ton
WS1206 DWHG	1 200 x 600 (4 x 2)	1 810 (71)	1.5/2.0	2.3
WS1212 DWHG	1 200 x 1 200 (4x4)	2 410 (95)	2.2/3.0	3.0
WS1218 DWHG	1 200 x 1 800 (4x6)	3 010 (119)	3.0/4.0	3.8
WS1224 DWHG	1 200 x 2 400 (4x8)	3 610/142)	3.0/4.0	4.5
WS1230 DWHG	1 200 x 3 000 (4x10)	4 218 (166)	4.0/5.0	5.4
WS1236 DWHG	1 200 x 3 600 (4 x 12)	4 818 (190)	4.0/5.0	6.0

Wet LIMS – Dense media (DM)



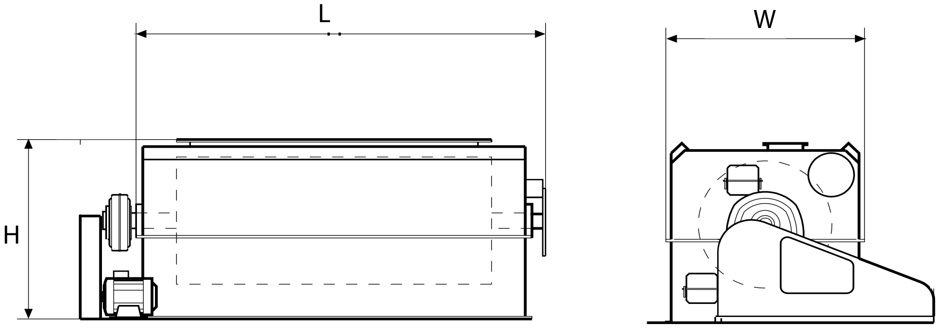
Model	**Drum mm (ft)** **D x L**	**L mm (inch)**	**Power** **kW/hp**	**Weight (empty)** **ton**
WS 1206 DM	1 200 x 600 (4 x 2)	1 810 (71)	1.5/2.0	2.1
WS 1212 DM	1 200 x 1 200 (4 x 4)	2 410 (95)	2.2/3.0	2.9
WS 1218 DM	1 200 x 1 800 (4 x 6)	3 010 (119)	3.0/4.0	3.6
WS 1224 DM	1 200 x 2 400 (4 x 8)	3 610 (142)	3.0/4.0	4.3
WS 1230 DM	1 200 x 3 000 (4 x 10)	4 218 (166)	4.0/5.0	5.0
WS 1236 DM	1 200 x 3 600 (4 x 12)	4 818 (190)	4.0/5.0	5.8

Wet LIMS – Dense media (DMHG)



Model	**Drum mm (ft)** **DxL**	**L mm (inch)**	**Power** **kW/hp**	**Weight (empty)** **ton**
WS1206 DMHG	1 200 x 600 (4 x 2)	1 810 (71)	1.5/2.0	2.3
WS1212 DMHG	1 200 x 1 200 (4 x 4)	2 410 (95)	2.2/3.0	3.0
WS1218 DMHG	1 200 x 1 800 (4 x 6)	3 010 (119)	3.0/4.0	3.8
WS1224 DMHG	1 200 x 2 400 (4 x 8)	3 610 (142)	3.0/4.0	4.5

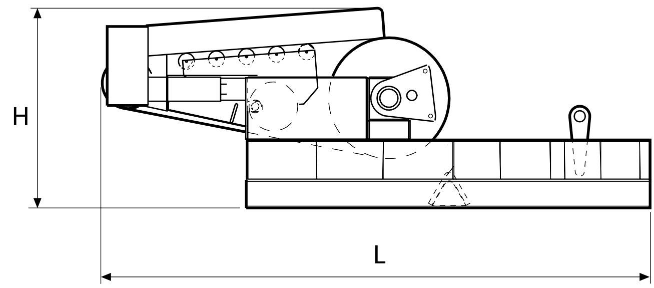
Dry LIMS – Drum separator – (DS)

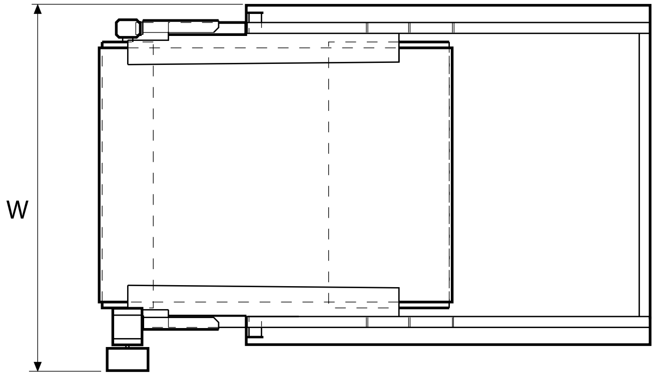


Model	Drum mm (ft) D x L	H mm (inch)	L mm (inch)	W mm (inch)	Power kW/hp	Weight ton
DS 903	916 x 300 (3 x 1)	1 400 (55)	1 242 (49)	1 360 (54)	4.0/5.5	1.2
DS 906	916 x 600 (3 x 2)	1 400 (55)	1 550 (61)	1 360 (54)	4.0/5.5	1.6
DS 912	916 x 1 200 (3 x 4)	1 400 (55)	2 166 (85)	1 360 (54)	5.5/7.5	2.5
DS 915*	916 x 1 500 (3 x 5)	1 400 (55)	2 474 (97)	1 360 (54)	5.5/7.5	2.9
DS 918	916 x 1 800 (3 x 6	1 400 (55)	2 782 (110)	1 360 (54)	7.5/10	3.2
DS 924	916 x 2 400 (3 x 8)	1 400 (55)	3 398 (134)	1 360 (54)	7.5/10	3.9
DS 1206	1 200 x 600 (4 x 2)	1 670 (66)	1 550 (61)	1 844 (73)	5.5/7.5	1.8
DS 1212	1 200 x 1 200 (4 x 4)	1 670 (66)	2 166 (85)	1 844 (73)	5.5/7.5	2.8
DS 1215*	1 200 x 1 500 (4 x 5)	1 670 (66)	2 474 (97)	1 844 (73)	7.5/10	3.2
DS 1218	1 200 x 1 800 (4 x 6)	1 670 (66)	2 782 (110)	1 844 (73)	7.5/10	3.5
DS 1224	1 200 x 2 400 (4 x 8)	1 670 (66)	3 398 (134)	1 844 (73)	11/15	3.9
DS 1230	1 200 x 3 000 (4 x 10)	1 670 (66)	4 014 (158)	1 844 (73)	11/15	5.0

*Max lenght – high speed plastic drum

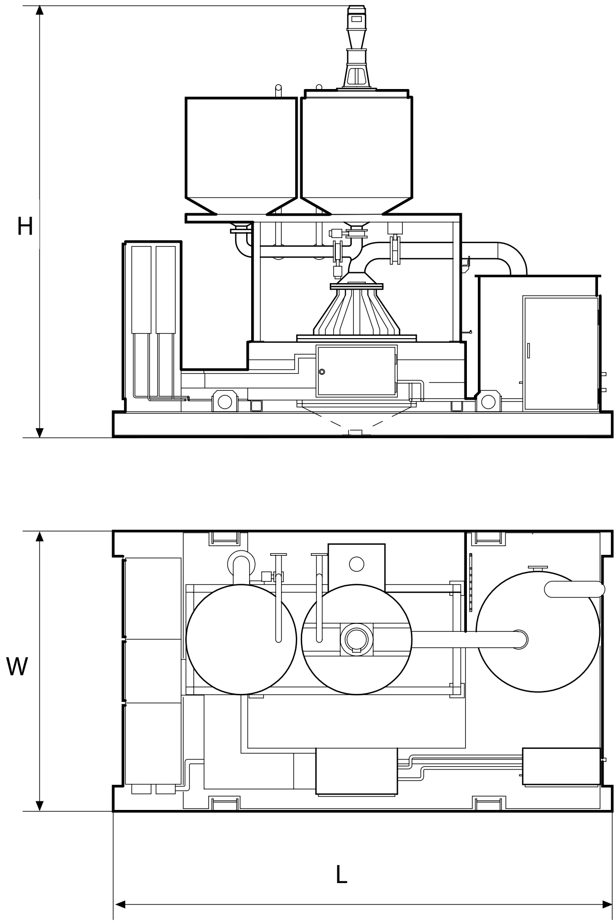
Dry LIMS – Belt separator (BSA and BSS)





Model	Drum mm (ft) DxL	H mm (inch)	L mm(inch)	W mm(inch)	Power kW/hp	Weight ton
BS 1206	1 200 x 600 (4 x 2)	2 000 (79)	4 360 (172)	1 800 (71)	5.5/7.5	2.1
BS 1212	1 200 x 1 200 (4 x 4)	2 000 (79)	4 360 (172)	2 400 (95)	7.5/10	3.8
BS 1218	1 200 x 1 800 (4 x 6)	2 000 (79)	4 360 (172)	3 000 (118)	7.5/10	5.6
BS 1224	1 200 x 2 400 (4 x 8)	2 000 (79)	4 360 (172)	3 600 (142)	7.5/10	7.5
BS 1230	1 200 x 3 000 (4 x 10)	2 000 (79)	4 360 (172)	4 200 (166)	11/15	9.3

Wet cyclic HGMS



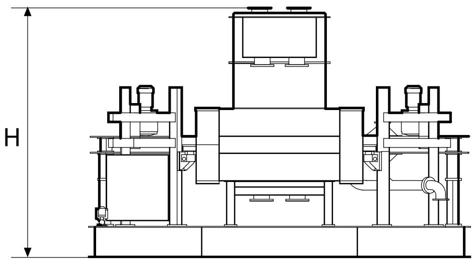
Model	H mm (ft)	L mm (ft)	W mm (ft)	Power (magnet) kW	Weight (empty) ton	Matrix area m^2 (ft^2)
38-15-10*	4 000 (13)	3 800 (12)	2 450 (8)	40	10	0.11 (1.18)
56-15-10	4 100 (13)	4 000 (13)	2 450 (8)	46	13	0.19 (2.05)
76-15-10	4 100 (13)	4 200 (14)	2 450 (8)	53	14	0.43 (4.63)
107-15-10	4 380 (14)	5 150 (17)	2 900 (10)	63	26	0.85 (9.15)
152-15-10	**	**	**	80	46	1.75 (18.84)
214-15-10	**	**	**	103	**	3.42 (36.81)
305-15-10	**	**	**	-	**	7.30 (78.58)

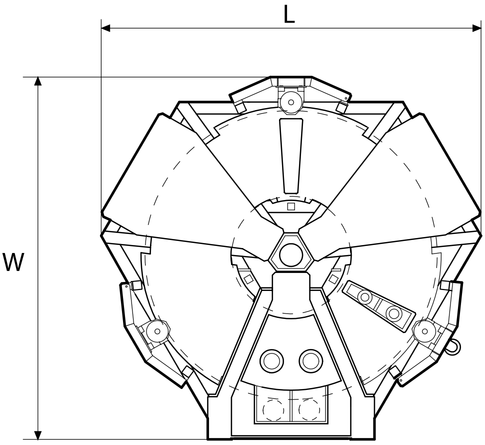
*38-15-10= 38(Outer diameter in cm)-15(matrix height in cm)-10 (field rating in kGauss)

Magnetic field available 5,10,15 and 20 kGauss

** Site specific

Wet carousel HGMS



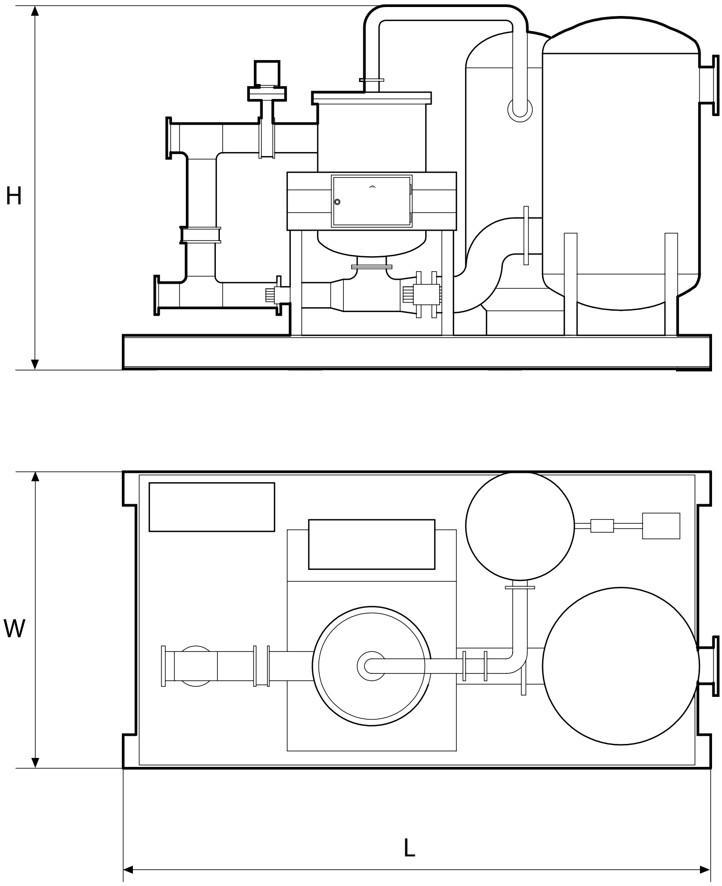


Model	H mm (ft)	L mm (ft)	W mm (ft)	Power/head kW	Weight/frame ton	Weight/head ton
120-10 (2)*	2 800 (9)	2 600 (9)	2 200 (7)	75	6	3
120-15 (2)	2 800 (9	2 600 (9)	2 200 (7)	175	5	5
185-7 (2)	3 600 (12)	4 100 (13)	3 700 (12)	65	10	9
185-10 (2)	3 600 (12)	4 100 (13)	3 700 (12)	85	10	18
185-15 (2)	3 600 (12)	4 100 (13)	3 700 (12)	200	10	31
250-5 (2)	3 600 (12)	6 300 (21)	4 500 (15)	40	20	22
250-7 (2)	3 600 (12)	6 300 (21)	4 500 (15)	75	20	32
250-10 (2)	3 600 (12)	6 300 (21)	4 500 (15)	120	20	54
250-15 (2)	3 600 (12)	6 300 (21)	4 500 (15)	260	20	95
350-5 (3)	4 600 (15)	7 000 (23)	7 500 (25)	78	40	26
350-7 (3)	4 600 (15)	7 000 (23)	7 200 (24)	136	40	37
350-10 (3)	4 600 (15)	7 200 (24)	7 200 (24)	165	40	66
350-15 (2)	4 600 (15)	8 200 (27)	7 000 (23)	326	40	120

*120-10 (2)=120 (ring diameter in cm)-10(field rating magnet head, kGauss) (2) number of magnetic heads

Nominal capacity/head: 120-6t/h, 185-35t/h, 250-107t/h, 350-150t/h.

High gradient magnetic filter – HGMF



Model	H mm (ft)	L mm (ft)	W mm (ft)	Power(magnet) kW	Matrix area m² (ft²)
38-15-3*	1 905 (6)	3 048 (10)	1 321 (4)	9	0.07 (0.8)
45-15-3	2 032 (7)	3 556 (12)	1 524 (5)	12	0.11 (1.2)
56-15-3	2 210 (7)	4 064 (13)	1 829 (6)	12	0.19 (2.0)
76-15-3	2 464 (8)	4 115 (14)	1 829 (6)	24	0.43 (4.6)
107-15-3	3 073 (10)	5 588 (18)	1 981 (7)	24	0.85 (9.15)
152-15-3	**	**	**	28	1.75 (18.84)
214-15-3	**	**	**	37	3.42 (36.81)

*38-15-3= 38 (Outer diameter in cm)-15 (matrix height in cm) -3 (field rating in kGauss)

Magnetic field available 3,5,10,15 and 20 kGauss

** Site specific

Upgrading – Introduction

With upgrading we understand, the further processing of the final products from the enrichment stages in a process.
This is valid both concerning the valuable minerals (the concentrate) and the waste minerals (the tailings).

In the first case upgrading means improving the product value by bringing the concentrate to transportability or into a completely dry form. Processing can also go further to calcining and sintering.
On the tailing side upgrading means that waste material (wash water, process effluents etc.) is properly taken care of in order to protect the environment, to recover process water and to turn certain portions into valueables.

Upgrading by methods

Sedimentation
Clarification/Thickening (conventional)
Clarification/Thickening (compact)

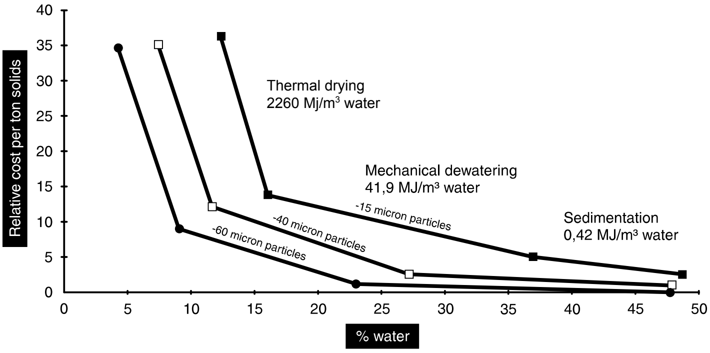
Mechanical dewatering
Gravity
Low pressure
Medium pressure
High pressure

Thermal drying
Direct
Indirect

Thermal processing
Calcining
Sintering (pelletizing)

Upgrading by operation costs

Upgrading has its price, increasing with the energy input for removal of the process water (or process liquid).



The curves above must always be considered when we are selecting equipment for an upgrading circuit for concentrate drying or disposal of a washing effluent.
The rules are simple!

1. Can we do the job with sedimentation only? If not - how far can we reach by sedimentation thereby saving money in the following dewatering stage?
2. How far can we reach with mechanical dewatering? Can we save a thermal stage by increasing the dewatering pressure?
3. If the particles are coarse, can gravity dewatering do the job? The cost is close to the same as for sedimentation.
4. If thermal dewatering is needed, can energy be saved in drying by improved mechanical dewatering?

Sedimentation

Sedimentation is a continuous solid-liquid separation process with settling of solids by gravity. **Clarification** is the process for removal of solids from a dilute solid/liquid suspension. **Thickening** is the process for concentrating particles in a supension by gravity compression

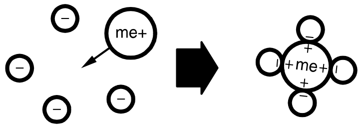
Flocculation

All sedimentation technologies are related to particle size. One way of improving the settling speed generally is therefore to increase the size of the particles.

Fine particles can be connected together by coagulation or flocculation. The settling rate of the combined particles will be higher than that of each individual particle.

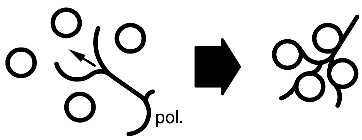
Coagulation: Surface charges are neutralized by addition of chemicals of opposite charge.

Ex: *Fe^{+++} (iron sulphate)*
Al^{+++} (aluminium sulphate)
Ca^{++} (lime)



A coagulated aggregate will reform after breaking (e.g. pumping).

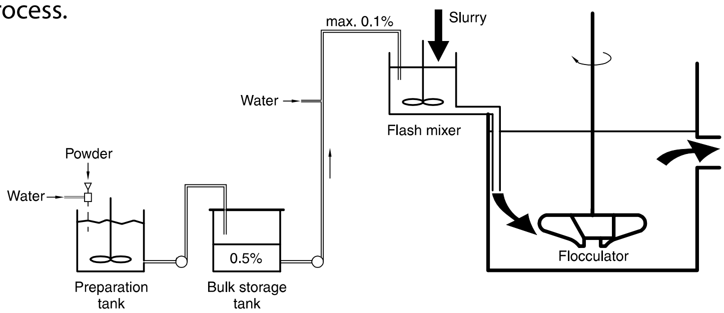
Flocculation: Polymeres with molecule chains which physically link the particles together (mechanical bridging).



A flocculated aggregate will not reform after breaking.

Flocculation system

A handling system is needed for flocculant utilisation. This comprises provision to mix, store and dilute the polymer. The dilute polymer is then mixed with the feed slurry and allowed to condition (or age) before a sedimentation or dewatering process.

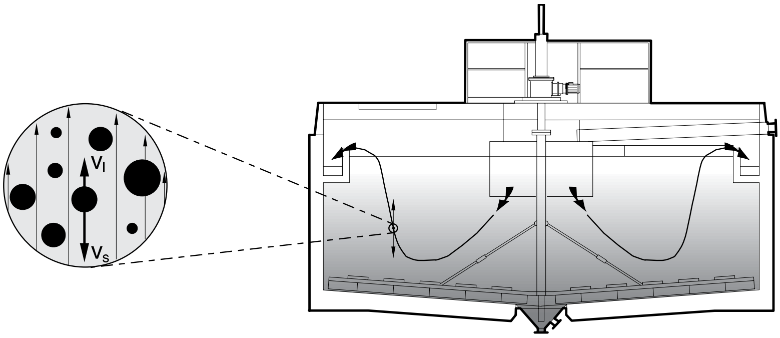


Flocculation - addition and mixing time

Application	Flocculant	Mixing time min	Addition rate (g/m^3)
Sand wash water	an- or non-ionic	0.5 - 1	0.5 - 5
Flue gas	an-ionic	1 - 3	0.5 - 2
Scrubber water (steel plant)	an-ionic	0.5 - 2	0.5 - 2
Coal tailings	non- and cat.ionic	0.5 - 1	2 - 10
Mineral tailings	an-ionic	0.5-1	1-5

Conventional clarifier

Clarification is achieved when the liquid "upstream" velocity V_L is lower than the sedimentation velocity of the solids V_S



Conventional clarifier – sizing

Clarifier diameter is selected to give a suitable upstream velocity (m/h). This is also expressed as "Surface Load", meaning the volume of slurry m^3/h fed per m^2 of clarifier surface. Typical surface areas are given below.

Surface load material	Feed %	Surface load (m^3/m^2, h)	Surface load (ft^3/ft^2, min)	
Brine purification	0.1 - 2	0.5 - 1.2	0.03 - 0.07	
Coal refuse	0.5 - 6	0.7 - 1.7	0.04 - 0.09	
Clean coal fines	-	1.0 - 1.9	0.06 - 0.10	
Heavy media magnetite	20 - 30	6 - 7.5	0.32 - 0.41	
Flue dust. blast furnace	0.2 - 2	1.5 - 3.7	0.08 - 0.20	
Flue dust. BOF	0.2 - 2	1.0 - 1.7	0.06 - 0.09	
Magnesium oxide	0.5	0.6 - 1.2	0.03 - 0.07	(with flocculation)
Foundry waste water	1.0	0.7 - 1.0	0.04 - 0.06	(with flocculation)
Plating waste	2 - 5	1.2	0.07	
Green liquor	0.2	0.8	0.04	
Gypsum desulphurization	1 - 3	1 - 2	0.06 - 0.12	
Sand wash water	1 - 5	0.3 - 1	0.02 - 0.06	(without flocculation)
	1 - 5	1 - 4	0.06 - 0.22	(with flocculation)
Ore flotation tailings	10 - 20	0.1 - 0.3	0.005 - 0.02	(without flocculation)
	10 - 20	0.5 - 1.5	0.03 - 0.08	(with flocculation)

Example

A wash water (100 m^3/h) coming from a sand operation needs to be clarified. Surface load is 0.5 m3/h/m2. Select clarifier diameter.

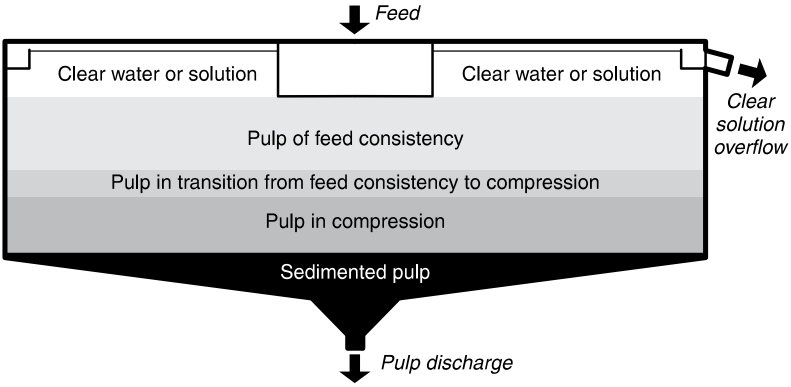
Required area is: 100/0.5 = 200 $m^2 = \frac{\pi d^2}{4} = 200$ where d is required diameter = 15.9.

Select a 16 m clarification tank!

Note! When thickening is also a critical part of the sedimentation process, the tank diameter has to be cross-checked with the diameter for thickener duty, see next page.

Conventional thickener

Continuous thickening to give the required solids concentration in the underflow depends on balancing the volumetric solids flow rate at a critical concentration with the diameter of the thickener.



Conventional thickeners – Sizing

Thickener selection is based upon the **unit area**, defined as m^2 of thickener area required per tph of solids. Typical figures for unit area are given below.

Clarification/ thickening – cross checking (metric)

Clarification and thickening are process definitions. The equipment can be applied to both duties. If this is the case we have to select the tank area for each duty and select the largest of the two.

Ex: Cu concentrate (k80= 80 µm), 10 t/h or 18m^3/h

Surface load (with flocculation) = 1.5 m/h

Unit area = 2 m^2/(t/h)

Clarification area = 18/ 1.5 = 12 m^2

Thickening area = 10x2 = 20 m^2

Select a clarifier/thickener of 20m^2 , diameter 5 m.

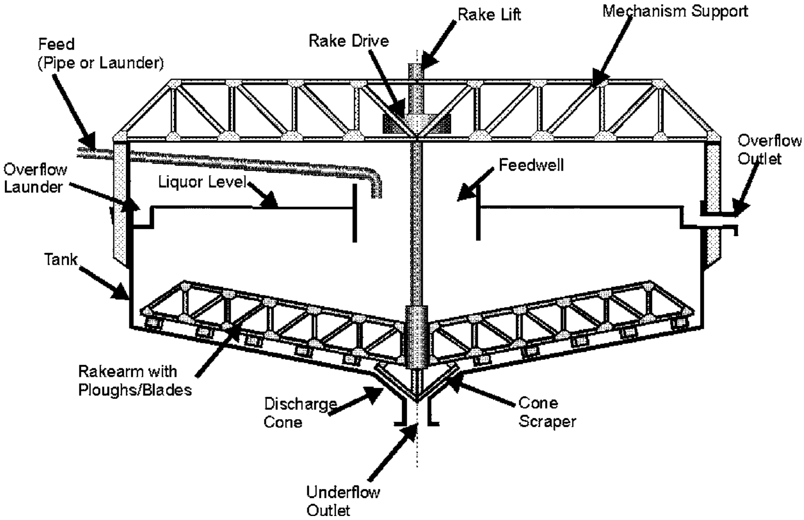
Application		Feed (% w/w)	Underflow solids (% w/w)	Solids (m^2 / (t/h)	Unit area (ft^2/st x 24h)
Ni - conc	k_{80} 35 µm	27	65	3.5	1.6
Apatite conc	k_{70} 74 µm	27	60	10.5	5
Calcite conc	k_{80} 180 µm	30	60	0.07	0.03
Bauxite	k_{25} 100 µm	10	40	420	188
Phosphate conc	k_{80} 60 µm	18	70	25	11
Tailings sulphide ores	k_{80} 90 µm	40	57	7	3
Tailings iron ores	k_{80} 70 µm	12	50	60	27
Molybdenum concentrate	k_{80} 35 µm	10	30	20 - 35	9 - 16
Fe - conc	k_{80} 130 µm	30	75	4	2
Pyrite	k_{80} 40µm	19	65	26	11.5
Cu - conc	k_{80} 50 µm	40	75	2	1
Zn - conc	k_{80} 40 µm	20	68	0.7	0.3
Pb - conc	k_{80} 30 µm	20 - 25	60 - 80	15 - 30	6.5 - 13

Conventional clarifier/thickener – Design

Bridge type

For smaller thickeners, up to 30 – 40 m diameter, the rakes and drive mechanism are supported on a bridge superstructure, which straddles the tank as shown.

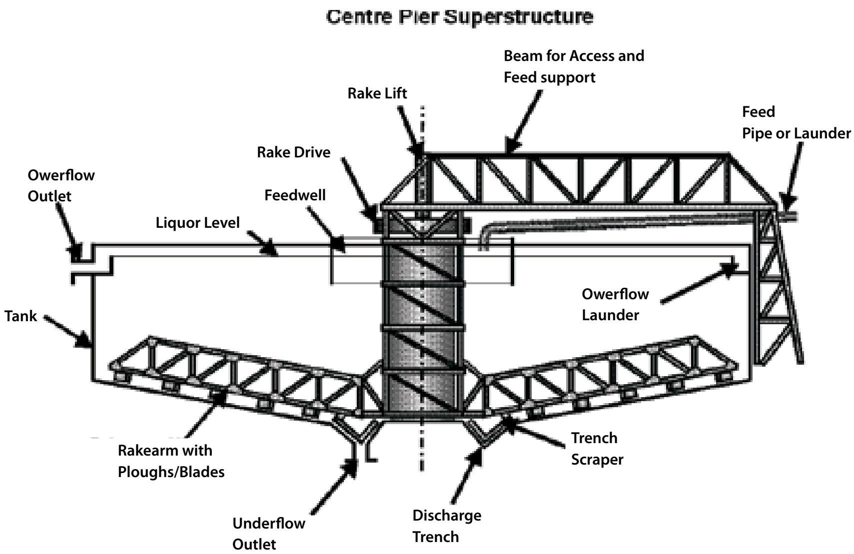
See data sheet 6:54.



Centre pier type

For tanks over 30 – 40 m diameter a bridge structure will be imractical. The mechanism and rakes are therefore supported from a centre pier and the bridge is only used for access and to support feed pipe and launder.

See data sheet 6:55.

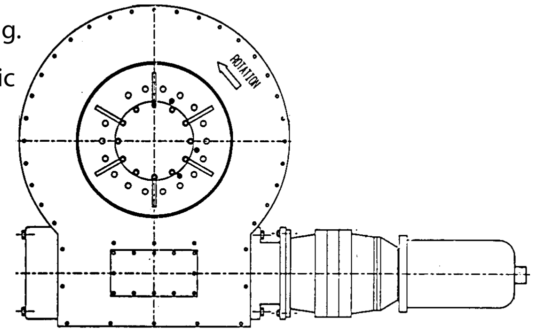


Design options

Up to 20 m elevated tank with underflow at ground level. Above 20 m tank at ground level with underflow in a tunnel.

Conventional clarifier/thickener – Drive system

Drive mechanism



For bridge and centre pier mounting.

Options with and without automatic rake lifting system.

Automatic torque monitoring

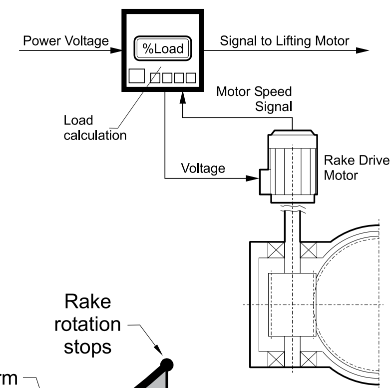
Slewing ring bearing to accommodate out of balance loads on rakes
Worm and wheel and multistage epicyclic gearbox drive

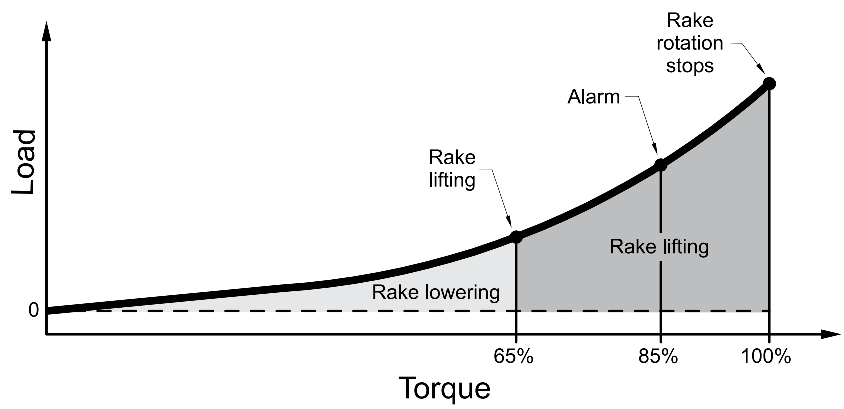
Conventional clarifier/thickener drives – torque definitions

10 year torque	The torque loading at which the drive head will have a calculated wear life of 10 years (also called equivalent torque)
Cut out torque	Nominal 3000 hours wear life. App. 3 x "10 year torque". If the monitoring system detects a torque above this level the drive head will stop and a alarm will be raised in order to protect the rakes.
Peaktorque	Practical maximum torque. App. 2 x "cut out torque".

Conventional clarifier/thickener – control

Torque is electronically detected and monitored. Increased torque is a sign that the solids loading in the thickener may be building up. This could indicate a process problem (change in feed, blocked underflow etc.). In all these cases rakes and drive have to be protected.





Conventional clarifier/thickener drive – Sizing

Duty classification

	Very light duty	Light duty	Standard duty	Heavy duty	Extra heavy duty
Separation/clarification classification	**(1)**	**(2)**	**(3)**	**Thickening (4)**	**(5)**
Solids loading					
$m^2/t/h$	>120	48-120	7-48	4-7	<4
$ft^2/st/day$	>50	20-50	3-20	1.5-3	<1.5
Underflow concentration					
% solids by weight	<5	5-30	30-60	>60	>60
Specific gravity					
dry solids	<2.5	<2.5	2.0-3.5	3.0-4.5	>4.0

Typical duties

(1) Water treatment, river or lake water clarification, metallic hydroxides, brine clarification.

(2) Magnesium hydroxide, lime softening, brine softening.

(3) Copper tails, iron tails, coal refuse tails, coal, zinc or lead concentrates, clay, titanium oxide and phosphate tails.

(4) Uranium counter-current decantation (CCD), molybdenum sulphide.

(5) Iron oxide concentrates, magnetite, iron pellet feed, ilmenite.

Examine solids loading or specifications to determine whether duty is thickening or clarification. Proceed to relevant section to select drive head.

Drive head torque rating

Drive head size	kW/hp	Design options	Cut-out torque (Nm)	10 year torque (Nm)
10	1.5/2.0	B only	32 000	10 000
12	1.5/2.0	Bonly	45 000	17 000
14	1.5/2.0	B only	72 000	26 000
17	3.0/4.0	B only	120 000	45 000
20	3.0/4.0	B & C	190 000	65 000
24	4.0/4.0	B & C	310 000	112 000
28	5.5/7.4	B & C	450 000	164 000
32	5.5/7.4	B & C	610 000	225 000
36	11.0/14.8	B & C	800 000	301 000
40	11.0/14.8	B & C	1 100 000	397 000

BN and CN = drives without lifting

BL and CL = drives with lifting

Clarifier drive selection

Clarifiers, see duty page 6:8, operate with a low solids loading and drives are selected according to formula below

$$Tc = KxD^2$$

Tc = Process Cut Off torque (Nm)

K = Clarifier duty factor (see below)

D = Clarifier Diameter (m)

Duty factor

Clarifying application	Duty factor
Brine purification	60
Lime softening	80
Metal hydroxides	150
Magnesium hydroxide (sea water)	185
Rolling Mill water	190
Lime sludge	210
Calcium carbonate	210
Pulp and paper sludge	250
Pickle liquors and rinse water	255
Plating waste	255
Blast furnace dust	320
Oxygen furnace dust	350
Heat treatment (metal) sludge	440

Select a drive head from the" Drive Head Torque" values above, so that the specified "cut out torque" is greater then calculated Tc.

Example: Select a bridge mounted drive head for a 35 m diameter clarifier (no lift required). Application: lime sludge clarifying.

K factor = 210 giving a Tc = 210 x 35^2 = 257 250 Nm. Select a drive head type BN 24, cut out torque 310 000 Nm.

Thickener drive selection

Here we are calculating with Process Equivalent Torque (or 10 year torque), see page 6:8, according to formula

$$Te = 256 \times D \times \sqrt{M}$$

Te = Process Equivalent Torque

D = Thickener diameter (m)

M = Solids in underflow (tph), see duty above

Select a drive head from the "Drive Head Torque" values above, so that the 10 year torque is greater than Te calculated above.

Example: Select a pier mounted drive head with a lift suitable for a 50 m diameter thickener handling an underflow of 130 tph of solids.

Te = $256 \times 50 \times \sqrt{130}$ = 145 952 Nm. Select CL 28 drive head with a 10 year torque of 164 000 Nm.

Conventional clarifier/thickener – Areas

Diameter (m)	Diameter (ft)	Area (m²)	Area (ft²)	Diameter (m)	Diameter (ft)	Area (m²)	Area (ft²)
10	33	78	839	38	125	1 134	12 206
12	39	113	1 216	40	131	1 257	13 530
14	46	154	1 658	42	138	1 385	14 913
16	52	201	2 164	44	144	1 521	16 367
18	59	254	2 734	46	151	1 662	17 889
20	66	314	3 380	48	157	1 810	19 479
22	72	380	4 090	50	164	1 963	21 130
24	79	452	4 865	52	170	2 124	22 860
26	85	531	5 716	54	177	2 290	24 653
28	92	616	6 631	56	184	2 463	26 512
30	98	706	7 599	58	190	2 642	28 440
32	105	804	8 654	60	197	2 827	30 430
34	111	908	9 773				
36	118	1 018	10 958				

Conventional clarifier/thickener – Tank depth

Thickener dia (m)	Tank depths	Standard (centre) (m)	Standard (centre) (ft)	Minimum (centre) (m)	Minimum (centre) (ft)
3.5 - 5.5	See page 6:54-55	2.4	7.9	2.3	7.5
6.0 - 15	See page 6:54-55	3.0	9.8	2.7	8.9
16 - 23	See page 6:54-55	3.6	11.8	3.0	9.8
24 - 26	See page 6:54-55	4.6	15.1	4.3	14.1
27 - 38	See page 6:54-55	5.2	17.0	4.9	16.1
38 - 42	See page 6:54-55	5.5	18.0	4.9	16.1
43 - 46	See page 6:54-55	5.8	19.0	5.2	17.0
47 - 49	See page 6:54-55	7.0	23.0	5.8	19.0
50 - 52	See page 6:54-55	7.3	24.0	6.4	21.0
53 - 55	See page 6:54-55	7.6	25.0	6.7	22.0

Use minimum depth if feed volume flow rate is less than 1.2 m^3/m^2,h.

Conventional clarifier/ thickener – Tank bottom slope

Application	Tank slope (mm/m)	Degrees	
Fine particle sediments	80	5	
Metallurgical sludges	145	8	(standard slope)
Coarse and or heavy particles	200	11	

For small thickeners no slope restrictions (up to 45°).

For larger diameter thickeners (>dia 45 m) a two-slope tank is recommended for height saving reasons. Inner 1/3 (9 °) out 2/3 (5 °)

Slope for 1/3 of dia 165 mm/m (9 degrees)

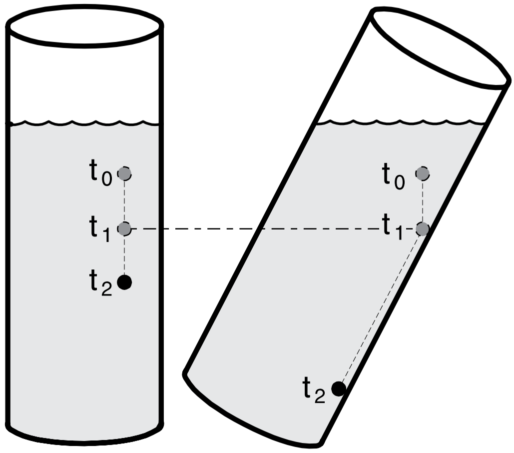
Slope for 2/3 dia (outer) 80 mm/m (5 degrees)

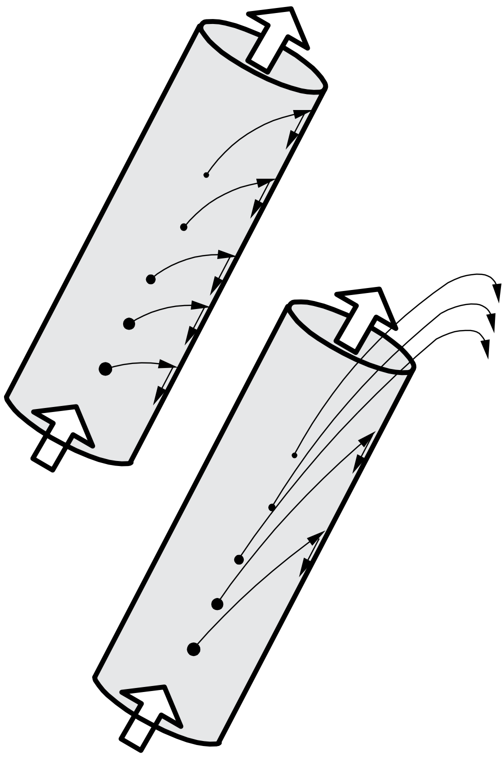
See also data sheet 6:55 - 56.

Lamella or inclined plate sedimentation – Introduction

"By tilting a clarifier to an angle of 55° we have a lamella clarifier with a new relation between solids and liquids, compared to a conventional clarifier".

By a combination of a short distance of sedimentation and "friction free sliding" the separation speed is increased.

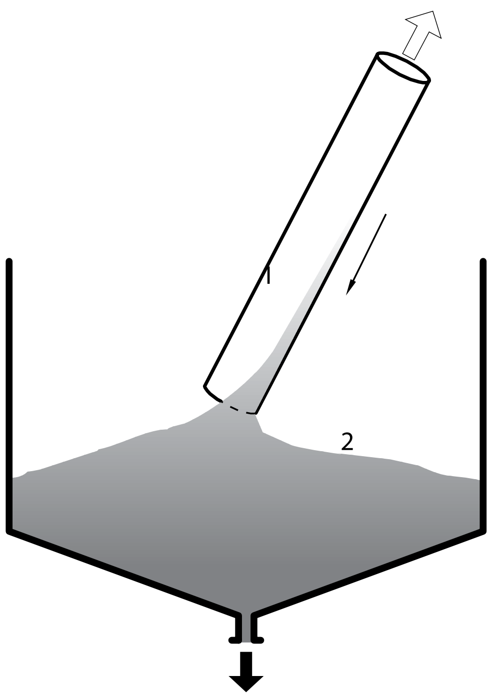




Clarification is achieved when upstream velocity is low enough to allow solids to report to the "Lamella plate".

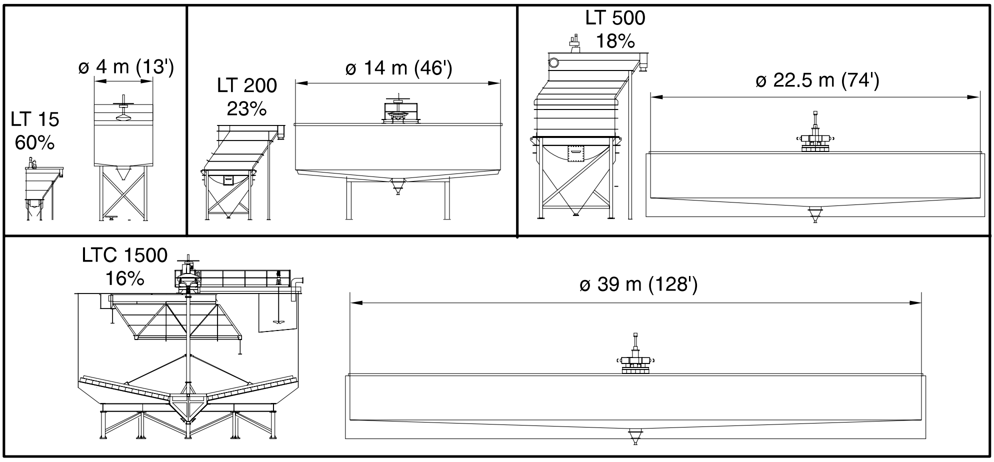
Clarification is not achieved when upstream velocity is too high and solids will not report to the "lamella plate".

Lamella thickening is achieved as primary thickening (1) on the lamella plates and secondary thickening (2) (conventional) in the lamella tank.



Lamella plates – principle

The Clarifiers and Thickeners are utilising the "Lamella or Inclined Plate Principle" to perform sedimentation processes in much more compact equipment than would be possible using conventional techniques. Some typical comparisons of floor area requirements are given below:



Upgrading

The Lamella concept offers many practical advantages:

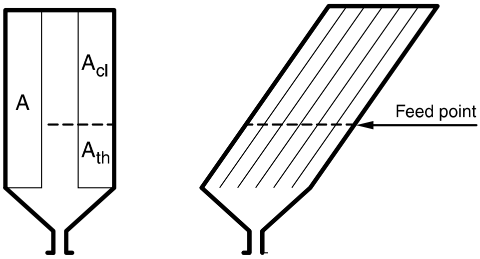
- Reduced plant area requirements
- Reduced retention time
- Possibility to optimise the ratio of clarification & thickening area
- Low heat losses – easy to insulate
- Low water losses due to evaporation – easy to cover
- Transport of the unit is more practical
- More suitable for indoor installation
- Quicker installation
- Easier to manufacture special designs (rubber lined, stainless steel etc.)
- Lower capital costs

There are limitations to the 'lamella concept' and in some of these cases conventional thickeners can be preferred. Examples are:

- High surface loads (above approx. 5.0 m^3/m^2h (0.28 ft^3/ft^2min)
- Feeds with very high solids content / sludge volumes
- High froth content (flotation concentrates)

Lamella plates – function

The area above the feed points is regarded as clarification area (A^{cl}), this can be up to 80% of the total plate area. The area beneath the feed point is thickening area (A^{th}), this can be up to 50% of the total plate area.



Inclined plate settler

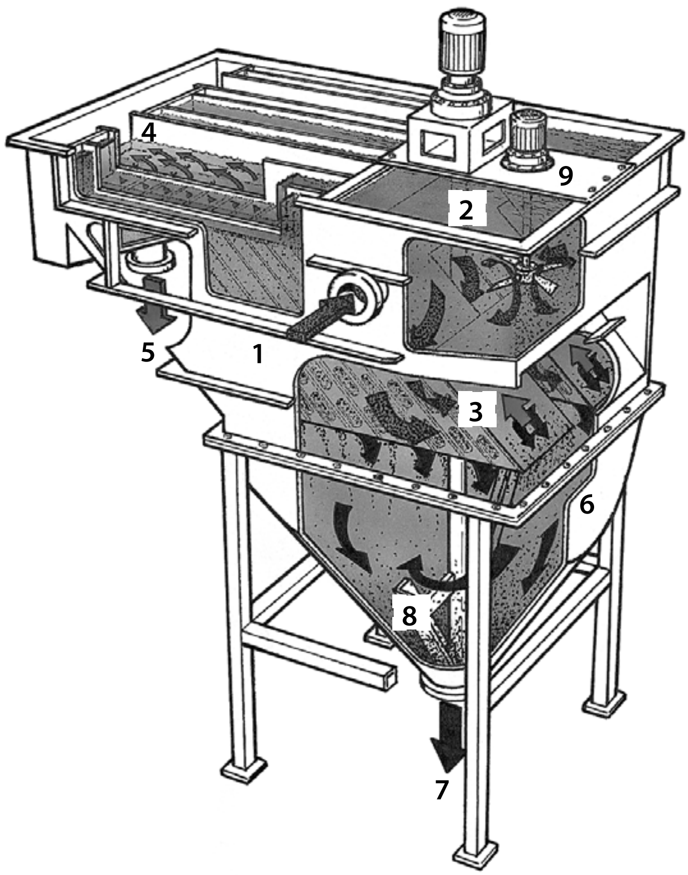
Design

The Inclined Plate Settler consists of two main components, the upper tank containing the lamella plates inclined at 55° and the lower conical or cylindrical sludge container.

The feed for the Inclined Plate Settler enters through vertical chambers on either side of the lamella packs and passes into each plate gap through slotted feed ports. Clarification takes place above the suspension inlet so there is no mixing of the clarified fluid with the incoming feed.

Above each pack is a full-length overflow launder fitted with throttling holes to create a slight hydraulic back pressure on the incoming feed stream. This method of feed control guarantees equal distribution to all lamella chambers with minimum turbulence at the entry points.

The solids settle onto and slide down each lamella plate to the sludge container where the solids are further thickened and compressed with the assistance of the raking system.

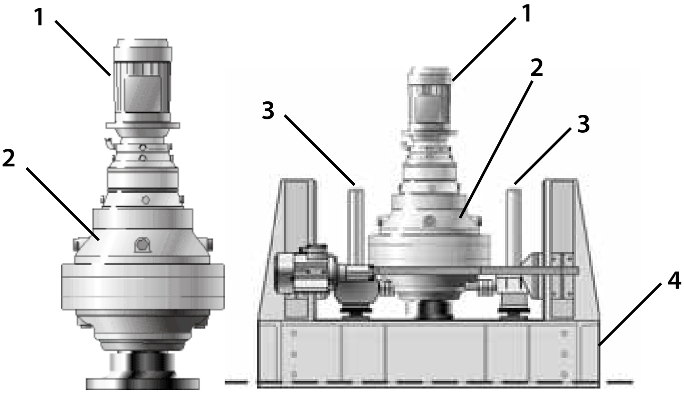


1. *Feed inlet*	4. *Overflow launders*	7. *Underflow outlet*
2. *Flocculation chamber*	5. *Overflow outlet*	8. *Rake with drive unit*
3. *Lamella plate packs*	6. *Sludge hopper*	9. *Flocculation agitator*

Inclined plate settler – Drives

Design

1. Gear motor
2. Planetary gear
3. Screw jack
4. Frame



Sizes

Drive unit size	Max. operating torque (Nm)	Max. operating torque (ft lbs)	Cut - out torque (Nm)	Cut - out torque (ft lbs)	Power range (kW)	Power range (hp)	Lifting capacity (kN)	Lifting capacity (lbf)
SFL 02	2 000	1 475	2 700	1 990	0.18 - 0.75	$^{1}/_{4}$ - 1	50	11 2400
SFL 05	5 000	3 690	6 750	5 000	0.37 - 2.2	$^{1}/_{2}$ - 3	50	11 2400
SFL 10	10 000	7 380	13 500	9 956	0.37 - 5.5	$^{1}/_{2}$ - 7$^{1}/_{2}$	50	11 2400
SFL 20	20 000	14 760	27 000	19 900	0.55 - 4.0	$^{3}/_{4}$ - 5	50	11 2400
SFL 30	30 000	22 140	40 500	29 900	0.75 - 5.5	1 - 7$^{1}/_{2}$	50	11 2400
SFL 60	60 000	44 255	80 000	59 005	0.75 - 5.5	1 - 7$^{1}/_{2}$	100	22 4800

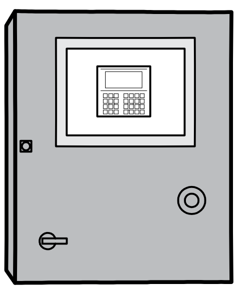
Lifting sequences

Definition: 100% load equal to max torque recommended by supplier.

Load	Function
< 50%	Normal operation with rakes in lower position.
> 75%	Rakes are lifted until 100% load is reached. Rakes stay in upper position until 70% is reached, then lowering towards bottom position.
> 100%	Cut-out torque stops rotation of rakes. Lifting to the top position and alarm. Starts up normally from drive head control panel.

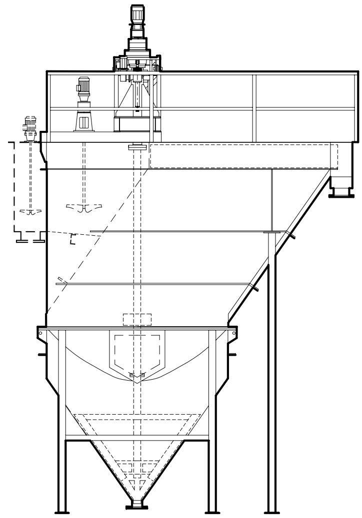
Control panel

- PLC controlled
- Fully automatic incl. functions for:
  - – Speed control of flocculator
  - – Torque signal
  - – Start and stop sequences
  - – Alarm indications for levels, flows etc.
  - – Control of underflow valve and pump



Inclined plate settler – Product range

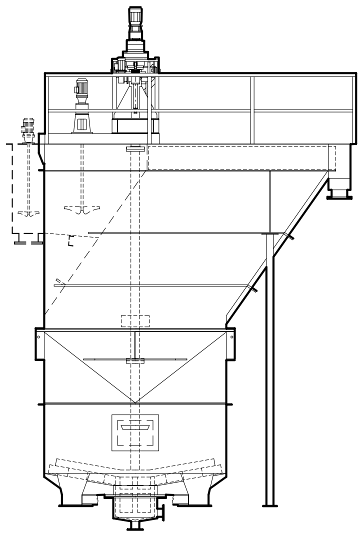
Type LT



- Sizes up to 400 m² (4300 ft²) effective clarification area
- Effective also with coarser material
- Limited solids content in feed
- Extension of lower part as option
- Lifting device as option

See also data sheet 6:57.

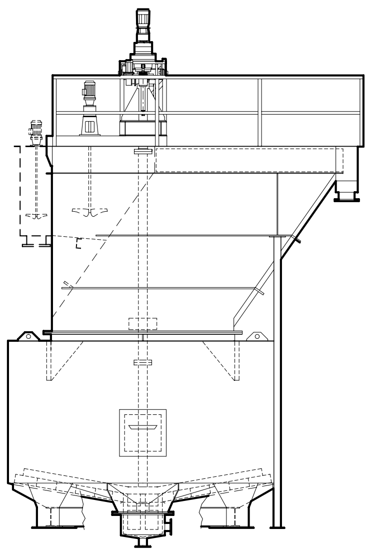
Type LTS



- Sizes up to 400 m² (4300 ft²) effective clarification area
- Not suitable for coarse material (> 0.5-1 mm, 32 - 16 Mesh)
- Higher solids load
- Extension of lower part as option
- Lifting device as option

See also data sheet 6:58.

Type LTK

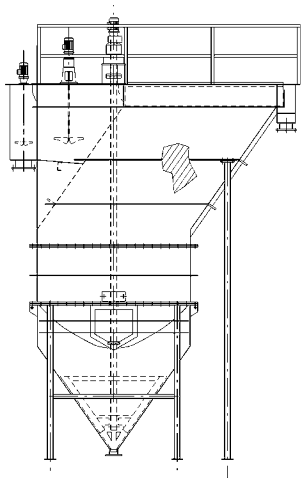


- Sizes up to 400 m² (4300 ft²) effective clarification area
- For higher solids load
- Used when storage and thickening is critical
- Extension of lower part as option
- Lifting device as standard

See also data sheet 6:59.

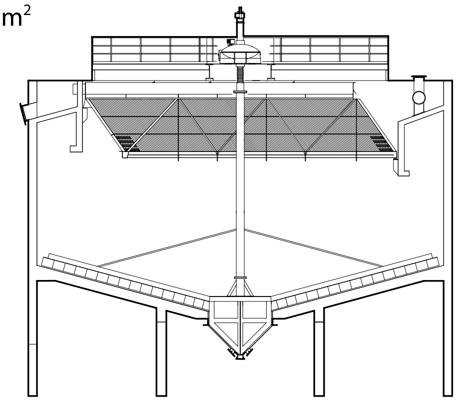
Type LT, LTS, LTK with extended tank

- By lower tank extensions the volume can be increased giving better storage and improved thickening.



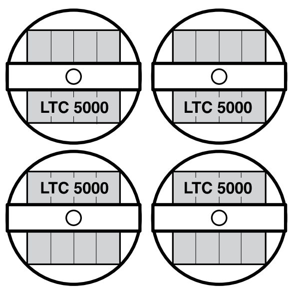
Type combi LTC

- Sizes up to tank dia 25 m (82 ft) = 5000 m^2 (53800 ft^2)
- For light and heavy duties
- High storage capacity
- Improved thickening
- Plate or concrete tank
- Conventional thickener drives



"Combi lamellas built up by using lamella packs in circular tanks have principally no limitation in sizes.

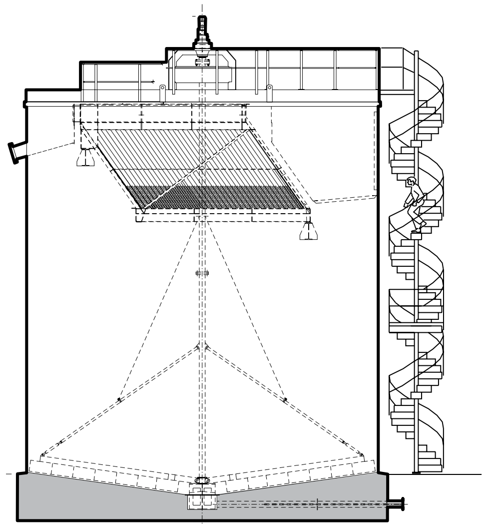
From design point, however, max. practical area for each lamella unit is approx. 5000 m^2. These sizes can then be combined in modules 5000 m^2 + 5000 m^2 + ... (53800 ft^2 + 53800 ft^2 + ...)



Type LTE

- Sizes up to 1 040 m^2 (11 194 ft^2) sedimentation area.
- Increased solids storage capacity for installation prior to a batch process such as a filter press.

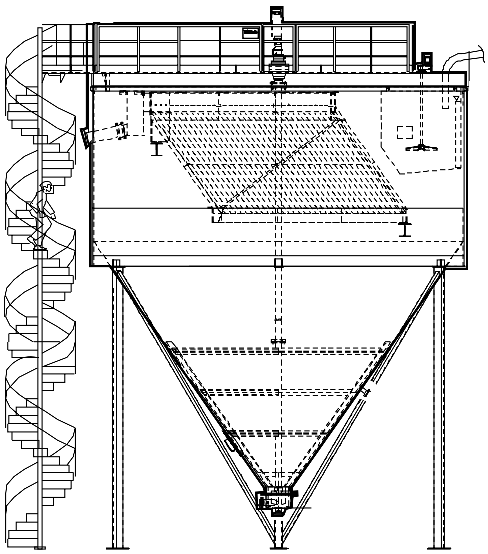
See also data sheet 6:60.



Type LTE/C

- Similar to LTE above.
- Conical bottom for denser underflow.
- Improved access to underflow valves, pump and piping.

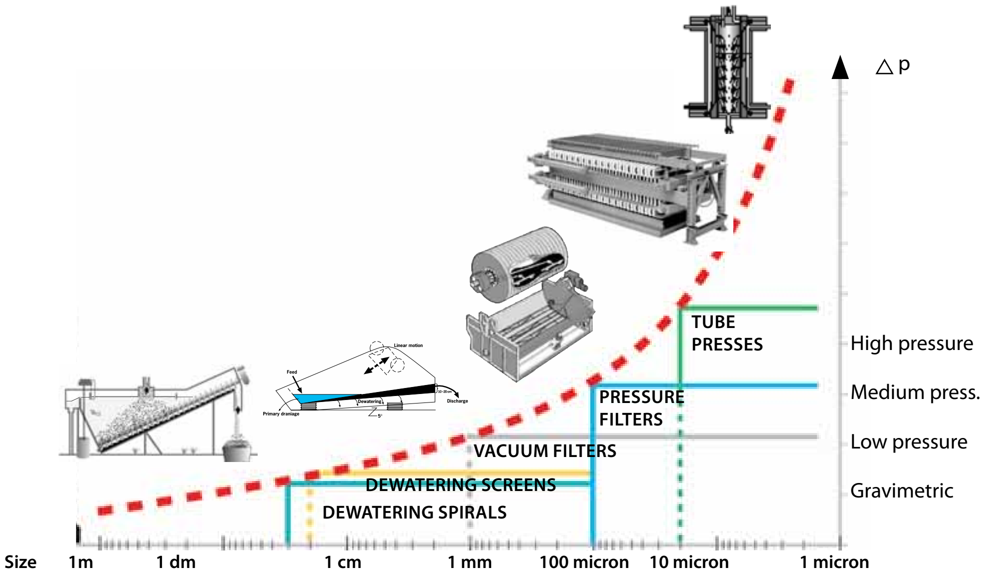
See also data sheet 6:61.



Mechanical dewatering – Introduction

Mechanical dewatering means mechanical removal of liquids from a slurry to obtain the solids in a suitable form and/or recovery of a valueable liquid for:

- Further processing
- Transportation
- Agglomeration
- Disposal
- Recovery of valuable liquids



Mechanical dewatering – Methods and products

Gravimetric dewatering

- Dewatering spirals
- Dewatering screens
- Dewatering wheels

Low pressure dewatering

- Drum Vacuum filters
- Belt drum vacuum filters
- Top feed vacuum filters
- Disc vacuum filters (not covered)
- Horizontal belt vacuum filters (not covered)

Medium pressure dewatering

- Air pressure filters (compression and through-blow)

High pressure dewatering

- Tube presses (compression and air-purged)

Gravimetric dewatering

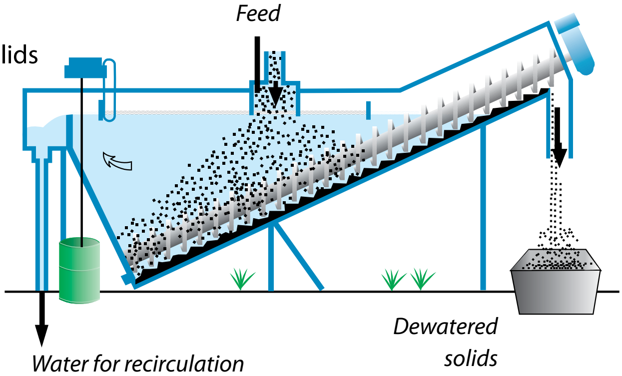
When the particles in a slurry are too coarse for the capillary forces to "trap" the water, the use of gravity is enough to remove the water and give at least transportable solids.

Spiral dewaterer

Spiral dewaterer for coarse solids (not deslimed).

- Feed 1% solids by w.
- 10 – 1 000 m3/h (44-44 000 USGPM)
- Remaining moisture approx. 30% h2O
- Large sedimentation-pool
- Oil scimmer as option

See also data sheet 6:62.



Spiral dewaterer – Sizes

Model	Pool area (m^2)	Pool area (ft^2)
SD60-8	8	86
SD60-10	10	108
SD60-20	20	215
SD60-30	30	324
SD60-38*	38	409
SD60-100*	100	1 076
SD60-25	25	269

* With Lamella plate

Spiral dewaterer – Sizing

Required pool area = Volume / surface load

Regarding surface loads m/h (m^3/m^2 and hour) see page 6:3

For preliminary sizings use for:

Water from continuous casting	10 - 20 m/h	(0,55 - 1,1 ft/min)
Water from steel rolling	10 - 20 m/h	(0,55 - 1,1 ft/min)
Water from slag granulation	2 m/h	(0,11 ft/min)

Ex: Cooling water from continuous casting must be treated for recirculation. Particles up to about 100 µm are accepted in the cooling water spray nozzles.

The flow is 650 m^3/h with 2 g/l mill scale.

Surface load of approx. 20 m^3/m^2 x h will give required separation.

Pool area: 650 / 20 =32,5 m^2

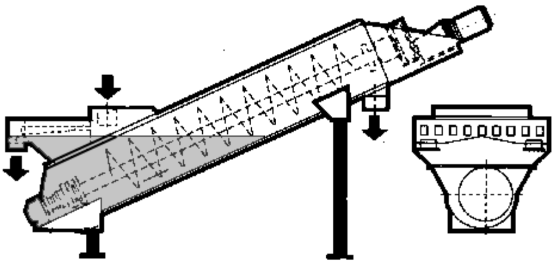
Select spiral dewaterer SD 60 - 38

Sand screw

This is a simpler version of the Spiral dewaterer mainly used for natural sand. These sands are normally classified (particles below 10-50 micron are removed) meaning that the sedimentation pool is very limited compared to the Spiral Dewaterer.

- Feed ratio sand : water app. 1:3
- Capacity 6-95 m^3/h
- Remaining moisture content 20-25 % H_2O by weight
- Screw inclination app. 25°

See also data sheet 6:63.

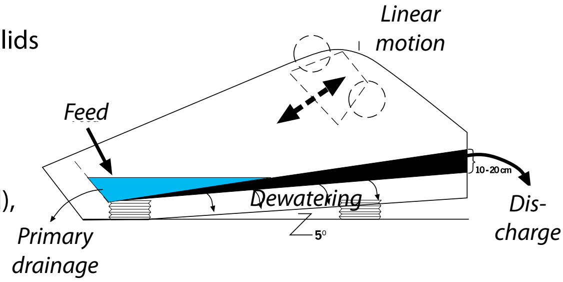


Dewatering screen

This is a version of a screen in linear motion moving the solids upwards on an inclined plane at an inclination of 5°. Dewatering takes place in the moving sand bed.

- Only for sand, coal or other deslimed solids
- Feed containing max. 50 % solids by weight
- Remaining moisture content 13-17 % H_2O by weight
- Capacities 70-190 ton/h (sand), 5-55 ton/h (coal)

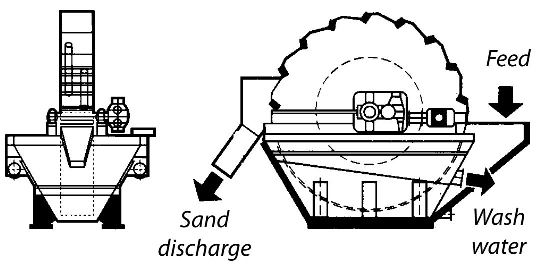
See also data sheet 6:64



Dewatering wheel

The dewatering wheel is mainly used in dredging of natural sand and gravel. The machine has a simple water draining arrangement at the sand removal buckets. Therefore the water content can be reduced down to 15-18 % H_2O by weight even if the feed contains certain fines. The pool is limited meaning that the machine is sensitive to high volume flows.

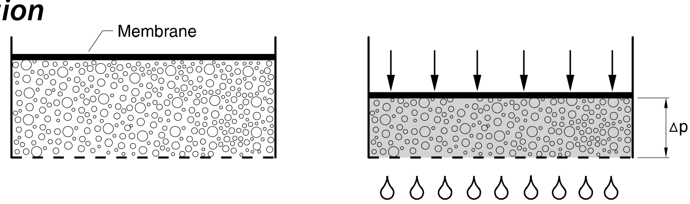
- Feed size (typical) 0-2 mm
- Variable speed as option
- Feed flow 1 500-2 400 m^3h
- See also data sheet 6:65



Mechanical dewatering by pressure – Introduction

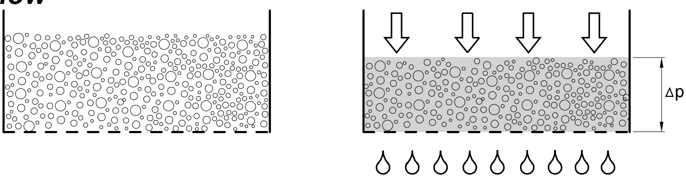
As particles get finer the resistance against removing water increases. Gravity dewatering can no longer be used. We have to use pressure.
By creating a differential pressure Δp across a cake of solids, liquid can be removed by

Compression



"Dewatering by compression means replacing the liquid in a cake with particles"

Through blow



"Dewatering by through-blow means replacing the water in a cake with air"

For ***vacuum filters*** *air-through blow* is used

For ***vertical plate pressure filters*** either compression or a combination of compression and air through-blow is used

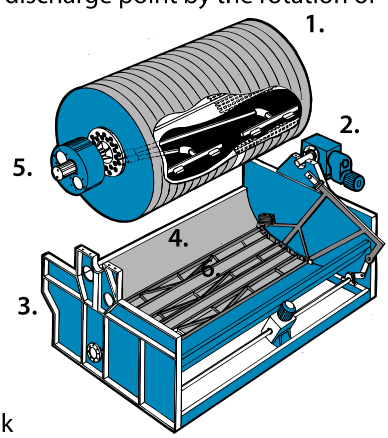
For ***tube presses*** either compression or a combination of compression and air-purge is used. The Tube Press also enables cake washing.

Cake wash can be applied to any of these filters

Drum vacuum filters

Vacuum filtration is the simplest form of "through blow" dewatering. A pressure differential created by a vacuum applied to the inside of the filter drum causes air to flow through the filter cake thereby displacing the contained water. The solids are retained on a filter cloth and are carried to discharge point by the rotation of the drum.

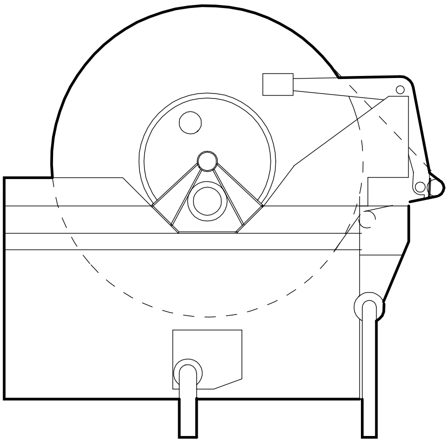
Drum filter

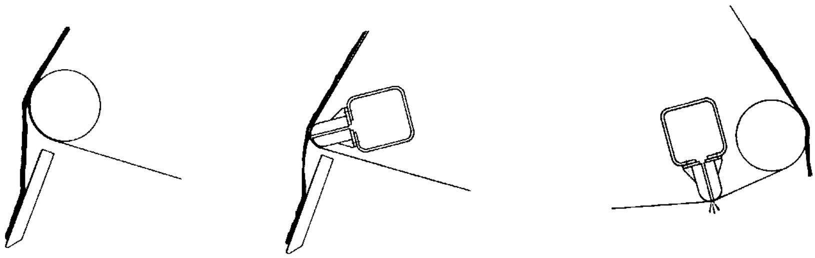


1. **Drum** – filter cloth mounted on segment grids. Internal drainage pipes.
2. **Drum drive** – variable speed
3. **Support frame**
4. **Tank**
5. **Vacuum head** – seal arrangement to connect rotating drum to stationary vacuum piping
6. **Agitator** – to suspend solid particles in tank

Belt drum filter

The belt discharge drum filter is similar to the standard drum version except that the cloth is separated from the drum and allowed to pass over a discharge system.
This design allows cloth washing and is preferred for dewatering of slurries containing fine particles which produce a filter cake that is sticky and difficult to discharge.
Three cake discharge options are available.

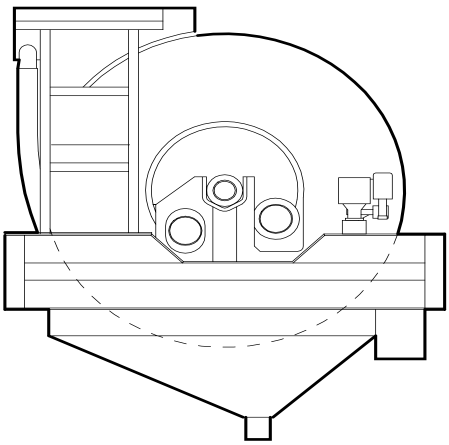




Break roller *Air knife* *Break roller and air knife*

Top feed drum filter

A top feed drum filter is designed to dewater slurries containing coarser particles.
The Top feed principle promotes segregation of the coarser particles forming a "pre –coat" on the filter cloth thereby increasing filtration rate.



Drum vacuum filters – Effective area

A practical aspect of Vacuum Drum Filter design is that there is a "dead area" on the drum between the discharge point and where the drum re-enters the slurry in the tank. The effective area is always less than the total area as listed below

Drum filter effective area	75% of total
Belt Drum Filter effective area	65% of total
Top Feed Drum Filter effective area	50% of total

Note!

When sizing vacuum filter note that in this book filtration rates area based on capacity per effective filter area.

When considering data from other sources it must be confirmed whether the "effective" or" total" area is being used!

Drum vacuum filter – effective Area, cont.

Size	Total area (m²)	Total area (ft²)	Drum fliter (TF) effective area (m²)	Drum fliter (TF) effective area (ft²)	Belt drum filter (BFT) effective area (m²)	Belt drum filter (BFT) effective area (ft²)	Top feed filter (TFF) effective area (m²)	Top feed filter (TFF) effective area (ft²)
903	0.9	10	0.7	8	0.6	6	0.45	5
906	1.7	18	1.3	14	1.1	12	0.85	9
916	3.4	37	2.6	28	2.2	24	1.7	18
1206	2.2	24	1.7	18	1.9	20	1.1	12
1212	4.5	48	3.4	37	3.9	42	2.25	24
1218	6.8	73	5.1	55	5.8	62	3.4	37
1812	6.8	73	5.1	55	5.8	62	3.4	37
1818	10	108	7.5	81	6.5	70	5	54
1824	14	151	10.5	113	9.1	98	7	75
1830	17	183	12.8	138	11.1	119	8.5	91
2418	14	151	10.5	113	9.1	98	7	75
2424	18	194	13.5	145	11.7	126	9	97
2430	23	247	17.3	186	15	161	11.5	124
2436	27	291	20.3	218	17.6	189	13.5	145
2442	32	344	24	258	20.8	224	16	172
3030	29	312	21.8	235	18.9	203	14.5	156
3036	34	366	25.5	274	22.1	238	17	183
3042	40	430	30	323	26	280	20	215
3048	46	495	34.5	371	29.9	322	23	247
3054	52	560	39	420	33.8	364	26	280
3060	57	613	42.8	461	37.1	399	27.5	296
3636	41	441	30.8	331	26.7	287	20.5	221
3642	48	516	36	387	31.2	336	24	258
3648	55	592	41.3	444	35.8	385	27.5	296
3654	61	656	45.8	493	39.7	427	30.5	328
3660	68	732	51	549	44.2	476	34	366
3666	75	807	56.3	606	48.8	525	37.5	404

See also data sheets 6:66 - 6:68.

Drum vacuum filters – Filtration rates

The size of a vacuum filter is calculated from effective area (see above), and Filtration rate (see below).

Application	Filtration rate (kg/m²eff/hour)	Filtration rate (lb/ft²/h)	Rest moisture % (% H2O by weight)
Magnetite conc. fine 80% minus 44 microns	1000	200	8
Magnetite conc. medium 80% minus 74 microns	1500	300	7
Pyrite conc. medium 80% minus 63 microns	1000	300	7.5
Cu conc. fine 80% minus 24 microns	400	80	10

Drum filter – Filtration rate cont.

Application	Filtration rate (kg/m²eff/hour)	Filtration rate (lb/ft²/h)	Rest moisture % (% H2O by weight)
Cu conc. medium 80% minus 63 microns	500	150	7
Zn conc. fine 80% minus 30 microns	350	70	10
Zn conc. medium 80% minus 63 microns	450	90	8
Pb con. medium 80% minus 53 microns	700	140	6
Ilmenite conc medium 80% minus 54 microns	800	160	8
Ni-conc medium-fine 80% minus 36 microns	600	120	11
Volastonite medium 80% minus 54 microns	800	160	12

Belt drum filter – Filtration rate

Application	Filtration rate (kg/m²eff/hour)	Filtration rate (lb/ft²/h)	Rest moisture (% H_2O by weight)
Froth coal 80% minus 74 microns	400 (flocculation needed)	80	23
Coal conc coarse 80% minus 100 microns	500 (flocculation needed)	150	20
Coal prep. tailings 80% minus 120 microns	150 (flocculation needed)	30	32
Sulphide ore tailings medium 80% minus 44 microns	500 (not deslimed)	150	22

Top feed drum filter – Filtration rate

Application	Filtration rate (kg/m²eff/hour)	Filtration rate (lb/ft²/h)	Rest moisture (% H_2O by weight)
Magnetite coarse 80 % minus 120 microns	2 000	400	6
Apatite coarse 80 % minus 150 microns	2 000	400	8
Calcite coarse 80 % minus 150 microns	1 200	250	7.5
Chromite 50 % minus 180 microns	3 800	780	5

Vacuum filters – Sizing

By knowing the filtration rate we can calculate the required vacuum filter size.

Ex. Dewatering of medium Cu concentrate 10 t/h (22050 lb/h)

1. *Application needs internal flow drum vacuum filter*
2. *Filtration rate from page 16 is 500 kg/m^2 eff. and hour. (100lb/ft^2 eff and hour)*
3. *Filter area is 10000 / 500 = 20 m^2 or 22050/100 =221 ft^2*

   Drum filter TF 2436 has an effective filter area of 20,3 m^2 (218 ft^2) and a total area of 27 m^2 (290 ft^2)

Vacuum filters – Vacuum requirement

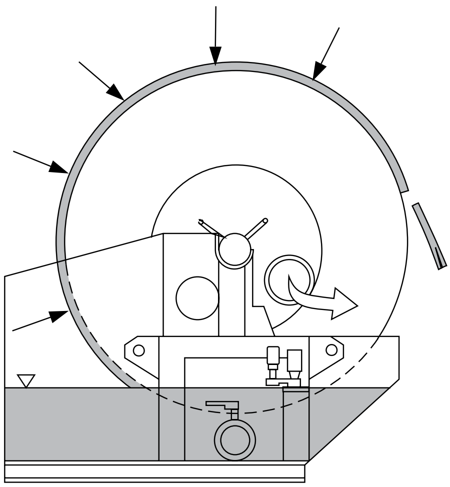
Principle

By evacuating the air inside the filters dewatering can be achieved by air “through-blow”.

Vacuum requirement is calculated as the volume of thinned air per effective filter surface area per minute.

Thinned air volume is volume at actual reduced pressure.

Free air volume (used for sizing of compressors) is the volume at normal atmospheric pressure.



Vacuum requirements – Low vacuum applications (∆p 60 - 70 kPa, 8 - 10 psi)

Application	Requirement of throughblow (thinned) air	
	(m^3/m^2 (eff) / min)	(ft^3/ft^2 (eff) / min)
Frothed coal 80% minus 74 microns	2	7
Frothed coal tailings	1	3
Flue dust	1	3
Barium sulphate	0.3	1
Calcium carbonate	0.6	2
Caustic lime mud	2	7
Sodium hypochlorite	1	3
Titanium dioxide	0.6	2
Zinc stearate	1	3

Vacuum requirement - High vacuum applications (∆p 80 - 90 kPa, 12 - 13 psi)

Application	Requirement of throughblow (thinned) air $(m^3/m^2(eff)/min)$	$(ft^3/ft^2(eff)/min)$
Magnetite conc fine 80% minus 44 microns	3	10
Magnetite conc medium 80% minus 74 microns	4	13
Pyrite conc medium 80% minus 63 microns	4	13
Cu conc fine 80% minus 24 microns	2	7
Cu-conc medium 80% minus 63 microns	4	13
Zn-conc fine 80% minus 30 microns	2	7
Zn-conc medium 80% minus 63 micron	4	13
Pb-conc medium 80% minus 53 microns	3	10
Ilmenite conc medium 80% minus 54 microns	3	10
Ni-conc fine 80% minus 36 microns	2	7
Wollastonite conc medium 80% minus 54 microns	3	10
Magnetite coarse	8	26
Apatite coarse	6	20
Calcite coarse	6	20
Chromite	8	26

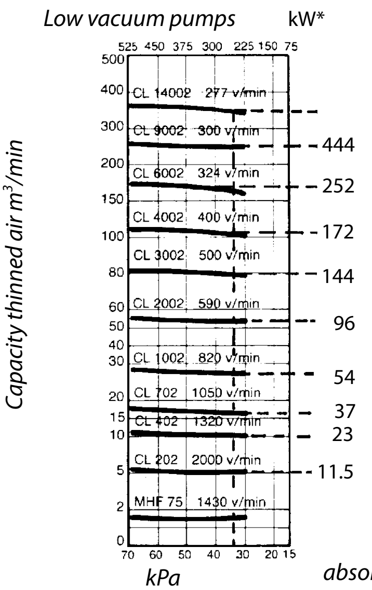
Vacuum pump – Sizing

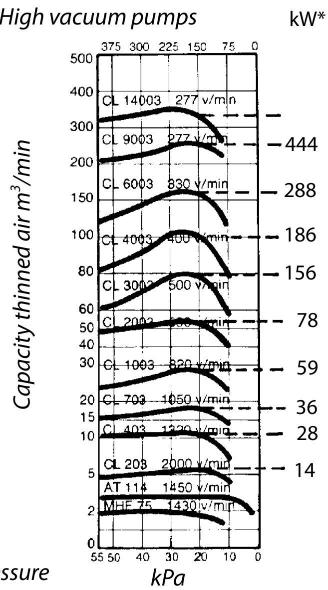
By multiplying the effective area of the vacuum filter required with the requirements of throughblow (thinned) air we have the required capacity of the vacuum pump.

Ex. Drum filter with effective area of 3,4 m^2 and a required vacuum of 1,5 $m^3/m^2/min$ needs a vacuum pump with a capacity of 3,4 x 1,5 = 5,1 m^3/min.

Selection of pump

(For our estimations we will use Nash data.)





absolute pressure

* kW refers to installed motor power. For low vacuum pumps at 35 kPa and for high vacuum pumps at 20 kPa absolute pressure.

Vacuum pump – Sizing cont.

If the pressure drop across a filter cake is 80 kPa ("gauge vacuum"), the absolute pressure under the filter cloth is 100 - 80 = 20 kPa. The inlet pressure of the vacuum pump in this case is 20 kPa and the volumetric flow of air is specified at this pressure.

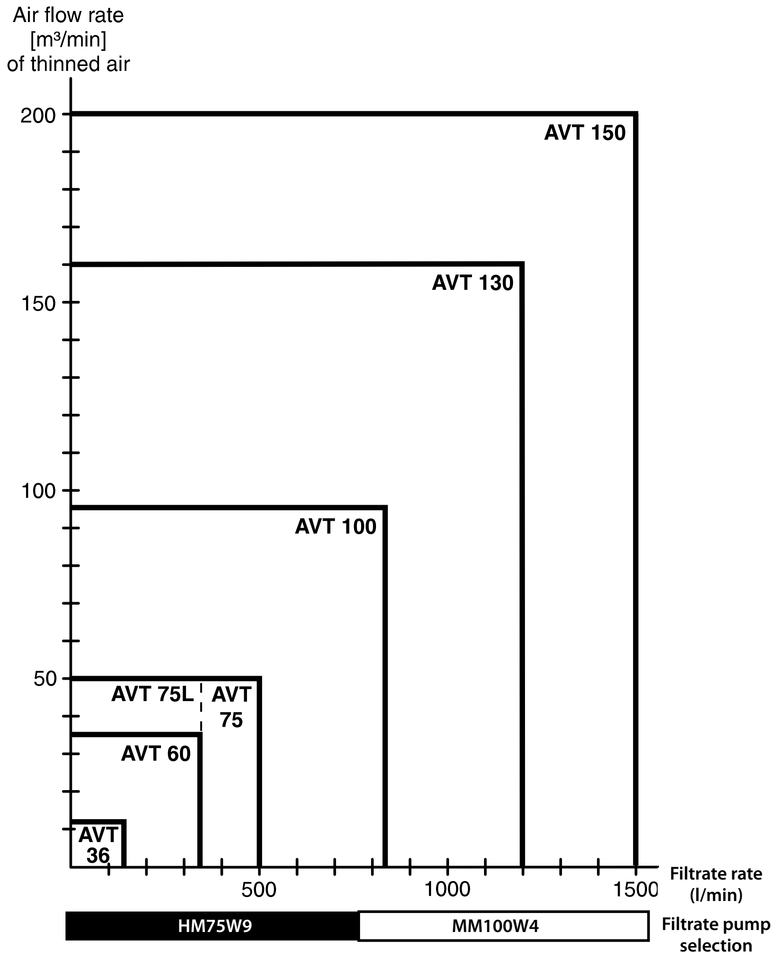
Example:

30 m^3 of thinned air at a gauge vacuum of 80 kPa (pressure drop across filter cake) corresponds to (30 x (100-80)) / 100 = 6 m^3 of free air at atmospheric pressure.

Vacuum Pump size selection: An application of performance filtration of a Cu-conc. requires a throughput of 30 m^3/min of thinned air at a pressure drop (gauge vacuum) of 80 kPa. For estimation of model (Nash) and required power, see curves above.

From the high vacuum pump series select a Nash CL 1003 with a power requirement of approx. 60 kW.

Vacuum tank and filtrate pump – Sizing



Vacuum tanks are sized from two criteria
- Air velocity in tank < 2 m/sec.
- Retention time of filtrate > 0,5 min.

Calculation of filtrate volume

Ex. Feed to filter: 60% solids by weight

Capacity: *10 ton dry solids/hour*

Rest moisture: *6% H_2O by weight*

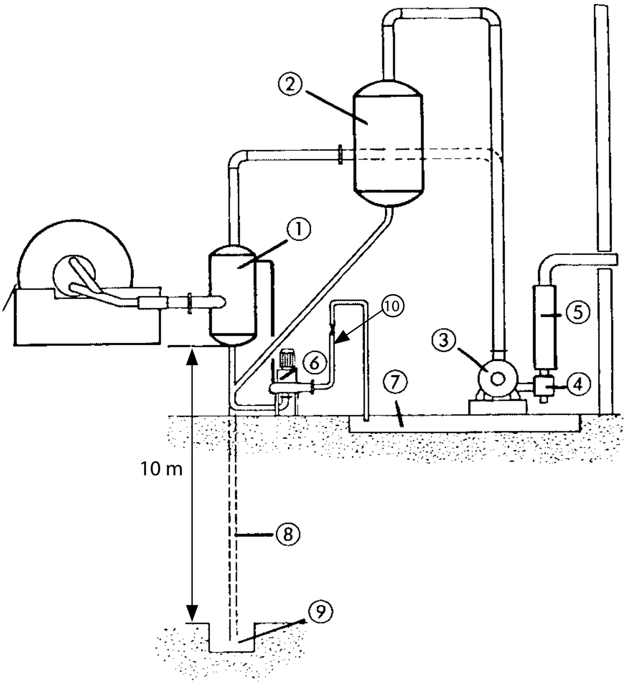
Water in feed = 0,40 x (10 / 0,6) = 6,667 t/h = 6667 l/h

Water in cake = *0,06 x (10 / 0,94) = 0,638 t/h = 638 l/h*

Filtrate volume is 6667-638 = 6029 l/h = 100 l/min.

Check with diagram above!

Vacuum plant – Arrangement



1. Vacuum receiver
2. Moisture trap*
3. Vacuum pump
4. Liquid separator
5. Silencer
6. Filtrate pump
7. Floor drain

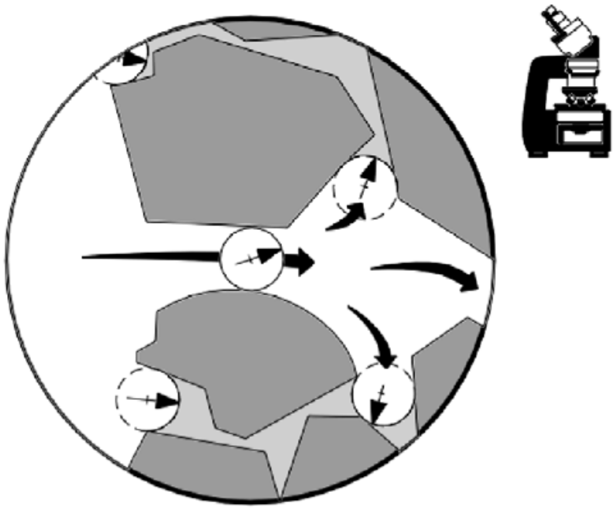
For plants without filtrate pump also:

8. Drain line from vacuum tank (barometric leg)
9. Water lock
10. Non-Return Valve

* Normally used for agressive filtrates only.

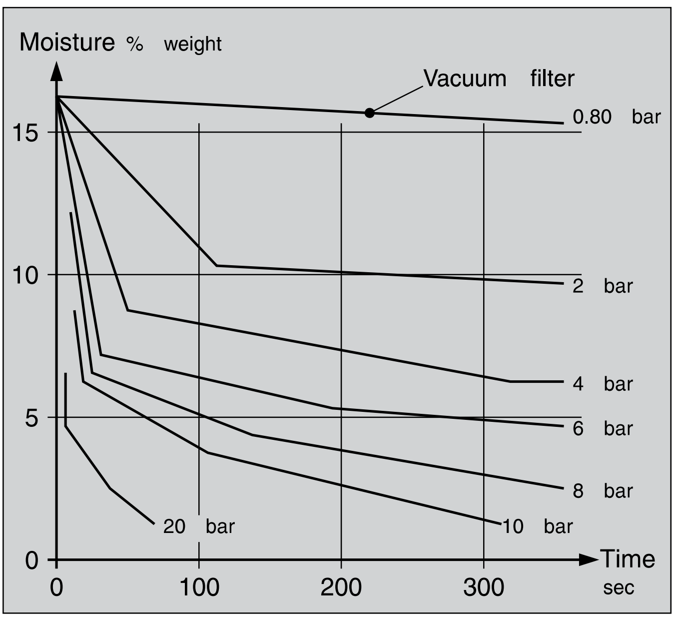
Vertical plate pressure filter – Introduction

The Pressure Filter model VPA is of "medium pressure" type operating in the pressure range of 6-10 bar. The machine mainly relies on the "air through blow" dewatering concept, whereby water is displaced by air as it passes through a filter cake.

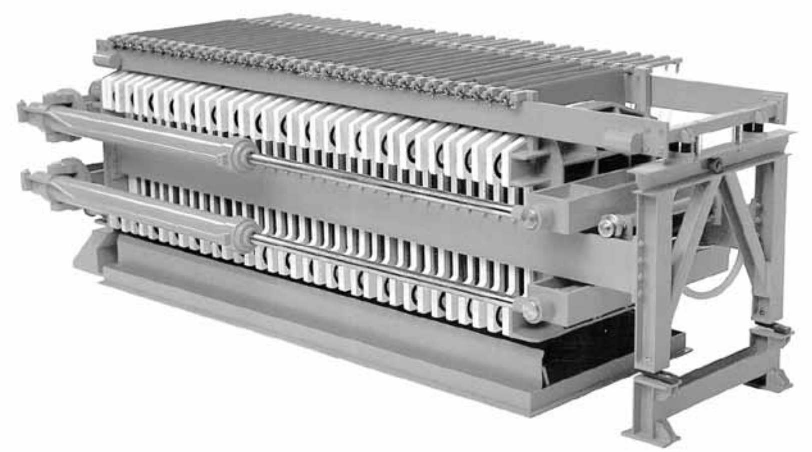


Air penetration through a pore system

The driving force of this filtration method is the pressure differential across the cake. A higher pressure drop will give a faster dewatering rate and a lower residual moisture.



Vertical plate pressure filter – Design



- **VPA** = **V**ertical **P**ressure Filter **A**ir through blow
- Lightweight polypropylene filter plates are mounted on a bolted steel frame and are moved by hydraulic cylinders
- Adjacent "filter and compression" plates form a filtration chamber. The filter cloths hang between each pair of plates. Rubber membranes are protected by the filter cloth thereby reducing wear.
- By mounting the filter on a load cell system the filtration cycle is monitored and controlled.
- Chambers are top fed for optimum filling. Two sided filtration speeds up the "filling" cycle.
- Openings for pulp, water and air are generously dimensioned to reduce energy losses and wear
- Service and maintenance requirements are low. The VPA design facilitates easy cloth changing.
- Air blow pressure 5-8 bar (73-116 psi). Membrane pressure 6-9 bar (87-131 psi)

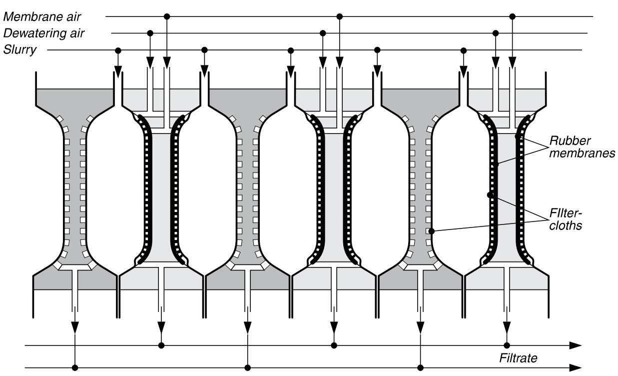
Pressure filter VPA – Operation

Pretreatment

For optional results of filter operation the pulp fed to the machine should be as high in solids as possible.

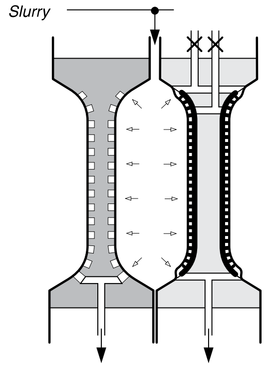
Dewatering cycle

Start position



Step 1 – Filtration

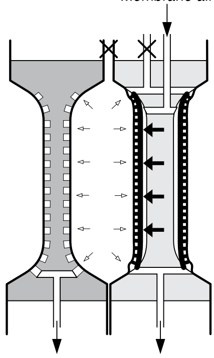
Slurry is pumped into the filter chambers and the filtrate is expelled.



Step 2 – Compression

in which the rubber membrane in each chamber is activated and the filter cake is compressed (densely packed).

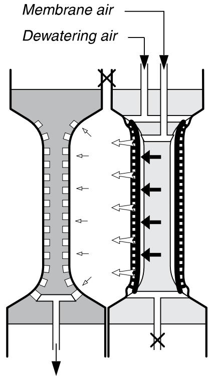
Dense cake formation avoids unnecessary leakage of air during subsequent drying.



Step 3 – Air drying

Compressed air is forced through the filter cake driving out more liquid.

The rubber membrane remains activated throughout this cycle to counteract cracking of the shrinking cake.



These are the dewatering steps. In cases when throughblow is not applicable and filter is used for compression, only step 1 and 2 are used.

Service cycle

In addition to the above dewatering steps the complete process includes a number of so called service steps.

Step 4 – *9 Service cycle*

4. Opening cake discharge doors
5. Opening the filter, discharging the filter cakes
6. Vibrating the filter cloths (discharge control)
7. Closing the cake discharge doors
8. Rinsing the filter cloths
9. Closing the filter

Pressure filter – Sizes

The VPA pressure filter is available in 3 chamber sizes:

VPA 10 with chamber dimensions (outer) of 10 x 10 dm (max 40 chambers)

VPA 15 with chamber dimensions (outer) of 15 x 15 dm (max 54 chambers)

VPA 20 with chamber dimensions (outer) of 20 x 20 dm (max 50 chambers)

Pressure filter VPA – Chamber data

Chamber area (working area)

Chamber area VPA 10 = 0.65 m^2/chamber (7 ft^2/chamber)

Chamber area VPA 15 = 1.70 m^2/chamber (18 ft^2/chamber)

Chamber area VPA 20 = 3.90 m^2/chamber (42 ft^2/chamber)

Filtration area = 2 x chamber area (each chamber has double cloths and filtering takes place on both sides).

Drying (or throughblow) area = chamber area (air enters from one side).

Chamber volume

VPA 1030 (32 mm chamber depth) = 20.0 litre (5 USG)

VPA 1040 (42 mm chamber depth) = 25.0 litre (7 USG)

VPA 1530 (32 mm chamber depth) = 55.0 litre (15 USG)

VPA 1540 (42 mm chamber depth) = 68.0 litre (18 USG)

VPA 2030 (32 mm chamber depth) = 129 litre (34 USG)

VPA 2040 (42 mm chamber depth) = 165 litre (44 USG)

VPA 2050 (53 mm chamber depth) = 205 litre (54 USG)

Chamber depth

For VPA 10 and VPA 15 two chamber depths are available.

32 mm ($1^1/_4$") for fine particle dewatering (long cycle time)

42 mm ($1^3/_5$") for medium particle dewatering (normal cycle time)

VPA 20 can be supplied with three chamber depths 32. 42. 53 mm.
($1^1/_4$". $1^3/_5$". $2^1/_{10}$")

Pressure filter VPA – Nomenclature

VPA 1040-20 = Pressure filter type VPA with chamber dimensions 10 x 10 dm, chamber depth 40 mm and number of chambers 20.

See also data sheet 6:69 - 6:71.

Pressure filter VPA – Sizing

We are using the cycle method:

1. Cake bulk weights

Specific dry weight of the filter cake inside each chamber is called the **cake bulk weight** (kg/litre or lb/ft^3)

Approximate cake bulk weights (ρ_{cake})

Material	kg/dm^3	Lb/ft^3
Cu-conc (80%-45 micron)	2.2	137
Pb-conc (80%-40 micron)	3.1	193
Zn-conc (80%-30 micron)	2.1	131
Magnetite conc. (80%-x micron)	3.0	187
Coal	0.9	56
Chalk	1.3	81

2. Plant capacity

By dividing the required throughput S (t/h or lb/h) with cake bulk weight the required cake volume per hour is obtained. $V=S/\rho_{cake}$

3. Cycle time

Is calculated as the sum of

- Filtration
- Compression
- Washing
- Throughblow (drying)
- Service time (discharge, washing and closing)

Total cycle time t (min/cycle)

Number of cycles per hour n=60/t.

Approximate cycle times (min)

Application	k_{80}	t min
Cu-conc	50	7
	15	11
Pb-conc	40	7
	20	9
Zn-conc	40	7
	20	9
Magnetite	40	5
Flotation tailings	36	8

4. Filter volume

The required volume per cycle equals required filter volume.

Filter volume = V / n = (S x 1000 x t) / (ρ_{cake} x 60) litre

Ex. A zinc concentrate should be dewatered to 8% H_2O.

The capacity is 12 t/h (dry solids) and k_{80} 35 mm.

1. Cake bulk weight ρ_{cake} = 2.1 (from table).
2. Plant capacity V = 12 / 2.1 = 5.7 m^3/h
3. Cycle time t = 8 min. (estimated from table).
   Cycles per hour n = 60 / 8 = 7.5
4. Filter volume V / n = (5.7 x 1 000) / 7.5 = 760 l
   Select VPA-1040-32 (800 l)

Pressure filter VPA - Moisture in filter cake

Following approximate moistures in the dewatered cakes (using 6 bar air blow) can be expected.

Material	Moisture % H_2O by weight
Cu-conc medium (80% - 45 microns)	7.0
Cu-conc fine (80% - 15 microns)	9.0
Pb-conc medium (80% - 40 microns)	5.0
Zn-conc. medium (80% - 30 microns)	8.0
Pyrite conc. coarse (80% - 60 microns)	5.0
Hematite conc. fine (80% - 7 microns)	18.5
Magnetite medium (80% - 40 microns)	6.0
Calcite conc. fine (80% - 8 microns)	15.0
Chalk fine (80% - 2.4 microns)	15.0

Pressure filter VPA - Compressor sizing

Compressed air for pressure filters are calculated as
"Normal cubic metres of free air at normal temperature and atmospheric pressure required per m^2 of filter area per minute".
Requirement of compressed (throughblow)

Material	Moisture % H_2O by weight	Compressed air ($Nm^3/m^2/min$)	($ft^3/ft^2/min$)
Cu-conc medium (80% - 45 microns)	7.0	0.7	2.3
Cu-conc fine (80% - 15 microns)	9.0	0.5	1.6
Pb-conc medium (80% - 40 microns)	5.0	0.6	2.0
Zn-conc. medium (80% - 30 microns)	8.0	0.5	1.6
Pyrite conc. coarse (80% - 60 microns)	5.0	0.8	2.6
Hematite conc. fine (80% - 7 microns)	18.5	0.5	1.6
Magnetite medium (80% - 40 microns)	6.0	0.6	2.0
Calcite conc. fine (80% - 8 microns)	15.0	0.4	1.3
Chalk fine (80% - 2.4 microns)	15.0	0.4	1.3

Ex. A fine Cu-conc requires 0.5 Nm^3/m^2/min for drying to requested moisture. A filter of type VPA 15-40 will be used.

Air consumption 0.5 x 40 x 1.7 = 34 Nm^3 per min.
"Select a suitable compressor". see below.

Atlas Copco 38.7 Nm^3/min. installed power 250 kW (50 Hz).

Atlas Copco 37.8 Nm^3/min. installed power 285 kW (60 Hz).

Pressure filter VPA – Compressor power

(Table below shows Atlas Copco medium pressure water-cooled two-stage screw compressors (oil free), unload pressure 8 bar (50 Hz) 8.6 bar (60 Hz).

Model	Capacity		Installed power		Model	Capacity		Installed power	
(50 Hz)	(Nm^3/min)	(ft^2/min)	(kW)	(hp)	(60 Hz)	(Nm^3/min)	(ft^3/min)	(kW)	(hp)
ZR3-50	11.0	389	75	100	ZR3-60	12.7	449	104	139
51	13.6	480	90	120	61	15.8	558	127	170
52	16.6	586	110	147	62	19.1	675	148	198
53	19.5	689	132	177	63	22.5	795	180	241
54	22.4	791	160	215	ZR4-60	24.6	869	184	246
ZR4-50	25.1	887	160	215	61	30.8	1 088	230	308
51	30.7	1 085	200	268	62	37.8	1 335	285	382
52	38.7	1 367	250	335	ZR5-60	44.6	1 576	285	382
ZR5-50	46.4	1 639	315	422	61	51.0	1 802	360	483
51	50.3	1 777	315	422	62	56.6	2 000	405	543
52	61.3	2 166	400	536	63	60.9	2 152	405	543
53	68.9	2 434	450	603	ZR6-60	76.2	2 692	-	-
ZR6-50	79.8	2 819	-	-	61	88.2	3 116	-	-
51	100.5	3 551	-	-	62	1 02.0	3 604	-	-
52	112.5	3 975	-	-	63	1 02.8	3 632	-	-

Pressure filter VPA – Feed pump selection (guidance only)

For **VPA 10**, choose **4"** slurry pump
For **VPA 15**, choose **6"** slurry pump
For **VPA 20**, choose **8"** slurry pump

Pressure filter VPA - Feed pump power (approximate)

VPA 10-8 to VPA 10-20	55 kW	74 hp
VPA 10-22 to VPA 10-40	75 kW	100 hp
VPA 15-10 to VPA 15-20	75 kW	100 hp
VPA 15-22 to VPA 15-60	132 kW	177 hp
VPA 20-10 to VPA 20-20	160 kW	215 hp
VPA 20-22 to VPA 20-60	200 kW	268 hp

Pressure filter VPA - Product system

In a complete dewatering plant the compressed air filter is only one part of what we call the VPA system.

The VPA system consists of the following equipment:

Thickener to feed the filter with correct pulp density. (1)

Buffer tank for deaeration and pulp density control prior to pump feeding. (2)

Slurry pump for feeding during the filtration cycle. (3)

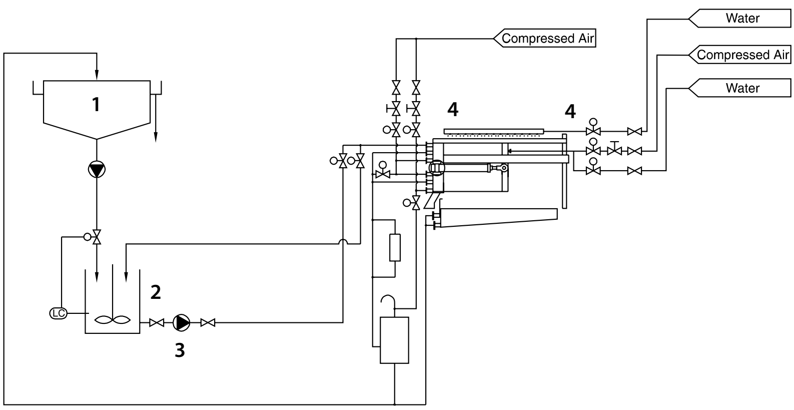
Valves for pulp, water and air. (4)

Rinse water system for the filter cloths. (5)

Weighing system for optimization of the operational parameters of filtration, compressed air drying, etc.

Compressor for compressed air supply. (6)

Computer based control system for operation and control of the filtration process.

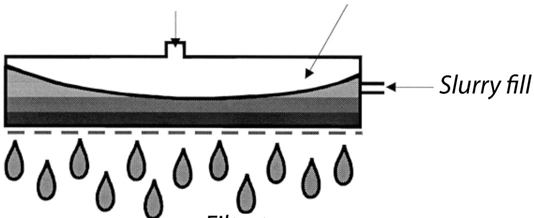


Tube press – Introduction

As particles continue to gets even finer,"low pressure dewatering" is not longer enough to overcome the strong capillary forces in the particle binding to liquid. To overcome this powerful binding with mechanical dewatering, the pressure has to be increased.

The tube press is special designed to operate at high pressure in applications were the process requires pressure up to 100bar.

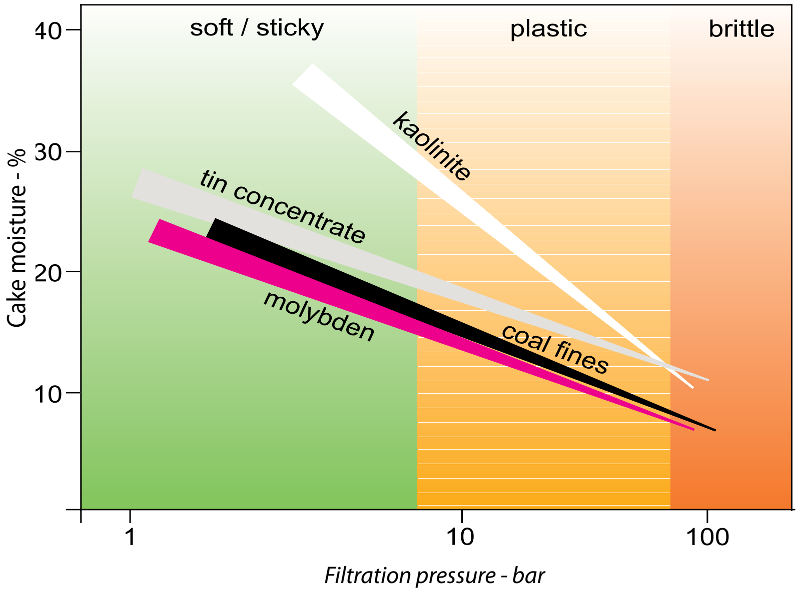
The tube press is a variable volume filter using flexible membrane to apply high pressure mechanical compression to the slurry that is dewateried.



Upgrading

Upgrading

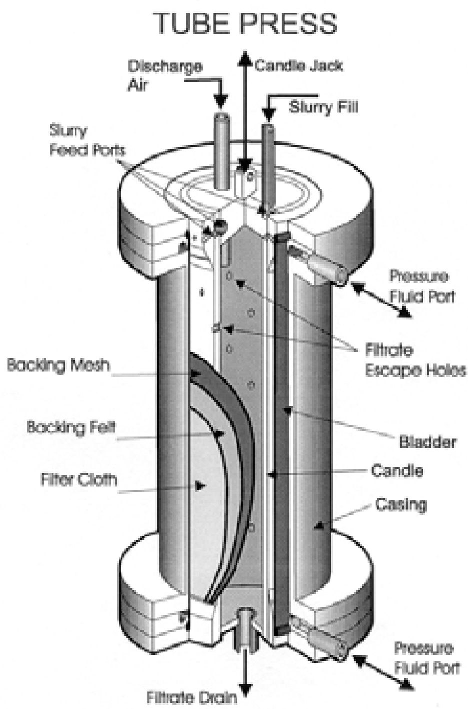
By applying a higher pressure or "driving" force to the filtration process a drier filter cake with better handling characteristics can be produced.



The tube press operates at pressures of up to 100 bar (1 450 psi) and was originally developed for dewatering of fine Kaolin slurries. It has since been applied to a variety of difficult filtration operations.

Tube press – Design

- The outer casing has a flexible membrane (bladder) fastened at each end
- The inner candle has a filter media around its outer surface
- The candle has a series of filtrate drain holes around its circumference
- The feed slurry enters the tube press through the feed ports
- Fluid is pumped into and out of the unit through the pressure ports to create the filtration pressure
- The filtrate drains away through the drain pipe

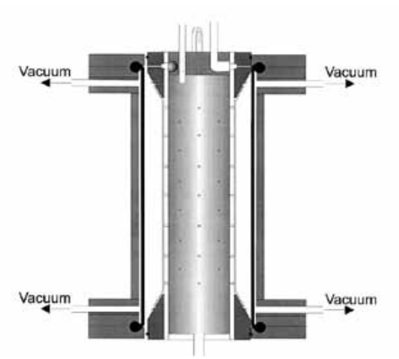


Tube press – Operation

The filtration cycle

Step 1 – Starting cycle

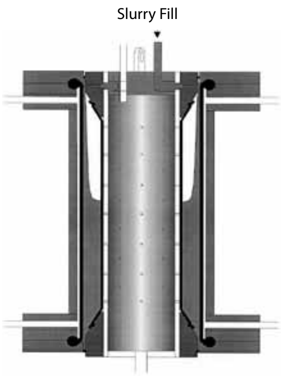
The tube press will start each cycle empty.



- The candle is in the closed position
- Hydraulic vacuum is applied
- The Bladder is pulled back against the casing

Step 2 – Slurry fill

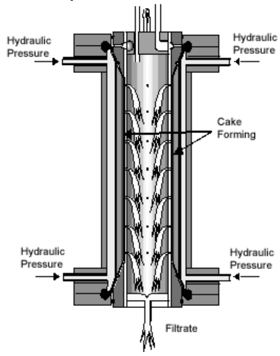
The Tube Press is then filled with the feed slurry.



The slurry enters the Tube Press through the porting in the top of the Candle and fills the annular space between the Filter and the Bladder.

Step 3 – Pressure phase

The filtration is applied by pumping a fluid, usually water, into the tube press through the pressure ports.

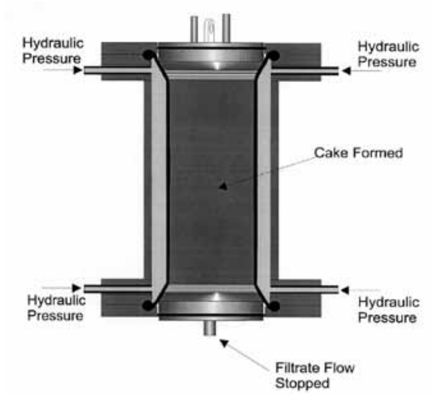


- The pressure water pushes the Bladder squeezing the slurry against the filter cloth
- The filtrate passes through the fliter cloth and runs to drain
- The solids are held by the filter cloth forming a cake

In order to take advantage of the faster filtering which occurs in the early stages and to take any slack in the system, the pressure is initially applied at low pressure/ high volume. At the appropriate point high pressure water is applied.

Step 4 – Filtration complete

Eventually the stage is reached where no further filtration will take place.

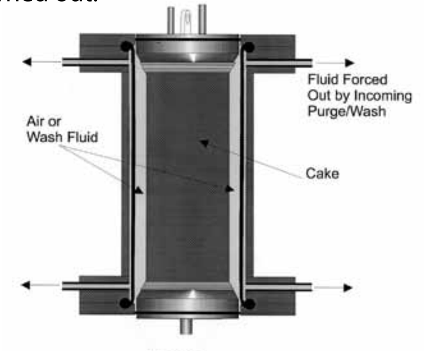


- Cake will be formed
- Filtrate will no longer flow

The next step in the process will depend on wheter the cycle will include the air purging or washing of the cake. If air purge or cake wash is required then the next stage will be step 4. If not the next stage will be step 6.

Step 5 – Air purge / Cake wash

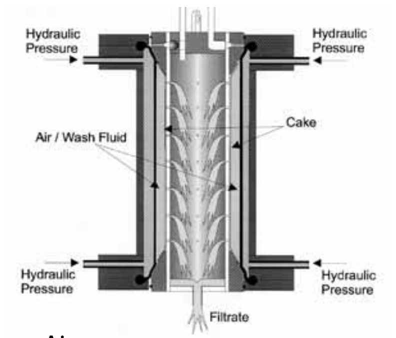
If it is necessary to treat the cake by air purging or washing, the following is carried out:



- The pressure fluid is forced out of the tube press by the incoming air or wash fluid
- The pressure fluid is restricted by a flow restrictor in order that the internal pressure in the Tube is maintained. This is necessary to ensure that the cake does not fracture

Step 6 – Repeat high pressure

Once the tube press unit has been filled with air or wash fluid the hydraulic high pressure is reapplied.

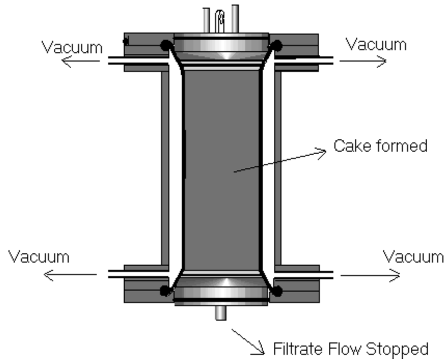


- Air purge:
  - The air will force further filtrate from the cake resulting in a drier cake
  - The wash fluid may also be used to remove soluble materials from the cake

It is possible to carry out multiple air purges or cake washers

Step 7 – Vacuum

When the final high pressure stage is completed it is necessary to enter the discharge sequense.

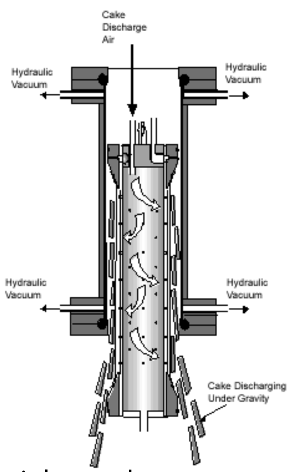


- The hydraulic vacuum draws the pressure fluid out of the tube press, pulling the Bladder away from the cake
- The bladder is pulled tight against the casing wall

To ensure the Bladder is fully against the Casing wall and away from the candle the system is equipped with a vacuum detector which will give a "proceed" signal when the appropriate level of vacuum is reached.

Step 8 – Discharge

When the vacuum level has been achieved the discharge will proceed.



- Candle is lowered
- Air is blown into the candle expanding the Filter Cloth which in turn fractures the cake which drops under gravity

- The candle then returns to the closed position
- For cakes which are reluctant to discharge, the system allows for multiple candle movements
- The candle returns to the closed position to commence the next cycle
- The system will check that the tube is empty and if so the nect cycle will commence
- Should the system detect that more than a set amount of cake is retained then the tube Press will be parked and the alarm sound

Tube press – Examples of applications

MINERALS

- Kaolin
- Calcium Carbonate (including ground calcium carbonates)
- Clays (other than Bentonitic types)
- Seawater Magnesia
- Steel making Sludges (BOF sludge)
- Titanium Dioxide
- Iron Oxide
- Molybdenium
- Copper Concentrate
- Zink oxide
- Lime
- Gypsum
- Tin Concentrate
- Underground water at precious metal mines

CHEMICALS

- Tri-Calcium Phosphate
- Di-Calcium Phospate
- Copper Pyro-Phosphate
- Calcium Hypochlorite

EFFLUENTS

- Titanium Dioxide wastes
- Fluoritic muds
- Spent bed slurry

OTHERS

- Pharmaceuticals
- Sugar refining carbonates
- Pigments
- Yeasts
- Waxes (in oil production)

The following materials are not suited for dewatering in a Tube Press

- Fibrous materials (sewage, water treatment sludges, pulp & paper, fruit)
- Oily materials (oil contaminated muds, scrap effluents)
- Very dilute slurries
- Bentonite type clays
- Rubber wastes and latex materials
- Hot processes

Tube press – Material of construction

Wetted parts – All metallic components of the tube press which come into contact with the process slurry is made from duplex stainless steel.

Casing – The casing and non-wetted parts are generally made from carbon steel.

Bladder – Standard material is natural rubber. Other elastomers can be considered for special process applications.

Filter cloth – Selected against specific process requirements.

Tube press – Sizes

The Tube Press 500 serie is available mainly in two different sizes.

500 series. Casing diameter 500 mm. Nominal lengths available 1 500 mm and 3000 mm. Maximum pressure 100 bar (1 450 psi).

Model	500 Series 1.5 m	500 Series 3 m
Filtration pressure - max. (bar)	100	100
Length of candle (mm)	1 500	3 000
Candle diameter (mm)	389	389
Filter area (m^2)	1.75	3.47
Effective volume (litres)	100	200
Candle weight (kg)	580	1 100
Total weight (kg)	2 000	3 000
Crane height (m)	6.17	9.17

See also data sheet 6:72

Tube press – Sizing

The throughput for a tube press depends on:

- Cycle time
- Weight of each cake drop (chamber capacity)

Typical cycle time without air-purge

Low pressure hydraulics	0 - 5 sec.
Slurry fill	10 - 30 sec.
Low pressure hydraulics	10 - 30 sec.
High pressure hydraulics (100 bar)	60 - 360 sec.
(could be less than 60 sec. to more than 10 min.)	
Vacuum and discharge	45 - 90 sec.
Total cycle time	***125 - 515 sec.***

Cycle time with one air - purge

Low pressure hydraulics	0 - 5 sec.
Slurry fill	10 - 30 sec.
Low pressure hydraulics	10 - 30 sec.
High pressure hydraulics (100 bar)	30 - 180 sec.
Air - purge I:	
Air injection	30 - 60 sec.
High pressure hydraulics (25 bar)	60-360 sec.
Vacuum and discharge	45-90 sec.
Total cycle time	***185-755 sec.***

Second and third air-purge could be applied but are very seldom used.

Most effect is obtained with the first air purge, and the throughput for the press is reduced considerably with each air-purge applied.

A cycle incorporating cake wash would be similar to air-cycle above.

Tube press – Cycle times and cake moisture

Typical cycle times and rest cake moisture:	time (sec)	moisture (%)
Fine coal. without air purge	220	23
Fine coal. with air purge	280	15
Zinc concentrate. without air purge	174	9.4
Zinc concentrate. with air purge	200	6.2
Zinc concentrate with air purge	273	13.2
Lead concentrate without air purge	297	12.1

Tube press – Capacity

The amount of solids filled into the tube each cycle depends on optimal cake thickness, solids specific gravity, feed slurry density (cake build up) etc.

The capacity per unit (500 series) for some typical applications are given in following table:

Product	Slurry feed	Cake moisture	Output/Tube 3m	
	(% solids w/w)	(%)	(kg/h dry)	(lb/h dry)
Tin concentrate	45	9.0	1 250	2 750
Coal fines	45	15.5	1 200	2 650
Copper fume	35	20.0	450	990
Copper supergene	60	11.5	1 300	2 900
Lead concentrate	60	7.0	2 250	5 000
Zinc concentrate	60	7.5	2 250	5 000
China clay filler	25	16.5	350	770
Iron oxide	55	20.0	1 500	3 300
Acid effluent	15	35.0	375	825
Sulphur effluent	20	35.0	415	910
Mixed sulphides	40	14.0	2 250	5 000

Ex: Dewatering of 9.5 t/h (dry) tin concentrate (well thickened) in tube press.

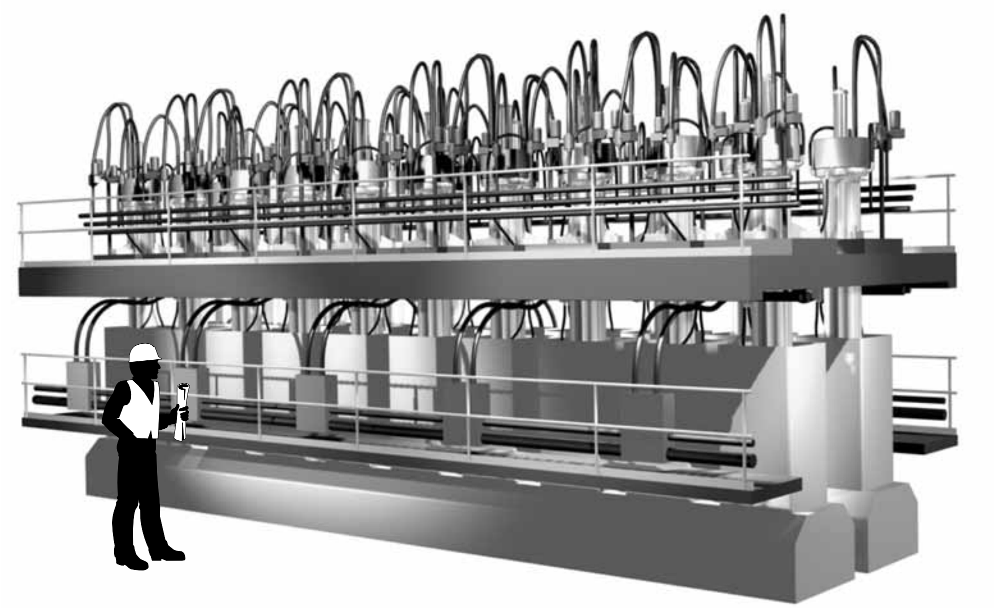
Capacity per tube = 1250 kg/h (dry)

9500/1250 = 7,6

Select 8 Tube presses type 500 !

Tube press – Product systems

Pump drive



A tube press plant will contain the appropriate number of tube units according to the overall capacity required.

The units are usually supplied and installed in modules. Each module consists of a support raft to take two tube units, complete with all local valving and service header pipework. The rafts are designed to be coupled to allow the tube units to be configured in single or double lines.

The support steelwork, ladders, walkways, etc., will be purpose designed to suit the installation.

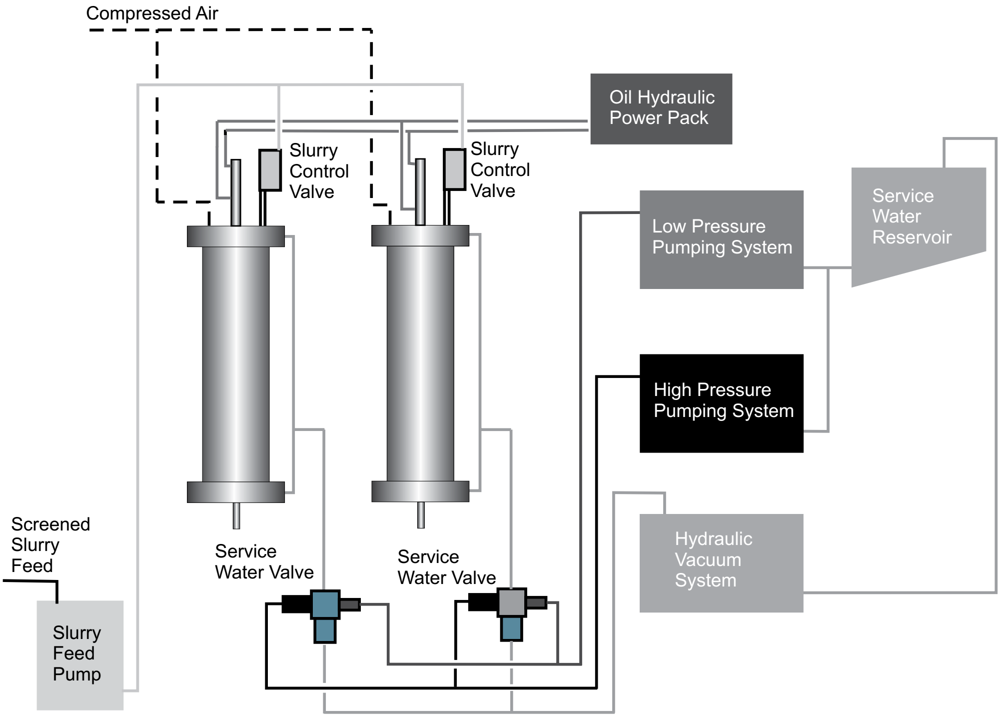
The service ancilliaries to operate the plant are usually supplied as independent skid mounted units and consist of the following

- Slurry pump set
- Low pressure filtration pump set
- High pressure filtration pump set
- Vacuum vessel and pump set
- Filtration fluid storage tank
- Oil hydraulic power pack (for candle movement at discharge)

The pipework and cabling to connect these items to the raft modules will be purpose designed to suit the installation.

The plant is controlled by a PLC based system which will normally incorporate full graphics and data storage/handling for optimum plant management.

For the tube press to operate it requires an infrastructure of ancillary equipment to provide the necessary services. A general pump drive product system is shown below.



These services are:

- Slurry feed
- Filtration pressure system
- Low pressure
- High pressure
- Vacuum
- Candle jack hydraulics
- Oil hydraulic power pack
- Compressed air
- PLV based control system

Tube press booster system

The tube press booster is a compact intelligent dewatering system for small scale applications in mineral, chemical and pharmaceutical industries.

"Compact filtration unit" / Booster system

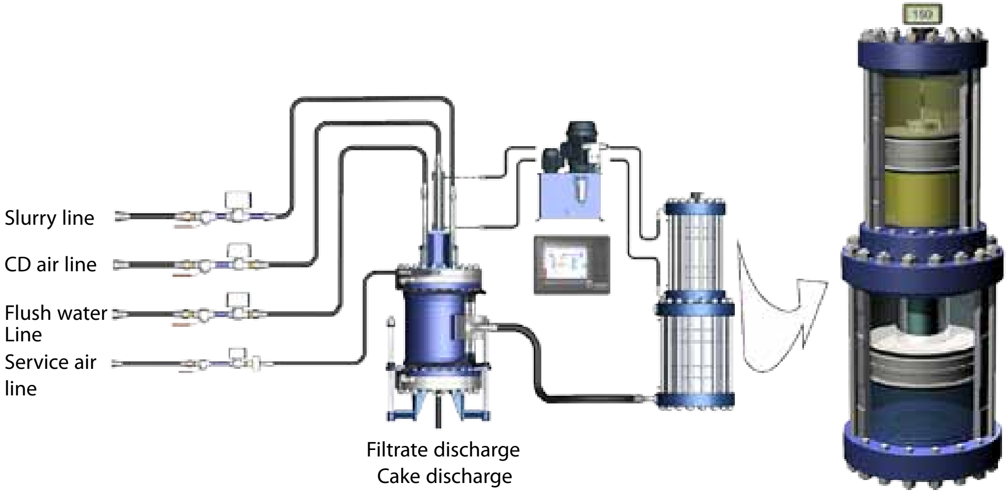
The booster is an individual drive system closely coupled with the tube press.

The installation is compact and combining one motor to generate the mechanical dewatering press force.
The system incorporates fully optimized control of the complete process, including feed back and statistical analysis of each press cycle.

Mechanical description

The drive unit incorporates an oil hydraulic power pack and a booster. The oil driven hydraulic power pack provides the driving force, which is converted via the bBooster unit into a water based pressure medium.

The pressure and dewatering speed is controlled via the control system, which is constantly receiving feed back from sensors and a positional pump. This results in the ability to continuously increase the pressures matching the dewatering curve of the material.



Control system

The tube press is operated from the operator's monitor located on the control panel.

The monitor is connected to a PLC that handles the control logics and interlockings.

All process specific data and parameters can be set and adjusted from the monitor in the settings menu.

Cycle time, press weight, etc., are presented on the monitor.

The booster system

Small to medium installation size installation advantages:

- Low cake moisture
- Excellent liquid/solid separation
- Compact design and is easy to install.
- Fully optimized control
- Useful quality production information and data exchange
- Easy to expand
- Few moving parts
- Increased efficiency by on line process control
- Environmental advantage by high grade of recovery
- Maximum energy exchange
- Closed media circuit
- Low installed power
- Maintenance friendly
- Fully automated

Thermal processing – Introduction

Dewatering by using tube presses represents the highest energy level of mechanical upgrading of minerals. If further upgrading is required we have to use thermal processing.
Thermal processing is normally classified according to operating temperature.

Thermal low (100-200° C)

Used for drying - evaporating of liquids from solids - drying
Type of equipment

- Direct heat rotary dryers
- Indirect heat rotary dryers
- Steam tube dryers
- Indirect heat screw dryers (Holo-Flite[R])
- Fluid bed dryers

Thermal medium (850 -950°C)

Used for calcining, clay swelling, limestone burning and foundry sand burn out
Type of equipment

- Direct heat rotary kilns
- Indirect heat rotary kilns
- Vertical kilns
- Fluid bed kilns

Thermal high (1300-1400°C)

Used for pelletizing of iron ore concentrates and petroleum coke calcining
Type of equipment

- Direct heat rotary kiln

Thermal processing – basics

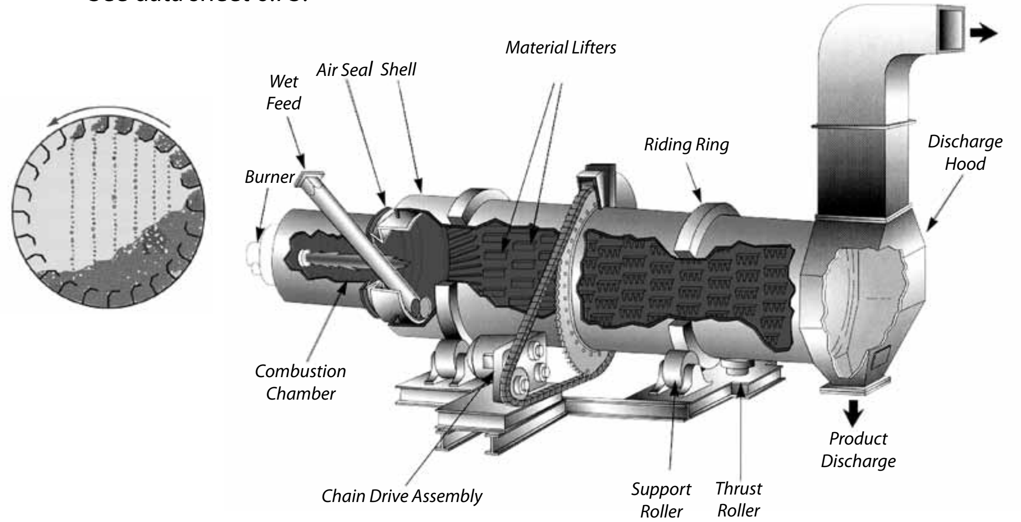
Thermal processing is expensive. This means that lowest input in calories/ton is the key issue. With raising operating temperatures this issue is getting more and more critical.
Dryers are normally not insulated but the kilns are refractory lined to protect the mechanical parts from the high temperatures needed for processing. Also the systems for heat recovery are getting more and more advanced with higher energy input.
Thermal processing equipment is always supplied as an integrated system consisting of:

- Mechanical dryer or kiln, see above
- Feed and product handling equipment
- Combustion system (burner, fans, fuel system, etc.)
- Offgas handling equipment
- Dust collection system (wet or dry)
- Cooling system (optional)

Direct heat rotary dryer (Cascade type)

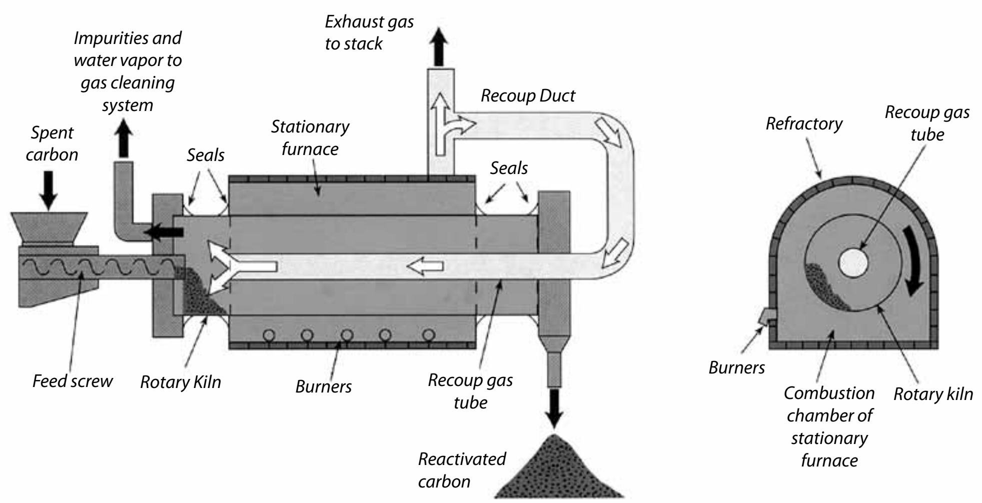
- Work horse of the mineral industry
- Wide range of internal designs for effective drying from start to end
- Special seals for closely controlled atmosphere
- Effective combustion and low maintenance burners, safe and reliable
- Diameter <0,6-5 m (2-17 ft), length 5-30 m (7-100 ft). Feed rates from less than 1 ton to 500 tons per hour
- Applications in minerals, clay, sand,aggregates, heavy chemicals and fertilizers

See data sheet 6:73.



Indirect heat rotary dryer (Kiln)

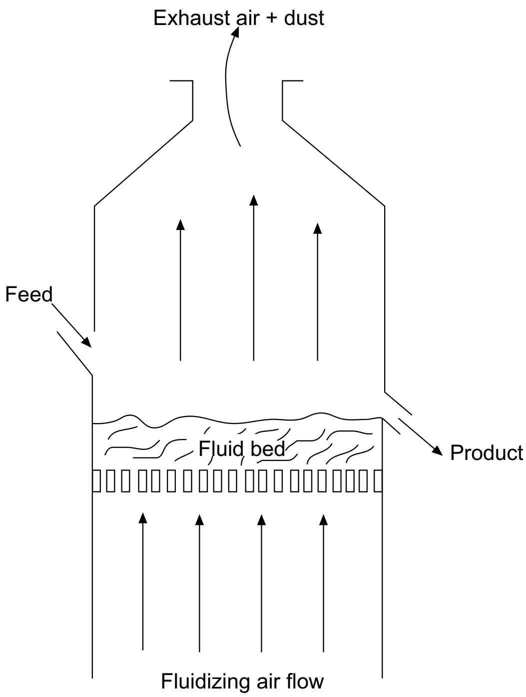
- Controlled environment interior excludes products of combustion
- Heat transfer by conduction and radiation
- Pulse-fired burners available
- Facilitates recovery of off-gases and product vapours
- Diameter 0,5m - 4,5 m (1.5-14 ft). Length 2.5 m to 30 m (8-96 ft).
- Applications in hazardous-, ultra fine- and combustible materials.
  Regeneration of active carbon, pyrolysis of waste rubber (car types)



Fluidized bed

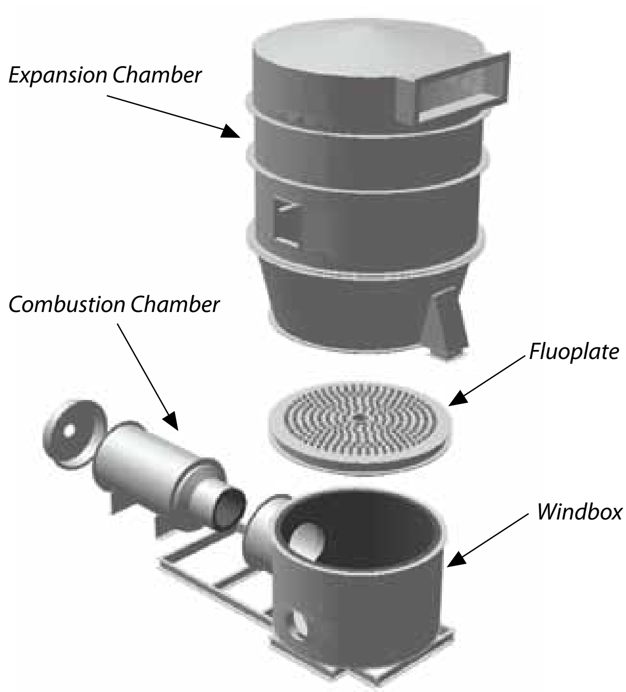
Principals
An air flow passes evenly through a particle bed. If this flow is high enough all particles become mobile within the bed.

We have a fluid bed where the upper surface is horizontal and products overflow the weir like a fluid.



Fluidized bed – key components

- Combustion chamber
- Windbox
- Fluoplate
- Expansion Chamber



Fluid bed – advantages

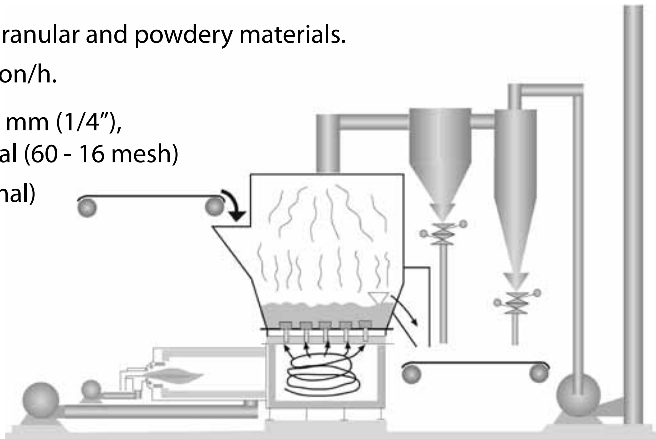
- A fluid bed behaves like a fluid allowing the use of equipment with no moving parts.
- The air/particle contact creates optimal heat and mass transfer
- Good agitation and mixing promotes consistent product quality

Fluid bed – applications

- Drying with bed temperature 100°C (212°F), (main application area)
- Cooling with bed cooled by water pipes
- Calcining with bed temperatures of 750 - 1200°C (1 382°F - 2 192°F)
- Combustion at operating temperatures of 750 - 900°C (1 382°F - 1652°F), (solid fuels combusted within a sand bed)

Fluid bed dryer

- For drying of most granular and powdery materials.
- Capacity up to 300 ton/h.
- Particle size minus 6 mm (1/4"), 0.25 - 1.0 mm optimal (60 - 16 mesh)
- Size range 6:1 (optimal)

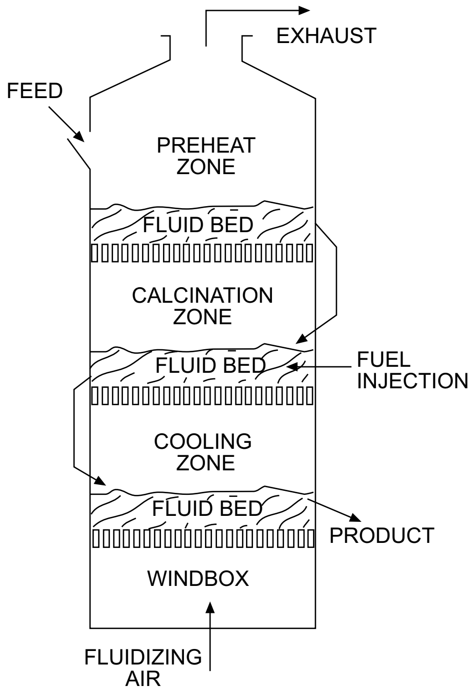


Fluid bed calciner

Operating temperatures 750 –1200°C.

At such temperatures fuel (gaseous, liquid or solid) is injected directly into the fluid bed.

Heat recovery is done by multistaging. Calcination gases preheat the feed whilst a cooling zone cools the product and preheats the fluidising air



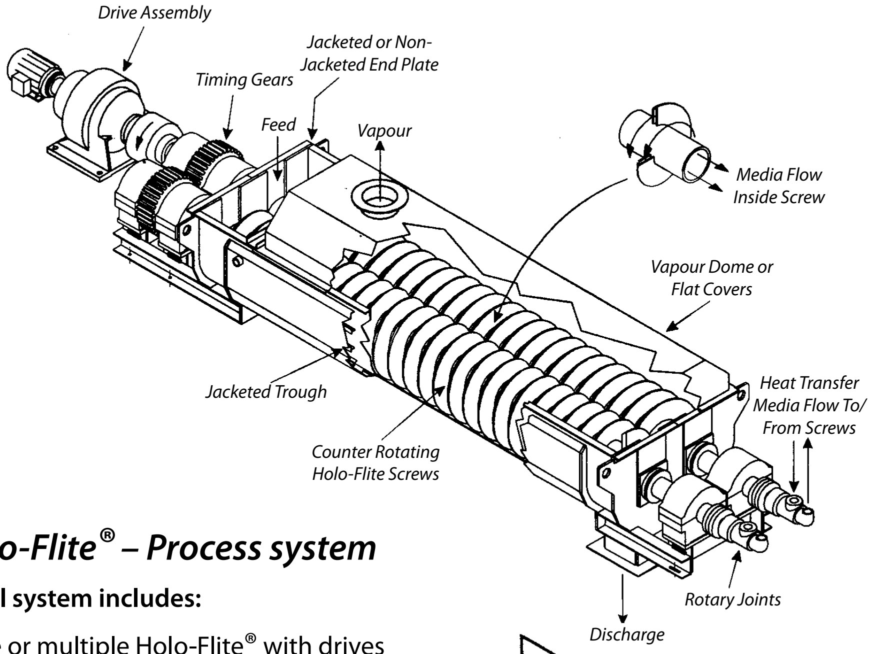
Indirect heat screw dryer (Holo-Flite®)

Operating principle

The principle for the Holo-Flite® dryer is the same as for the indirect heat rotary dryer (described above) with the difference that the product to be dried is continuously conveyed by means of the rotating screw flights. By controlling the temperature of the heat transfer medium and the screw speed the drying process can be closely controlled. Heat transfer medium is normally recycled giving a high thermal efficiency. The design is very compact giving certain advantages in application layouts.

Holo-Flite®– design

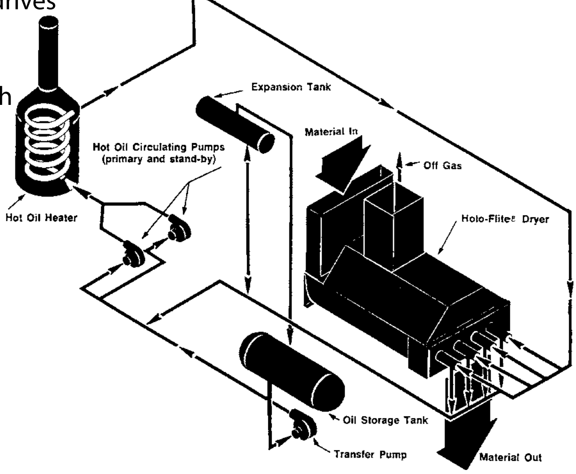
- Design can take up temperature variations 0 – 1200° C (30 – 2000° F)
- Construction material carbon steel, and various alloys as required by application for resistance to corrosion and abrasion.
- Screw diameter 178 – 915 mm (7 – 36"), 1,2 or 4 screws
- Concurrent or counter-current flow of heat transfer medium
- Patented twin pad design



Holo-Flite® – Process system

A typical system includes:

- Single or multiple Holo-Flite® with drives
- Heat transfer medium supply
- Medium heating system (heater with control system, fuel storage and expansion tank, heat medium transfer pump, hot medium circulation pumps
- Safety protection (sprinkler and nitrogen)
- Optional PLC controls
- Vapour exhaust fan
- Dust collector (when required)



Holo-Flite® – Heat transfer medium

Steam (up to 10 bar)	100 - 200°C	200 - 400°F
Hot Oil	150 - 350°C	300 - 660°F

Holo-Flite® – applications

The importance with a Holo-Flite® application is that the material shall be conveyed in a screw conveyor and that the material must not adhere to the transporting flights. Maximum recommended particle size is 12 mm (1/2").

With these restriction a lot of applications open up for this concept

- Coal fines
- Mineral fines
- Carbon black
- Iron powder
- Other valuable granular and powdery material

Holo-Flite® – sizing

As for the rest of thermal processing equipment sizing, this is a complicated computer exercise normally based on lab- or pilot test work.

Some typical drying application figures:

Limestone fines	**12 t/h**	**15°C in**	**138°C out**

Equipment used: one 4-screw machine, flight dia 600 mm(24"). Length 7.2m (24ft)

Potassium chloride	**9 t/h**	**0°C in**	**110°C out**

Equipment used: one 2-screw machine, flight dia 400 mm(16"). Length 6 m (20 ft)

See also data sheet 6:75.

Something about cooling

In most thermal processing the temperatures of discharged products are high. In order to lower that temperature, or to recover some heat, or both, coolers are used.

Most of the coolers are inversely working dryers, however, with a higher capacity per installed unit.

Coolers of rotating drum type

Normally there are three basic designs:

- **Air Swept Coolers** built similar as a counter flow direct heat rotary dryer, where hot gasses are replaced with ambient air
- **Water cooled shell coolers** where the drum shell is cooled with water or is submerged in a pool of water.
- **Water tube coolers** having the same design as a steam tube dryer, where the steam is replaced with cool water

Coolers of fluid bed type

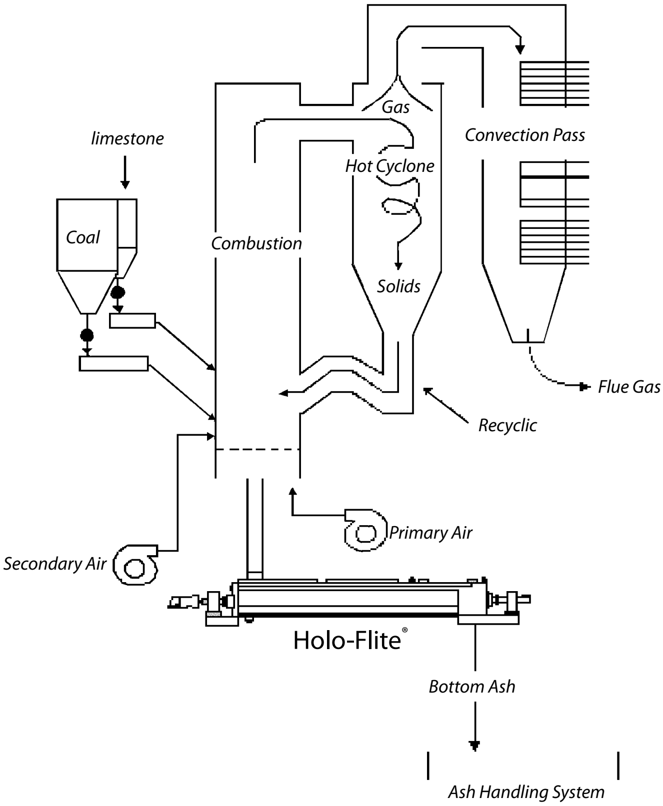
The principles of fluid bed can be used also for cooling purposes. In this case the fluid bed is cooled by internal water pipes.

Coolers of Holo-Flite® type

Most of the applications for Holo-Flite® is actually cooling. In this case the medium circulating inside the screw is water. As the design of the screw conveyor permits very high temperatures, ash cooling is a frequent application particularly where the compact design of the Holo-Flite® can be utilised, see below.

Ash cooling

Circulating fluidized bed boiler



Coolers and heat recovery

Thermal processing is a question of limiting the energy input for each part of the operation. This is the strongest argument (together with environmental issues) in a competitive situation for systems selection.

The system with the best heat balance has probably also the best heat recovery system utilizing the energy released from cooling.

Thermal processing systems – Medium and high temperature

As said before all thermal processing installations are normally supplied as process system including the basic heating equipment with auxiliary system modules for combustion, offgas, dust collection, heat recovery, preheating cooling, feed and discharge, instrumentation and controls etc.

Grate-Kiln system for iron ore pelletizing

The Grate-Kiln system economically converts a multitude of iron ores into high quality iron ore pellets which are later used in the steelmaking process. Pellets produced by means of the Grate-Kiln system serve as feed material for both blast furnace and direct reduction processes.

The Grate-Kiln system is comprised of the following major components:

Balling drum – a cylindrical machine which receives a finely ground mixture of iron ore and other additives and produces uniform spherical pellets through the addition of moisture and the dynamic forces of rotation.

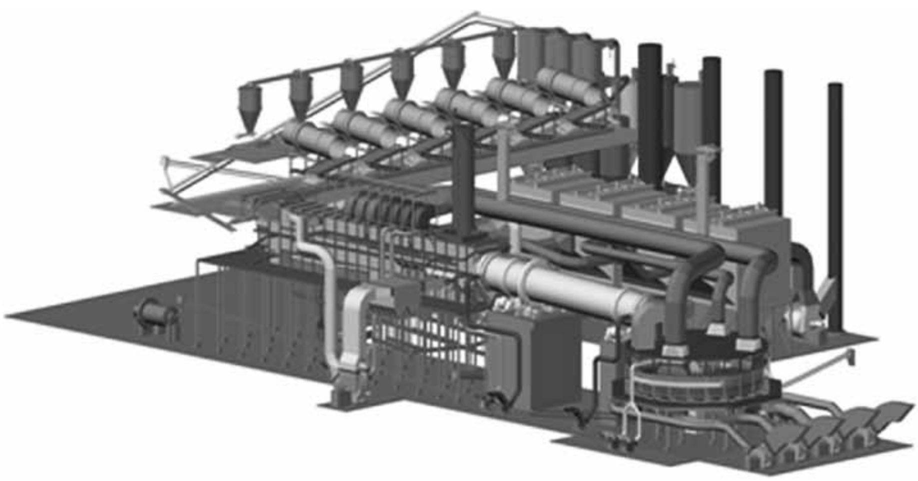
Traveling grate – a combined mechanical transport vehicle and thermal processor which receives iron ore pellets produced by the balling drum and removes pellet moisture through drying and strengthens the pellet by preheating and subsequent partial fusion (induration) of the pellet's mineral bonds.

Rotary kiln – a sloped rotating cylindrical furnace comprised of an axial burner at the discharge end which receives the partially indurated pellets from the traveling grate and through application of heat and uniform mixing of the pellet bed fully heat hardens and indurates the pellets, completing a unified formation of the mineral bonds.

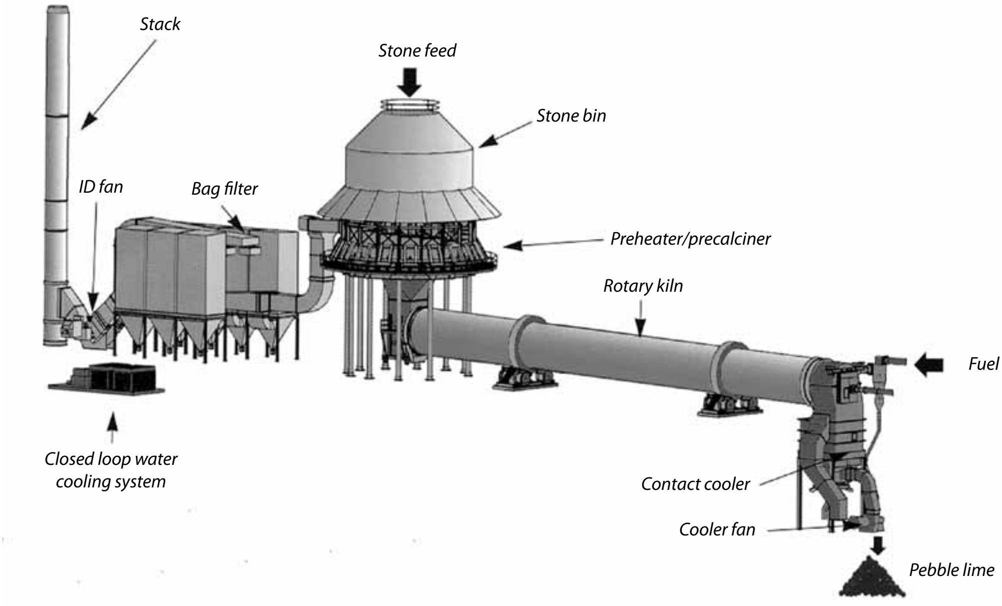
Annular cooler – a circular structure consisting of a rotating top and stationary bottom which receives the indurated pellets from the rotary kiln and cools them for subsequent safe handling, while simultaneously recuperating sensible heat for use in the traveling grate.

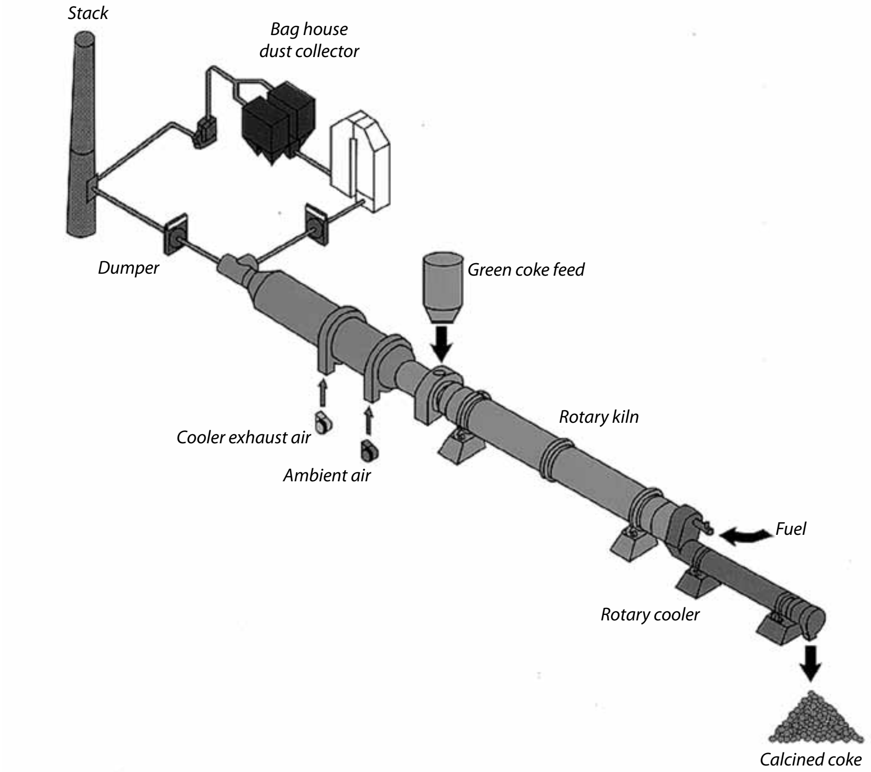
The Grate-Kiln system demonstrates the following benefits:

- Process – low fuel consumption due to heat recuperation from the annular cooler to the traveling grate, preheated combustion air, radiant heat transfer in the rotary kiln.
- Operations – independent control of preheating, indurating, and cooling through the use of three separate components (traveling grate, rotary kiln, annular cooler), flexibility to process a variety of iron ores, multiple fuel firing capabilities (coal, oil, gas, biomass, waste fuels, etc.)

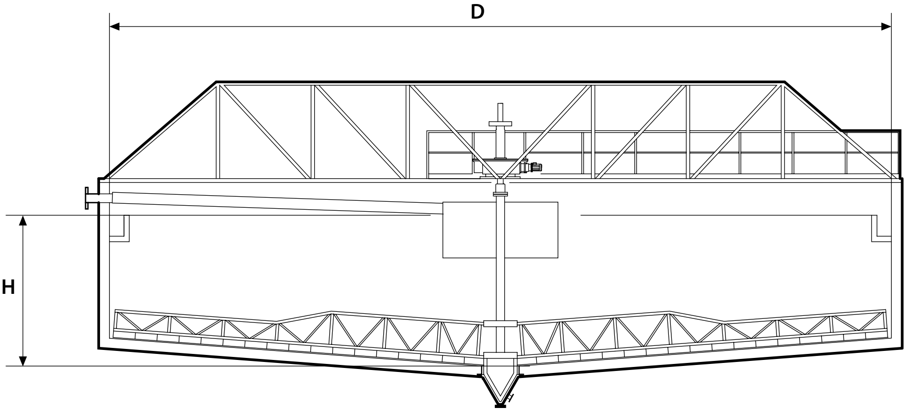


Lime calcining system



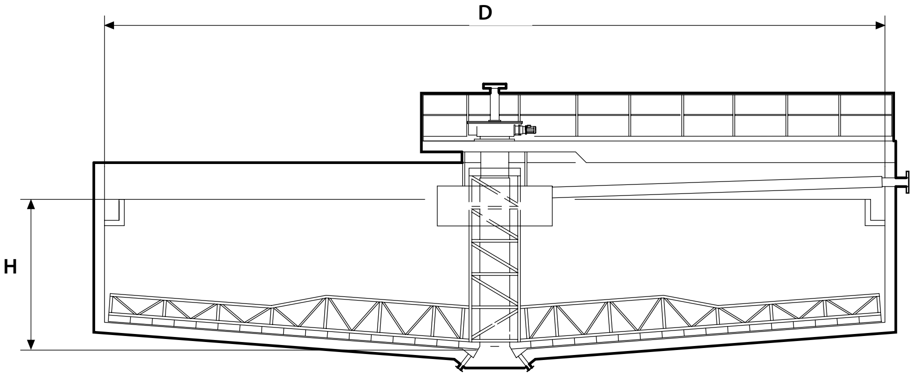


Clarifier / Thickener – Bridge



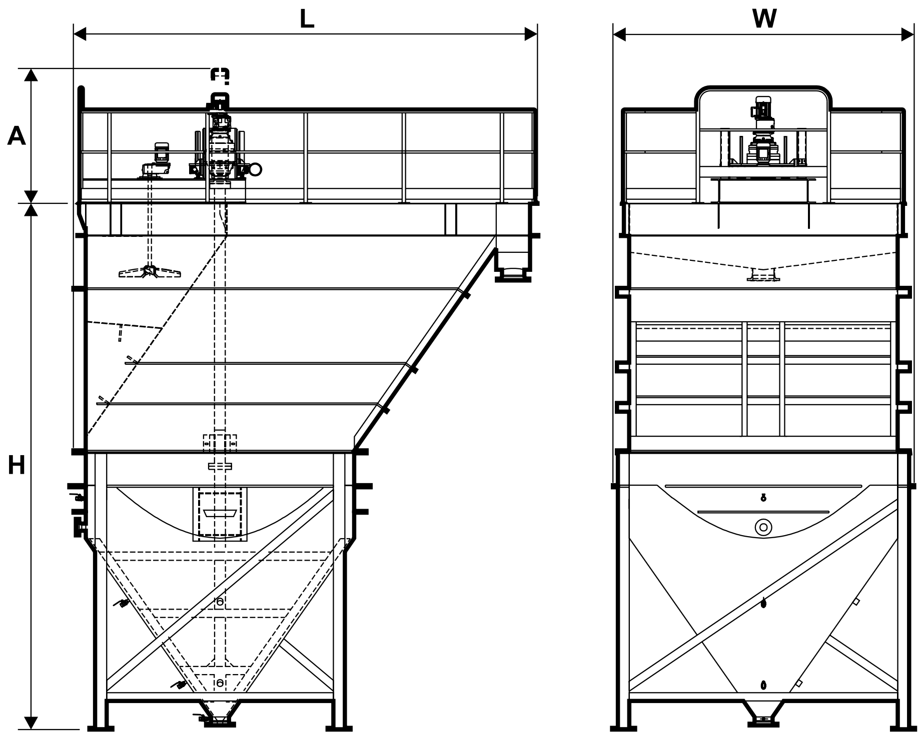
Diameter		Height		Area	
(m)	*(ft)*	*(m)*	*(ft)*	*(m^2)*	*(ft^2)*
10	33	3.0	10	78	839
12	39	3.0	10	113	1 216
14	46	3.0	10	154	1 658
16	52	3.6	12	201	2 164
18	59	3.6	12	254	2 734
20	66	3.6	12	314	3 380
22	72	3.6	12	380	4 090
24	79	4.6	15	452	4 865
26	85	4.6	15	531	5 716
28	92	5.2	17	616	6 631
30	98	5.2	17	706	7 599
32	105	5.2	17	804	8 654
34	111	5.2	17	908	9 773
36	118	5.2	17	1 018	10 958
38	125	5.2	17	1 134	12 206
40	131	5.5	18	1 257	13 530
42	138	5.5	18	1 385	14 913
44	144	5.8	19	1 521	16 367

Clarifier / Thickener – Centre pier



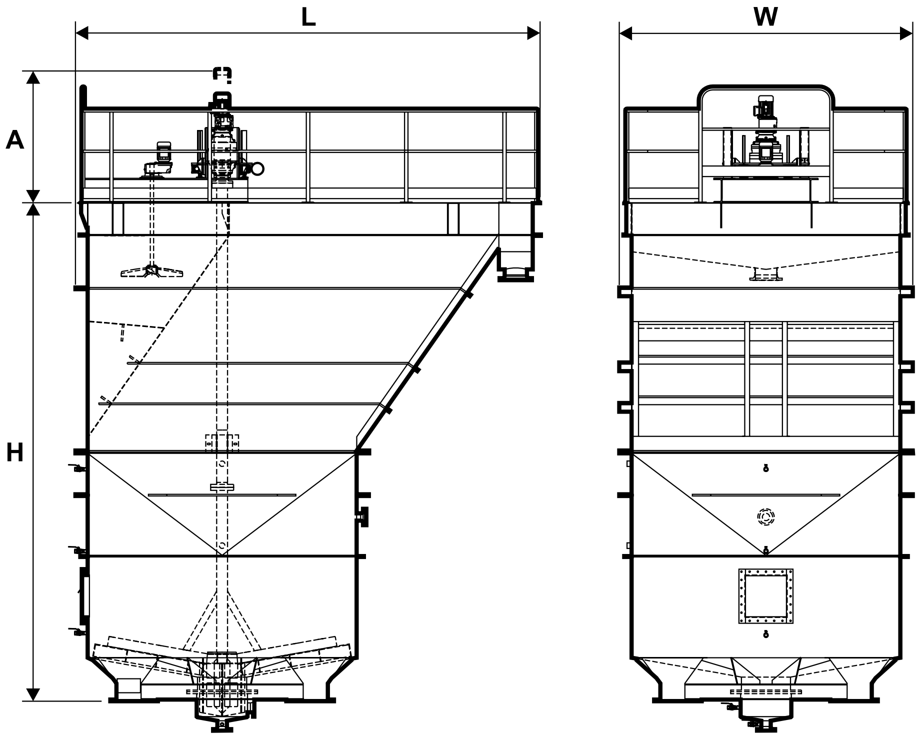
Diameter		Height		Area	
(m)	*(ft)*	*(m)*	*(ft)*	*(m^2)*	*(ft^2)*
40	131	5.5	18	1 257	13 530
42	138	5.5	18	1 385	14 913
44	144	5.8	19	1 521	16 367
46	151	5.8	19	1 662	17 889
48	157	5.8	19	1 810	19 479
50	164	6.4	21	1 963	21 130
52	170	6.4	21	2 124	22 860
54	177	7.0	23	2 290	24 653
56	184	7.0	23	2 463	26 512
58	190	7.0	23	2 642	28 440
60	197	7.3	24	2 827	30 430
65	213	7.6	25	3 318	35 715

Inclined plate settler – LT



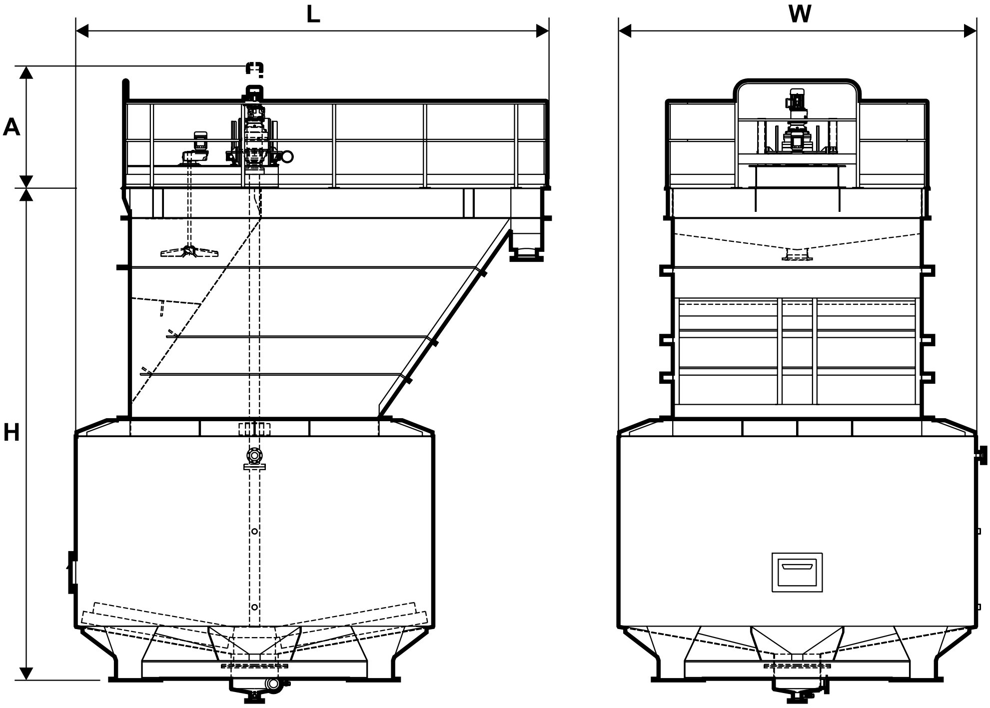
Model (max) mm	H mm (ft)	L mm (ft)	W mm (ft)	A volume mm^3 (ft)	Total volume m^3 (ft^3)	Sludge volume m^3 (ft^3)	Flocculator empty kg (ft^3)	Weight (lbs)
LT 15	3 485	2 640	1 345	1 800	4.6	1.1	0.8	1 800
	(11.4)	(8.7)	(4.4)	(5.9)	(162)	(39)	(28)	(3 968)
LT 30	4 300	3 430	1 830	1 800	9.2	2.3	0.8	3 500
	(14.1)	(11.3)	(6.0)	(5.9)	(325)	(81)	(28)	(7 716)
LT 50	4 650	3 865	2 230	1 800	16.2	4.2	2.0	4 800
	(15.3)	(12.7)	(7.3)	(5.9)	(572)	(148)	(71)	(10 582)
LT 100	5 400	4 510	2 870	1 800	28.7	9.4	3.0	7 800
	(17.7)	(14.8)	(9.4)	(5.9)	(1 014)	(332)	(106)	(17 196)
LT 150	5 950	5 540	3 100	1 800	41.5	14.5	4.0	10 500
	(19.5)	(18.2)	(10.2)	(5.9)	(1 466)	(512)	(141)	(23 149)
LT 200	6 500	5 740	3 690	1 800	54.6	18.8	5.0	13 200
	(21.3)	(18.8)	(12.1)	(5.9)	(1 928)	(664)	(177)	(29 101)
LT 350	8 100	6 910	4 500	2 000	105.8	47.8	7.0	24 300
	(26.6)	(22.7)	(14.8)	(6.6)	(3 736)	(1 688)	(247)	(53 572)
LT 500	8 630	7 810	5 780	2 000	160.8	72.8	8.0	39 500
	(28.3)	(25.6)	(19.0)	(6.6)	(5 679)	(2 571)	(283)	(87 082)

Inclined plate settler – LTS



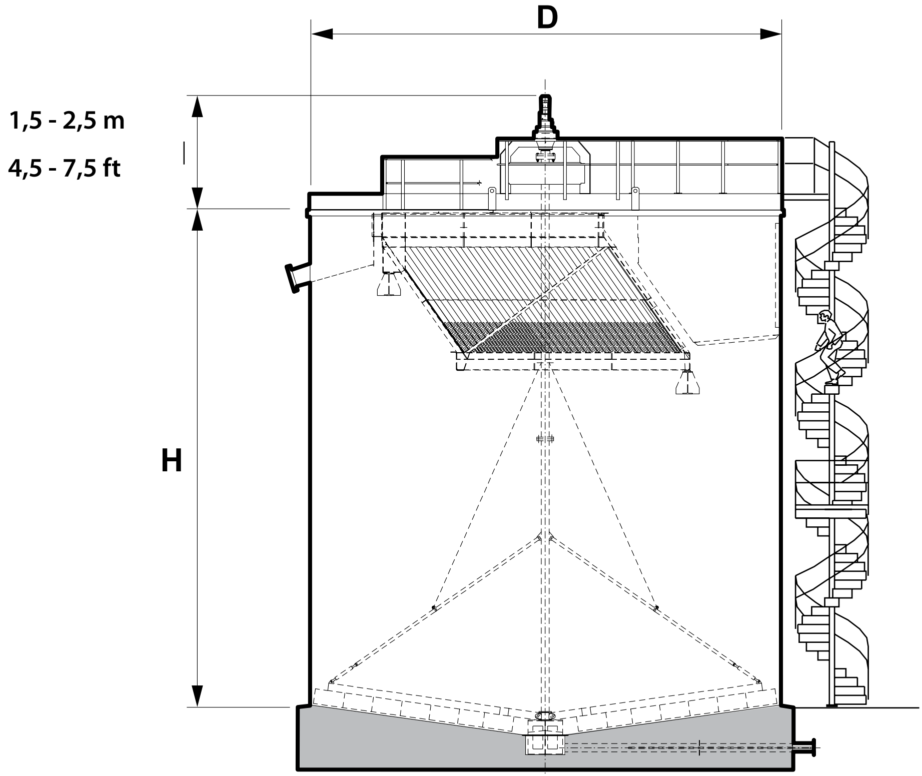
Model	H (max) mm (ft)	L mm (ft)	W mm (ft)	A max mm (ft)	Total volume m^3 (ft^3)	Sludge volume m^3 (ft^3)	Flocculator volume m^3 (ft^3)	Weight empty kg (lbs)
LTS 15	3 750 (12.3)	2 640 (8.7)	1 345 (4.4)	1 800 (5.91)	5.2 (184)	1.7 (60)	0.8 (28)	2 000 (4 409)
LTS 30	4 620 (15.2)	3 430 (11.3)	1 830 (6.0)	1 800 (5.91)	11.1 (392)	4.2 (148)	0.8 (28)	3 700 (8 157)
LTS 50	4 700 (15.4)	3 865 (12.7)	2 230 (7.3)	1 800 (5.91)	18.6 (657)	6.6 (233)	2.0 (71)	5 100 (11 244)
LTS 100	5 130 (16.8)	4 510 (14.8)	2 870 (9.4)	1 800 (5.91)	32.5 (1 148)	13.2 (466)	3.0 (106)	8 600 (18 960)
LTS 150	5 300 (17.4)	5 540 (18.2)	3 100 (10.2)	1 800 (5.91)	45.8 (1 617)	18.8 (664)	4.0 (141)	11 300 (24 912)
LTS 200	6 100 (20.01)	5 740 (18.8)	3 690 (12.1)	1 800 (5.91)	61.8 (2 182)	26.0 (918)	5.0 (177)	15 800 (34 833)
LTS 350	6 200 (20.3)	6 910 (22.7)	4 500 (14.8)	2 000 (6.56)	114.0 (4 026)	56.0 (1 978)	7.0 (247)	23 000 (50 706)
LTS 500	6 400 (21.0)	7 810 (25.6)	5 780 (19.0)	2 000 (6.56)	153.0 (5 403)	65.0 (2 295)	8.0 (283)	36 000 (79 366)

Inclined plate settler – LTK



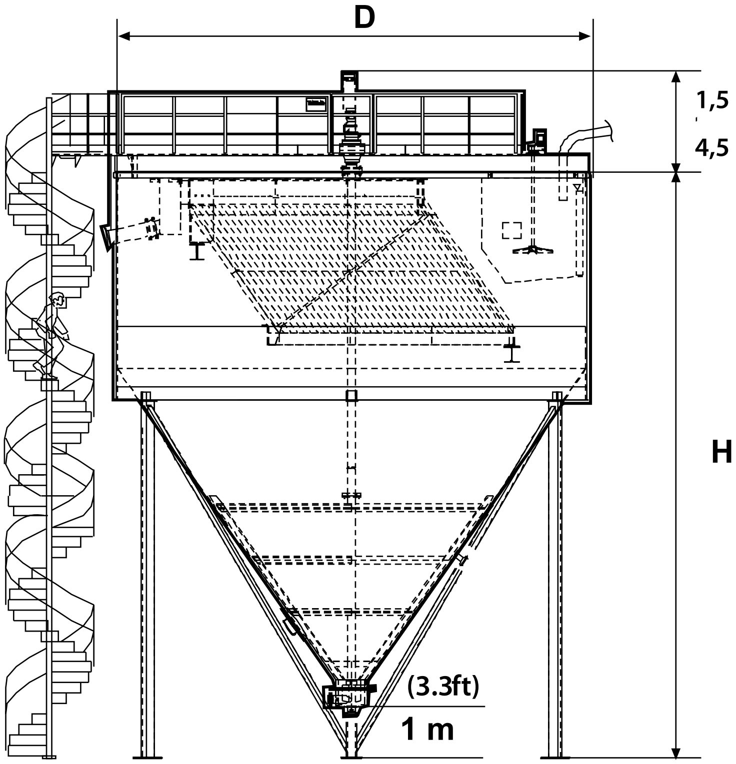
Model	H mm (ft)	L mm (ft)	W mm (ft)	A max mm (ft)	Total volume m^3 (ft^3)	Sludge volume m^3 (ft^3)	Flocculator volume m^3 (ft^3)	Weight empty kg (lbs)
LTK 15	5 100 (16.7)	2 795 (9.2)	1 610 (5.3)	1 800 (5.9)	8.0 (283)	4.5 (159)	0.8 (28)	2 200 (4 850)
LTK 30	4 550 (14.9)	3 690 (12.11)	2 310 (7.6)	1 800 (5.9)	14.5 (512)	7.6 (268)	0.8 (28)	4 500 (9 921)
LTK 50	4 800 (15.7)	4 170 (13.7)	2 810 (9.2)	1 800 (5.9)	23.5 (830)	11.5 (406)	2.0 (71)	6 200 (13 669)
LTK 100	5 390 (17.7)	5 020 (16.5)	3 715 (12.2)	1 800 (5.9)	45.5 (1 607)	26.2 (925)	3.0 (106)	10 100 (22 267)
LTK 150	5 800 (19.0)	5 885 (19.3)	4 490 (14.7)	1 800 (5.9)	61.0 (2 154)	34.0 (1 201)	4.0 (141)	13 000 (28 660)
LTK 200	6 500 (21.3)	6 235 (20.6)	4 715 (15.5)	1 800 (5.9)	87.0 (3 072)	51.2 (1 808)	5.0 (177)	16 500 (36 376)
LTK 350	6 930 (22.7)	7 485 (24.6)	6 220 (20.4)	2 000 (6.6)	143.0 (5 050)	85.0 (3 002)	7.0 (247)	26 500 (58 422)
LTK 500	6 940 (22,8)	8 705 (28,6)	7 520 (24,7)	2 000 (6,6)	200.0 (7 063)	112.0 (3 955)	8.0 (283)	46 500 (102 515)

Inclined plate settler – LTE



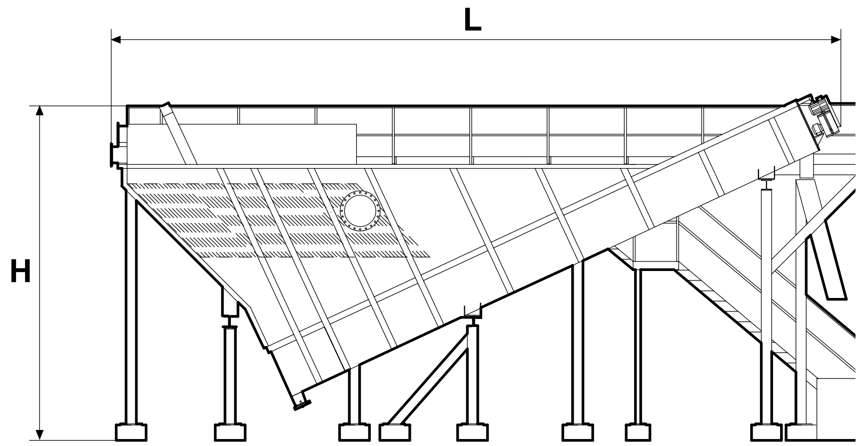
Model	Settling area m^2 (ft^2)	Tank dia (D) mm (ft)	Tank height (H) mm (ft)	Sludge volume m^3 (ft^3)	Total volume m^3 (ft^3)
TE 220-6.3	220 (2 386)	6 300 (20.7)	6 000 (19.7)	86 (3 037)	192 (6 780)
			9 000 (29.5)	179 (6 321)	285 (10 065)
LTE 275-7.1	275 (2 960)	7 100 (23.3)	6 000 (19.7)	110 (3 884)	244 (8 617)
			9 000 (29.5)	228 (8 052)	363 (12 819)
LTE 440-8.3	440 (4736)	8 300 (27.0)	6 000 (19.7)	151 (5 333)	335 (11 830)
			9 000 (29.5)	314 (11 089)	497 (17 551)
			12 000 (39.4)	476 (16 810)	660 (23 308)
LTE 550-9.0	550 (5 920)	9 000 (29.5)	6 000 (19.7)	179 (6 321)	395 (13 949)
			9 000 (29.5)	370 (13 066)	586 (20 694)
			12 000 (39.4)	561 (19 811)	777 (27 440)
LTE800-10.5	800 (8 611)	10 500 (34.4)	6 000 (19.7)	246 (8 687)	541 (19 105)
			9 000 (29.5)	506 (17 869)	801 (28 287)
			12 000 (39.4)	766 (27 051)	1 060 (37 434)
LTE1040-12	1 040 (11 194)	12 000 (39.4)	6 000 (19.7)	326 (11 513)	710 (25 073)
			9 000 (29.5)	665 (23 484)	1 050 (37 080)
			12 000 (39.4)	1 004 (35 456)	1 389 (49 052)

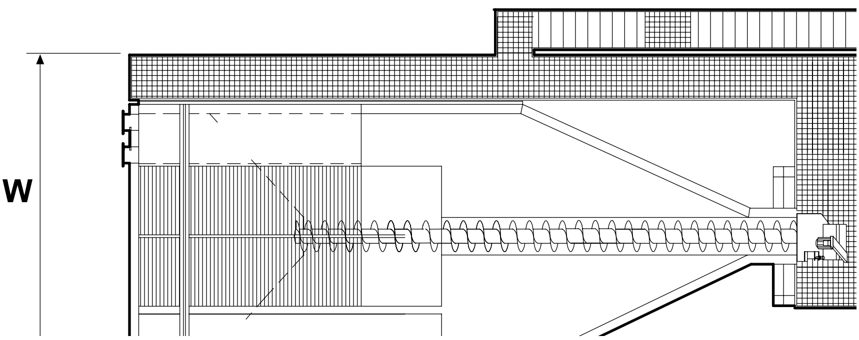
Inclined plate settler – LTE/C



Model	Settling area m^2 (ft^2)	Tank dia (D) mm (ft)	Tank height (H) mm (ft)	Sludge volume m^3 (ft^3)	Total volume m^3 (ft^3)
LTE/C 220-6.3	220 (2 368)	6 300 (20.7)	8 500 (27.9)	66 (2 331)	172 (6 074)
LTE/C 275-7.1	275 (2 960)	7 100 (23.3)	10 000 (33.0)	91 (3 214)	225 (7 946)
LTE/C 440-8.3	440 (4 736)	8 300 (27.2)	11 000 (36.0)	140 (4 944)	324 (11 442)
LTE/C 550-9.0	550 (5 920)	9 000 (29.5)	11 500 (37.7)	175 (6 180)	391 (13 808)
LTE/C 800-10.5	800 (8 611)	10 500 (34.4)	12 500 (41.0)	269 (9 499)	563 (19 882)
LTE/C 1040-12	1 040 (11 194)	12 000 (39.4)	13 500 (44.3)	392 (13 843)	776 (27 404)

Spiral dewaterer





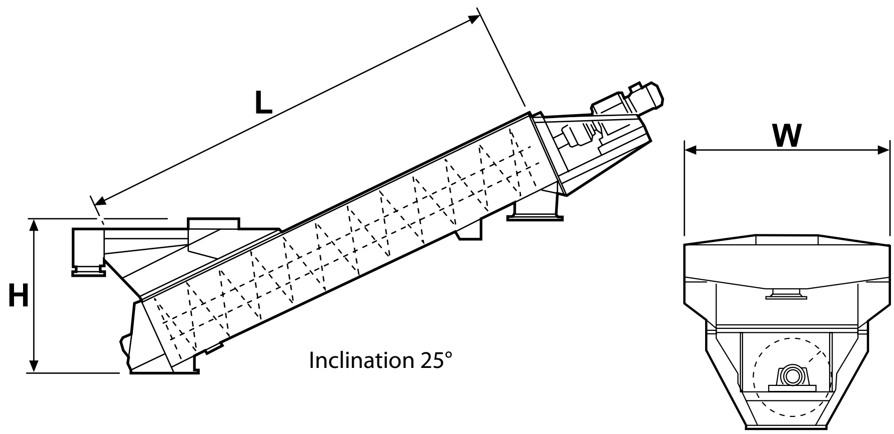
Model	H mm (inch)	L mm (inch)	W mm (inch)	Power kW/hp	Weight ton(empty)	Tank volume m^3 (ft^3)
SD 60-8*	2 815 (111)	7 340 (289)	2 300 (91)	1.5/2	9.0	8 (283)
SD 60-10	3 160 (124)	8 370 (330)	2 300 (91)	1.5/2	9.3	12 (424)
SD 60-20	4 000 (157)	10 600 (417)	3 200 (126)	3/4	12.5	30 (1 059)
SD 60-25	5 350 (211)	11 100 (437)	4 500 (177)	3/4	13.8	44 (1 554)
SD 60-30	6 400 (252)	14 000 (551)	5 000 (197)	4/5	23.0	70 (2 472)
SD 60-38**	5 350 (211)	11 100 (437)	4 500 (177)	3/4	14.4	44 (1 5 54)
SD 60-100**	6 400 (252)	14 000 (551)	5 000 (197)	4/5	24.4	70 (2 473)

*60-8, 60 = spiral dia in cm (24inch) -8 = settling area 8m² (86ft²)

10m² (108ft²), 20m² (216ft²), 25m² (270ft²), 30m² (323ft²), 38m²(409ft²), 100m² (1 080ft²)

** With lamella plates

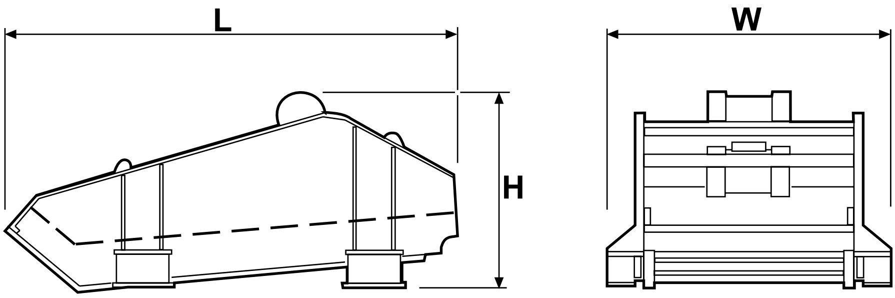
Sand screw



Model	H mm (inch)	L mm (inch)	W mm (inch)	Power kW/hp	Weight ton	Capacity solids* m^3/h (USGPM)
SS 4050	1 430 (56)	5 000 (197)	1 400 (55)	2.2/3.0	1.8	6 /26
SS 5060	1 540 (60)	6 000 (236)	1 500 (59)	3.2/4.3	2.7	11/48
SS 6060	1 720 (68)	6 000 (236)	1 720 (68)	5.5/7.4	3.3	16/70
SS 7065	1 810 (71)	6 500 (256)	1 810 (71)	7.5/10	4.0	23/101
SS 8070	1 900 (75)	7 000 (276)	1 900 (75)	9.2/12	4.8	35/154
SS 9075	1 995 (79)	7 500 (295)	1 995 (79)	11/15	5.6	45/198
SS 10075	2 080 (82)	7 500 (295)	2 080 (82)	15/20	7.6	60/264
SS 12580	2 500 (98)	8 000 (315)	2 500 (98)	18.5/25	11.0	95/418

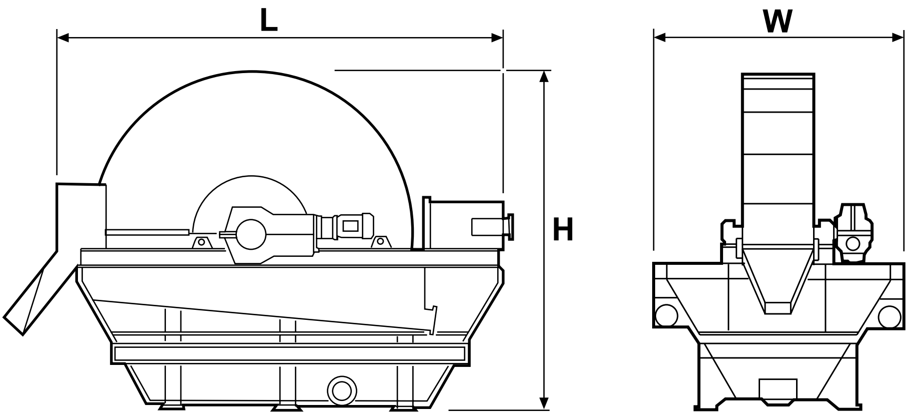
* Feed: sand/water ratio approx. 1:3

Dewatering screen



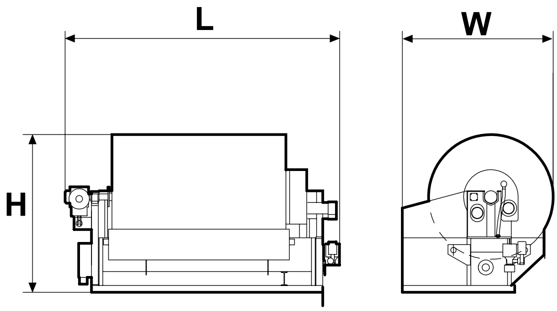
Model WxL (deck)*	H mm (inch)	L mm (inch)	W mm (inch)	Power kW/hp	Weight ton	Capacity coal (sand) ton/h
900x3 000	1 680 (66)	4 057 (160)	920 (36)	2x 2.7/36	2.4	5 - 15 (70)
1 200x3 000	1 730 (68)	4 057 (160)	1 226 (48)	2x3.4/46	2.9	15 - 30 (110)
1 500x3 000	1 730 (68)	4 057 (160)	1 530 (60)	2x4.8/64	3.0	30 - 45 (150)
1 800x3 000	1 730 (68)	4 057 (160)	1 835 (72)	2x4.8/64	3.2	45 - 55 (190)

Dewatering wheel



Model	H mm (inch)	L mm (inch)	W mm (inch)	Power kW/hp	Weight ton	Capacity solids m^3/h (USGPM)
SR6507x8543	7 000 (276)	10 000 (394)	4 300 (169)	11/15	31.5	150/660
SR6509x8545	7 000 (276)	10 000 (394)	4 500 (177)	15/20	33.5	200/880
SR6511x8547	7 000 (276)	10 000 (394)	4 700 (185)	18.5/25	36.5	250/1 100
SR6514x8550	7 000 (276)	10 000 (394)	5 000 (197)	22/30	39.5	350/1 540
SR6518x8554	7 000 (276)	10 000 (394)	5 400 (213)	30/40	45.0	400/1 760
SR6522x8558	7 000 (276)	10 000 (394)	5 800 (228)	2x22/30	54.5	550/2 422

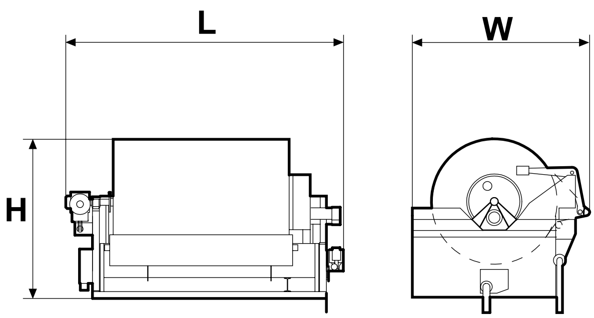
Drum vacuum filter – TF



Model	H mm (ft)	L mm (ft)	W mm (ft)	Power (drive) kw/hp	Power (agit.) kW/hp	Weight (empty) ton
TF1206*	1 600 (5)	1 600 (5)	1 600 (5)	0.25/0 35	1 5/2	1.2
TF1212	1 600 (5)	2 200 (7)	1 600 (5)	0.25/0 35	1 5/2	2.0
TF1218	1 600 (5)	2 800 (9)	1 600 (5)	0.25/0 35	1 5/2	2.8
TF1812	2 300 (8)	2 500 (8)	2 200 (5)	0.75/1	3/4	3.9
TF1818	2 300 (8)	3 100 (10)	2 200 (7)	0.75/1	3/4	4.2
TF1824	2 300 (8)	3 700 (12)	2 200 (7)	0.75/1	4/5	4.5
TF1830	2 300 (8)	4 300 (14)	2 200 (7)	0.75/1	4/5	4.8
TF2418	2 865 (9)	3 260 (11)	2 850 (9)	0.75/1	4/5	8.8
TF2424	2 865 (9)	3 860 (13)	2 850 (9)	3/4	4/5	9.1
TF2430	2 865 (9)	4 460 (15)	2 850 (9)	3/4	4/5	9.5
TF2436	2 865 (9)	5 060 (17)	2 850 (9)	3/4	4/5	9.7
TF2442	2 865 (9)	5 660 (19)	2 850 (9)	3/4	4/5	10.0
TF3030	3 480 (11)	4 480 (15)	3 630 (12)	3/4	5 5/7.4	9.8
TF3036	3 480 (11)	5 080 (17)	3 630 (12)	4/5	5 5/7.4	10.9
TF3042	3 480 (11)	5 680 (19)	3 630 (12)	4/5	5 5/7.4	12.0
TF3048	3 480 (11)	6 280 (21)	3 630 (12)	4/5	7.5/10	13.1
TF3054	3 480 (11)	6 880 (23)	3 630 (12)	4/5	7.5/10	14.2
TF3060	3 480 (11)	7 480 (25)	3 630 (12)	4/5	7.5/10	15.3
TF3636	4 075 (13)	5 160 (17)	3 910 (13)	4/5	7.5/10	11.5
TF3642	4 075 (13)	5 760 (19)	3 910 (13)	4/5	7.5/10	12.5
TF3648	4 075 (13)	6 360 (21)	3 910 (13)	5.5/7.4	7.5/10	13.5
TF3654	4 075 (13)	6 960 (23)	3 910 (13)	5.5/7.4	7.5/10	14.5
TF3660	4 075 (13)	7 560 (25)	3 910 (13)	5.5/7.4	7.5/10	15.5
TF3666	4 075 (13)	8 160 (27)	3 910 (13)	5.5/7.4	7.5/10	16.5

*1 206 , 12 = drum diameter 1 200mm (4ft), 06 = drum length 600 mm(2ft)
Drum dia.18=1 800mm(6ft), 24=2 400mm(8ft), 30=30 00mm(10ft), 36=3 600mm(12)
Drum length in ft: L(ft)- 3ft for dia 1 200
Drum length in ft: L(ft)- 4ft for dia 1 800
Drum length in ft: L(ft)- 5ft for dia 2 400, 3 000 and 3 600mm

Belt drum vacuum filter – BTF



Model	H mm (ft)	L mm (ft)	W mm (ft)	Power (drive) kw/hp	Power (agit.) kW/hp	Weight (empty) ton
BTF1206*	1 600 (5)	1 600 (5)	2 200 (7)	0.25/0.35	1.5/2	1.3
BTF1212	1 600 (5)	2 200 (7)	2 200 (7)	0.25/0.35	1.5/2	2.1
BTF1218	1 600 (5)	2 800 (9)	2 200 (7)	0.25/0.35	1.5/2	2.9
BTF1812	2 300 (8)	2 500 (8)	2 700 (9)	0.75/1	3/4	4.5
BTF1818	2 300 (8)	3 100 (10)	2 700 (9)	0.75/1	3/4	4.8
BTF1824	2 300 (8)	3 700 (12)	2 700 (9)	0.75/1	4/5	5.2
BTF1830	2 300 (8)	4 300 (14)	2 700 (9)	0.75/1	4/5	5.6
BTF2418	2 865 (9)	3 260 (11)	3 500 (11)	0.75/1	4/5	9.7
BTF2424	2 865 (9)	3 860 (13)	3 500 (11)	3/4	4/5	10.0
BTF2430	2 865 (9)	4 460 (15)	3 500 (11)	3/4	4/5	10.4
BTF2436	2 865 (9)	5 060 (17)	3 500 (11)	3/4	4/5	10.6
BTF2442	2 865 (9)	5 660 (19)	3 500 (11)	3/4	4/5	10.9
BTF3030	3 480 (11)	4 480 (15)	4 310 (14)	3/4	5.5/7.4	10.3
BTF3036	3 480 (11)	5 080 (17)	4 310 (14)	4/5	5.5/7.4	11.5
BTF3042	3 480 (11)	5 680 (19)	4 310 (14)	4/5	5.5/7.4	12.7
BTF3048	3 480 (11)	6 280 (21)	4 310 (14)	4/5	7.5/10	13.9
BTF3054	3 480 (11)	6 880 (23)	4 310 (14)	4/5	7.5/10	15.1
BTF3060	3 480 (11)	7 480 (25)	4 310 (14)	4/5	7.5/10	16.3
BTF3636	4 075 (13)	5 160 (17)	4 600 (15)	4/5	7.5/10	13.0
BTF3642	4 075 (13)	5 760 (19)	4 600 (15)	4/5	7.5/10	14.0
BTF3648	4 075 (13)	6 360 (21)	4 600 (15)	5.5/7.4	7.5/10	15.0
BTF3654	4 075 (13)	6 960 (23)	4 600 (15)	5.5/7.4	7.5/10	16.0
BTF3660	4 075 (13)	7 560 (25)	4 600 (15)	5.5/7.4	7.5/10	17.0
BTF3666	4 075 (13)	8 160 (27)	4 600 (15)	5.5/7.4	7.5/10	18.0

*1206 , 12 = drum diameter 1 200 mm (4ft), 06 = drum length 600 mm (2ft)

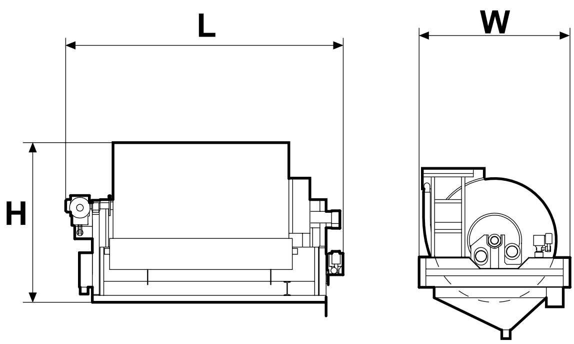
Drum dia.18 = 1 800 mm (6ft), 24 = 2 400 mm (8ft), 30 = 3 000 mm (10ft), 36 = 3 600mm (12)

Drum length in ft: L (ft)- 3ft for dia 1 200

Drum length in ft: L (ft)- 4ft for dia 1 800

Drum length in ft: L (ft)- 5ft for dia 2 400, 3 000 and 3 600mm

Top feed drum vacuum filter – TFF



Model	H mm (ft)	L mm (ft)	W mm (ft)	Power (drive) kw/hp	Weight (empty) ton
TFF1206*	1 600 (5)	1 600 (5)	2 200 (7)	0.25/0.35	1.3
TFF1212	1 600 (5)	2 200 (7)	2 200 (7)	0.25/0.35	2.1
TFF1218	1 600 (5)	2 800 (9)	2 200 (7)	0.25/0.35	2.9
TFF1812	2 300 (8)	2 500 (8)	2 700 (9)	0.75/1	4.5
TFF1818	2 300 (8)	3 100 (10)	2 700 (9)	0.75/1	4.8
TFF1824	2 300 (8)	3 700 (12)	2 700 (9)	0.75/1	5.2
TFF1830	2 300 (8)	4 300 (14)	2 700 (9)	0.75/1	5.6
TFF2418	2 865 (9)	3 260 (11)	3 500 (11)	0.75/1	9.7
TFF2424	2 865 (9)	3 860 (13)	3 500 (11)	3/4	10.0
TFF2430	2 865 (9)	4 460 (15)	3 500 (11)	3/4	10.4
TFF2436	2 865 (9)	5 060 (17)	3 500 (11)	3/4	10.6
TFF2442	2 865 (9)	5 660 (19)	3 500 (11)	3/4	10.9
TFF3030	3 480 (11)	4 480 (15)	4 310 (14)	3/4	10.3
TFF3036	3 480 (11)	5 080 (17)	4 310 (14)	4/5	11.5
TFF3042	3 480 (11)	5 680 (19)	4 310 (14)	4/5	12.7
TFF3048	3 480 (11)	6 280 (21)	4 310 (14)	4/5	13.9
TFF3054	3 480 (11)	6 880 (23)	4 310 (14)	4/5	15.1
TFF3060	3 480 (11)	7 480 (25)	4 310 (14)	4/5	16.3
TFF3636	4 075 (13)	5 160 (17)	4 600 (15)	4/5	13.0
TFF3642	4 075 (13)	5 760 (19)	4 600 (15)	4/5	14.0
TFF3648	4 075 (13)	6 360 (21)	4 600 (15)	5.5/7.4	15.0
TFF3654	4 075 (13)	6 960 (23)	4 600 (15)	5.5/7.4	16.0
TFF3660	4 075 (13)	7 560 (25)	4 600 (15)	5.5/7.4	17.0
TFF3666	4 075 (13)	8 160 (27)	4 600 (15)	5.5/7.4	18.0

*1206 , 12 = drum diameter 1 200 mm (4ft), 06 = drum length 600 mm (2ft)

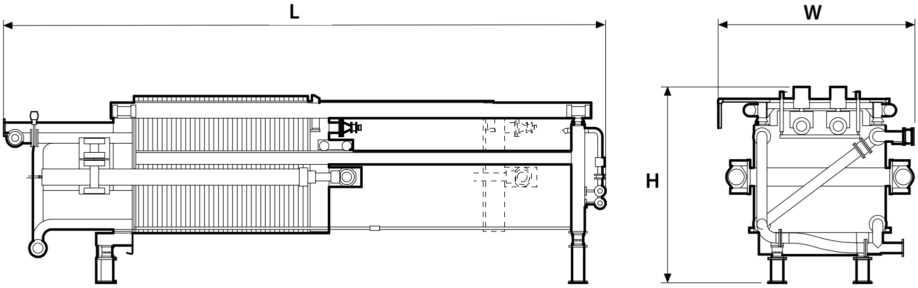
Drum dia.18 = 1 800 mm (6ft), 24 = 2 400 mm (8ft), 30 = 3 000 mm (10ft), 36 = 3 600 mm (12ft)

Drum length in ft: L (ft)- 3ft for dia 1 200

Drum length in ft: L (ft)- 4ft for dia 1 800

Drum length in ft: L (ft)- 5ft for dia 2 400, 3 000 and 3 600 mm

Pressure filter – VPA 10

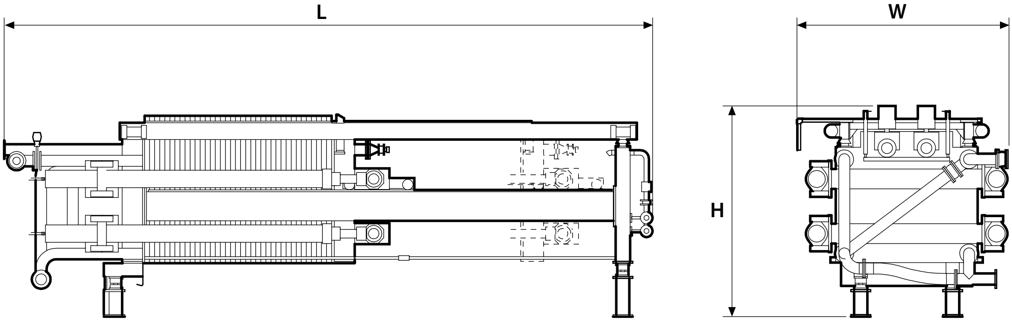


Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight (empty) ton	Power** (hydraulic motor) high kW/hp	low kW/hp
VPA 10..-12*	2 310 (91)	5 500 (217)	2 750 (108)	7.2	22/30	11/15
VPA 10..-16	2 310 (91)	6 100 (240)	2 750 (108)	8.1	22/30	11/15
VPA 10..-20	2 310 (91)	6 700 (264)	2 750 (108)	9.0	22/30	11/15
VPA 10..-24	2 310 (91)	7 300 (287)	2 750 (108)	10.0	22/30	11/15
VPA 10..-28	2 310 (91)	7 900 (311)	2 750 (108)	11.8	22/30	11/15
VPA 10..-32	2 310 (91)	8 500 (335)	2 750 (108)	12.9	22/30	11/15
VPA 10..-36	2 310 (91)	9 100 (358)	2 750 (108)	14.0	22/30	11/15
VPA 10..-40	2 310 (91)	9 700 (382)	2 750 (108)	15.1	22/30	11/15

* 1012, 10 = filter chamber size10x 10 dm (40x40 inch),12 = number of chambers

** High = high pressure stage, Low = low pressure stage

Pressure filter – VPA 15

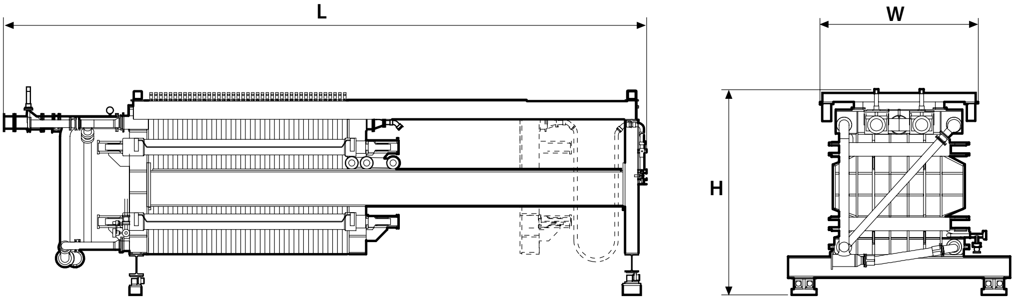


Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight (empty) ton	Power** (hydraulic motor) high kW/hp	low kW/hp
VPA 15..-16*	3 160 (125)	7 600 (299)	3 800 (150)	24.7	45/60	22/30
VPA 15..-20	3 160 (125)	7 900 (311)	3 800 (150)	26.1	45/60	22/30
VPA 15..-24	3 160 (125)	8 500 (335)	3 800 (150)	27.5	45/60	22/30
VPA 15..-28	3 160 (125)	9 100 (358)	3 800 (150)	28.9	45/60	22/30
VPA 15..-32	3 160 (125)	9 700 (382)	3 800 (150)	31.2	45/60	22/30
VPA 15..-36	3 160 (125)	10 300 (406)	3 800 (150)	32.0	45/60	22/30
VPA 15..-40	3 160 (125)	10 900 (429)	3 800 (150)	33.2	45/60	22/30
VPA 15..-46	3 160 (125)	11 800 (465)	3 800 (150)	34.3	45/60	22/30
VPA 15..-50	3 160 (125)	12 400 (488)	3 800 (150)	37.5	45/60	22/30
VPA 15..-54	3 160 (125)	13 100 (516)	3 800 (150)	39.2	45/60	22/30

* 1516, 15 = filter chamber size 15x 15 dm (60x60 inch),16 = number of chambers

** High = high pressure stage, Low = low pressure stage

Pressure filter – VPA 20

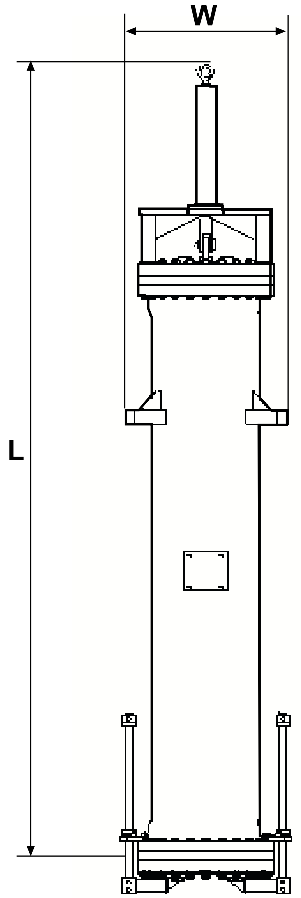


Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight (empty) ton	Power** (hydraulic motor) high kW/hp	low kW/hp
VPA 20..-20*	4 580 (180)	10 203 (402)	4 250 (167)	56.0	75/100	30/40
VPA 20..-24	4 580 (180)	11 000 (433)	4 250 (167)	59.2	75/100	30/40
VPA 20..-28	4 580 (180)	11 800 (465)	4 250 (167)	62.4	75/100	30/40
VPA 20..-32	4 580 (180)	12 600 (496)	4 250 (167)	65.6	75/100	30/40
VPA 20..-36	4 580 (180)	13 400 (528)	4 250 (167)	68.8	75/100	30/40
VPA 20..-40	4 580 (180)	14 200 (559)	4 250 (167)	72.0	75/100	30/40
VPA 20..-46	4 580 (180)	14 800 (583)	4 250 (167)	76.8	75/100	30/40
VPA 20..-50	4 580 (180)	15 600 (615)	4 250 (167)	80.0	75/100	30/40

* 2020, 20 = filter chamber size 20x 20 dm (80x80 inch), 20 = number of chambers

** High = high pressure stage, Low = low pressure stage

Tube press

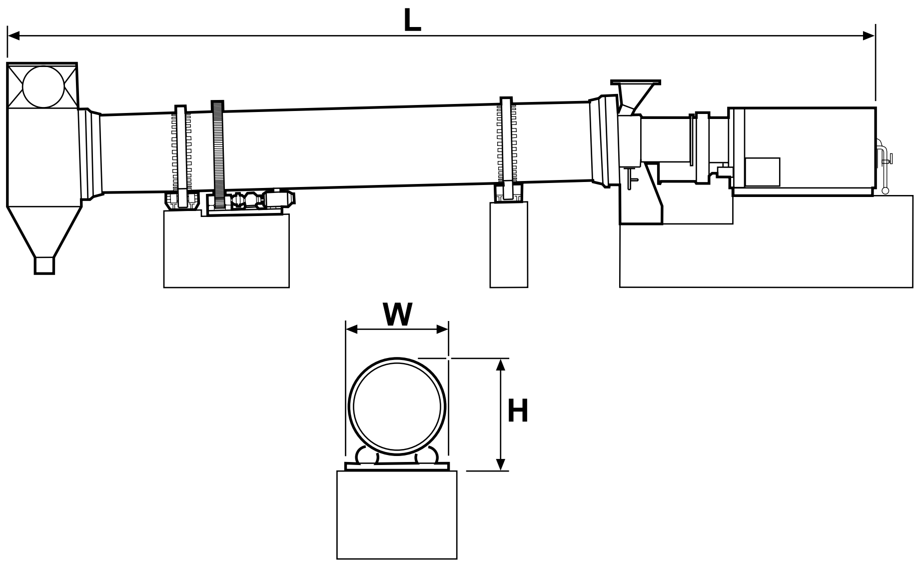


Model	L mm (inch) tube length	W mm (inch)	Weight (empty) ton	Filter area m^2 (ft^2)	Max op. pressure bar (psi)
SC 500-1,2	3 500 (138)	860 (34)	1.8	1.35 (14.5)	100 (1 450)
SC 500-1,5	3 800 (150)	860 (34)	2	1.73 (18.6)	100 (1 450)
SC-500-3,0	5 200 (205)	860 (34)	3	3,45 (37.1)	100 (1 450)

Tube press booster

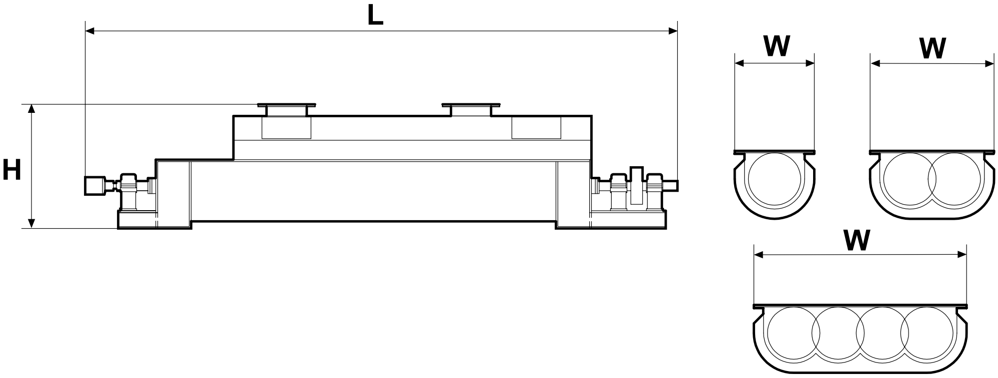
Model	Tube chamber volume cm^3 ($inch^3$)	Filter area m^2 ($ft^{2)}$)	Max. pressure bar (psi)	Installed power kW (hp)
SC 500-1,2	75 (4.6)	1,35 (14.5)	100 (1 450)	7,5 (10)
SC 500-1,5	100 (6.1)	1,73 (18.6)	100 (1 450)	7,5 (10)
SC-500-3,0	200 (12.2)	3,45 (37.1)	100 (1 450)	11 (15)

Rotary dryer – Direct heat



Diameter m (ft)	Dryer length m (ft)	H m (ft)	L m (ft)	W m (ft)	Weight, dryer only ton
1.5 (5.0)	8.0 (26.0)	3.2 (10.5)	15.0 (49.2)	2.0 (7.0)	4.0
1.5 (5.0)	10.5 (34.5)	3.2 (10.5)	17.5 (57.4)	2.0 (7.0)	4.6
1.5 (5.0)	12.5 (41.0)	3.2 (10.5)	19.5 (64.0)	2.0 (7.0)	5.2
2.0 (7.0)	11.0 (36.1)	4.3 (14.1)	20.3 (66.6)	2.6 (8.5)	9.6
2.0 (7.0)	14.0 (45.9)	4.3 (14.1)	23.3 (76.4)	2.6 (8.5)	12.0
2.0 (7.0)	17.0 (55.8)	4.3 (14.1)	26.3 (86.3)	2.6 (8.5)	12.4
2.5 (8.2)	13.5 (44.3)	5.4 (17.7)	25.2 (82.7)	3.3 (10.8)	18.6
2.5 (8.2)	17.5 (57.4)	5.4 (17.7)	29.2 (95.8)	3.3 (10.8)	21.6
2.5 (8.2)	21.0 (68.9)	5.4 (17.7)	32.7 (107.3)	3.3 (10.8)	24.2
3.0 (10.0)	16.6 (54.5)	6.5 (21.3)	30.5 (100.0)	3.9 (12.8)	32.6
3.0 (10.0)	21.0 (68.9)	6.5 (21.3)	35.0 (114.2)	3.9 (12.8)	37.3
3.0 (10.0)	25.6 (84.0)	6.5 (21.3)	39.5 (129.6)	3.9 (12.8)	42.1
3.5 (12.0)	19.0 (62.3)	7.5 (24.6)	35.3 (115.8)	4.6 (15.1)	51.3
3.5 (12.0)	24.5 (80.4)	7.5 (24.6)	40.8 (133.9)	4.6 (15.1)	59.3
3.5 (12.0	29.5 (96.8)	7.5 (24.6)	45.8 (150.3)	4.6 (15.1)	66.6
4.0 (14.0)	22.0 (72.2)	8.6 (28.2)	40.7 (133.5)	5.2 (17.1)	77.2
4.0 (14.0)	28.0 (91.9)	8.6 (28.2)	46.7 (153.2)	5.2 (17.1)	88.6
4.0 (14.0)	34.0 (11.5)	8.6 (28.2)	52.7 (172.9)	5.2 (17.1)	99.9

Indirect heat screw dryer – Holo-Flite®



Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight ton	Power kW/hp
S 710 - 4*	335 (13)	4 140 (163)	310 (12)	0.8	0.55 - 1.1/075 - 1.5
S 714 - 4	335 (13)	5 360 (211)	310 (12)	1.0	0.55 - 1.1/0.75 - 1.5
D 710 - 4	335 (13)	4 170 (164)	460 (18)	1.2	0.55 - 2.2/0.75 - 3
D 714 - 4	335 (13)	5 390 (212)	460 (18)	1.5	0.55 - 2.2/0.75 - 3
S 1210 - 5	565 (22)	4 270 (168)	460 (18)	1.3	1.1 - 4/1.5 - 5
S 1218 - 5	565 (22)	6 710 (264)	460 (18)	1.9	1.1 - 4/1.5 - 5
D 1210 - 5	565 (22)	4 550 (179)	720 (28)	2.3	1.5 - 5.5/2 - 7.5
D 1218 - 5	565 (22)	6 990 (275)	720 (28)	2.5	1.5 - 5.5/2 - 7.5
S 1616 - 6	641 (25)	6 200 (244)	560 (22)	2.3	2.2 - 5.5/3 - 7.5
S 1618 - 6	641 (25)	6 810 (268)	560 (22)	2.4	2.2 - 5.5/3 - 7.5
D 1616 - 6	641 (25)	6 510 (256)	890 (35)	3.8	2.2 - 7.5/3 - 10
D 1618 - 6	641 (25)	7 120 (280)	890 (35)	4.2	2.2 - 7.5/3 - 10
S 2414 - 6	881 (35)	5 720 (225)	770 (30)	3.3	2.2 - 7.5/3 - 10
S 2424 - 6	881 (35)	8 770 (345)	770 (30)	5.1	4 - 11/5 - 15
D 2414 - 6	881 (35)	6 150 (242)	1 220 (48)	6.4	4 - 11/5 - 15
D 2424 - 6	881 (35)	9 200 (362)	1 220 (48)	6.9	5.5 - 15/7.5 - 20
Q 2414 - 6	881 (35)	6 760 (266)	2 160 (85)	12.0	7.5 - 30/10 - 40
Q 2424 - 6	881 (35)	9 200 (262)	2 160 (85)	17.0	7.5 - 37/10 - 50
S 3020 - 7	1 092 (43)	8 260 (325)	970 (38)	10.2	5.5 - 15/7.5 - 20
S 3028 - 7	1 092 (43)	10 700 (421)	970 (38)	13.0	7.5 - 22/10 - 30
D 3020 - 7	1 092 (43)	8 740 (344)	1 600 (63)	16.8	7.5 - 18/10 - 25
D 3028 - 7	1 092 (43)	11 180 (440)	1 600 (63)	21.6	11 - 22/15 - 30
Q 3020 - 7	1 092 (43)	8 740 (344)	2 720 (107)	33.2	15 - 37/20 - 50
Q 3028 - 7	1 092 (43)	11 180 (440)	2 720 (107)	42.9	8.5 - 55/25 - 75

*S 710 - 4, S = single screw, 7 = screw diameter, inch, 10 = screw length 10ft, – 4= screw pitch 4 inch

D = double screw, Q = Quadruple screw

Introduction

In the process stages of size reduction, size control, enrichment and upgrading the values of the minerals or rock are brought to their optimum.

We will now look closer into what forms these process stages into a continuous operation.

With materials handling we understand the technologies for moving the process forward with a minimum of disturbances in capacity and flow. These technologies are:

- Loading and unloading
- Storing
- Feeding
- Transportation

For practical reasons we are using the term materials handling for dry processes only.

Of course, the technologies for moving a wet process forward are equally important. We call this slurry handling and the subject will be covered in section 8!

Loading and unloading

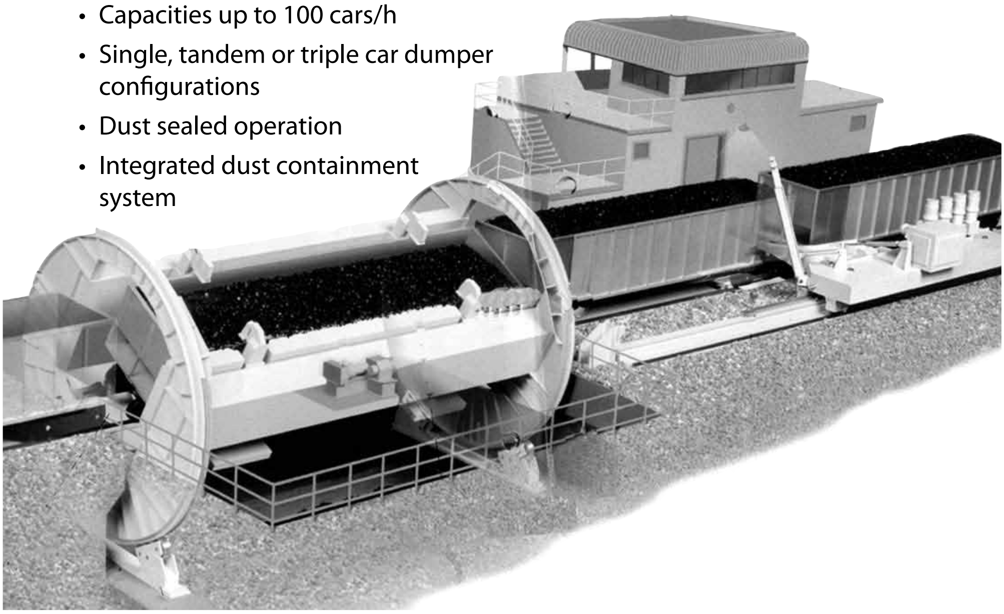
In this section we will only cover loading and unloading conditions related to rail cars and sea vessels (high capacity conditions)

Railcar dumpers

Rail is the most common inland way of hauling large quantities of raw ore, upgraded minerals and coal etc, and unit trains up to 200 rail cars have to be unloaded during shortest possible time observing safety and environmental requirements.

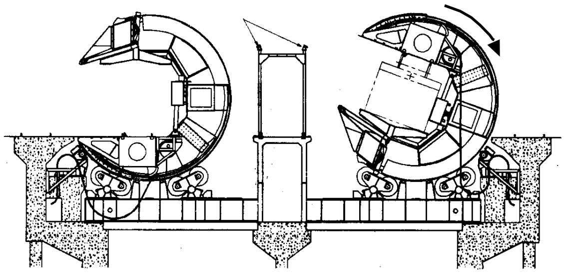
Railcar dumper – rotary type

- Reliable and proven design
- Capacities up to 100 cars/h
- Single, tandem or triple car dumper configurations
- Dust sealed operation
- Integrated dust containment system



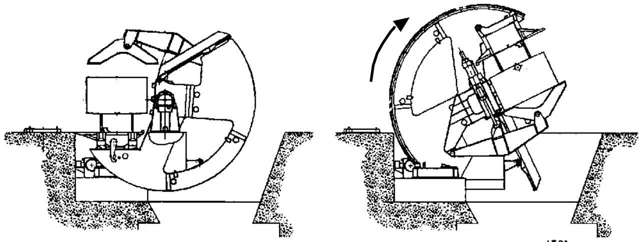
Railcar dumper – "Crescent" design

- Low in energy (rotation axis close to gravity centre of loaded cars).
- Hopper position close to rail track
- Hydraulic car clamping system (closed loop)
- Rate of unloading 60 cars/h and line



Rail car dumper - Rotaside® type

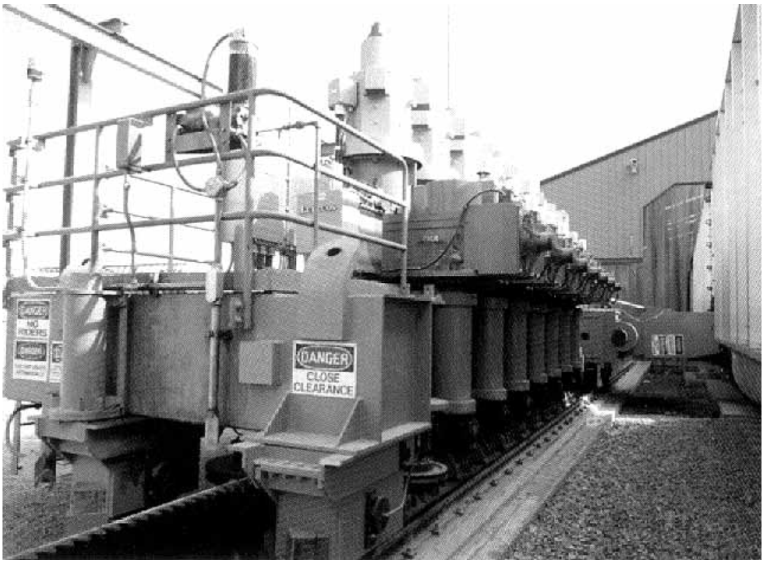
- Hopper position at the side of rail track gives simplified installation.
- Proven and simple design
- Low in maintenance
- Rate of unloading 12 cars/h



Train positioners

A train positioner has to have a high utilisation capability to enable it to precisely position blocks of 1-10 railcars up to heavy train in excess of 200 railcars using a preset velocity pattern. In duties ranging from 5 to 90 cars unloading per hour there are a number of options for Positioners.

System	Unloading duty
Side arm system (rack and pinion drive), see picture nest page	Heavy 100 car, or more, trains at high capacity
Reversible hydraulic indexer system	25 ton pull, 5-15 cars/hour
Wire rope car pullers	From 2-12 ton pull at variable speeds
Vertical capstan system	Manual operation - limited pull and distances
Double side arm system (Gemini®)	For very high unloading rates



Side Arm System

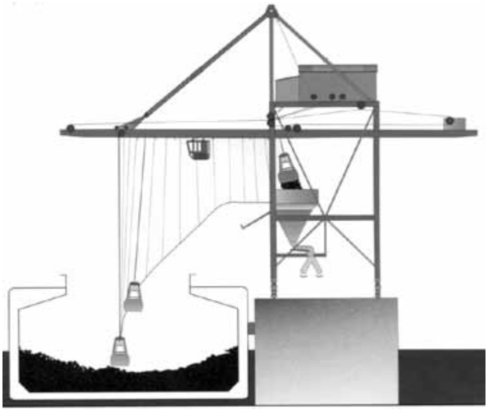
Unloaders

Grab unloader

Grab unloading is a classical way of unloading ships and barges. This concept is still valid but has undergone a massive development.

Today's high speed grab unloaders feature short duty cycles and large capacity buckets for greater unloading volume and efficiency.

- Reliable equipment
- Low operating costs
- ABC system (Automatic Bucket Control) with grab control on closing,
  filling, loading and positioning
- Integrated dust containment system



Unloading capacities (typical)

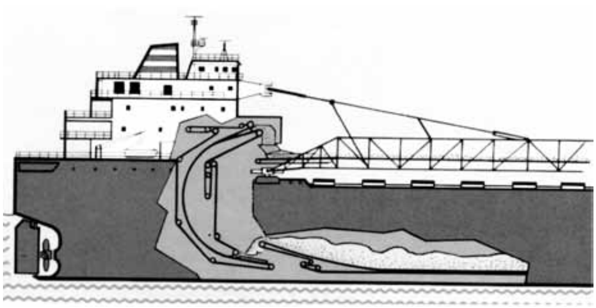
Grab capacity coal 6 to 25 tonnes
Grab capacity iron ore 6 to 40 tonnes
Duty cycle: 36 to 45 sec
Free digging rate coal 500 to 2000 tonnes/h
Free digging rate iron ore 500 to 3 400 tonnes/h

Continuous unloading

For high capacity unloading applications (for faster ship or barge turnarounds) continuous unloading is an option.

CBU (Continuous Barge Unloaders) and **CSU** (Continuous Ship Unloaders) can be manual, semi automatic or fully automatic "Self-Unloading" systems of type

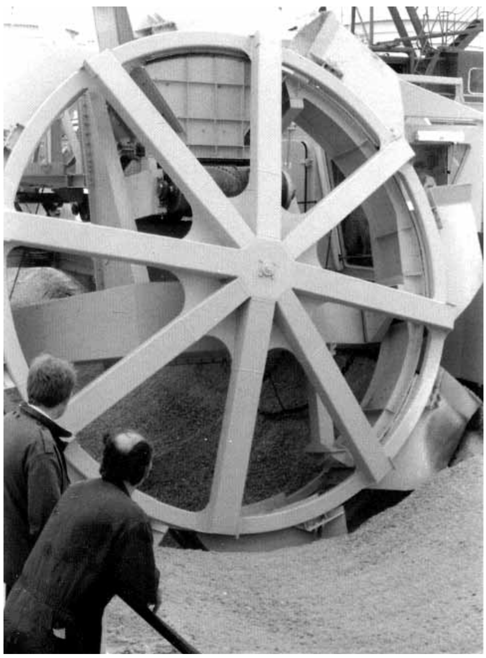
- Inclined bucket elevator
- Loop belt system
- Vertical conveying system see also conveying, page 7:10 and 7:21
- Capacities up to 6000 tonnes per hour
- Operator friendly, less polluting operation (dust & noise)
- Long service life
- Flexible in sizes and capacities



Loop Belt System

CSU- bucket wheel type

- Optimal for unloading sea dredged sand or other suitable bulk material.
- Varying number of buckets to suit vessel size (1400-4500m^3)
- Discharge rate to shore 1200 m^3/h
- Bucket wheel protected in "sea position"



Storage buffering

Buffer storage is some time called “the key to processing”, meaning that without a proper storage throughout a continuous rock or mineral process, production up-time will be gone.

Storage in operation

The main purpose of storage is to smooth out:

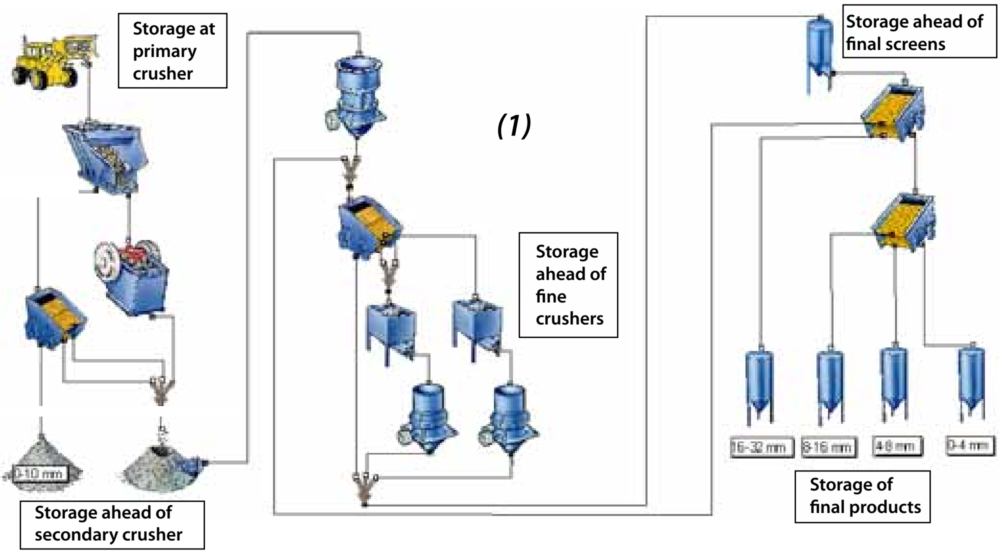
- Different production rates (cont cyclic)
- Shift variations
- Interruptions for repair
- Size variations
- Flow variations
- Variations in mineral value (metal content etc.)

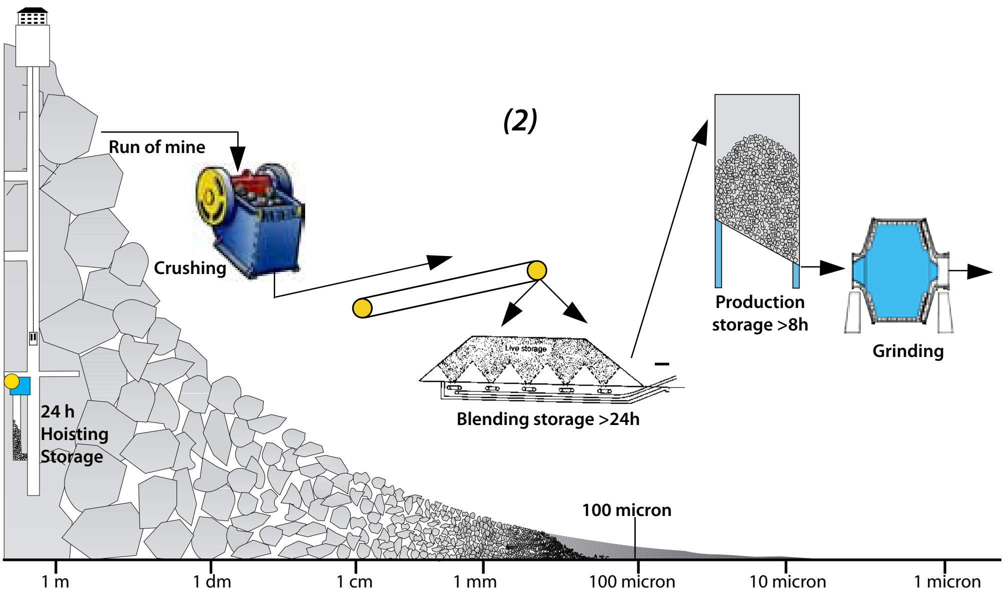
Storage of rock (1)

A matter of material flow (retention time)

Storage of ore and minerals (2)

A matter of material flow (retention time) and blending





Stacker reclaimer

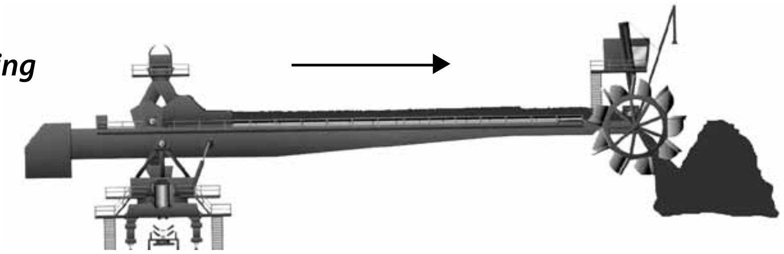
Large storages with high capacities for feeding mineral processing plants, combustion plants (coal),ships etc. cannot use loader and truck technology. Here effective stacker reclaimers are the only option

Trenching type stacker reclaimers are used for low-volume, high active storage capacities between 30 000 and 60 000 tons. Reclaiming operations are accomplished by longitudinal pass through the pile.
Stacking and reclaiming rate usually vary from 2 000 - 4 500 tons per hour.

Slewing type stacker reclaimers are typically used where large quantities of material must be readily available, where blending of material grades is required and where yard length is limited.

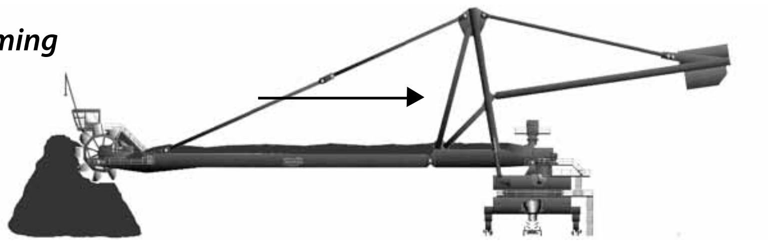
Stacking and reclaim rate up to 6000 tons/h for coal and 8 000-10 000 tons/h for iron ore.

Stacking



Straight-through boom configuration max length 38 m

Reclaiming



Masted boomconfiguration length over 38 m

Scraper reclaimer

These reclaimers are designed to handle materials as (typical) phosphate, coal, sulphur, fertilizers and woodchips servicing parallel storage piles from booms mounted on either or both sides of the machine.

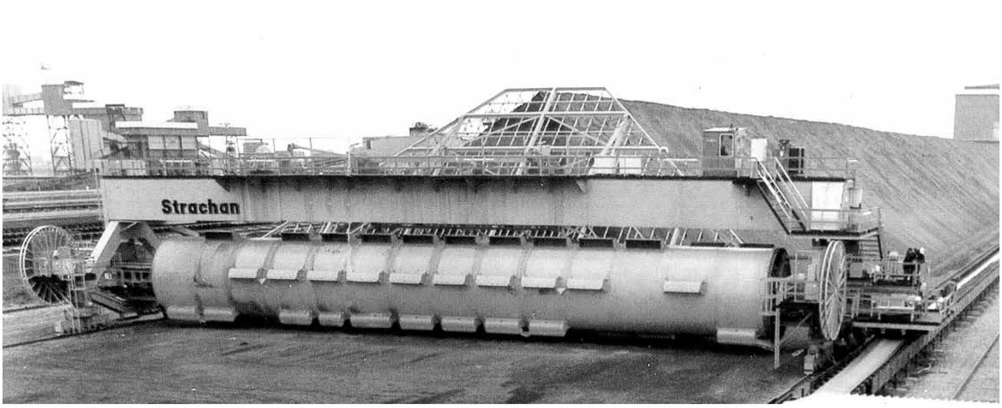
They incorporate the cost advantage of "back stacking" (the ability to reverse boom flight direction up the storage pile).

- Capacities up to 4 000 tons /h
- Single, twin and double-boom options

Barrel reclaimer for "Full cross section recovery"

The optimal machine reclaiming from a blending pile is the barrel reclaimer. The heart of the machine is a rotating barrel fitted with a large number of buckets. Material collected in the buckets is discharged into an internal conveyor feeding a downstore conveyor running alongside the pile.

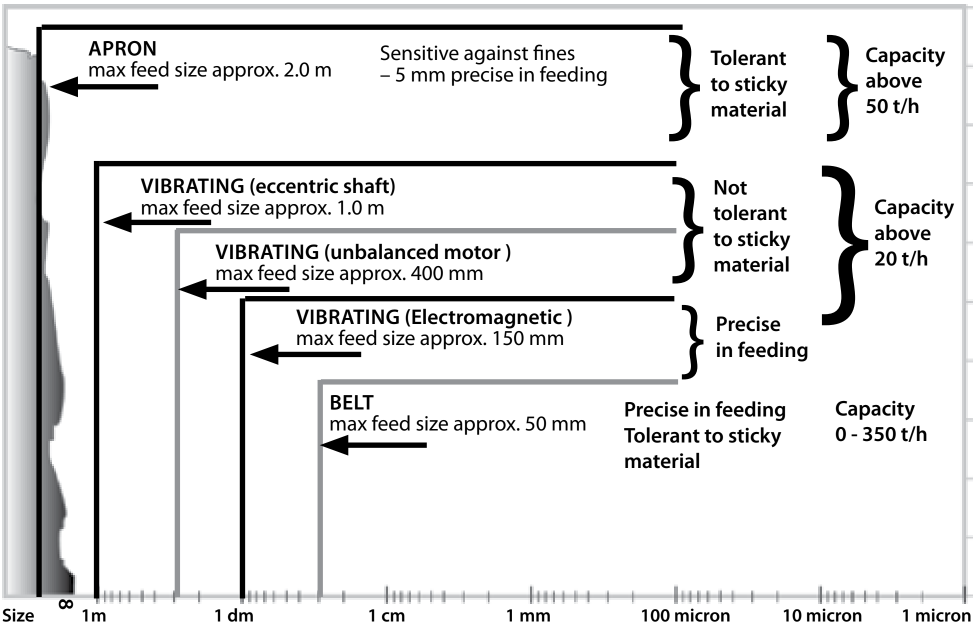
- Very robust a reliable design for high capacities · Variable speed for differing reclaim rates
- Automatic operation (optional)



Feeding

Feeders are necessary whenever we want to deliver a uniform flow of dry or moist fractions of rock or minerals.
Generally they are categorised by the size of material to be fed, see below.

Feeding vs Feed sizes

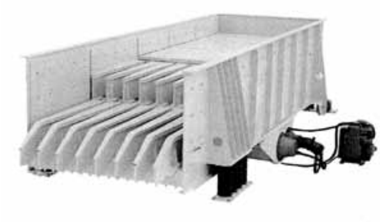


Primary feeders (For installation under feed bumper hoppers & rail car dumpers)

Capacity
300 - 12 000 t/h

Apron

Capacity
300 - 1 200 t/h



Vibrating

"In circuit" feeders (For installations under ore stockpiles, bins & crusher dischargers)

Capacity
50 - 3 000 t/h

Apron

Capacity
80 - 350 t/h

Belt

Capacity
30 - 600 t/h

Vibrating (eccentric shaft)

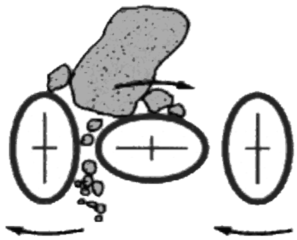
Capacity
55 - 460 t/h

Vibrating (unbalance motor)

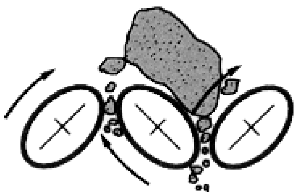
See also data sheets 7:14 - 7:20.

Wobbler feeders

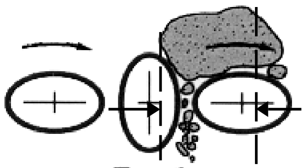
Feeding and scalping - when things get sticky!



Openings between eliptic bars remain constant



Fines, mud or dirt drop through the openings



Oversize moves forward

Size range

- See apron and table feeders

Applications

- Wet and sticky for:

  metallic, industrial and construction minerals

Pitch (scalping)

- Fixed and adjustable

Capacity range

- Up to 3 500 t/h (5 sizes)

See data sheet 7:19.

Conveying

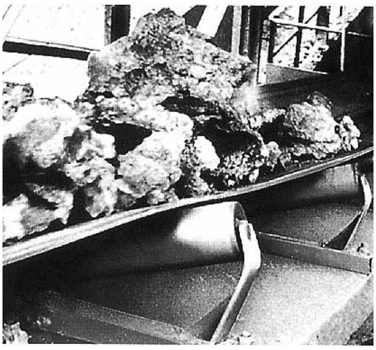
In this section we will focus on mineral mass flow by conveying, by far the dominating method when transporting dry material in a mineral processing operation.

Conveyor – general

Conveyors are selected from 4 key parameters:
- Tonnage
- Material and size
- Inclination
- Distance

We also must consider wear in operation and the environment (dust, heat, oil or chemicals etc)

Wear Part



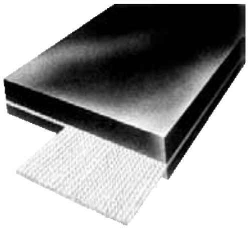
Tonnage and size

Distance

Inclination

Conveyor belts

Although the conveyor structure is important, most of the conveying work falls back on the conveyor belt, exposed to the material.
Flat belts are dominating, conveying up to a lifting or lowering angle of approx. 18°. Depending on duty the belts are reinforced with different materials (Polyester/ Polyamide, Aramid and Steel Cords) , protected by top and bottom covers.
The polymer material in the belt (mainly rubber) is selected according to appearance of heavy wear, heat, flames, oil etc.

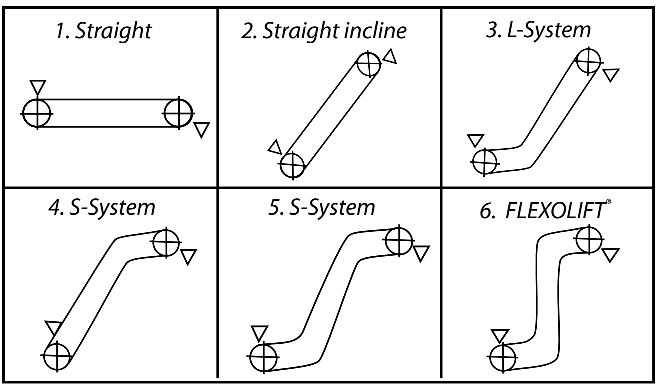

Profile belts must be used when lifting angle is exceeding 18° . With a limitation of approx. 30° different profiles of the top cover must be selected to prevent bulk material or unit loads from sliding backward. Otherwise reinforcement and material selection criteria are similar as for flat belts above.

See data sheet 7:20

Conveying systems

Vertical conveyor system "When space is critical"

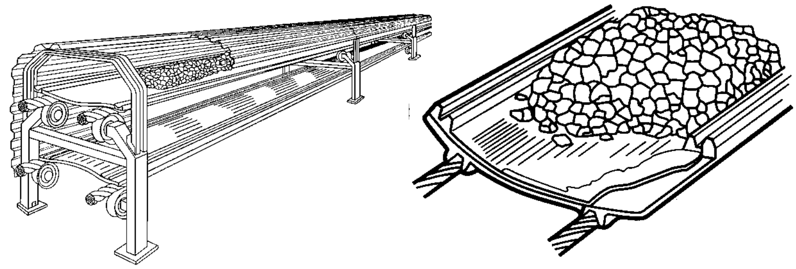
Vertical conveying systems normally is the only option when lifting angle is exceeding 30°. The system is very flexible and gives a number of transportation solutions when space and lifting angles are critical.



See data sheet 7:21

Cable Belt® conveyor system "When distance is critical"

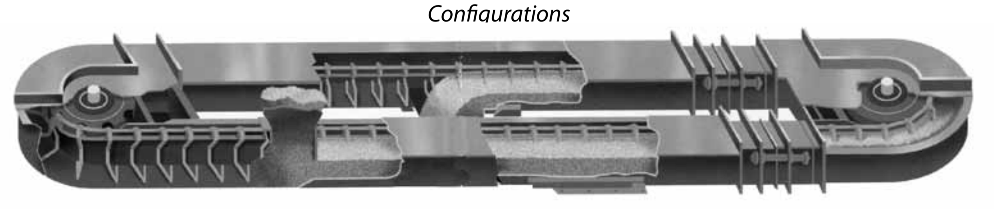
Conveying with high capacities over long distances means that conventional conveying systems are out. An alternative to truck hauling is Cable Belt® conveyors which become competitive from, say, 500 m and upwards taking on capacities from 500 up to 5000t/h.

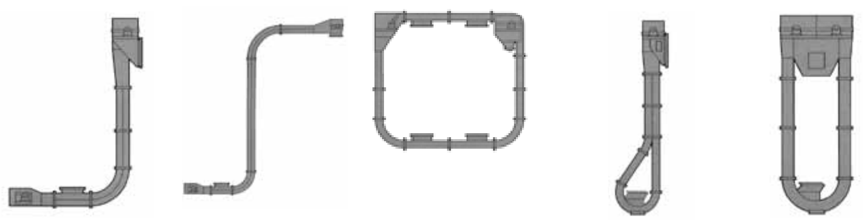


En-masse conveying system "When dust and emissions are critical"

Transportation of free-flowing bulk material with or without gas emissions or high temperatures places special demands on the conveyor system. En-Masse conveying system is aiming at gentle handling and a closed material flow system for transportation in all directions. Material moves in a solid placid column along with the conveying chain equipped with different types of conveying flights depending on duty.

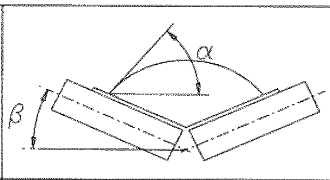
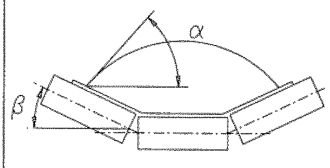
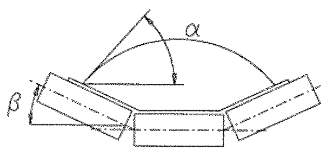
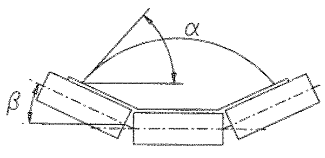
Configurations





Conveyor capacities

In order to estimate the capacity and max. recommended inclination of a conventional conveyor the figures below can be of use.

Conveyor capacity in m³ per hour by belt speed 1 m/sec							
Angle of idler sets ß		Material-angle α	Belt width				
			500	650	800	1000	1200
25°		0°	61	-	-	-	-
		5°	72	-	-	-	-
		10°	84	-	-	-	-
		15°	96	-	-	-	-
		20°	108	-	-	-	-
		25°	122	-	-	-	-
		30°	136	-	-	-	-
15°		0°	-	60	95	162	239
		5°	-	85	134	226	334
		10°	-	110	173	291	430
		15°	-	136	213	358	530
		20°	-	163	256	428	634
		25°	-	192	300	503	745
		30°	-	223	350	585	865
25°		0°	-	96	151	256	378
		5°	-	119	187	316	466
		10°	-	142	224	376	555
		15°	-	166	261	439	647
		20°	-	192	300	504	743
		25°	-	218	343	574	846
		30°	-	248	388	649	957
30°		0°	-	112	175	300	442
		5°	-	134	209	356	526
		10°	-	156	244	413	610
		15°	-	179	280	472	698
		20°	-	203	318	535	790
		25°	-	229	358	600	887
		30°	-	257	400	673	993

Volume weight and angle of inclination

The capacity and the inclination of the conveyors depend on the character of the material to be conveyed.

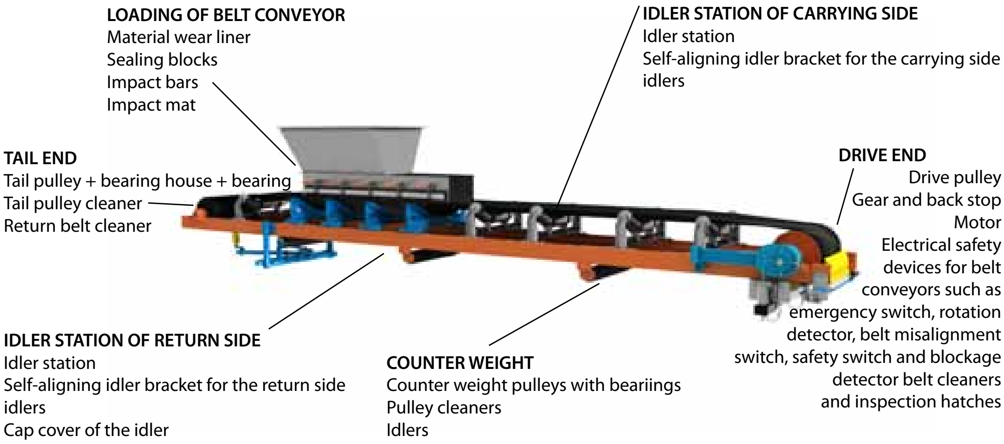
Material	Volume weight in tons/cbm.	Max. inclination in degrees
Bauxit, crushed	1.3	18
Briquettes, normal	0.7-0.82	15-18
Briquettes, oviform	0.7-0.82	12-13
Cement	1.2-1.6	20-22
Cement clinkers	1.2-1.3	18
Chalk, crushed	1.2-1.4	18
Charcoal	0.2-0.25	18
Clay, lumps, moist	1.5-1.7	18
Clinkers	1.2-1.5	18
Coal, bituminous, fine	0.67-0.75	15-20
Coal, bituminous, moist	0.67-0.75	18-20
Coal, pit coal	0.7-0.8	18-20
Coke	0.4-0.67	18-20
Concrete, moist	1.6-2.2	24-27
Dolomit stone	1.4-1.6	18
Earth, dry	1.2-1.3	20
Earth, moist	1.5-1.7	23
Fertilizers	0.9-1.2	20
Granite, broken	1.5-1.6	18
Gravel, dry	1.45-1.55	15
Gravel, moist	1.6-1.75	18
Gypsum, lumps	1.4-1.6	18
Gypsym, powder	0.95-1.05	23
Iron ore, dry	2.5	18-20

Material	Volume weight in tons/cbm.	Max. inclination in degrees
Iron ore, moist	3.5	20-22
Iron ore, primary crushed	2.0-3.0	18
Iron ore, secondary crushed	2.4-3.5	22
Kaolin	1.0	19
Lime, lumps	1.05-1.15	23
Lime, powder	1.0-1.2	21-23
Limestone, crushed	1.3-1.5	18
Manganese ore	2.0-2.25	18
Marble, crushed	1.5-1.6	18
Peat	0.4-0.6	16
Potash	1.1-1.6	18
Pyrites, crushed	2.2	20
Rubble	1.7-2.1	20-22
Salt, fine	1.1-1.3	15
Salt, rock salt	1.0-1.2	18-24
Sand, dry	1.5	15
Sand, moist	2.0	22
Sinter	1.4	12
Sinter, coal sinter	3.5	-
Slag, coarse	0.75-0.9	18
Slate, crushed	1.2-1.35	18-20
Soot	0.4-0.8	-
Splinters	0.2-0.48	22-24
Stone, crushed	1.5-1.6	18

Conveyor – More than a rubber belt

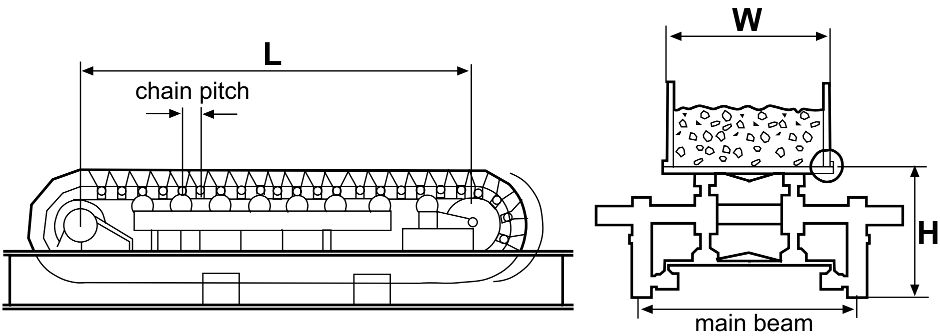
The conveyors are the working horses of every dry processing plant in mineral processing, of key importance to keep the process flow stable.

Pictures below indicate the vital parts of the conveyor and the critical service points to be checked regularly for reliable operation.



Conveyor – service points

Feeder – Apron



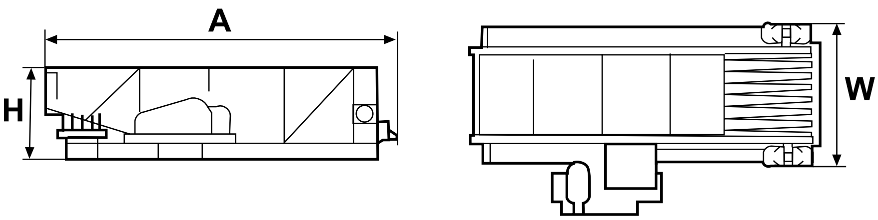
Model Width (pan) mm/inch	AF 4 Weight* ton/lbs	AF 5 Weight* ton/lbs	AF 8 Weight* ton/lbs	AF 10 Weight* ton/lbs	AF 12 Weight* ton/lbs	AF 14 Weight* ton lbs	AF 16 Weight* ton/lbs	AF 18 Weight* ton/lbs
610/24	4.1/9 280							
762/30	4.3/9 734	5.1/11 580						
914/36	4.6/10 300	5.8/1 306						
107/42	4.8/10 840	6.3/14 020						
1219/48	5.6/12 610	6.6/14 850	8.6/19 160					
1372/54	6.0/13 430	7.1/15 840	9.1/20 440	11.8/26 470				
1524/60	6.5/14 480	7.5/16 770	9.9/22 080	12.7/28 340	17.1/38 360			
1829/72	7.6/16 930	8.8/19 600	11.5/25 870	13.9/31 080	18.4/41 120	22.7/50 800		
2134/84	8.1/18 070	9.8/22 060	12.8/28 630	16.2/36 260	19.8/44 330	25.3/56 780	51.1/11 4400	
2438/96	8.8/19 650	11.4/25 450	14.2/31 850	17.5/39 120	21.1/47 210	27.0/60 550	56.1/12 5630	
2743/108	9.8/21 860	12.5/27 960	15.1/33 750	18.5/41 480	24.3/54 540	32.0/71 770	62.3/13 9650	66.3/14 6220
3048/120	10.7/24 010	13.4/29 950	16.1/36 100	21.3/47 710	25.6/57 442	32.9/73 730	63.9/14 3240	65.9/14 7660
3353/132						34.6/77 540	66.8/14 9730	68.7/15 3880

*Approx, weight of an Apron feeder, length 3 m (10ft) excl. load, skirts, chutes etc. For each additional feet (or 0.3 m) add 7 % in weight.

Feed size approx, 50% of pan width. Capacity range 50 - 12 000 t/h

Model	AF 4	AF 5	AF 8	AF 10	AF 12	AF 14	AF 16	AF 18
Chain pitch mm (inch)	140 (5.5)	171 (6.8)	202 (8.0)	216 (8.5)	229 (9.0)	260 (10.3)	260 (10.3)	317 (12.5)
Main beam width mm (inch)	Width pan +356 (14)	Width pan +457 (18)	Width pan +457 (18)	Width pan +457 (18)	Width pan +508 (20)	Width pan +584 (23)	Width pan +584 (23)	Width pan +610 (24)
Feeder length	suitable	suitable	suitable	suitable	suitable	suitable	suitable	suitable
Height (H) mm (inch)	889 (35)	1 041 (41)	1 268 (50)	1 372 (54)	1 625 (64)	1 753 (69)	1 803 (71)	on site demands

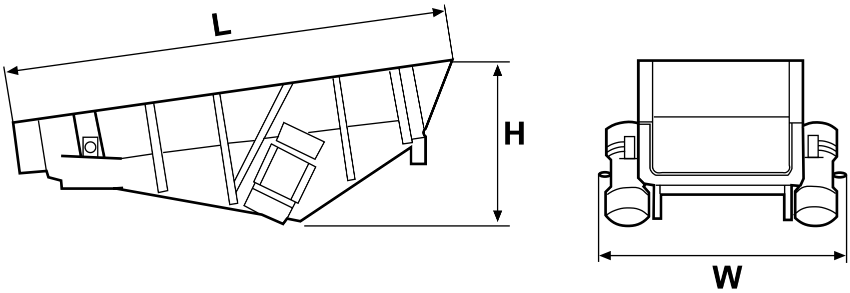
Feeder – Vibration (linear motion)



Model (VMHC)*	H mm (inch)	L mm (inch)	W mm (inch)	Weight ton	Capacity ton/h	Max. size mm (inch)
48/12	1 300 (51)	5 200 (205)	2 050 (81)	6.8	280 - 400	650 (26)
48/15	1 300 (51)	5 160 (203)	2 350 (93)	10.0	420 - 600	850 (33)
60/10	1 870 (74)	6 800 (268)	1 860 (73)	13.2	250 - 350	500 (20)
60/12	1 870 (74)	6 800 (268)	2 060 (81)	14.0	280 - 400	650 (26)
60/15	1 950 (77)	6 800 (268)	2 380 (94)	15.0	420 - 600	850 (33)
60/18	1 650 (65)	6 550 (258)	2 680 (106)	16.5	550 - 800	1 000 (39)
72/21	2 250 (89)	7 800 (307)	2 980 (117)	21.5	700 - 1200	1 000 (39)

* One, two or three grizzly sections as option depending on size

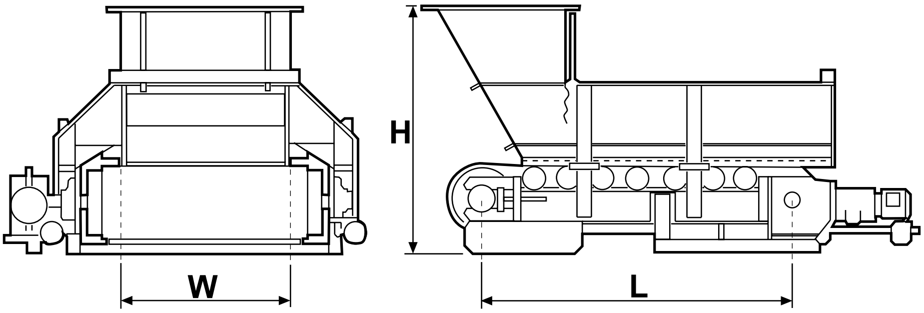
Feeders – Unbalanced motor



Model (VMO)	H mm (inch)	L mm (inch)	W mm/inch ton	Weight ton/h*	Capacity*
15/6.5 - 3014	780 (31)	1 770 (70)	1 260/50	0.5	30 - 160
17.5/8 - 40	830 (33)	2 050 (81)	1 410/56	0.7	40 - 210
20/10 - 40	950 (37)	2 300 (91)	1 670/66	1.1	60 - 320
30/10 - 40	1 000 (39)	3 300 (130)	1 670/66	1.5	60 - 300
30/10 - 45	1 000 (39)	3 300 (130)	1 720/68	1.7	100 - 500
20/12.5 - 45	950 (37)	2 300 (91)	1 030/41	1.3	90 - 550
25/12.5 - 45	1 050 (41)	2 790 (110)	1 970/76	1.8	90 - 550

* Capacity at 8° inclination. feed moist sand 1-7mm (16-3 mesh)

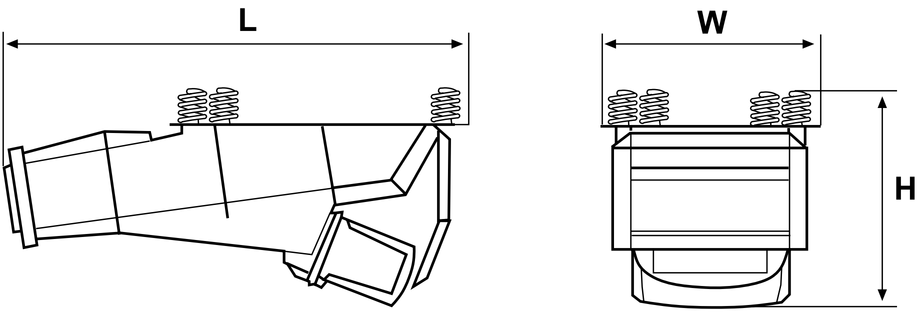
Feeder – Belt



Model (VMO)	H mm (inch)	L mm (inch)	W mm (inch)	Weight ton	Capacity* ton/h
10/4.5	1 050 (41)	1 000 (39)	450 (18)	0.64	180
15/4.5	1 050 (41)	1 500 (59)	450 (18)	0.71	180
20/4.5	1 050 (41)	2 000 (78)	450 (18)	0.80	180
10/6	1 200 (47)	1 000 (39)	600 (24)	0.77	250
15/6	1 200 (47)	1 500 (59)	600 (24)	0.89	250
20/6	1 200 (47)	2 000 (78)	600 (24)	0.94	250
10/8	1 200 (47)	1 000 (39)	800 (31)	0.98	350
15/8	1 200 (47(	1 500 (59)	800 (31)	1.10	350
20/8	1 200 (47)	2 000 (78)	800 (31)	1.20	350

* Max feed size 50 mm (2”)

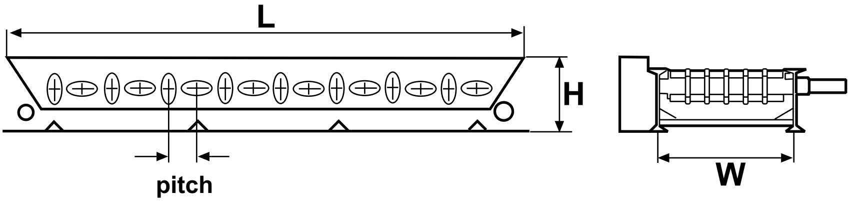
Feeder – Electromagnetic



Model (VMM)	H mm (inch)	L mm (inch)	W mm (inch)	Weight kg (lb)	Max. capacity* ton/h
6/4-8D	455 (18)	825 (32)	510 (20)	60 (130)	55
11/4-20D	570 (23)	1 260 (50)	540 (20)	115 (255)	60
8/5.6-20D	650 (26)	1 120 (44)	660 (27)	120 (265)	110
8/5.6 50D	765 (30)	1 120 (44)	660 (27)	195 (425)	150
14/5.6 50D	765 (30)	1 630 (64)	780 (30)	280 (615)	140
12/8-50D	835 (33)	1 580 (60)	950 (37)	330 (730)	230
12/8-100D	1 060 (42)	1 600 (63)	950 (37)	440 (975)	270
18/8-100D	1 060 (42)	2 175 (86)	970 (38)	560 (1235)	270
18/8-2x100D	1 430 (56)	2 170 (85)	970 (38)	795 (1750)	310
14/10-100D	1 105 (44)	1 960 (77)	1 210 (48)	580 (1280)	410
14/10-2x100D	1 485 (58)	1 960 (77)	1 180 (46)	815 (1795)	460
22/10-2x100D	1 485 (58)	2 710 (106)	1 210 (48)	1 170 (2580)	390
18/12.5-2x100D	1 430 (56)	2 395 (94)	1 435 (56)	1 150 (2535)	460

* Capacity calculated at bulk weight 1600 kg/m^3 (100 ^{3}lb/ft) and size of feed 16-25mm (0.75-1"), inclination 8°, feeder encapsulated. (Non-encapsulated will increase capacity 10%)

Feeder – Wobbler



Pitch 175 (7") Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight ton	Power kW/hp
609 (24)–14*	429 (17)	2 829 (111)	727 (29)	2.0	5.6/7.5
914 (36)–14*	429 (17)	2 829 (111)	1 032 (41)	2.3	7.5/10.0
1219 (48)-18	429 (17)	3 527 (139)	1 337 (53)	3.1	7.5/10.0
1372 (54)-18	429 (17)	3 527 (139)	1 489 (59)		7.5/10.0
* also with 16 and 18 bars	same	add 349 (14) for each double bar	same	add 10% for each double bar	same

*** 609(24) –14,** 609 (24) = width of wobble bars – 14 number of bars.

Max feed size 406 mm (16")

Pitch 229 (9") Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight ton	Power kW/hp
914 (36)-16*	648 (26)	4 178 (165)	1 105 (44)	5 4	11/15
1219 (48)-16*	648 (26)	4 178 (165)	1 410 (56)	6 0	11/15
1372 (54)-16*	648 (26)	4 178 (165)	1 562 (62)	6 7	15/20
1524 (60)-16*	648 (26)	4 178 (165)	1 715 (68)	7 7	15/20
1829 (72)-16*	648 (26)	4 178 (165)	2 019 (80)	8 3	15/20
* also with18. 20 and 22 bars	same	add 457 (18) for each double bar	same	add 10% for each double bar	same

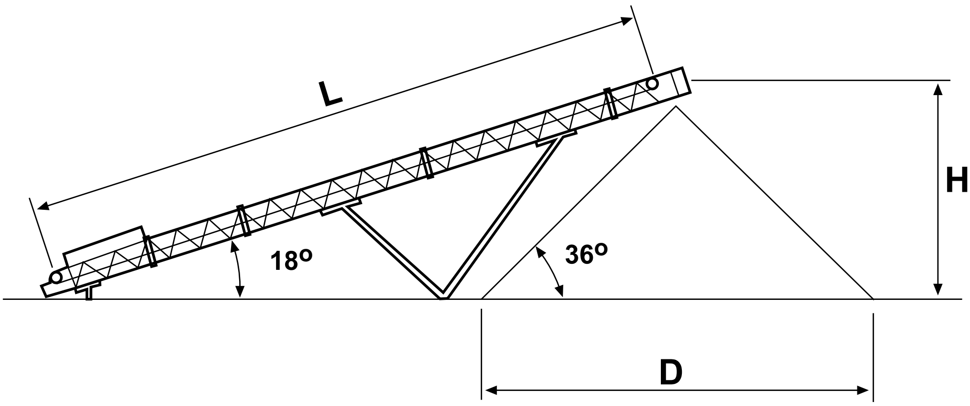
Max feed size 762 mm (30")

Pitch 292 (11.5") Model	H mm (inch)	L mm (inch)	W mm (inch)	Weight ton	Power kW/hp
914 (36)-16*	648 (26)	5 131 (202)	1 105 (44)	6.6	15/20
1219 (48)-16*	648 (26)	5 131 (202)	1 410 (56)	8.1	15/20
1372 (54)-16*	648 (26)	5 131 (202)	1 562 (62)	8.4	15/20
1524 (60)-16*	648 (26)	5 105 (201)	1 715 (68)	8.6	15/20
1829 (72)-16*	648 (26)	5 105 (201)	2 019 (80)	9.2	15/20
* also with18. 20 and 22 bars	same	add 584(23) for each double bar	same	add 10% for each double bar	same

Max feed size 762 mm (30")

Wobbler feeder also available with 318mm(12.5") pitch and 368mm(14.5") pitch for feed size up to 1900mm (75").

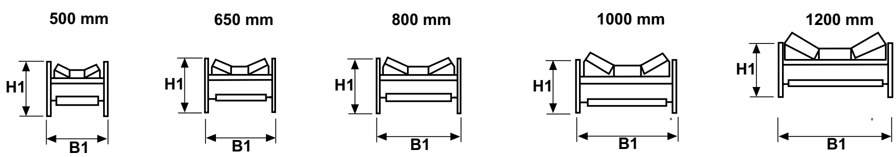
Conveyor – Standard belt



L m (ft)		H m (ft)		D mm (ft)		Volume m^3 (ft^3)	
6	(20)	2.4	(7.8)	6.5	(21.3)	26	(918)
7	(23)	2.7	(8.9)	7.3	(24.0)	38	(1 342)
8	(26)	3.0	(9.8)	8.2	(26.9)	53	(1 872)
9	(30)	3.3	(10.8)	9.0	(30.0)	71	(2 507)
10	(33)	3.6	(11.8)	9.9	(32.5)	93	(3 284)
12	(40)	4.2	(13.8)	11.6	(38.1)	149	(5 263)
14	(46)	4.8	(15.7)	13.3	(43.6)	225	(7 946)
16	(52)	5.4	(17.7)	15.0	(49.2)	323	(11 407)
18	(60)	6.1	(20.0)	16.7	(54.8)	446	(15 750)
20	(66)	6.7	(22.0)	18.4	(60.4)	596	(21 048)
22	(72)	7.3	(24.0)	20.1	(65.9)	777	(27 440)
24	(80)	7.9	(26.0)	21.8	(71.5)	992	(35 032)
26	(85)	8.5	(28.0)	23.5	(77.1)	1 243	(43 896)
28	(92)	9.2	(30.2)	25.2	(82.7)	1 533	(54 137)
30	(49)	9.8	(32.2)	26.9	(88.3)	1 865	(65 862)
35	(115)	10.8	(35.4)	31.1	(102.0)	2 861	(101 135)
40	(132)	12.9	(42.3)	35.4	(116.1)	4 232	(149 452)
45	(148)	14.4	(47.2)	39.7	(130.2)	5 942	(209 840)
50	(164)	16.0	(52.0)	44.0	(144.0)	8 109	(286 367)

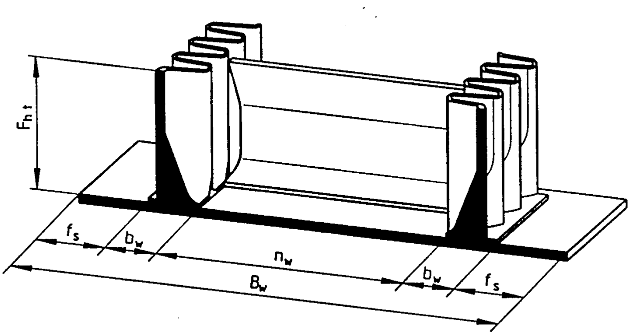
Frame height (H1) – width (B1)

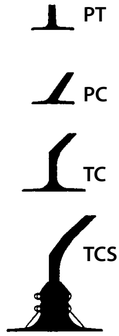
Lenght (belt) m/ft	Belt width 500mm/20 in H1 - B1mm/in	Belt width 650mm/26 in H1 – B1 mm/in	Belt width 800mm/32 in H1 – B1 mm/in	Belt width 1000 mm/40in H1 – B1mm/in	Belt width 1200mm/47 in H1 – B1/mm/in
6-14/20-46	800/32-890/35	800/32-1040/41	800/32-1240/49	800/32-1440/57	800/32-1690/67
15-24/49-79	800/32-890/35	800/32-1040/41	800/32-1240/49	800/32-1440/57	800/32-1690/67
25-30/82-98	1210/48-950/37	1210/48-1100/43	1210/48-1300/51	1210/48-1500/59	1210/48-1750/69
30-50/82-164	1210/48-950/37	1210/48-1100/43	1210/48-1300/51	1210/48-1500/59	1210/48-1750/69



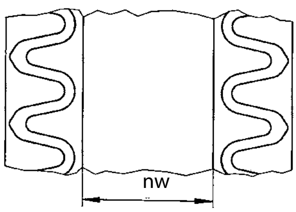
Vertical conveyor system

The vertical conveyer systems for material transportation is an engineered system with many variations.
Below you will find some basic data covering the belt, the sidewalls and the cleats to be considered.



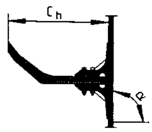


Belt width: (Bw)	depending on net width (see below)
Free lateral space (fs)	depending on belt deflection discs
Net belt width (nw)	depending on material size, see below
Sidewall height (Fht)	depending on material size, see below
Sidewall width (bw)	depending on sidewall height above
Cleat type	depending on duty, see below
Cleat height (Ch)	depending on material size, see below
Cleat pitch (Cp)	depending on material size, see below
Material (Lump) size (Ls)	



Net belt width: nw (min) ~ 2,1x**Ls** (max.)

Cleat pitch: **Cp** (min) ~1,5x**Ls** (max)



Cleat height: Ch (min) ~ **Ls** (α/100+0.5)

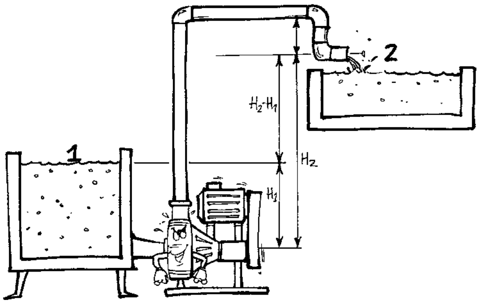
Cleat types: PT height 20 - 110 mm (0,8-4,3 inch), **PC** height 35 - 180 mm (1,4 –7,1 inch)
TC height 110-160 mm (4,3-10,2 inch), **TCS** height 400 - 500 mm (16-20 inch)

Sidewall heights **Fht** from 40mm (1,6 inch) to 630 mm (25 inch)

Slurry Handling – 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 Liquid / Liquid mixing, Solid / Solid separation, Liquid / Liquid separation, etc.

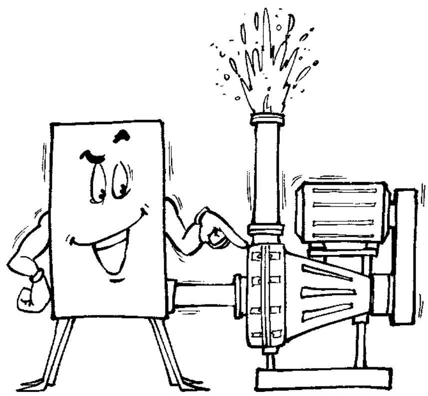


What type of solids?

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” or “pulp”!

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).

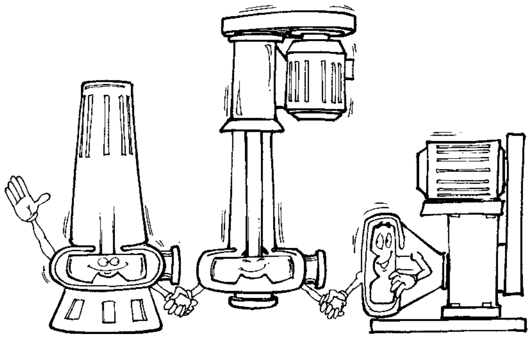
What are the limitations in flow?

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 m^3/hour (4 GPM)** up to **20 000 m^3/hour (88 000 GPM)**

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 to multiple pump installations).

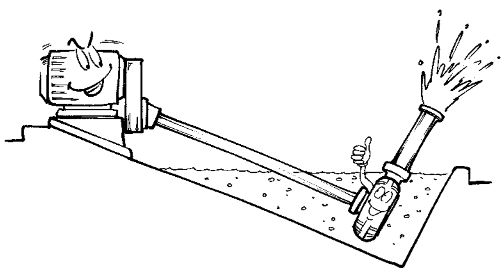


What are the limitations for solids?

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 **50 mm (2 inch).**

However, individual lumps of material passing through a large dredge pump can be up to **350 mm (14 inch)** (depending of the dimensioning of the wet end).



Slurry pumps as an operation concept

Of all centrifugal pumps installed in the process industry the ratio between slurry pumps 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"!

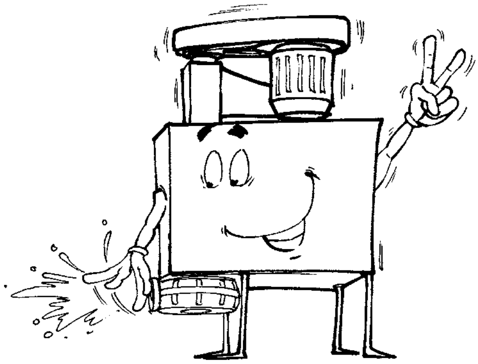
This is valid both for the end user and the supplier.

Basic definitions

Why slurry pumps?

By definition Slurry Pumps are heavy and robust versions of centrifugal pumps, capable in handling tough and abrasive duties.

"A 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, 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 (9 mesh)

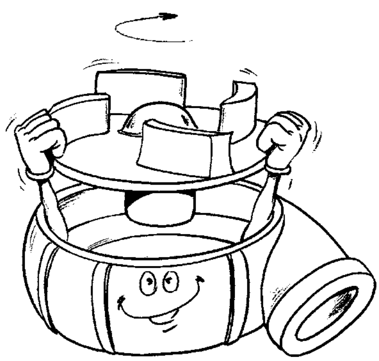
Size ranges are:

Mud/clay	minus 2 microns
Silt	2-50 microns
Sand, fine	50-100 microns (270 - 150 mesh)
Sand, medium	100-500 microns (150 - 32 mesh)
Sand, coarse	500-2 000 microns (32-9 mesh)

Sand & gravel pumps cover pumping of shingle and gravel in the 2-8 mm (9 - 2,5 mesh) size range

Gravel pumps cover pumping of solid sizes up to 50 mm (2 inch).

Dredge pumps cover pumping of solid sizes up to and above 50 mm (2 inch).



Slurry pump - name by application

Process applications also provide the terminology, typically

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

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

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

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

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:

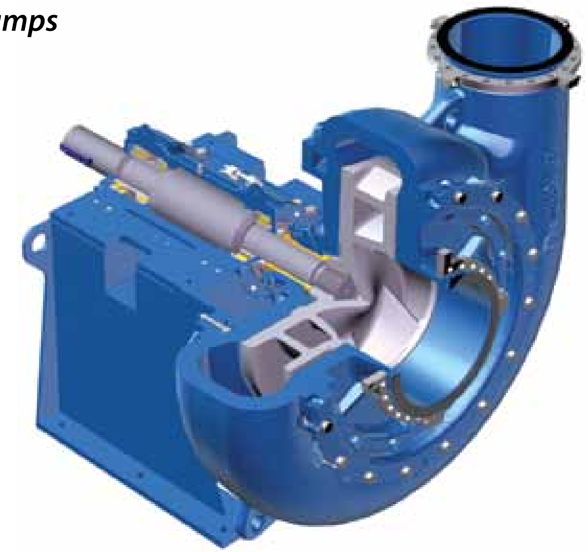
- Horizontal and vertical tank (dry installation) • Vertical sump (semi dry installation)
- Tank (dry installation) • Submersible (wet installation)

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

- Highly abrasive • Abrasive • Mildly abrasive

Slurry pump pange XM

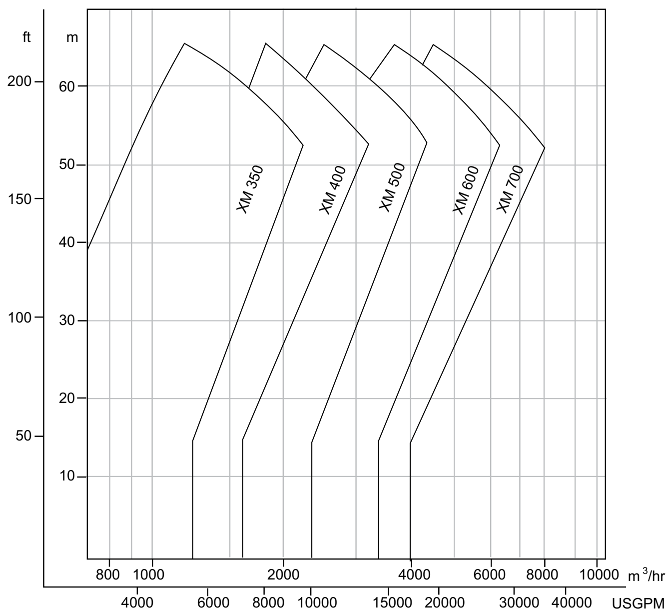
The Thomas series of extra heavy duty hard metal slurry pumps



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 See data sheet 8:32.

Selection chart



Slurry pump range XR and VASA HD

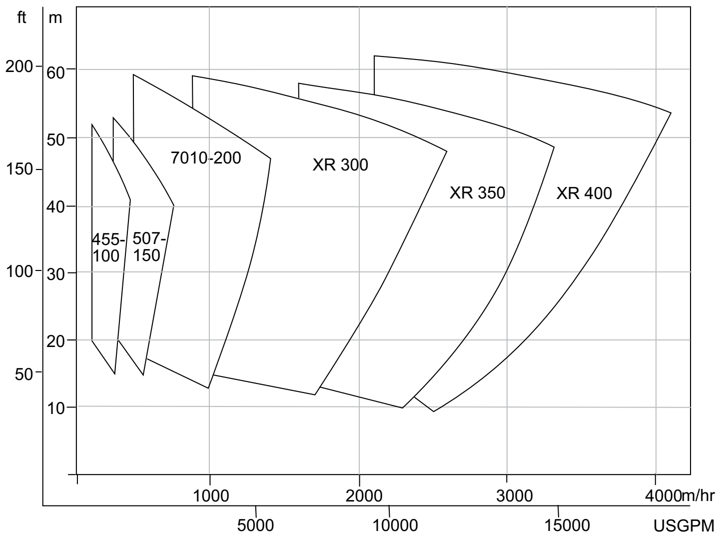
The Thomas and Sala series of extra heavy duty rubber lined slurry pumps

Summary of design features

- Modular design technology
- Robust construction, with ”back pull-out” feature, designed for highly abrasive, maximum duty and aggressive environments
- Maintenance Slide Base
- 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
- Ease of maintenance

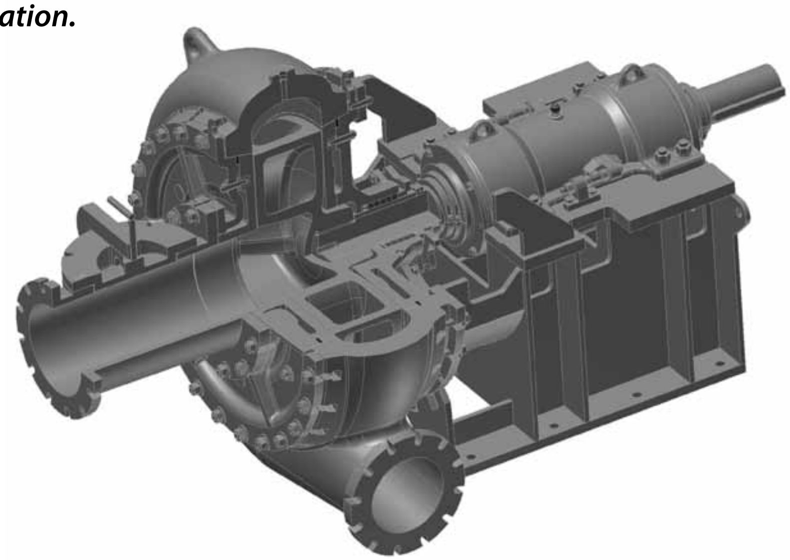
See data sheet 8:32 and 33.

Selection chart



Dredge pumps

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



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

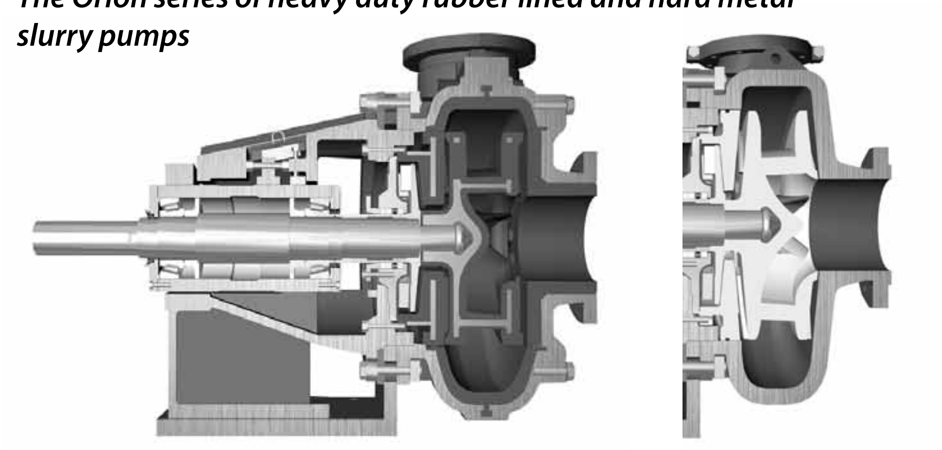
See datasheet 8:3

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″

Pump size	No. of vanes	Maximum
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″

Slurry pump range HR and HM

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



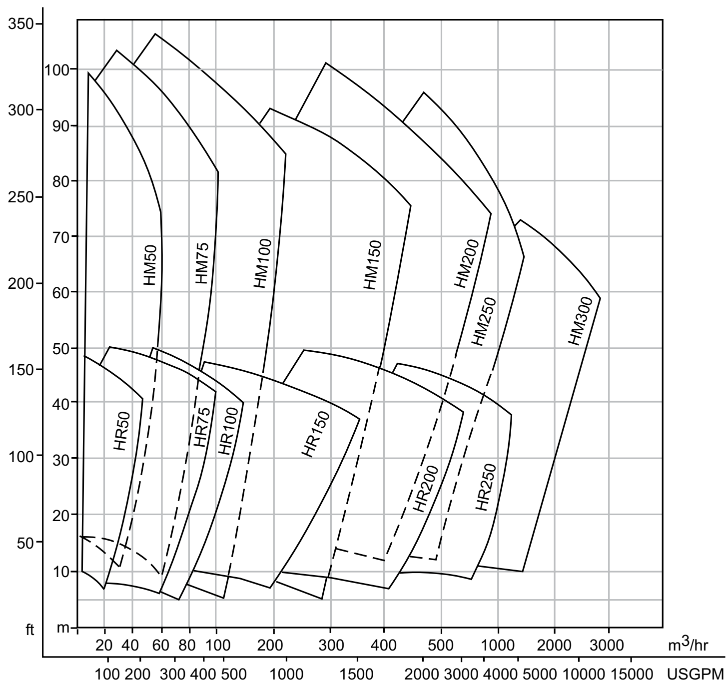
HR wet end *HM wet end*

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 resistant
- Self-contained bearing cartridge assembly with oversized pump shaft and anti-friction bearings
- Various shaft seal options
- Ease of maintenance

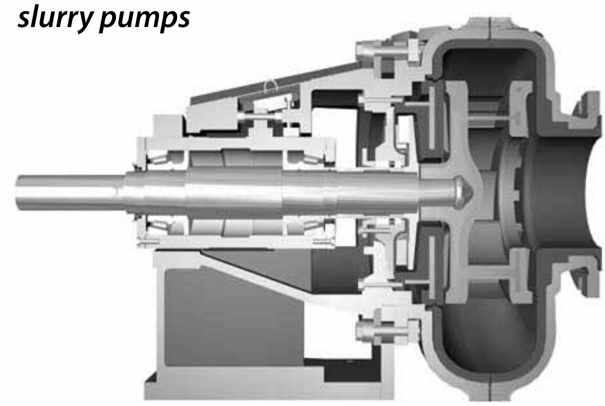
See data sheet 8:34.

Selection chart

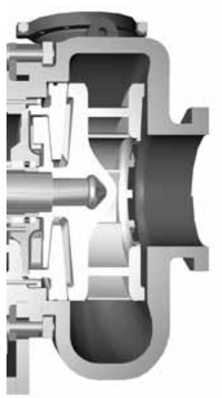


Slurry pump range MR and MM

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



MR Wet End



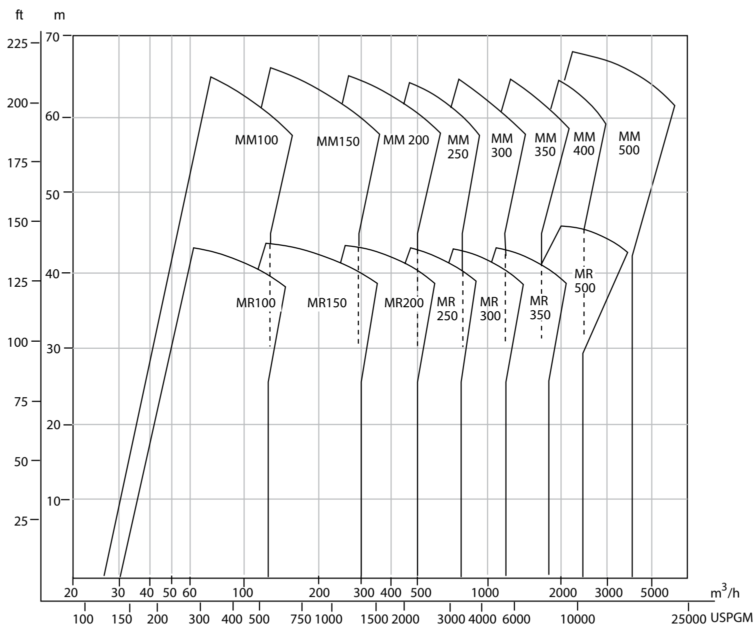
MM Wet End

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 resistant
- Self contained bearing cartridge assembly with oversized pump shaft and grease lubricated taper roller bearings
- Various shaft seal options
- Ease of maintenance
- Maintenace slide base option

See data sheet 8:35.

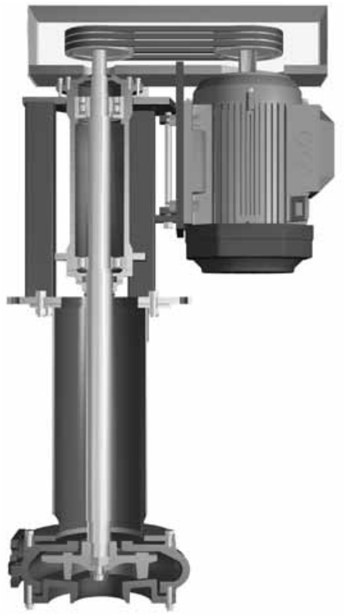
Selection chart



Slurry handling

Slurry pump range VS

The Sala series of vertical sump pumps

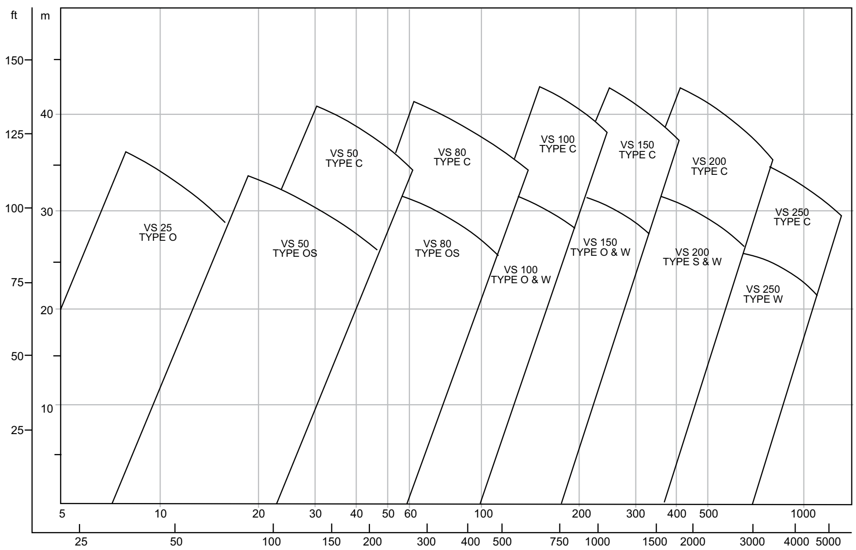


Summary of design features

- 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

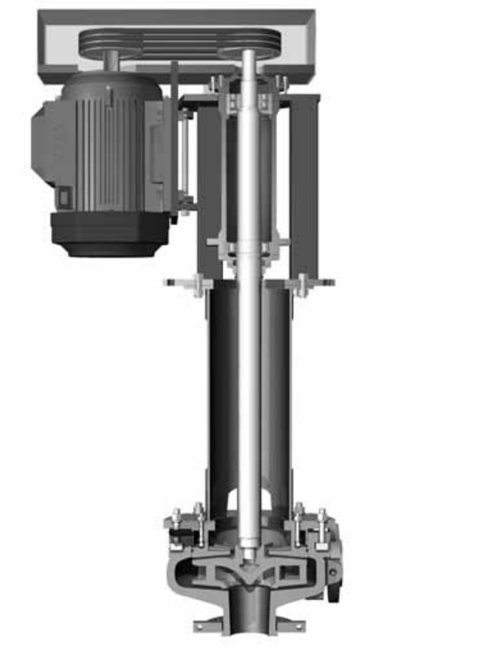
See data sheet 8:36.

Selection chart



Slurry pump range VSHM and VSMM

The Sala series of vertical sump pumps

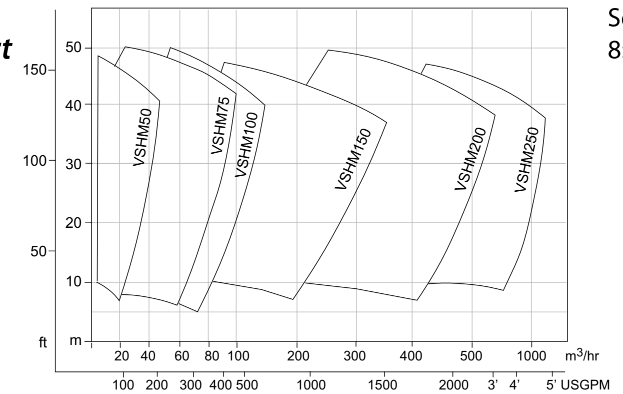


The VSH and VSM pumps are a new combination of our classic VS sump pumps and our Orion series horizontal pump wet ends.

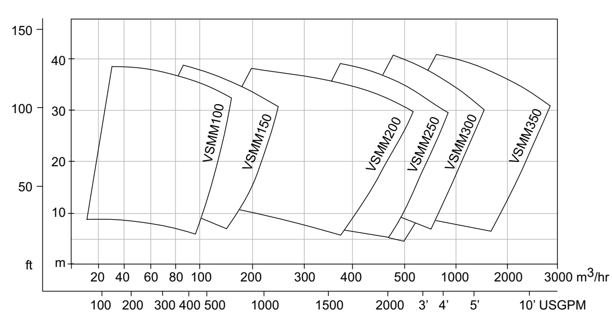
This provides a major advantage: the same wet end parts are used for both horizontal slurry pumps and sump pumps, thus reducing parts inventory and simplifying maintenance.

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

Selection chart

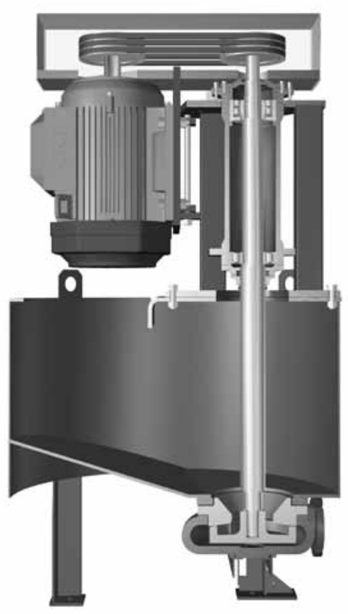


See data sheet 8:37.



Slurry pump range VT

The Sala series of vertical ank pumps

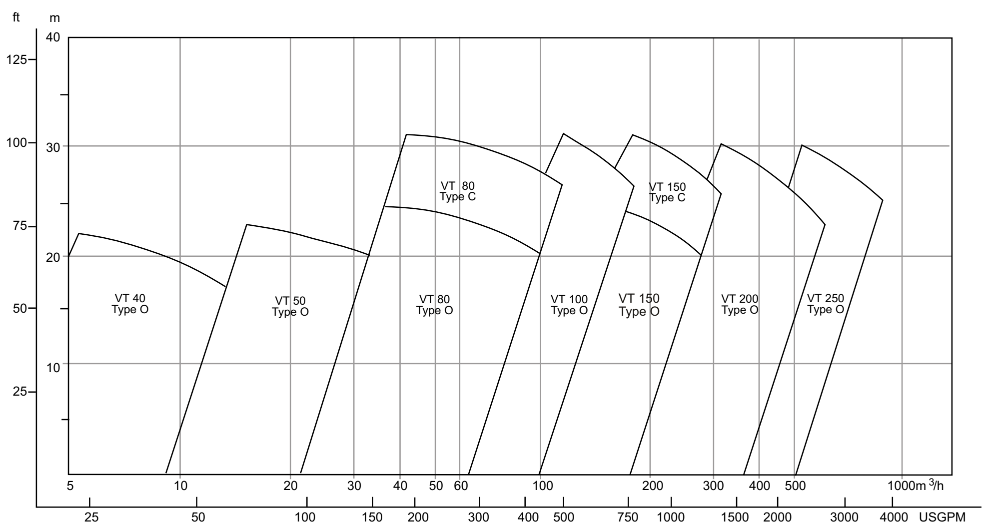


Summary of design features

- 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.

See data sheet 8:38.

Selection chart



Slurry Pump Range VF

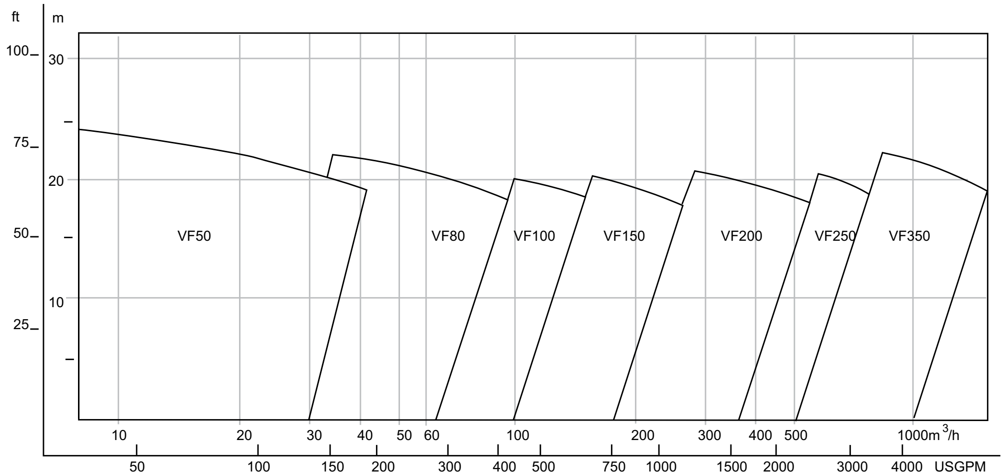
The Sala series of vertical vertical froth pumps

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.

See data sheet 8:39.

Selection chart



Application guide for slurry pumps

As mentioned before, the only limitation for hydraulic transportation is your own imagination.

This application guide is a simple way to find out what type of pump to be used for different slurry operations.

Selection by industrial segment

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 sharp - use rubber.

If particles are not sharp - 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).

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.

Selection by 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 11-92.

Risk for cavitation, see section 10.

Recommendation: All ranges.

Duty: Low flow

Comments: Compare to *BEP**, see section 12.

At low flows rubber linings can be overheated. 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.

Selection by 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 9 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: When viscosity is going up to 5 times the viscosity of water the pumping gets critical.

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.

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.

Industrial applications, minerals

Application: Pumps for grinding circuits

Comments: Our range 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 use multiple pumps in series.

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

Application: Pumps for hydro-cyclone 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 8:15.

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 applications, 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.)

Application: Drainage pumps

Comments: For lighter duties use horizontal pumps type PM, also diesel driven.

Recommendation: PM range.

Industrial applications, 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 coal/ water mixtures

Comments: Use conventional pumps M and PM ranges.

Recommendation: M and PM ranges.

Application: Pumps for general purpose (coal)

Comments: Coal industry normally does not use rubber pumps.

Recommendation: Use HM and MM.

Industrial applications, waste & recycling

Application: Pumps for effluent handling

Comments: Light-duty application. Use both horizontal and 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 is recommended for mobile and semi-mobile plants (no leaking seal and easy to transport and install).

Recommendation: All ranges.

Industrial applications, power & FGD

Application: Pumps for FGD reactor feed (lime)

Comments: Normally the mineral applications use X, H andM 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 above.

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 applications, pulp & paper

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 applications, 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 applications, 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 applications, 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!

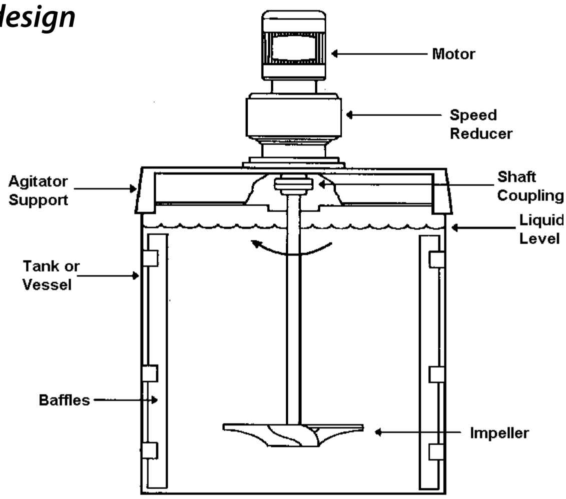
Recommendation: HM.

Agitation – Introduction

Agitation is a very important part of slurry handling. Agitation is the technique to create fluid motions into a vessel, needed for

- **Gentle mixing** (in flocculation)
- **Standard mixing** for dissolution, solids suspension, storage, leaching and conditioning
- **Intensive mixing** (attrition, scrubbing)

Agitator design



Agitation – impeller options

MIL® impeller

- Low in power, weight and shear
- High degree of axial flow, allowing high position – off tank bottom
- Can be situated as close as ½ prop dia to tank bottom without significant increase in power (tapered blade design)
- Does not require stabilizer fins giving increased drag and power consumption.
- Can be situated close to liquid level (1/4 prop dia) without causing serious vortexing
- Mild-or stainless steel. Rubber covered for abrasion or corrosion
- Available in sizes from 200 mm (8”) to 7620 mm (300”) with 3,4 or 6 blades

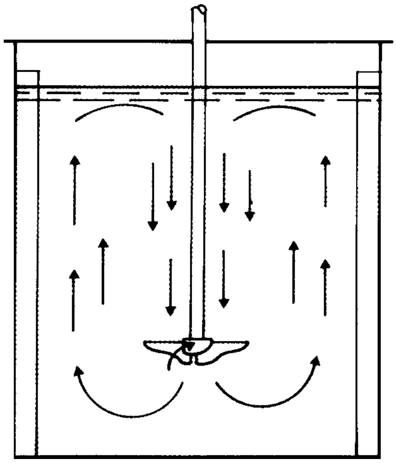
Helix impeller

- An option to the MIL® impeller when intense agitation is required
- Providing both axial and radial flow and high shear.
- Higher (30-40%) power consumption than MIL®
- High shear applications
- Rubber covering available
- Available from 200 mm (8”) up to 4570 mm (180”)

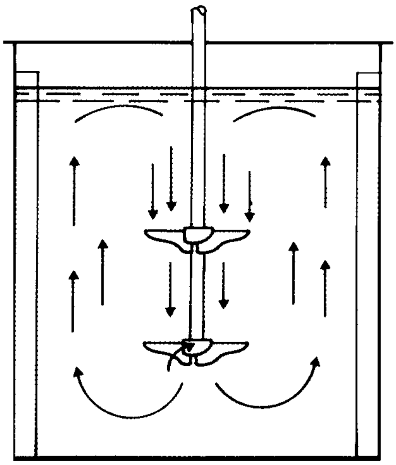
Agitation – typical configurations

Agitation – standard mixing

- **Single MIL®** impeller for most applications
- Axial flow
- Tank depth/diameter ratio 1,15:1

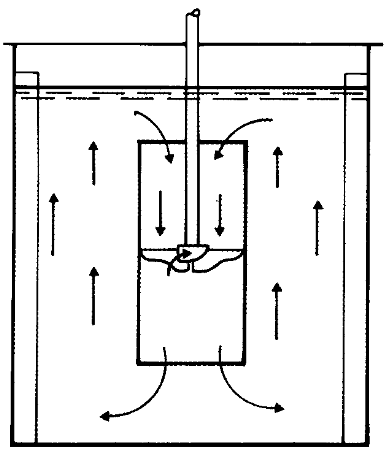


- **Double MIL®** impeller for deeper tanks
- Tank depth/diameter greater than 1,15:1 less than 1,8:1
- High viscosity
- High percent solids



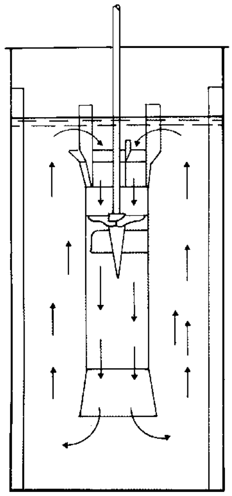
Agitation – conditioning

- Axial flow
- Draft tube to prevent short circuiting internal baffles as option
- Typical application is flotation (mixing of flotation reagents, Ph adjustment)
- Single MIL® with draft tube
- Double MIL® without draft tube
- Tank depth/diameter ratio less than 1.8:1
- MIL® or Helix impellers (Helix for highest shear)



Agitation – Draft tube

- Axial flow
- Depth to diameter ratio more than 1.8 : 1
- Special design for controlled circulation (leaching, agglomeration, crystal growth)
- Large flow volumes
- Low energy input
- Single propeller
- Max. 50% solids by weight
- Short shaft



Agitators – Tank selection

Agitator sizing is complex calculations based on several inter-dependent variables.

A preliminary indication of agitator requirements can be gained from the following procedure:

The tank dimensions are chosen to hold a certain volume of slurry or give a particular retention time.

Volume required (m^3) = Flow (m^3/min) x Retention time (min)

Retention times (typical):

Flotation - conditioning or activation	10 min
Flotation – Ph adjustment	3 min
Gold leaching (total for 4-10 tanks in series)	24 h
CIP adsorption (total for 4-8 tanks in series)	8h

Agitator tanks – effective volumes

Tank dimensions Dia. x Height (m)	Dia. x Height ft	Volume (effective including freeboard) m^3	ft^3
1.25 x 1.25	4 x 4	1.4	45
1.5 x 1.5	5 x 5	2.4	90
1.75 x 1.75	6 x 6	3.8	150
2 x 2	7 x 7	5.7	240
2.5 x 2.5	8 x 8	11.0	360
3 x 3	10 x 10	19.1	705
3.5 x 3.5	12 x 12	30.0	1 220
4 x 4	13 x 13	45	1 550
4.5 x 4.5	15 x 15	64	2 385
5 x 5	16 x 16	88	2 900
6 x 6	20 x 20	153	5 650
7 x 6	23 x 20	208	7 480
8 x 7	26 x 23	317	11 000
9 x 8	30 x 26	458	16 500
10 x 9	33 x 30	636	23 100
12 x 12	40 x 40	1 221	45 200
14 x 12	46 x 40	1 662	59 800

Agitation – Impeller section , MIL®

Once the tank size has been established an estimation of the mechanism required for a "Standard" agitator or "Conditioner" can be made by defining the duty as "Light", "Medium" or "Heavy" as follows:

Standard Agitators - Duty

Duty	Light	Medium	Heavy
Slurry viscosity (cP)	300	500	1000
Maximum solids size (mm) (mesh)	0.1 (150)	0.2 (65)	0.35 (42)
Maximum dry solids s.g. (g/cm^3)	3.0	3.5	3.5
Maximum liquid s.g. (g/cm^3)	1.0	1.1	1.2
Maximum solids content (% by weight)	15	25	45

Conditioners - Duty

Duty	Medium	Heavy
Maximum solids size (mm) (mesh)	0.25 (60)	0.25 (60)
Maximum solids s.g. (g/cm^3)	2.7	3.5
Maximum liquid s.g. (g/cm^3)	1.0	1.0
Maximum solids content (% by weight)	20	45

Standard agitators (single MIL® impeller), Metric std

		Light duty			Medium duty			Heavy duty		
Tank dim. dia x height [m]	Vol m^3	Prop. dia mm	Prop. blade No.	Motor power kW*	Prop. dia mm	Prop. blade No.	Motor power kW*	Prop. dia mm	Prop. blade No.	Motor power kW*
1.25 x 1.25	1.4	305	3	0.18	380	3	0.37	610	3	1.1
1.5 x 1.5	2.4	380	3	0.25	455	3	0.55	610	3	1.1
1.75 x 1.75	3.8	455	3	0.37	610	3	1.1	760	3	2.2
2 x 2	5.7	610	3	0.75	610	3	1.1	915	6	3
2.5 x 2.5	11.0	610	3	0.75	760	3	1.5	1 065	6	4
3 x 3	19.1	760	3	1.1	915	6	2.2	1 220	6	5.5
3.5 x 3.5	30	915	6	2.2	1 065	6	3	1 370	6	5.5
4 x 4	45	1 065	6	3	1 220	6	4	1 525	6	7.5
4.5 x 4.5	64	1 220	6	3	1 370	6	5.5	1 830	6	11
5 x 5	88	1 370	6	4	1 525	6	5.5	2 135	6	15
6 x 6	152	1 525	6	5.5	1 830	6	7.5	2 440	6	18.5
7 x 6	208	1 830	6	7.5	2 135	6	11	2 745	6	22
8 x 7	317	2 135	6	11	2 440	6	15	3 050	6	30
9 x 8	458	2 440	6	11	2 745	6	18.5	3 660	6	45
10 x 9	636	2 745	6	15	3 050	6	22	4 570	6	75
12 x 12	1 226	3 050	6	18.5	3 660	6	30	4 570	6	75
14 x 12	1 662	3 660	6	30	4 570	6	55			

* kW as connected motor power

Standard agitators (single MIL® impeller), US std

		Light duty			Medium duty			Heavy duty		
Tank dim. Dia x Height ft	Vol ft^3	Prop. dia inch	Prop blade No.	Motor power hp*	Prop. dia inch	Prop. blade No.	Motor power hp*	Prop. dia inch	Prop. blade No.	Motor power hp*
4 x 4	45	12	3	0.25	15	3	0.50	24	3	1.5
5 x 5	90	15	3	0.34	18	3	0.75	14	3	1.5
6 x 6	150	18	3	0.50	24	3	1.5	30	3	3.0
7 x 7	240	24	3	1.0	24	3	1.5	36	6	4.0
8 x 8	360	24	3	1.0	30	3	2.0	42	6	5.4
10 x 10	705	30	3	1.5	36	6	3.0	48	6	7.5
12 x 12	1 220	36	6	3.0	42	6	4.0	54	6	7.5
13 x 13	1 550	42	6	4.0	48	6	5.4	60	6	10.2
15 x 15	2 385	48	6	4.0	54	6	7.5	72	6	15.0
16 x 16	2 900	54	6	5.4	60	6	7.5	84		
20 x 20	5 650	60	6	7.5	72	6	10.2	96	6	20.0
23 x 20	7 480	72	6	10.2	84	6	15.0	108	6	30.0
26 x 23	11 000	84	6	15.0	96	6	20.0	120	6	40.0
30 x 26	16 500	96	6	15.0	108	6	25.0	144	6	61
33 x 30	23 100	108	6	20.0	120	6	30.0	180	6	102
40 x 40	45 200	120	6	25.0	144	6	40.0	180	6	102
46 x 40	59 800	144	6	40.0	180	6	75.0	-	-	-

* hp as connected motor power

Conditioners (single MIL® impeller), metric std

		Medium Duty			Heavy Duty		
Tank dim. Dia x height m	Volume m^3	Prop. dia mm	Prop. blades No.	Motor power kW*	Prop. dia mm	Prop. blades No.	Motor power kW*
1.25 x 1.25	1.4	380	3	0.37	455	3	0.75
1.5 x 1.5	2.4	455	3	0.55	610	3	1.5
1.75 x 1.75	3.8	610	3	1.1	610	3	1.5
2 x 2	5.7	610	3	1.1	760	3	2.2
2.5 x 2.5	11.0	760	3	1.5	915	6	3
3 x 3	19.1	915	6	2.2	1065	6	4
3.5 x 3.5	30	1065	6	3	1220	6	5.5
4 x 4	45	1220	6	4	1370	6	7.5
4.5 x 4.5	64	1370	6	5.5	1525	6	11
5 x 5	88	1525	6	7.5	1830	6	11
6 x 6	152	1830	6	11	2135	6	15
7 x 6	208	2135	6	11	2440	6	22
8 x 7	317	2440	6	15	2745	6	30

* kW power as connected motor power

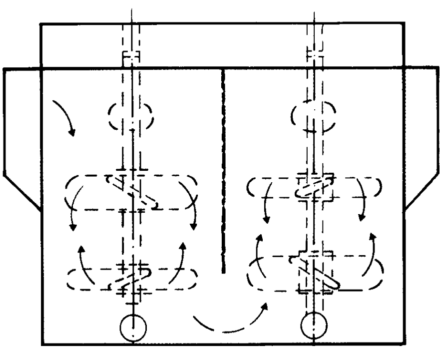
Conditioners (single MIL® impeller), US std

Tank dim. Dia x height ft	Volume ft³	Medium Duty Prop. dia inch	Medium Duty Prop. blades No.	Medium Duty Motor power hp*	Heavy Duty Prop. dia inch	Heavy Duty Prop. blades No.	Heavy Duty Motor power hp*
4 x 4	45	15	3	0.50	18	3	1.0
5 x 5	90	18	3	0.75	24	3	2.0
6 x 6	150	24	3	1.5	24	3	2.0
7 x 7	240	24	3	1.5	30	3	3.0
8 x 8	360	30	3	2.0	36	6	4.0
10 x 10	705	36	6	3.0	42	6	5.4
12 x 12	1 220	42	6	4.0	48	6	7.5
13 x 13	1 550	48	6	5.4	54	6	10
15 x 15	2 385	54	6	7.5	60	6	15
16 x 16	2 900	60	6	7.5	72	6	15
20 x 20	5 650	72	6	10.2	84	6	20
23 x 20	7 480	84	6	15.0	96	6	25
26 x 23	11 000	96	6	20.0	108	6	40

Agitation – Attrition scrubber

Attrition scrubbing is a bit more than storing and agitation of slurry. It is close to the processes of washing and separation.

Attrition scrubbers are simple, yet highly efficient, unit for scrubbing particles at slurry densities of 70-80% solids. Two opposed Helix impellers on each shaft create an intensive mixing action forcing individual particles against each other resulting in scrubbing, surface cleaning and disintegration of agglomerates.



Typical applications:

Removal of Fe stains from sand particles. Disintegration of clay agglomerates in sand. Delamination of minerals such as Kaolin and Graphite. Blunging or slurrifying of dry clay prior to wet processing. Oil/Sand separation. Lime Slaking.

Attrition scrubber – Sizing

Restriction: Maximum size of individual particle to scrubber is 10 mm.

Due to the flow pattern an even number of cells must be selected (e.g. 2,4,6 cells). Base the retention time on test results or on an existing installation. In the absence of any other information assume a retention time of 6-8 minutes at 75% solids w/w for a typical sand scrubbing duty.

	Max. flow/double cell	
Scrubber size	m^3/h	USGPM
24 x 24	13	56
32 x 32	22	99
40 x 40	32	141
48 x 48	64	282
56 x 56	96	424
64 x 64	112	493
72 x 72	128	564

Attrition cells - Size and power

	Volume per cell		Connected motor power per cell		
Type	m^3	ft^3	kW	hp	
11 x 11*	0.028	1	0.75	1	V-belt drive
16 x 16*	0.085	3	4.0	5.4	"
24 x 24	0.285	10	7.5	10	"
32 x 32	0.710	25	11.0	15	"
40 x 40	1.280	45	18.5	25	"
48 x 48	2.130	75	30	40	Reducer drive
56 x 56	3.550	125	45	60	"
64 x 64	5.300	185	55	74	"
72 x 72	6.870	242	75	100	"

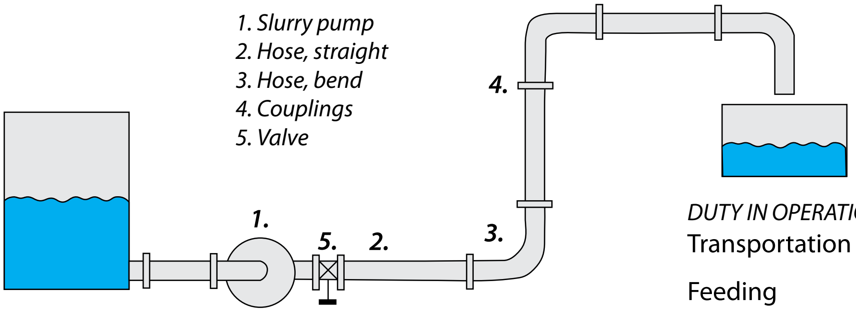
* Lab and Pilot sizes

"The slurry line"

Slurry pumps are important being the energy source in all hydraulic systems for slurry handling. However, the slurry pumps are mainly just energy converters in the systems (converting electric energy to hydraulic flows). Equally important is to design "the slurry line" with the correct sizing of hoses (or pipes) including

- Hose lay-out geometry (vertical and horizontal) needed for the transportation job
- Hose material giving resistance to the wear and to the chemical environment
- Hose diameter enabling maximum efficiency of the slurry system

The slurry line



SLURRY OPERATIONS
Grinding
Classification
Separation
Sedimentation
Mechanical dewatering

DUTY IN OPERATION
Transportation

Feeding

Slurry handling – Hoses

Hoses are for slurry handling what conveyor belts are for dry materials handling. Simple products – which just have to maintain their functions. Otherwise the process flow will be interrupted and the up-time is gone.

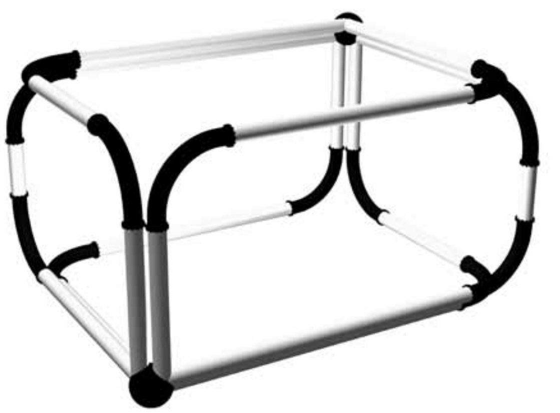
As most of the mineral process applications are continuous operations in an wearing environment, we will focus on rubber hosing in this section.

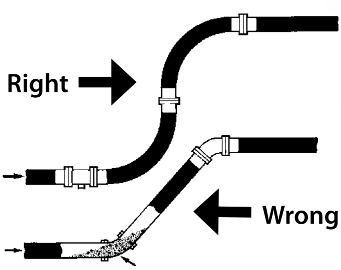
Slurry hose layout geometry

There is just one rule for lay-outs of slurry hoses and pipes, but a golden one.

" Never use sharp bends when connecting them hydraulically! "

Rule of thumb 1:
Hose bend radius
> 3 x hose diameter

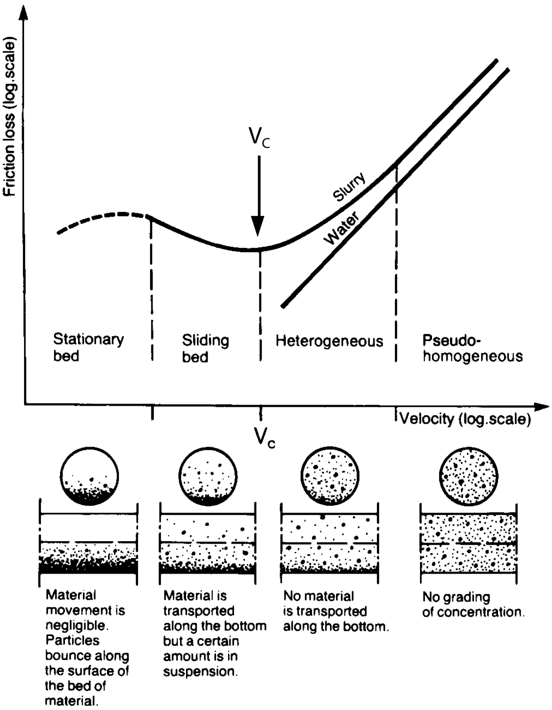


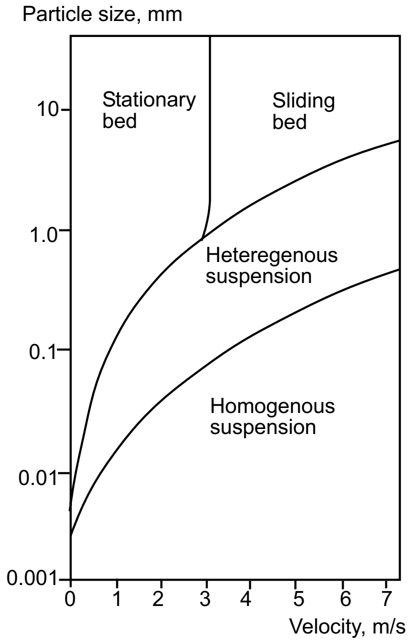


Rule of thumb 2:
Going up – go vertically if you can!

Slurry hoses – diameter

- Every slurry handling system needs proper hosing.
- Carrying velocity in the hose must exceed the settling velocity.
- Too high carrying velocity means increased power and wear.
- To balance the optimum slurry speed with the correct hose diameter is important.





Flow conditions for sand (density= 2.7)

Vc = critical velocity = the velocity between sliding bed and heterogeneous flow conditions. Below this velocity particle clogging is at risk.

Typical Vc (hose i.d. 75-150 mm, 3-6")

Flotation feed (80% passing 50 micron)	1.0 m/s
Tailings (medium coarse)	1.5-2.1 m/s
Sand fine	2.4-3.0 m/s
Sand, medium	3.4 m/s
Sand, coarse	3.7-4.0 m/s

Example:

Flotation feed 120 m^3/h, V_c = 1 m/s. Select hose diameter.

120/3600=108 m^3/h, 0.03/1=0.03 m^2

D^2=0.03x4/3.14, D=0.195 m =195 mm

Hose inner diameter, see next page

Select diameter 204.

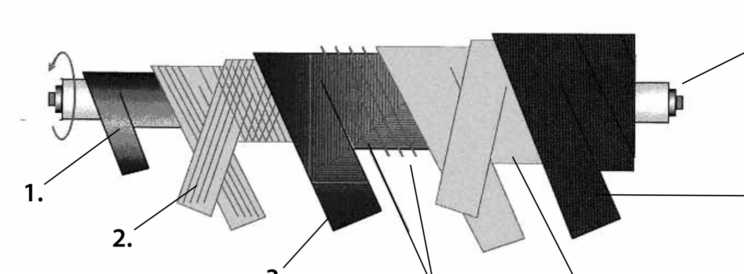
Slurry hose – material

For most slurry applications polymer is first option (steel pipes not covered here). Reason is low weight, easy installation and long service life.

- If slurry temperature is high or aggressive chemicals are present use polyurethane lined pipes!
- In all other cases use rubber hoses

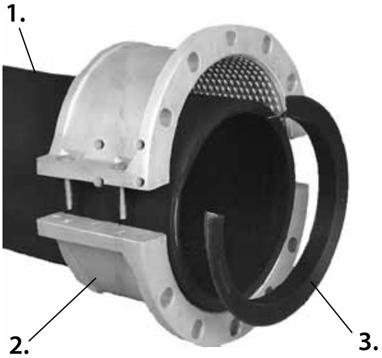
Regarding wear in slurry lines, see 9:12!

Slurry hose system - rubber



Design

1. Natural rubber (40 ShA)
2. Polyester cord
3. “Sandwich” rubber
4. Steel wire
5. Polyester cord
6. Outer cover
7. Production tool



- Long service life
- Simple installations
- 3 basic modules; 1) hose 2) couplings 3) gasket
- Lower cost (modular design)
- Tapered gasket for easier installation
- Easily configured
- Less vibration
- Lower noise level

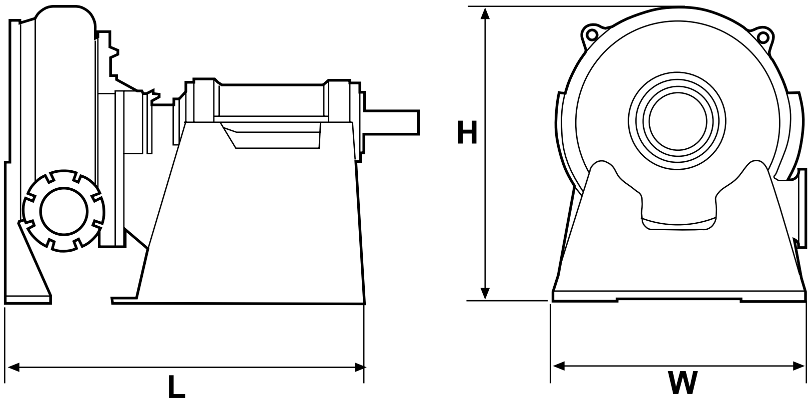
See data sheets pages 43 - 47

Slurry hoses - inside diameters*

mm	inch	mm	inch
51	2	204	8
63	2 1/2	254	10
76	3	305	12
80	3,1	355	14
102	4	405	16
116	4 1/2	457	18
127	5	508	20
152	6	610	24

* Maximal length 40 m (130 ft)

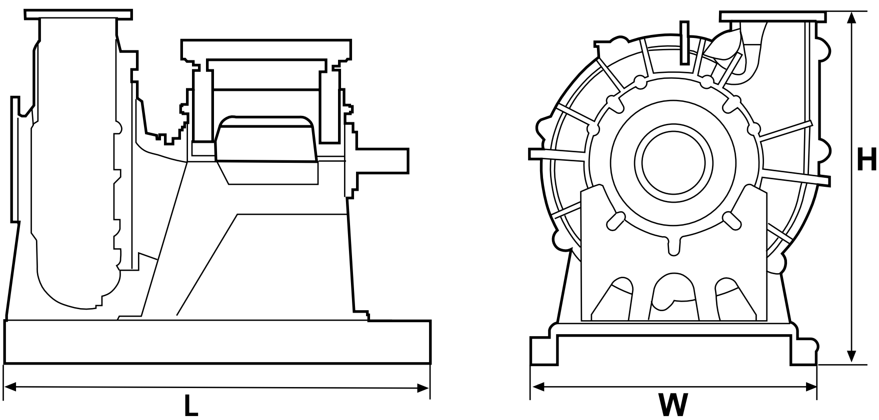
Slurry pump - XM



Model	Inlet mm (inch)	Outlet mm (inch)	H mm (inch)	L mm (inch)	W mm (inch)	Weight* ton	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

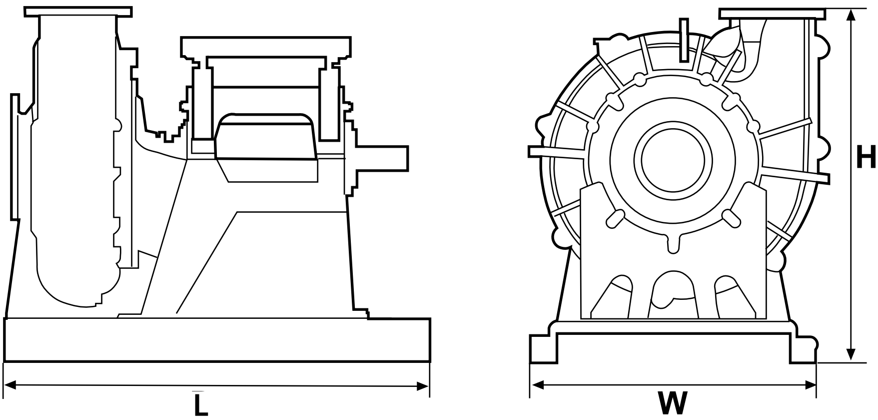
Slurry pump - XR



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

Slurry pump - VASA HD



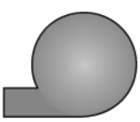
Model	Inlet mm (inch)	Outlet mm (inch)	H mm (inch)	L mm (inch)	W mm (inch)	Weight* ton	lb
VASA HD455-100	150 (6)	100 (4)	825 (33)	1171 (46)	610 (24)	0,9	2 016
VASA HD507-150	200 (8)	150 (6)	1 055 (42)	1 554 (61)	700 (28)	1,5	3 360
VASA HD7010-200	250 (10)	200 (8)	1 400 (55)	1 724 (68)	950 (37)	2,9	6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

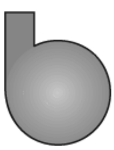
* Bare shaft weight

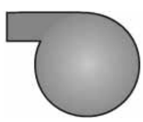
Dredge pumps

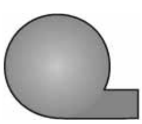
		Deck mounted pumps						Underwater pumps		
Pump size Inches	Impeller size Inches	12 ft./sec velocity *GPM	**TPH	17 ft./sec velocity *GPM	**TPH	21 ft./sec velocity *GPM	**TPH	17 ft./sec Velocity *GPM	TPH min.	max.
4	18,00	480	17.6	680	39	830	62	N/A	N/A	N/A
6	24,00	1058	39	1 540	88	1 900	108	1 540	154	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

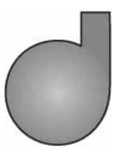
** Gallons per minute **Tons per hour of coarse sand*

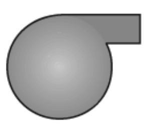

Left-hand
Bottom discharge
Left-hand rotation


Left-hand
Top vertical discharge
Left-hand rotation

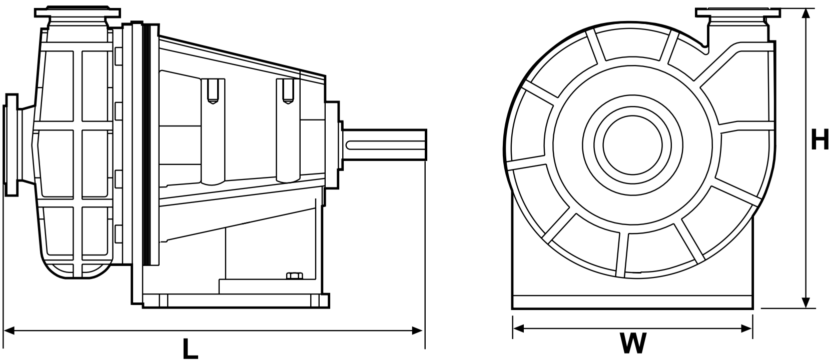

Left-hand
Top horizontal discharge
Right-hand rotation


Right-hand
Bottom discharge
Right-hand rotation


Right-hand
Top vertical discharge
Right-hand rotation


Right-hand
Top horizontal discharge
Left-hand rotation

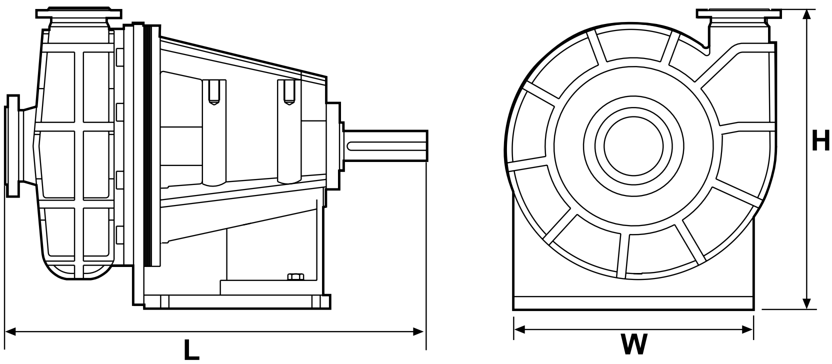
Slurry pump - HM



Model	Connection dimensions Inlet		Outlet		General dimensions H		L		W		Total weight* Double adjustm.		Total weight* Single adjustm.	
	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

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

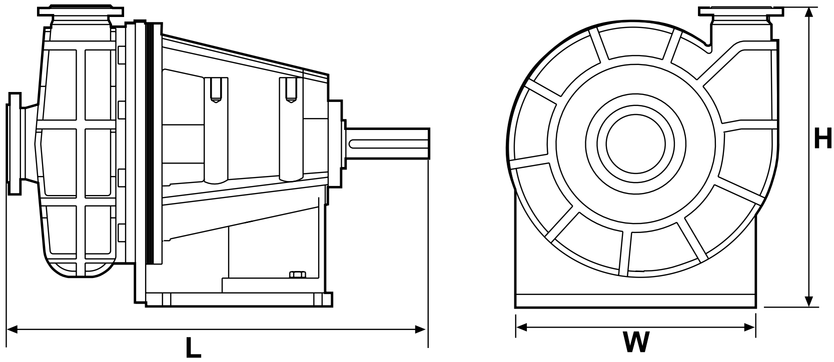
Slurry pump - HR



Model	Connection dimensions Inlet		Outlet		General dimensions H		L		W		Total weight* Double adjustm.		Total weight* Single adjustm.	
	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	kg	lbs	kg	lbs
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

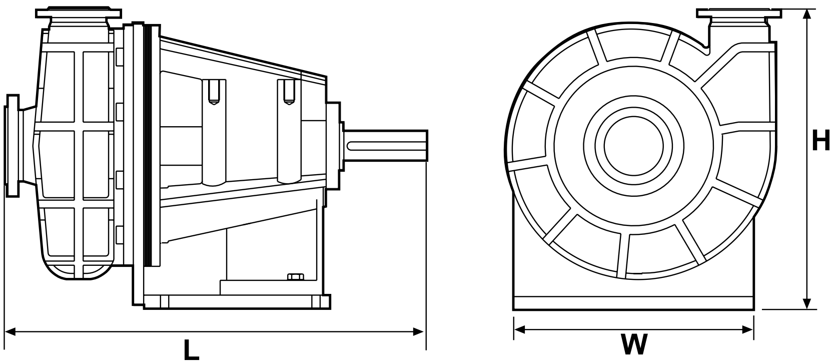
**Bare shaft weight*

Slurry pump - MM



Model	Connection dimensions Inlet		Outlet		General dimensions H		L		W		Total weight* Double adjustm.		Total weight* Single adjustm.	
	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	2105	4 641
MM500	500	20	450	18	1 726	68	2 180	86	1 110	44	—	—	5 980	13 184

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

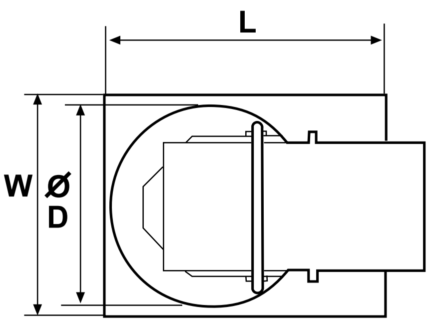


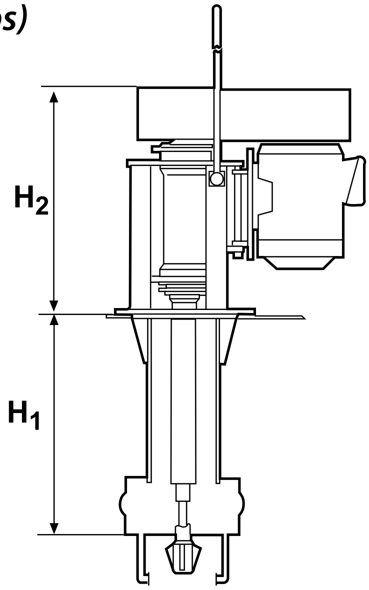
Slurry pump - MR

Model	Connection dimensions Inlet		Outlet		General dimensions H		L		W		Total weight* Double adjustm.		Total weight* Single adjustm.	
	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	kg	lbs	kg	lbs
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 pump weight*

Slurry pump – VS (Vertical sump pumps)





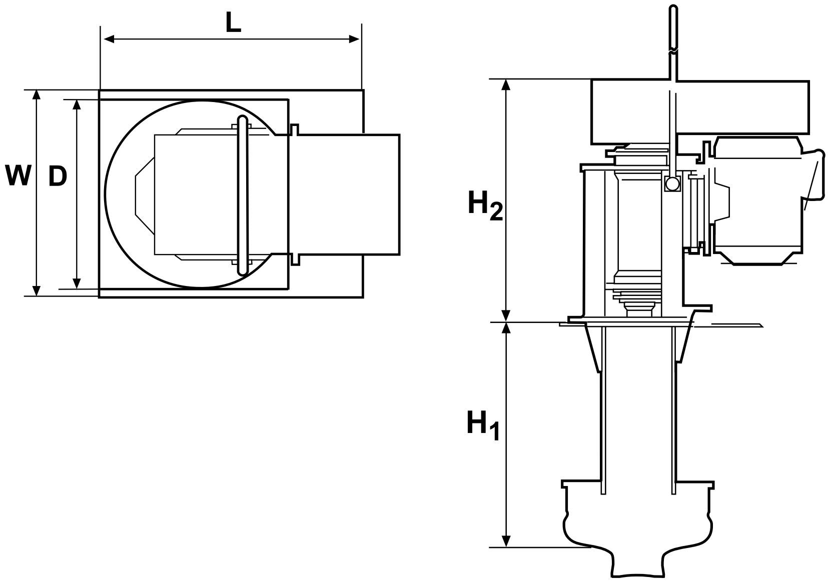
Model*	H_1 mm (inch)	H_2 mm (inch)	D mm** mm (inch)	L** mm (inch)	W** mm (inch)	Weight*** kg/lb
VS25 (1)	800 (32)	585 (23)	400 (15¾)			130/287
VS25 (1)	1200 (48)	865 (34)	530 (20¾)			350/772
VS25 (1)	1500(60)	865 (34)	530 (20¾)			375/827
VS25 (1)	1800 (72)	865 (34)	530 (20¾)			395/871
VS50 (2)	800 (32)	585 (23)	400 (15¾)			220/485
VS50 (2)	1200 (48)	865 (34)	530 (20¾)			480/1 058
VS50 (2)	1500 (60)	865 (34)	530 (20¾)			510/1 124
VS50 (2)	1800 (72)	865 (34)	530 (20¾)			540/1 190
VS80 (3)	800 (32)	870 (34¼)	530 (20¾)			435/959
VS80 (3)	1 200 (48)	975 (38½)	565 (22¼)			545/1 202
VS80 (3)	1 500 (60)	975 (38½)	565 (22¼)			580/1 279
VS80 (3)	1 800 (72)	975 (38½)	565 (22¼)			615/1 356
VS100 (4)	8 00 (32)	850 (33½)	530 (20¾)			465/1 025
VS100 (4)	1 200 (48)	960 (37¾)	565 (22¼)			575/1 268
VS100 (4)	1 500 (60)	960 (37¾)	565 (22¼)			610/1 345
VS100 (4)	1 800 (72)	960 (37¾)	565 (22¼)			645/1 422
VS150 (6)	1 200 (48)	965 (38)	565 (22¼)			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
VS300 (12)	1 500(60)	1 420 (56)		800 (31½)	800 (31½)	2 745/6 052
VS300 (12)	1 800 (72)	1 420 (56)		800 (31½)	800 (31½)	2 825/6 228

*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%.

Slurry pump – VSHM / VSMM / VSHR (Vertical sump pumps)



Pump size	Outlet	H*	D**	L Opt. base plate	W	Weight ***	
	mm (inch)	mm (inch)	mm (inch)	mm (inch)	mm (inch)	kg	lb
VSHM50 ●	32 (1,25)	87 (34)	Ø 530 (20¾)	600 (23½)	600 (23½)	390/405/420	860/893/926
VSHR50	32 (1,25)	87 (34)	Ø 530 (20¾)	600 (23½)	600 (23½)	380/395/410	838/871/904
VSHM75 ●	50 (2)	87 (34)	Ø 530 (20¾)	600 (23½)	600 (23½)	(L120) 415	915
VSHM75 ●	50 (2)	98 (38)	Ø 565 (22¼)	600 (23½)	600 (23½)	(L150/180) 530/565	1 168/1 245
VSHR75	50 (2)	87 (34)	Ø 530 (20¾)	600 (23½)	600 (23½)	399/424/449	880/935/990
VSHM100 ●	75 (3)	98 (38)	Ø 565 (22¼)	750(29½)	600 (23½)	535/565/605	1 180/1 246/1334
VSHR100	75 (3)	98 (38)	Ø 565 (22¼)	750 (29½)	600 (23½)	555/585/625	1 224/1 290/1378
VSHM150 ●	100 (4)	128 (50)	□800 (31½)	1 200 (47¼)	900 (35½)	1 314/1366/1418	2 897/3 012/3127
VSHR150	100 (4)	128 (50)	□800 (31½)	1 200 (47¼)	900 (35½)	1 405/1460/1515	3 098/3 219/3340
VSHM200	150 (8)	128 (50)	□800 (31½)	1 200 (47¼)	900 (35½)	1 650/1710/1770	3 638/3 770/3903
VSHR200	150 (8)	128 (50)	□800 (31½)	1 200 (47¼)	900 (35½)	1 680/1740/1796	3 704/3 836/3960
VSHM250	200 (10)	142 (56)	□ 800 (31½)	1 360 (53½)	1 220 (48)	2 310/2400/2480	5 093/5 291/5468
VSHR250	200 (10)	142 (56)	□800 (31½)	1 360 (53½)	1 220 (48)	2 365/2455/2535	5 214/5 413/5589
VSMM100 ●	75 (3)	87 (34)	Ø 530 (20¾)	600 (23½)	600 (23½)	430/465/500	948/1 025/1103
VSMM150 ●	100 (4)	98 (38)	Ø 565 (22¼)	750 (29½)	600 (23½)	560/590/630	1 235/1 301/1389
VSMM200 ●	150 (6)	128 (50)	□800 (31½)	1 200 (47¼)	900 (35½)	1 390/1445/1500	3 065/3 186/3307
VSMM250	200 (10)	128 (50)	□800 (31½)	1 200 (47¼)	900 (35½)	1 720/1780/1840	3 792/3 925/4057
VSMM300	300 (12)	142 (56)	□800 (31½)	1 360 (53½)	1 220 (48)	2 490/2570/2650	5 490/5 666/5843
VSMM350	300 (14)	142 (56)	□800 (31½)	1 360 (53½)	1 220 (48)	– /2745/2825	– /6 052/6 228

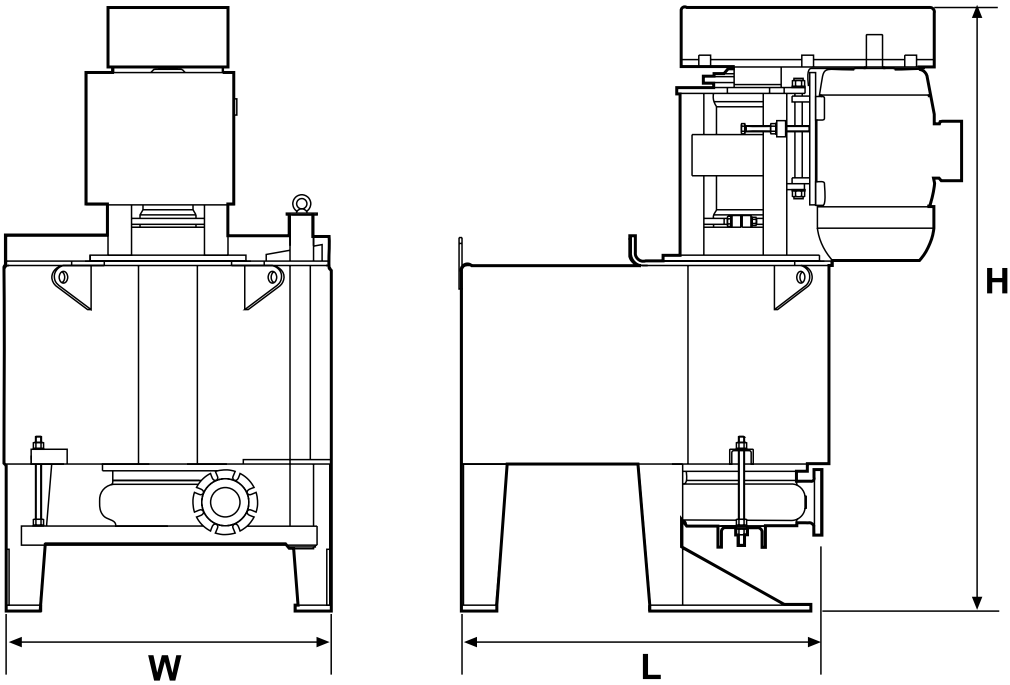
*Frame length (H_1) is available in 120, 150, 180 cm (48, 60, 72 inch) except VSMM350 which is available in 150, 180 cm (60, 72 inch).

** 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.

Slurry pump – VT (Vertical tank pump)

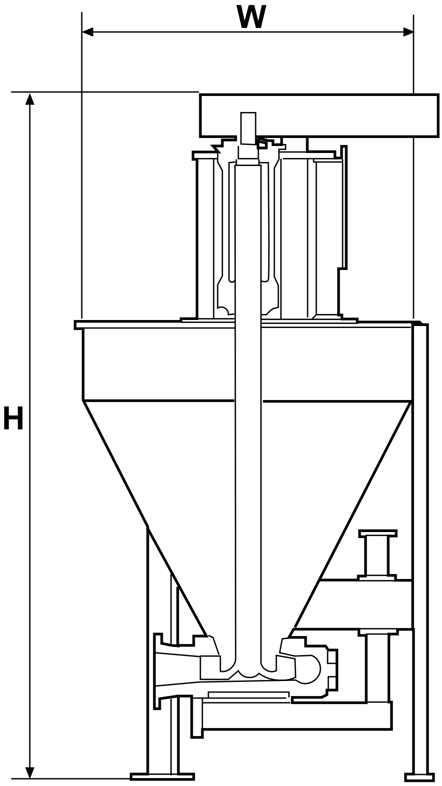


Model	Hmm (inch)	L mm (inch)	W mm (inch)	Weight** kg/lb	Sump volume m^3/USG
VT 40 (1.5) lab	955 (37.5)	640 (25)	400 (16)	90/198	0.03/8
VT 40 (1.5)	1 030 (40.5)	740 (29)	610 (24)	110/243	0.06/16
VT 50 (2)	1 470 (58)	1 035 (41)	1 010 (40)	305/672	0.25/66
VT 80 (3)	1 880 (74)	1 015 (40)	1 060 (42)	580/1279	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%.

Slurry pump – VF (Vertical froth pump)

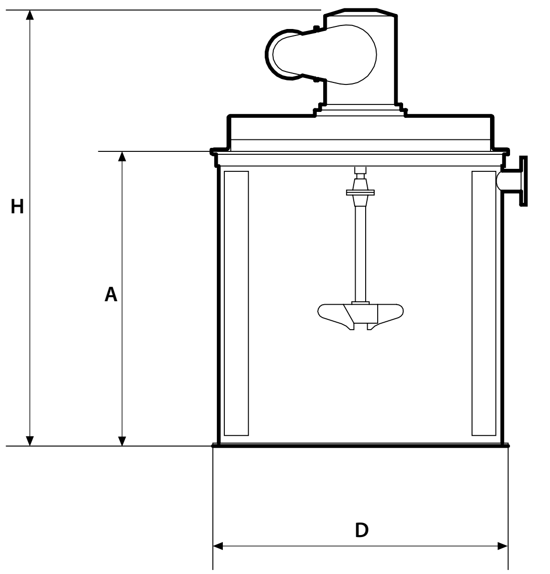


Model	H mm (inch)	W mm (inch)	Weight** kg/lb	Sump volume m^3/USG
VF50 (2)*	1 600 (63)	800 (31)	355/783	0.14/37
VF80 (3)	2 250 (88)	1 000 (39)	605/1 334	0.37/98
VF100(4)	2 700 (106)	1 400 (55)	975/2 150	0.82/217
VF150(6)	2 700 (106)	1 400 (55)	1 095/2 414	0.82/217
VF200(8)	3 760 (148)	1 850 (73)	2 700/5 952	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%.

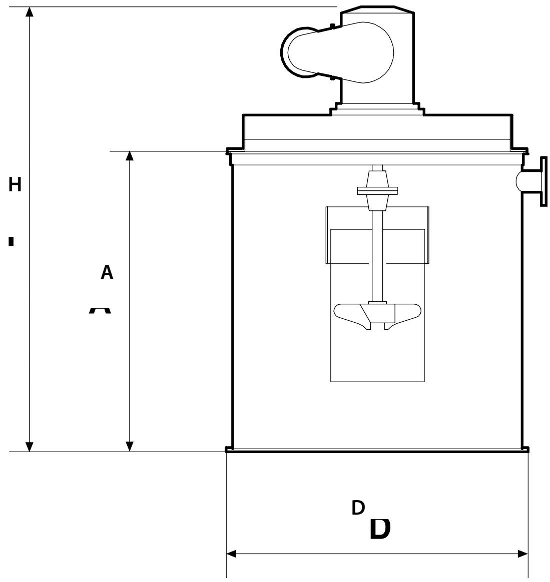
Agitator (Slurry mixer)



A mm (ft)	D mm (ft)	H mm (ft)]
1.25 (4)	1.25 (4)	1.85 (6)
1.50 (5)	1.50 (5)	2.10 (7)
1.75 (6)	1.75 (6)	2.35 (8)
2.00 (7)	2.00 (7)	2.70 (9)
2.50 (8)	2.50 (8)	3.20 (10)
3.00 (10)	3.00 (10)	3.80 (12)
3.50 (11)	3.50 (11)	4.40 (14)
4.00 (13)	4.00 (13)	4.90 (16)
4.50 (15)	4.50 (15)	5.50 (18)
5.00 (16)	5.00 (16)	6.10 (20)
6.00 (20)	6.00 (20)	7.10 (23)
6.00 (20)	7.00 (23)	7.30 (24)
7.00 (23)	8.00 (26)	8.50 (28)
8.00 (26)	9.00 (30)	9.70 (32)
9.00 (30)	10.00 (33)	10.70 (35)
11.00 (36)	12.00 (39)	[1]
12.00 (39)	14.00 (46)	[1]

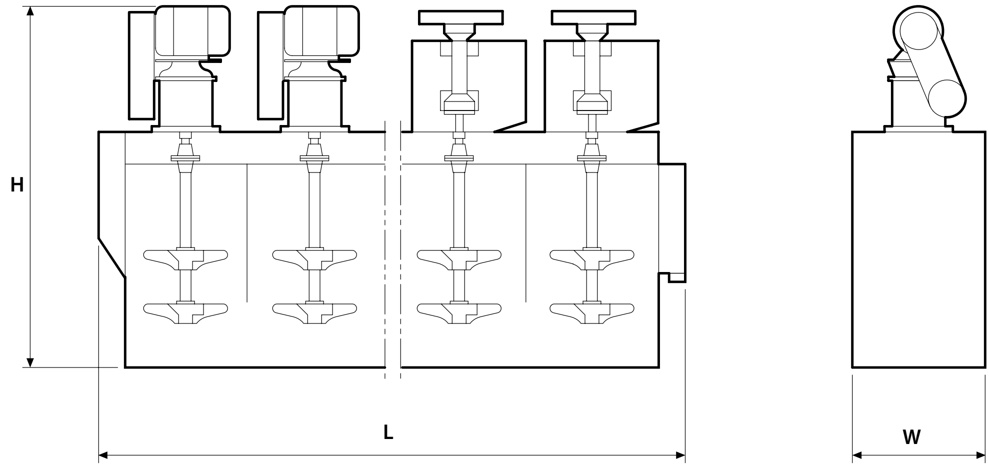
[1] Motor mounting may change for these sizes.

Conditioner



A mm (ft)	D mm (ft)	H mm (ft)
1.25 (4)	1.25 (4)	1.85 (6)
1.50 (5)	1.50 (5)	2.10 (7)
1.75 (6)	1.75 (6)	2.35 (8)
2.00 (7)	2.00 (7)	2.70 (9)
2.50 (8)	2.50 (8)	3.20 (10)
3.00 (10)	3.00 (10)	3.80 (12)
3.50 (11)	3.50 (11)	4.40 (14)
4.00 (13)	4.00 (13)	4.90 (16)
4.50 (15)	4.50 (15)	5.50 (18)
5.00 (16)	5.00 (16)	6.10 (20)
6.00 (20)	6.00 (20)	7.10 (23)
6.00 (29)	7.00 (23)	8.30 (27)
7.00 (23)	8.00 (26)	9.50 (31)

Attrition scrubber



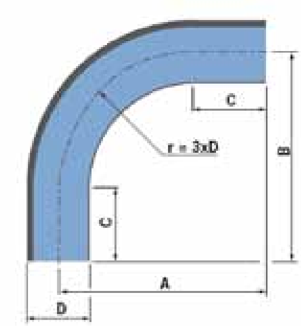
Model	L 2-cell mm (ft)	L 4-cell mm (ft)	L 6-cell mm (ft)	W mm (ft)	H mm (ft)	Weight/ cell [kg]
11x11 1)	795 (31)	1 385 (55)	1 975 (78)	300 (12)	940 (37)	100 (220)
16x16 1)	1 135 (45)	1 965 (78)	2 795 (110)	420 (17)	1 400 (55)	450 (992)
24x24 1)	1 660 (65)	2 915 (115)	4 165 (164)	630 (25)	1 800 (71)	650 (1 433)
32x32 1)	2 170 (85)	3 835 (151)	5 500 (217)	840 (33)	2 300 (91)	975 (2 150)
40x40 1)	2 690 (106)	4 775 (188)	6 860 (270)	1 050 (41)	2 900 (114)	1 500 (3 307)
40x40 2)	2 690 (106)	4 775 (188)	6 860 (270)	1 050 (41)	2 660 (105)	2 000 (4 409)
48x48 2)	3 250 (128)	5 735 (226)	8 220 (324)	1 250 (49)	3 400 (134)	2 800 (6 173)
56x56 2)	3 895 (153)	6 785 (267)	9 670 (381)	1 450 (57)	4 000 (158)	3 750 (8 267)
64x64 2)	4 415 (174)	7 705 (303)	10 900 (429)	1 650 (65)	4 400 (173)	4 650 (10 251)
72x72 2)	4 915 (194)	8 625 (340)	12 330 (485)	1 860 (73)	4 600 (181)	5 500 (12 125)

1) V-belt drive
2) Reducer drive

Trellex® Material handling hose

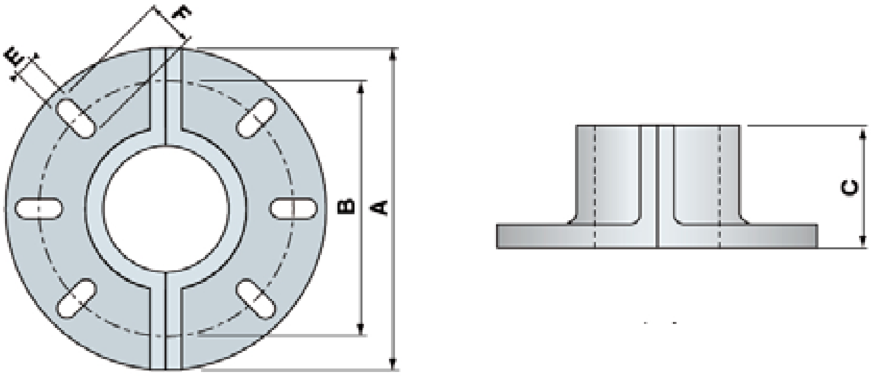
ID mm	ID inch	OD mm	Standard length m	Wear tube mm	Working pressure Mpa	Min.bend radius mm	Slurry hose kg/m
44	1.75	64	20	6	1.0	140	2.2
51	2.00	72	20	6	1.0	150	2.4
63	2.50	82	20	4.5	1.0	180	2.6
76	3.00	99.5	20	6	1.0	200	4.1
80	3.15	104	20	6	1.0	210	4.3
90	3.50	113	20	6	1.0	240	4.7
102	4.00	125	20	6	1.0	280	5.4
116	4.50	141	20	6	1.0	340	7
127	5.00	154	20	6	1.0	400	7.5
140	5.50	166	10	6	1.0	500	8.6
152	6.00	178	10	6	1.0	600	8.9
180	7.10	212	10	6	1.0	1000	12.6
190	7.50	224	10	7.5	1.0	1150	14.4
204	8.00	238	10	7.5	1.0	1300	16.2
240	9.50	281	10	7.5	0.5	1550	23.8
254	10.00	291	10	7.5	0.5	1600	21.3
305	12.00	341	10	7.5	0.5	1800	26.5
355	14.00	403	10	12	0.5	2200	40.8
405	16.00	456	10	12	0.5	2500	46.3
457	18.00	507	10	10.5	0.5	2900	55.2
508	20.00	558	10	12	0.5	3100	64.4
610	24.00	664	10	12	0.5	3700	87.7

Trellex® 3xD bend



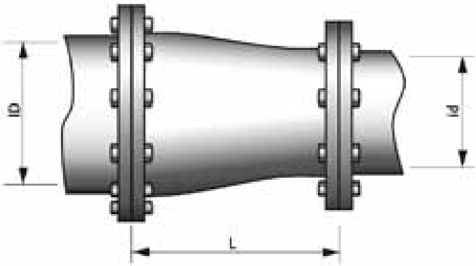
ID mm	OD mm	Wear tube Inner radius mm	Wear tube Outer radius m	Operating pressure Mpa	A x B	C	r
51	72	5	7	1.0	260 x 260	105	155
63	82	5	7	1.0	285 x 285	105	180
76	99.5	6	8	1.0	335 x 335	105	230
102	125	6	8	1.0	455 x 455	150	305
116	141	6	8	1.0	510 x 510	160	350
127	154	6	8	1.0	570 x 570	190	380
152	178	6	8	1.0	670 x 670	215	455
204	238	7.5	10	1.0	890 x 890	275	615
254	291	7.5	10	0.5	980 x 980	215	765
305	341	7.5	10	0.5	1170 x 1170	255	915
355	403	12	16	0.5	1145 x 1145	295	850
405	456	12	16	0.5	1615 x 1615	400	1215

Trellex® Couplings



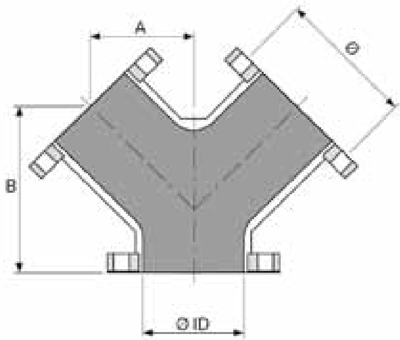
	Dimensions							Matches flange		
Coupl. size	A mm	B mm	C mm	ExF mm	Holes per joint	Sect./ segment	Weight kg	DIN 2632 PN 10	Ansi B16.1 Class 150	Operating press. Mpa
44	165	124	71	18x20	2	2	1.6	50	2″	1.0
51	165	124	91	18x20	2	2	1.8	50	2″	1.0
63	185	146	91	18x24	2	2	2.2	65	2.5″, 3″	1.0
76	200	158	91	18x24	2	2	2.4	80	3″	1.0
80	200	158	91	18x24	2	2	2.5	80	3″	1.0
90	220	184	113	18x24	3	2	3.0	100	3.5″, 4″	1.0
102	220	184	133	18x24	3	2	3.5	100	4″	1.0
116	250	213	143	23x26	3	2	4.5	125	5″	1.0
127	250	213	165	23x26	3	2	4.8	125	5″	1.0
140	285	238	175	23x27	3	2	5.9	150	6″	1.0
152	285	238	197	23x27	3	2	6.2	150	6″	1.0
180	308	260	217	23x26	3	2	7.5	-	-	1.0
190	343	295	237	23x26	3	2	10.2	200	8″	1.0
204	340	295	257	23x26	3	2	10.6	200	8″	1.0
240	406	355	197	25x31	5	2	11.0	250	10″	0.5
254	405	353	197	25x33	5	2	11.1	250	10″	0.5
305	476	401	237	25x30	5	2	18.4	300	-	0.5
1305*	495	424	237	25x40	5	2	21.4	-	12″	0.5
355	530	455	277	27x40	3	4	25.6	350	-	0.5
1355*	530	466	277	28x41	2	4	27.0	-	14″	0.5
405	600	521	400	27x51	3	4	45.4	400	16″	0.5
457	634	556	450	27x36	4	4	49.9	450	-	0.5
1457*	634	569	450	27x36	3	4	51.3	-	18″	0.5
508	698	621	500	27x44	4	4	61.7	500	20″	0.5
610	820	731	600	30x52	4	4	79.5	600	24″	0.5

Trellex® Reducers



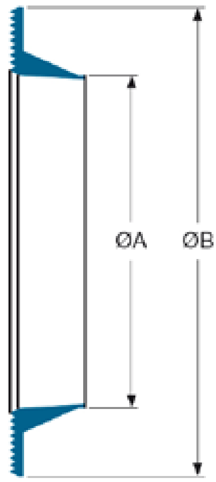
ID/id mm	Wear Tube mm	Working Pressure Mpa	Length mm L
63/51	6	1.0	380
102/51	6	1.0	380
102/63	6	1.0	380
102/76	6	1.0	380
102/82	6	1.0	380
127/82	6	1.0	380
127/102	6	1.0	380
152/102	6	1.0	380
152/127	6	1.0	380
178/152	6	1.0	380
204/127	6	1.0	380
204/152	6	1.0	380
204/178	6	1.0	380
254/204	7.5	1.0	380
305/204	7.5	1.0	380
305/254	7.5	1.0	380
355/204	7.5	1.0	380
355/254	7.5	1.0	380
355/305	7.5	1.0	380

Trellex® Branch pipes



ID/id mm	A mm	B mm	Hole division DIN mm	Hole division ANSI mm
102	107	184	180	7.00
127	125	216	210	8.25
152	140	241	240	9.25
204	187	323	295	11.50
254	226	390	350	14.00
305	268	463	400	16.00
355	320	550	460	18.50

Trellex® Gaskets



For internal hose diameter	A mm	B mm
44	42	82
51	49	89
63	58	99
76	74	118
80	78	122
90	88	132
102	98	144
116	113	160
127	123	175
140	137	188
152	148	202
180	177	232
190	187	244
204	198	258
240	238	302
254	248	314
305	298	365
355	350	415
405	400	466
457	452	520
508	503	578
610	605	684

Introduction

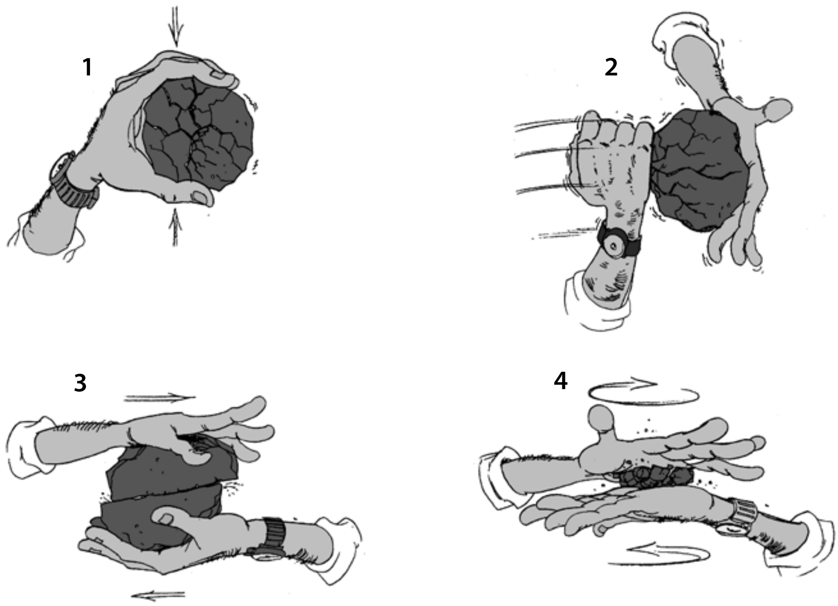
Mineral processing activities unavoidably result in wear. And wear costs money. Often lots of money. This is related to the structure of rock, ore or minerals, being crystals normally both hard and abrasive.

Why wear at all?

Wear is caused by the normal rock stress forces

- Compression (1)
- Impaction (2)
- Shearing (3)
- Attrition (4)

in combination with **mineral hardness and energy!**



Wear in operation

caused by

COMPRESSION

IMPACTION HIGH VELOCITY >7m/s

IMPACTION LOW VELOCITY <7m/s

SLIDING

METALS
- Manganese steel
- Ni hard Ni-Cr white iron
- High crome Cr white iron

protected by

Polymers
- Rubber
- Polyurethane

CERAMICS

Wear by compression

COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING

Metals

- Manganese steel
- Ni hard Ni-Cr white iron
- High crome Cr white iron

Applications:

Crushers: Gyratory, Cone, Jaw

Metals and compression

Manganese steel: The first option for compression wear is manganese steel. This alloy has a very special property, being self hardening and self healing when exposed to large amounts of compression and impact energy.
Normal standard is a 14% Mn alloy which is first option in most crushing applications.
18 % Mn alloy is a harder but also a more brittle alloy used in applications where the rock is softer (limited self hardening) but very abrasive.

Restrictions:
When installed in applications without work hardening service life will be poor!

The alloys of cast ”white iron” type (High-chrome and Ni- hard) shall be avoided in crushers submitted to heavy compression.

Wear by impaction (high)

COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING

Metals

- Manganese steel
- Ni hard Ni-Cr white iron
- High crome Cr white iron

Applications:

Impactors: HSI, VSI

Grinding mills

Slurry pumps

Metals and impaction

The metals can be classified as:

Manganese: Needs high impaction for self hardening. If impaction is getting lower and sliding is increasing Manganese is not suitable.
High Chrome: Opposite to manganese, can take heavy sliding but is more fragile and therefore limited against impaction.
Ni-hard: Somewhere between the two materials above.
Cr-Mo: Used in grinding when High Crome is too brittle

Note! *The use of chrome steel (less brittle than chrome iron) is increasing for liners, curtains and hammers.*

Wear by impaction (low)

COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING

Polymers: Rubber, Polyurethane

CERAMICS

Rubber and impaction
For low velocity impaction (material speed less than 7 m/s) SBR, styrene butadiene rubber (60 ShA) is always the first choice and will give the best cost effectiveness. The material is also very tolerant to material size and is excellent for use in grinding mills, dump trucks and primary hoppers.

Restrictions:
Look out for aromatic and fuel oils.
Impact angles have to be considered, see 9:4.

Applications:
Dump Trucks, Feeder hoppers, Transfer points, Grinding Mills Slurry pumps

Wear by sliding

COMPRESSION | IMPACTION HIGH VELOCITY >7m/s | IMPACTION LOW VELOCITY <7m/s | SLIDING

Polymers: Rubber, Polyurethane

CERAMICS

Rubber and sliding
Natural rubber is an outstanding option for the sliding abrasion of small, hard and sharp particles. Also for wet conditions.

Restrictions:
If sliding speed is exceeding 7 m/s (dry applications) temperature can start to rise and cause damage. Besides temperature oil is always a threat.

Polyurethane and sliding
Best option for tough sliding applications when particle size is lower than 50 mm. Excellent in wet applications. Tolerant to chemicals and oil.

Applications:
Chutes, Spouts

Restrictions:
Large sizes and high velocity might cause problems.

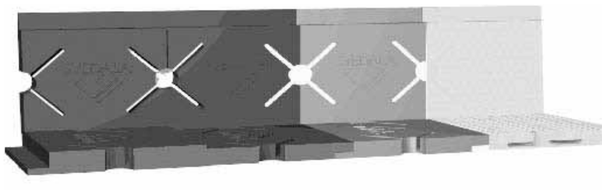
Ceramics and sliding
The natural choice when mission is too hard for the options above. Hardness, resistance to temperature and corrosion plus low weight gives a masterpiece for sliding.
Al_20_3 (Aluminium oxide) is the most cost-effective material.

Restrictions:
Impaction is dangerous for ceramics (cracking) and must be avoided. Combination ceramics + rubber is an option. Composition and quality can vary from supplier to supplier.

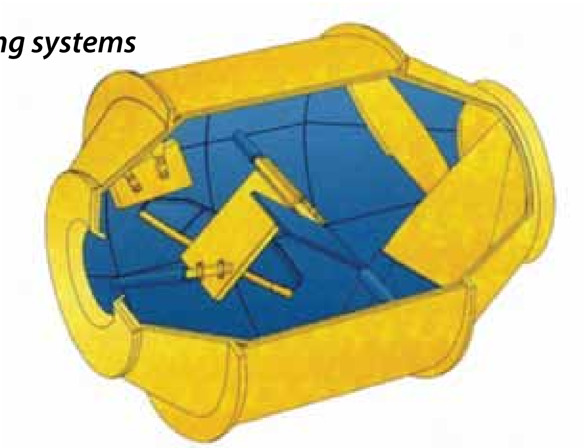
Wear protection – Wear products

Modules

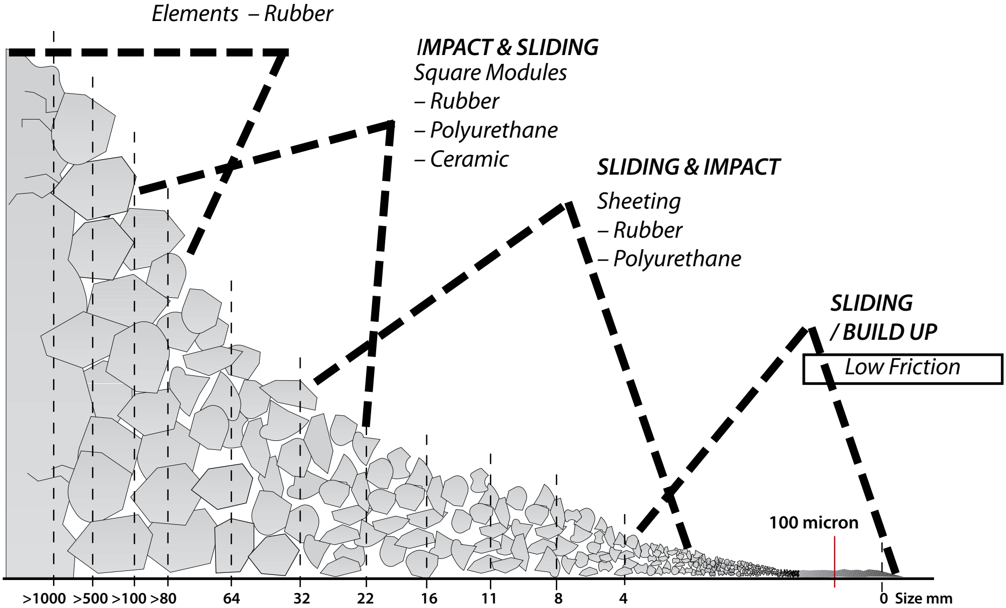
Sheets, elements and profiles



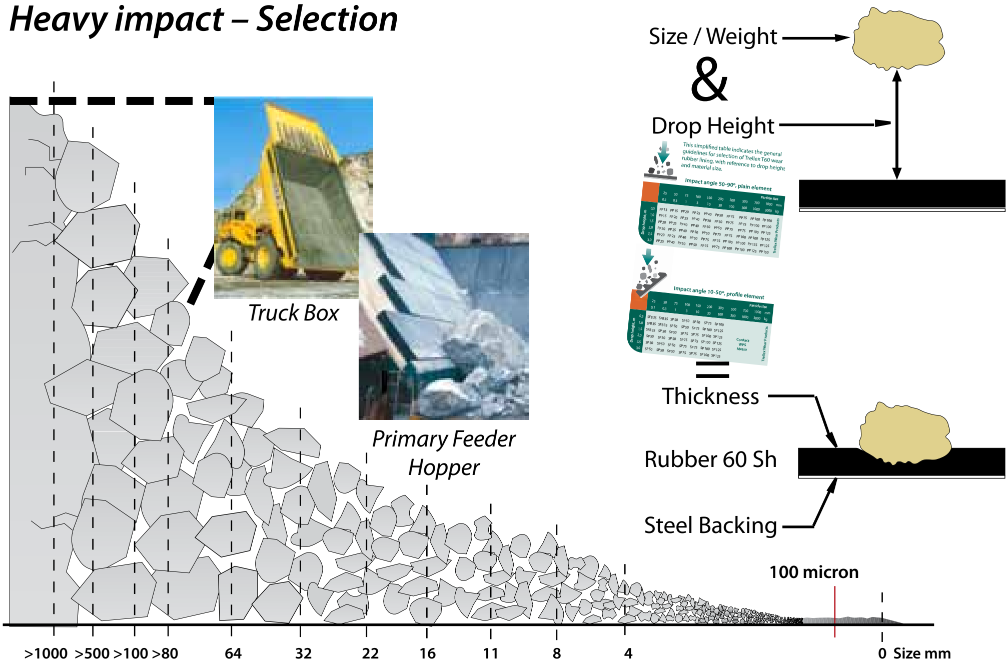
Customized lining systems



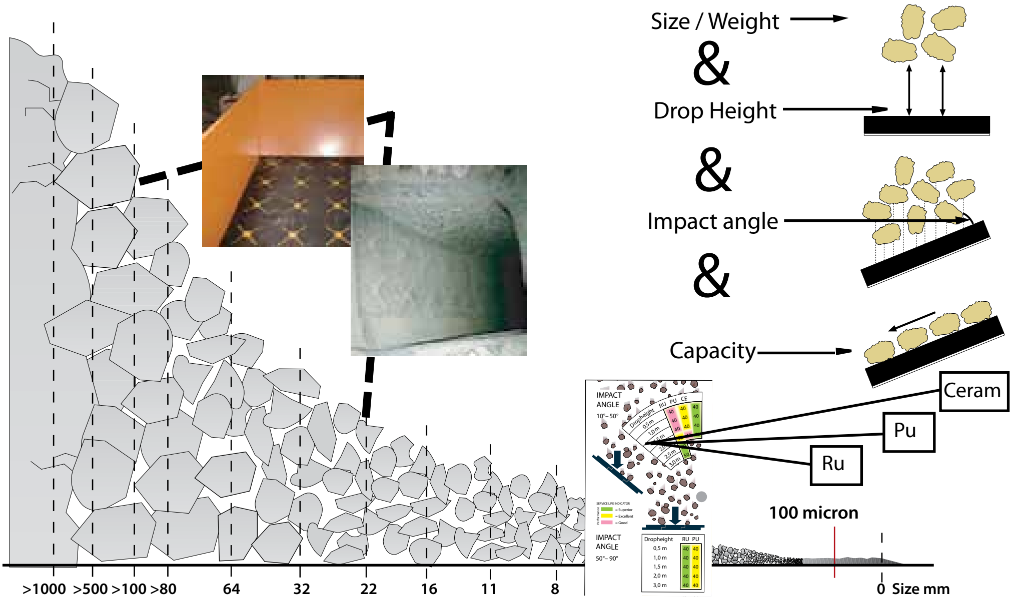
Wear products – applications



Heavy impact – Selection

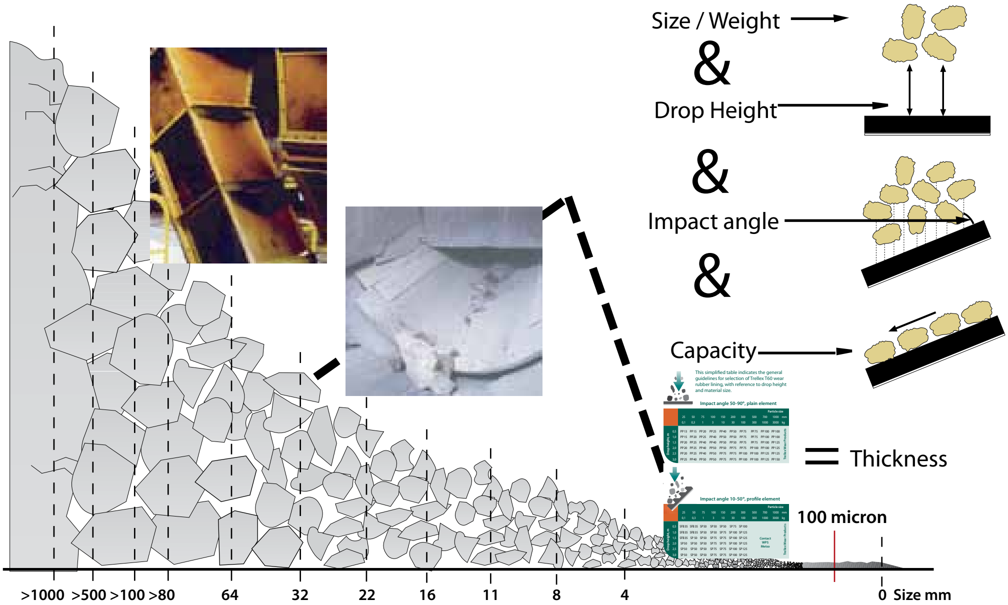


Impact and sliding – Selection (modules)



Wear in operation

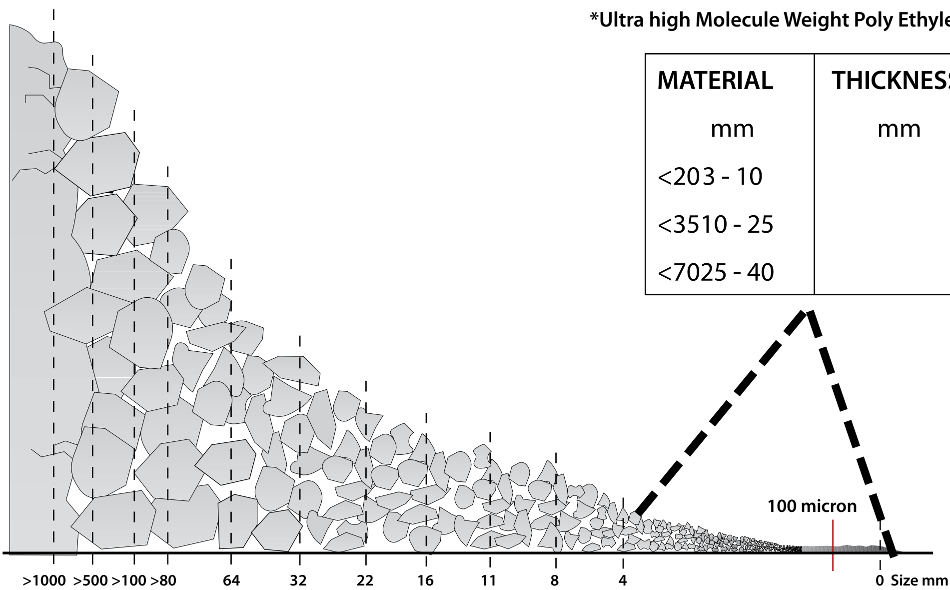
Impact and sliding – Selection (sheeting)



Sliding and build up – selection

Low Friction Elements – UHMWPE*
***Ultra high Molecule Weight Poly Ethylene**

MATERIAL	THICKNESS
mm	mm
<203 - 10	
<3510 - 25	
<7025 - 40	



Wear protection – Wear parts

Wear parts – Screening

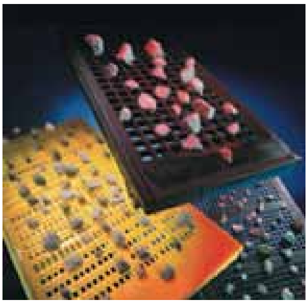
Self supporting rubber panels

Rubber & polyurethane tension mats

Rubber & polyurethane bolt down panels

Antiblinding rubber mats

Rubber / polyurethane modular systems



Wear parts – Grinding

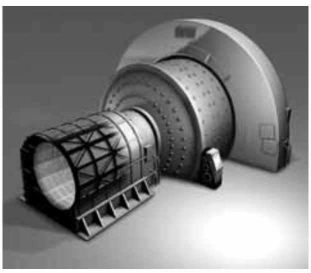
Rubber linings

Poly-Met® linings

Metallic linings

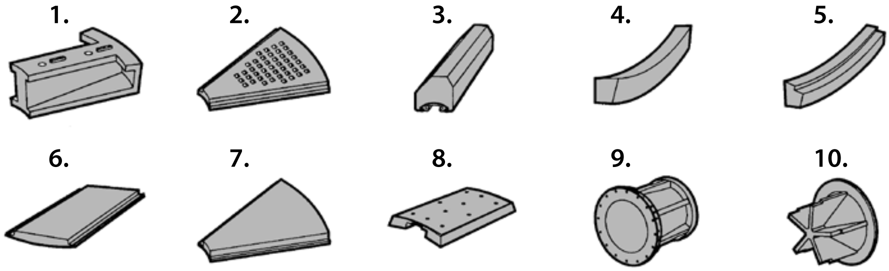
Orebed® linings

Trommel screens



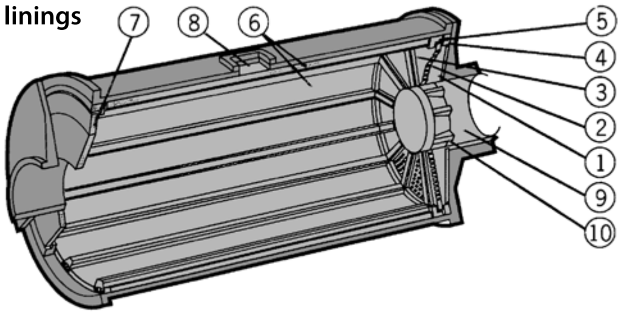
Discharge systems

Tumbling mill – lining components

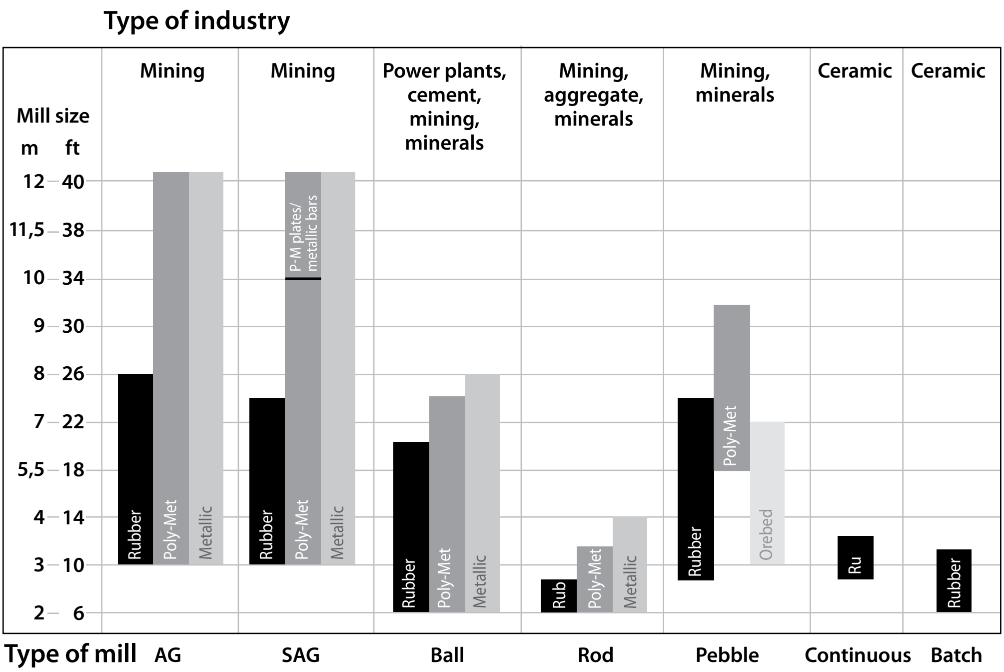


Lining life time – standard linings
"ball park figures"

Type of mill	Months
AG	12 – 24
SAG	3 – 12
Rod	6 – 24
Ball	6 – 36
Pebble	12 – 48



*Linings for mills**

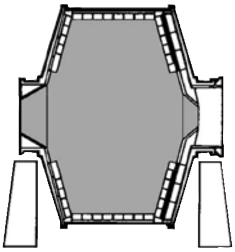


Discharge systems, trunnion linings and trommel screens are suitable for all sizes.

**This is a general view of suitable linings. Please contact Metso for more detailed information.*

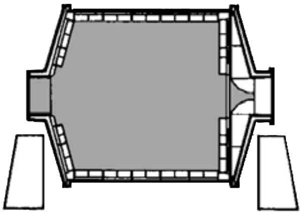
Tumbling mill liners – material

AG mills



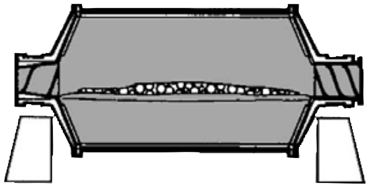
Dry: Metal (white iron)
Wet: Metal (white iron or Poly-Met)

SAG mills



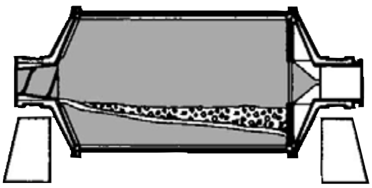
Dry: Metal (Cr-Mo)
Wet: Metal (Cr-Mo or Poly-Met)

Rod mills



Dry: Metal (white iron)
Wet: Metal (white iron)
Rubber and Poly-Met, (Poly-Met on shell only at mill ends)

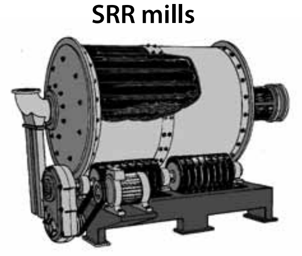
Ball and Pebble mills



Dry: Metal (or rubber if temperature not critical)

Wet: Rubber (secondary and regrind) Poly-Met

SRR mills



Dry-rod: Metal

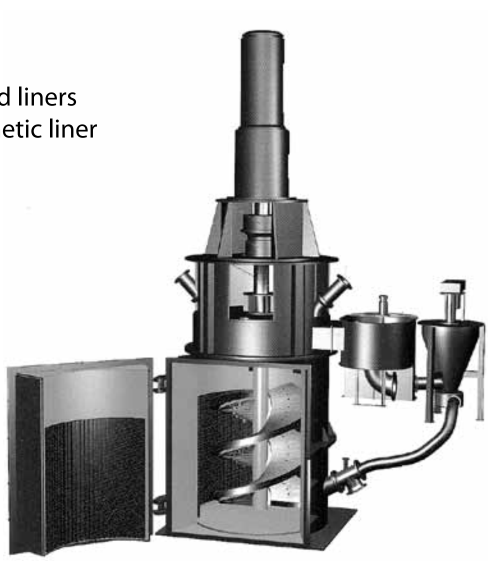
Dry-ball: Metal (or rubber if temperature not critical)

Wet-rod: Metal

Wet-ball: Rubber

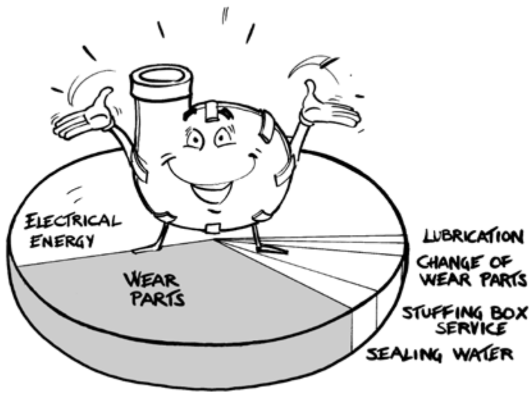
VERTIMILL® – Liners

Screw – metal with Nihard liners
Chamber – Orebed magnetic liner

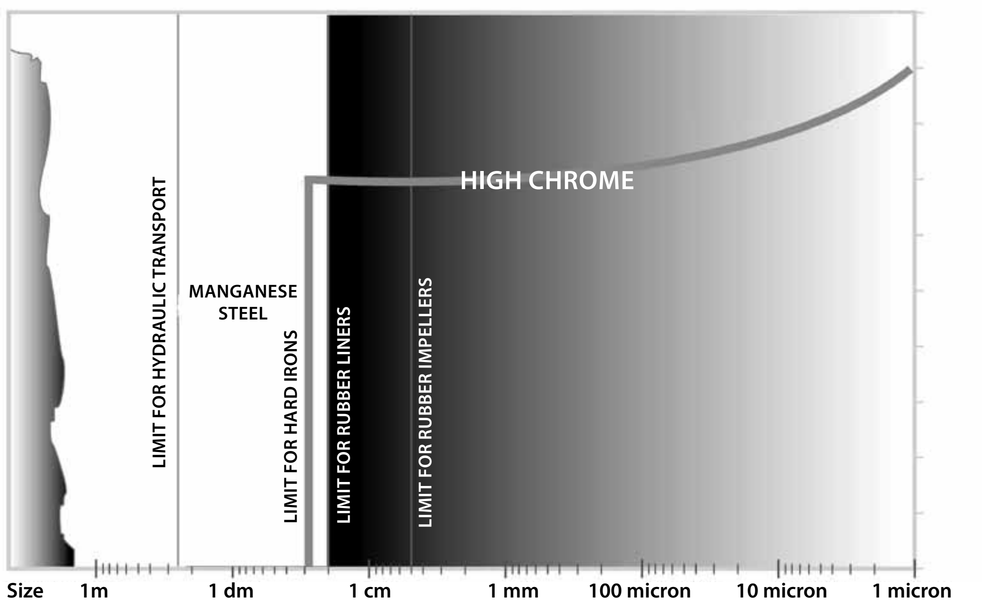


Wear parts – Slurry pumps

Although the size of solids in a slurry is smaller than the feed size to a crusher or a grinding mill, wear represents a high operation cost for slurry pumping. This is naturally related to the high dynamic energy input in the form of high tip speed of the pump impeller causing both sliding and impaction wear.



Wear material vs size



Wear parts pumps – metal

High chrome iron (600Br) can be used at Ph down to 2.5. Standard wear material for most pump ranges.

Ni – hard with hardness exceeding 600 Br used mainly as casing material for pumps in grinding circuits or dredging.

High density frozen Ni-hard with hardness up to 900 Br used as casing material in primary grinding circuits.

Manganese steel with hardness up to 350 Br used for dredging applications.

Wear parts pumps – elastomers

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) Contin.	Occasion.
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) to 45-50	65

Something about ceramic liners

Although ceramics have high resistance against wear, temperature and most chemicals, they have never really been accepted as day-to-day standards in Slurry Pumping.

Being both brittle and expensive to manufacture.

Development work on ceramics continue in an attempt to improve the possible acceptance.

Wear in slurry pipelines

It is not easy to compare wear rates for different materials in a slurry pipeline depending on variations in duty. As a guide the figures below can be used (Transport and Road Research Laboratory test report of wear in slurry pipelines).

From the first of two programs of wear tests, the following conclusions were reached:

– Over the range investigated (2 to 6 m/s) wear varied according to a power between the square and cube of the velocity.

– Over the range investigated (5 to 15% by volume) wear varied more or less linearly with concentration.

– Over the range investigated (0.015 to 1.5 mm) wear varied more or less linearly with particle size.

– Emery (Mohs Hardness 8 to 9) produced a wear rate several times greater than that for silica sand (Mohs hardness 6 to 7).

In the second program the operating conditions were kept constant (velocity 4 m/s, 10% slurry) while 18 different pipe materials were compared.

Among them, three were rubber "a" (Trellex T40) - rubber "b" (Trellex T60) and rubber "c" (a British make).

Material	Wear rate (mm/year)	Life expectancy of a 5 mm thick tube (years)
Rubber "a" (Trellex T40)	0.13	38
Zirconia/alumina ceramic	0.15	33
Ni-hard steel	0.19	26
Polyurethane "a"	0.20	25
Polyurethane "b"	0.22	22
Rubber "b" (Trellex T60)	0.35	14
Sintered alumina	0.40	12
Rubber "c" (not Trellex)	0.61	8
High Density polyurethane "b"	0.67	7
High density polyvinyl chloride	0.87	5
Unplasticised polyvinyl chloride	1.27	4
Stainless steel	1.29	4
Mild steel "a"	1.57	3
Polypropylene	1.59	3
Mild steel "b"	1.69	3
ABS	2.52	2
Asbestos/cement	94.68	–

Operation and environment – Introduction

From environmental, health and safety point of view most mineral processing operations have some negative affects on the working environment.

The main problems are related to

- **Dust (dry plants)**
- **Noise (wet and dry plants)**
- **Pollution (emissions other than dust to air and water)**

Regarding pollution of water and air by various emissions we refer to the process sections 5 and 6 above (enrichment and upgrading).

Dust

Dust – Size

When energy is introduced to rock, ore or mineral crystals will generate a dust emission. *With dust in mineral processing we practically understand particles below 100 micron in size*. Above this size dry particles are easy to control and are quite harmless.

Dust – Chemical composition

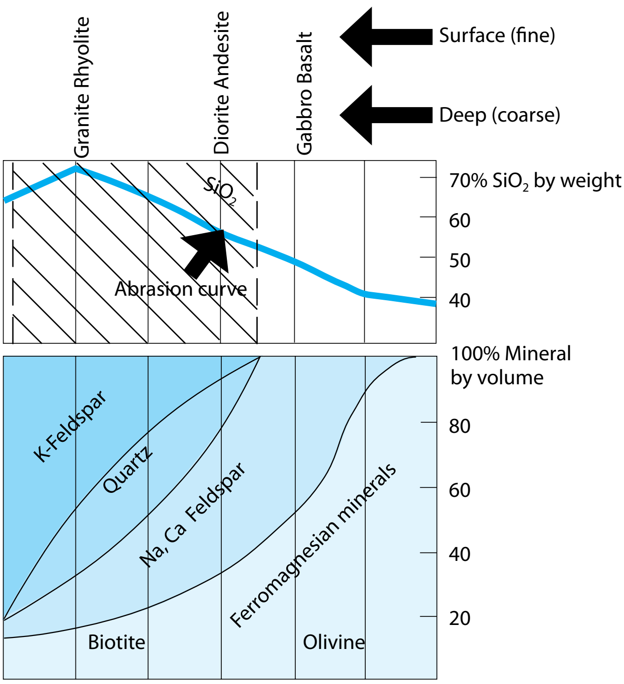
A parameter of interest is the chemical composition. Hard rock in many cases is hazardous due to the silica content.

Free quarts (SiO_2) is extremely dangerous and so are the rocks containing quarts like granite, gneiss a.o, see figure below. Fine silica can cause silicosis, a deadly lung disease. Mg-silicate of asbestos type is also very dangerous when inhaled, causing lung cancer.

As many of the silicates are hard and abrasive these dust fractions also are causing heavy wear when exposed to bearings, motors etc.

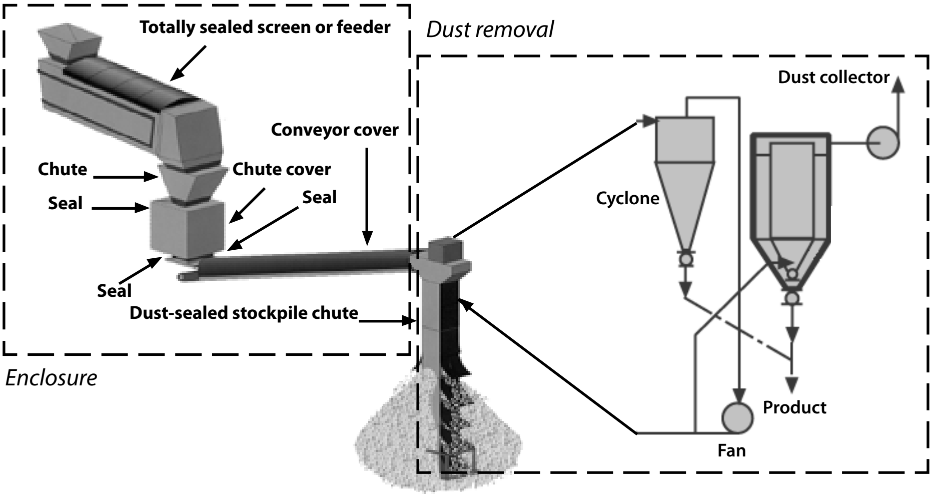
Dust – SiO_2 levels

Dust fractions of non - silica type are normally not too dangerous for the operators and give more lika a "housekeeping" problem.



SiO_2 levels in magmatic rock

Dust control – Basic



Some guidelines:

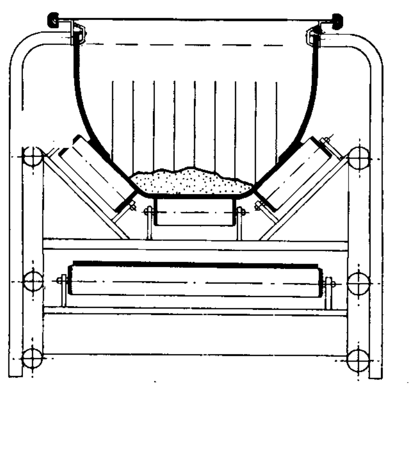
1. Let the dust *report to the material flow* by using dust suppression or enclosure.

2. Suppression by water or foam is cheap and handy but can only take care of the coarser dust. Fine dust will remain a problem. If too much water is used the dust will turn to sticky clay, causing down time in operation and freezing in cold climate.

3. Enclosures of machines are very effective provided that you only encapsulate the dust emitting part of the machine, not drives or other moving parts. Enclosures are also very effective against wind emission of fines from conveyors and for sealing off transfer points, see below.

*4. Dust remova*l by ventilation is used when the dust is the product (dry grinding of filler fractions) or when dust is not allowed in the final product or in the processing system, see ventilation criteria below.

Equipment enclosure



Wind enclosure

Ventilation criteria

Dust capture velocity in m/s (ft/min)

= Ventilation criteria **(Vc)** in $m^3/s/m^2$ ($ft^3/min/ft^2$)

= Air volume needed per open area of enclosure

Calculation of ventilation systems for dust removal is a tricky thing. Some estimation figures below:

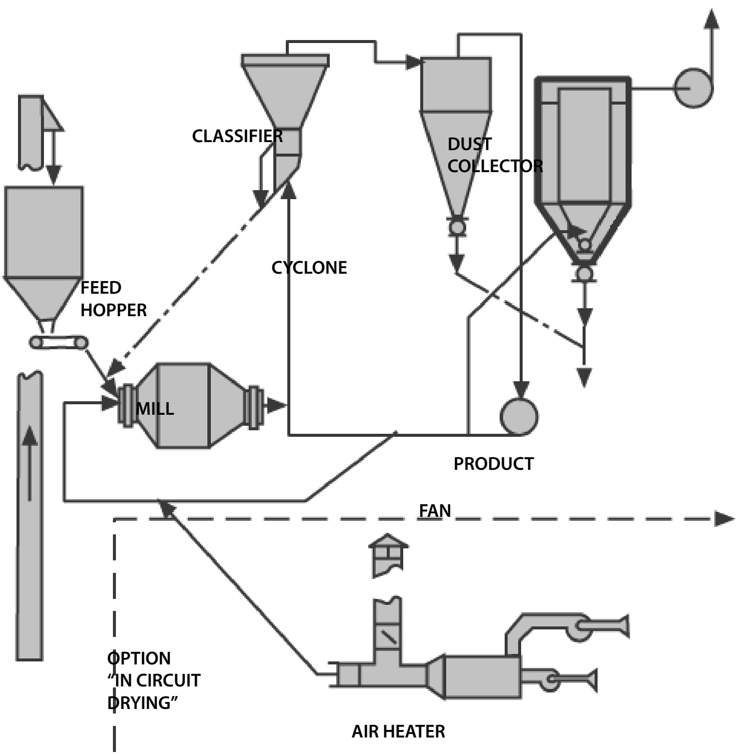
Application	**Vc**	**Comments**
Feeders, surge bin openings	1,02 (200)	General value for low-energy operations
Transfer points	2,33 (1500)	per enclosure area
Screens	0,26 (50)	per screen area
Crushers and dry mills	1,5 (300)	not for air swept mills

Dust collection

The dust removal and dust collecting systems are very similar to a normal dry classification circuit. Dry classification is in fact a dust removal system where the max size of the dust is controlled by a classifier (or ventilation criteria), See below.

Primary recovery of dust is normally done in a cyclone taking the major part. The final recollection is done in a wet scrubber or a fabric filter.

Wet scrubber has an advantage over fabric filter when the dust is combustible. In all other cases the dry fabric filtration is more effective as no sludge handling is required (being the case with wet scrubbers).



Noise

General

In mineral processing there are a number of machines considered to be very noisy (crushers, screens and grinding mills are typical).

By definition noise is an "undesirable" sound. As sound is **air borne sound pressure variations,** we have to find a sound pressure level, which can be tolerated by the operators. Noise is not only harmful to the hearing but also affects the heart action and the ability of concentration. It also restricts verbal communication and the observation of warning signals or dangerous situations.

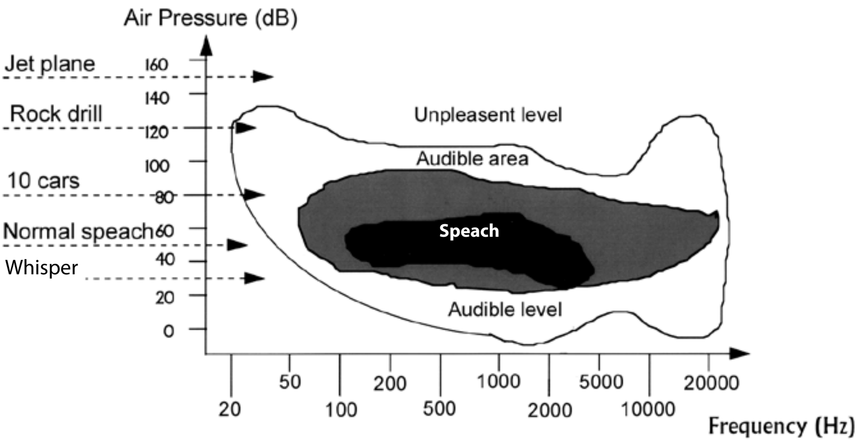
Sound – basic

The human sound pressure range from lowest sound to be heard and highest sound to stand without pain is
from 0,00002Pa (2µPa) to 20 Pa. (1 psi = 6,89kPa).

To be more practical the sound pressure range above is converted to a sound pressure level by the formula:

Lp = 20x log P/Po ***(Po = 2 µPa) converting the range above over to 0-120 dB (decibel)!***

Experienced sound	**change of dB**
Double sound level	+ 10dB
Double sound sources	+ 3 dB
Double the distance to sound source	– 6 dB



Hearing range for a normal ear

The lower limit is called the threshold of hearing and has a maximum sensitivity around 3500 Hz (resonance frequency of the ear).

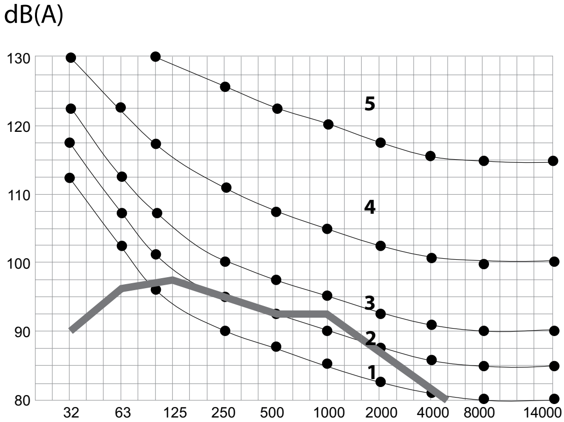
The upper line is the 120 dB sound pressure line (the pain line)

Mechanical noise is measured in dB (A) indicating that an A-filter is used, damping lower frequencies (of less harm to the operators).
Infra-sound is sound with a frequency below 22 Hz. (Can be harmful at longer exposures).
Ultra-sound is sound with a frequency above 18 kHz. (Can be harmful at longer exposures).

Noise – exposure risks

For continuous sound with a wide frequency range, a sound level below **85 dB(A)** is acceptable for an 8 hour exposure per day with respect to the risk of hearing damage.

If the sound level is higher an octave band analysis is necessary. This curve is compared to the standard risk curves, see below.



Maximum acceptable exposure per 8 hours:

5. Less than 5 min
4. Less than 20 min
3. 1 - 2 h
2. 2 - 5 h
1. 5 - 8 h

= middle frequency of octave Band (Hz) (Impact crusher on 1 m distance).

Noise reduction

There are 4 main ways to reduce the noise levels for processing systems including crushers, mills and screens.

- Optimum operation
- Use of "internal" polymers (wear material and wear products)
- Use of "external" polymers (dust enclosures)
- Enclosure with noise reduction walls

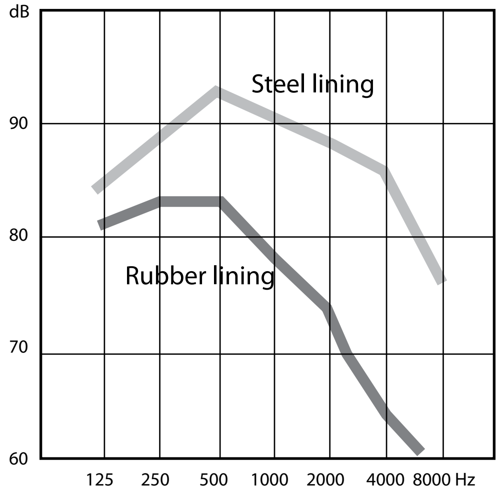
Optimum operation.

Mass flow equipment like crushers and screens are normally lower in noise when they are operated under optimum conditions and the material flow is absorbing part of the noise (e.g. choke fed cone crushers). Reduced circulating loads also lead to reduced noise levels.

Internal polymers

The use of polymers as mill liners, screening media and wear protection in material handling systems (chutes and transfer points) have a dramatic effect on noise reduction.

For grinding mills a rubber lining can reduce the noise level up to 10 dB(A) compared to a steel lining.

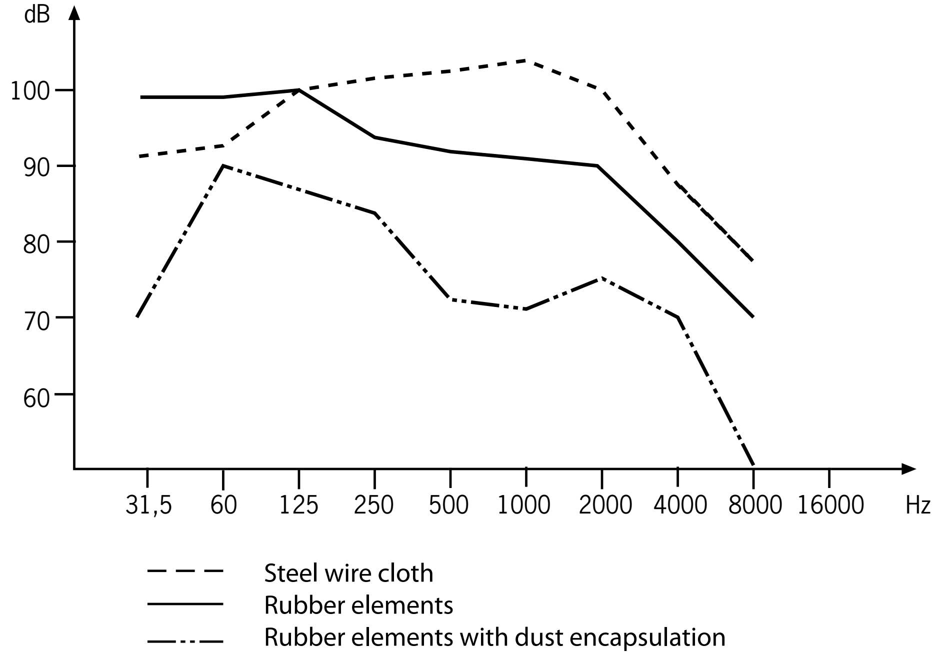


Operation and environment

Operation and environment

External polymers

Using polymers as dust sealing enclosures of crushers, screens, conveyors, chutes, transfer points etc. will give a noise reduction of approx. 5-10 dB (A). The difference for a screen with steel wire deck and rubber deck is shown below.



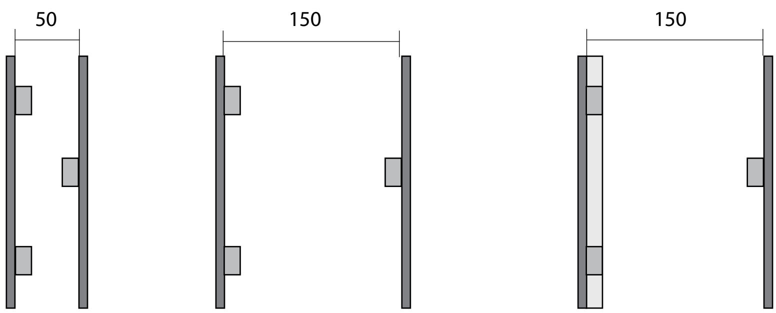
A simple rule: The more polymers used for various purposes in the mineral process systems the lower the noise levels!

Noise reduction walls

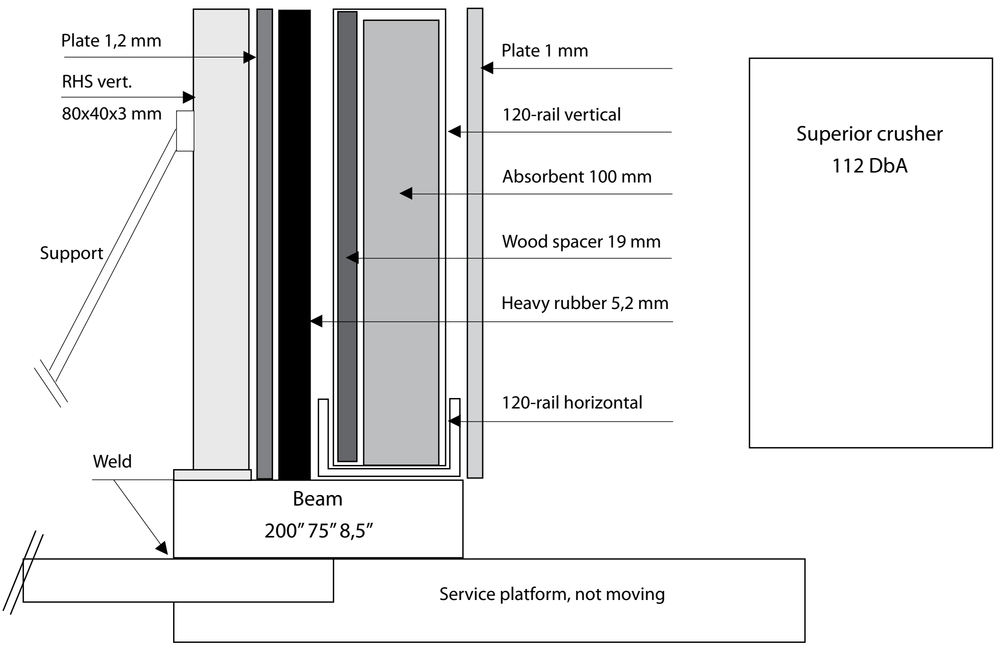
Enclosure is an effective way of reducing noise. Enclosure can be more or less extensive (enclosure of drive or machine or both). With a total enclosure noise levels can drop by 10-15 dB (A).

Depending on duty the design of the noise reduction walls can differ in design:

Light and medium duty walls



Heavy duty crusher wall , cross section



Ear protection

When working in environments with continuous and high noise levels it is important to use ear protection all the time. Also at sound levels of 75-80 dB (A) it is to be recommended to use ear protection even if recommendation says something else. Reason is that long exposure also at these levels can cause impairment of hearing.

Good rules about ear protection:

- Take some "noise breaks" now and then
- Go for regular hearing tests
- Check your ear protection equipment at certain intervals

Process system – Introduction

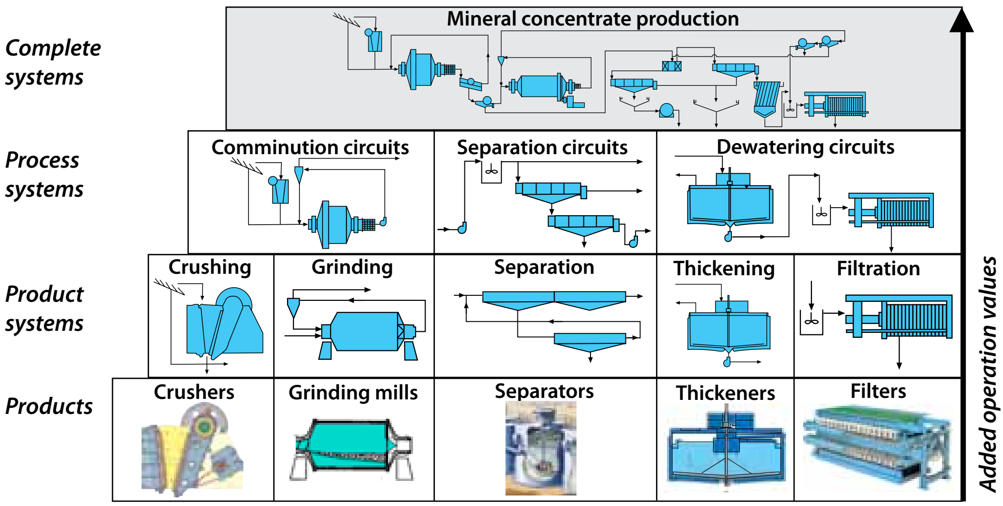
A machine working in a mineral process flow cannot perform better than the process environment will allow it to.

Parameters like type, size and amount of feed, % solids in slurries, additives, discharge conditions etc. will always guide equipment performance and operation economy.

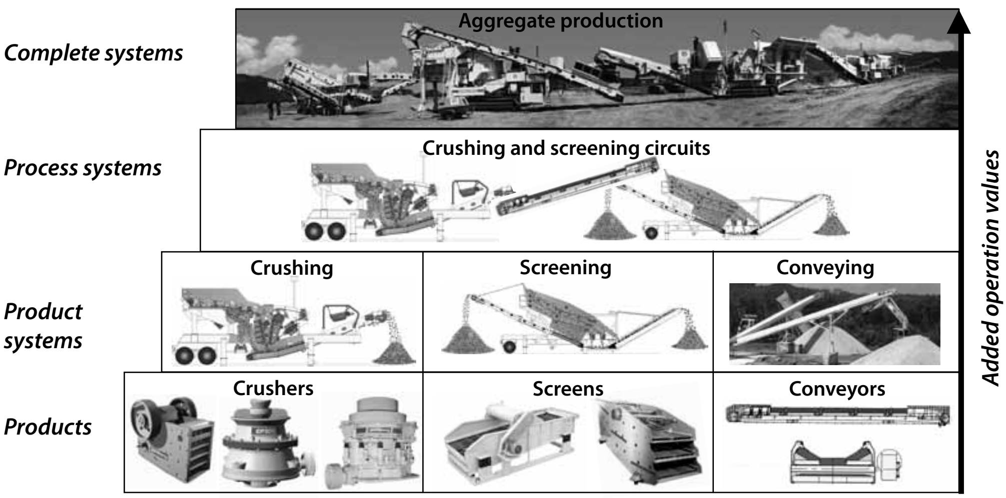
There is a strong trend amongst both suppliers and users to work in terms of systems, meaning solutions to various operation problems more than installing equipment. This will effectively increase the operation values as presented in section 2.9

Examples covering systems levels and system modules are shown in this section.

System levels in ore / Minerals processing



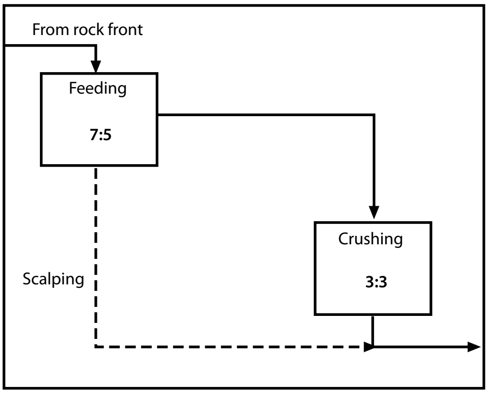
System levels in rock processing (Quarrying)



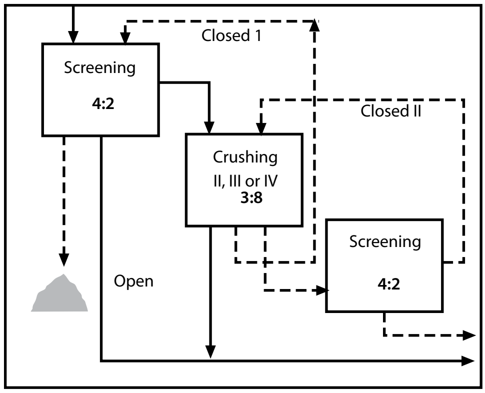
System modules – Aggregates

A good way to understand and work with process systems is to use **system modules** in various combinations.

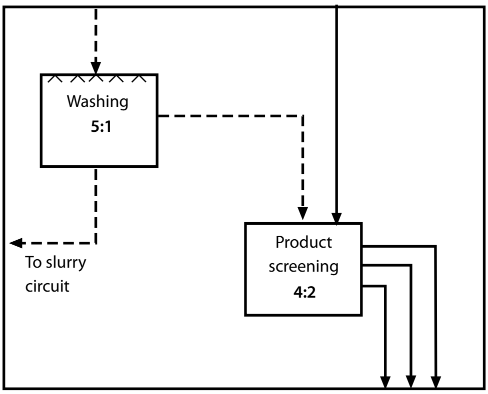
Primary crushing module



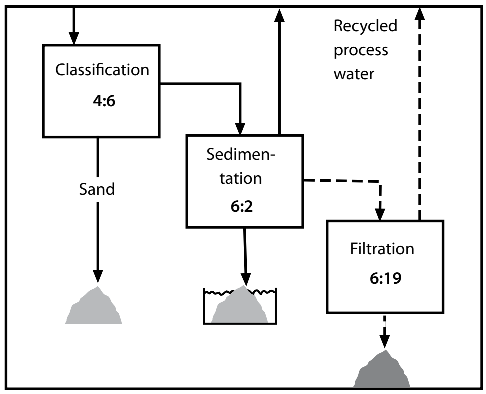
Intermediate crushing module



Final products module

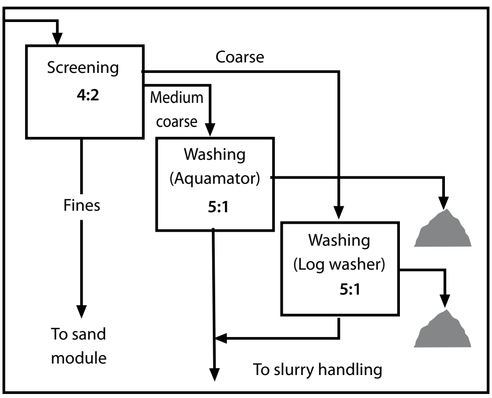


Slurry handling module

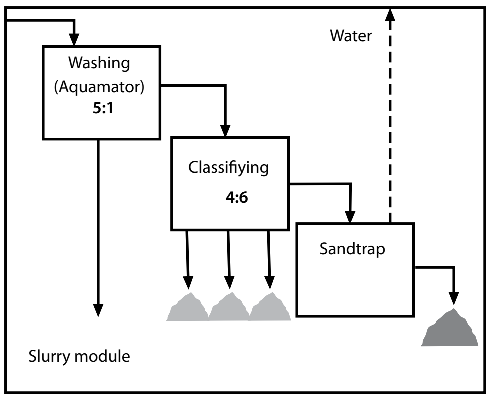


System modules – Sand and gravel

Sand and gravel module



Sand and gravel module



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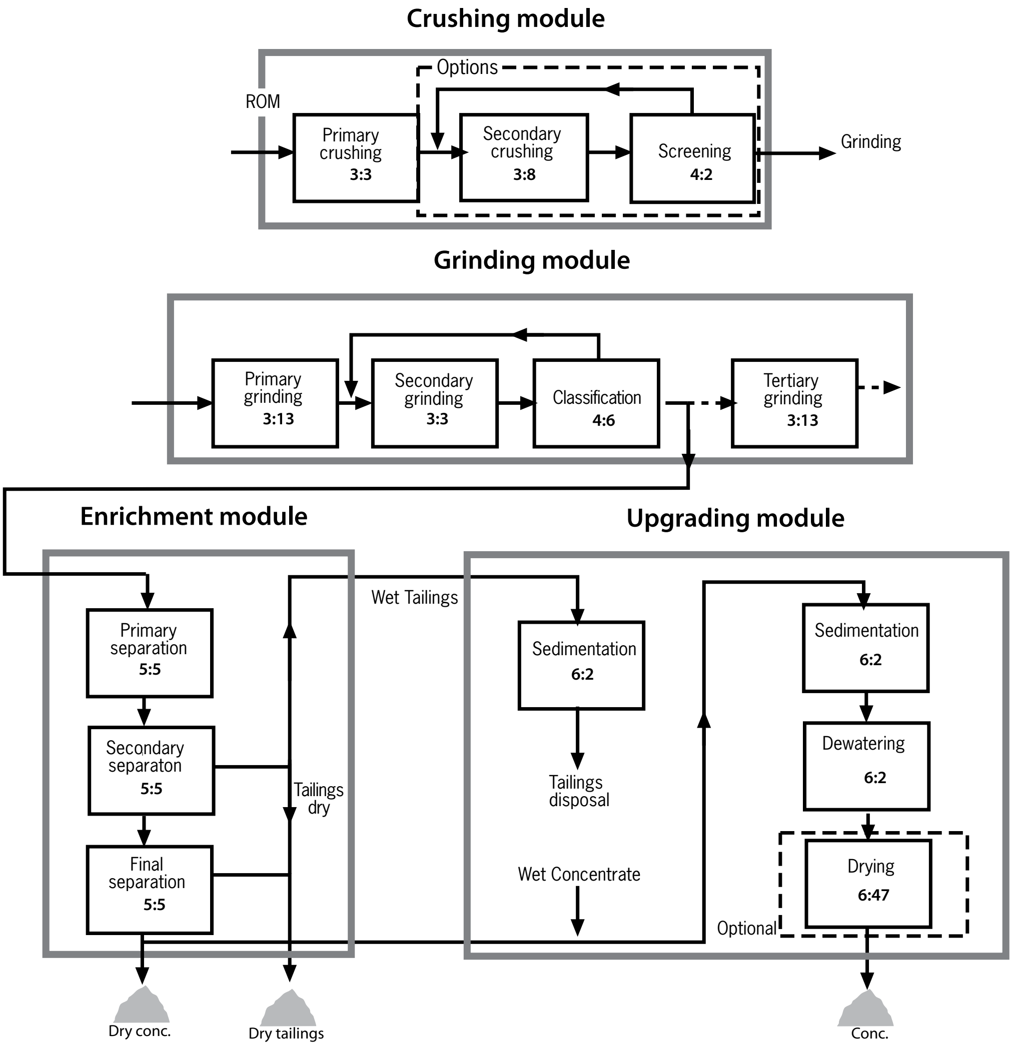
System modules – Ore and minerals



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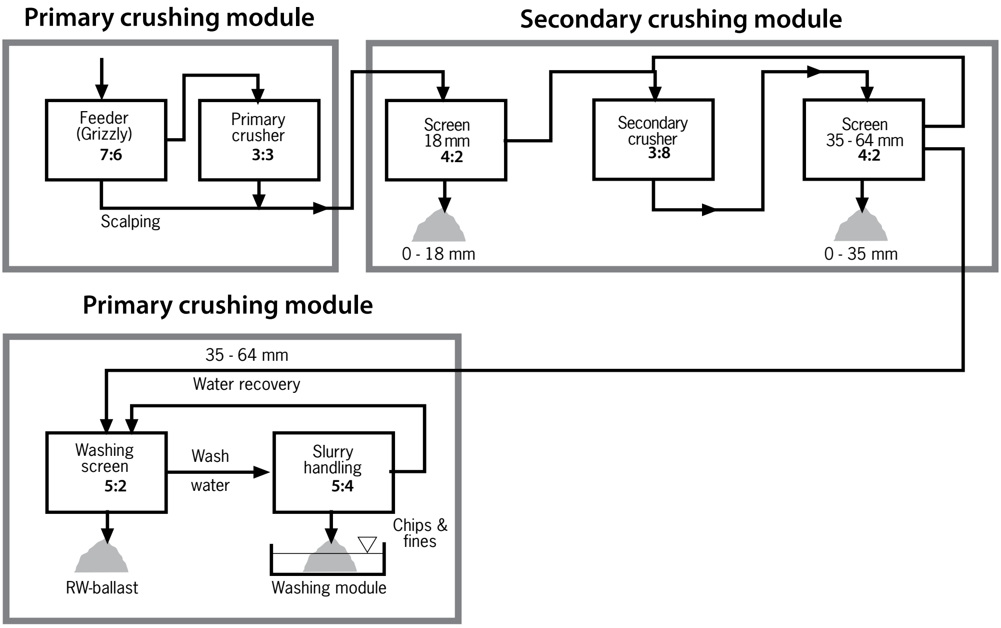
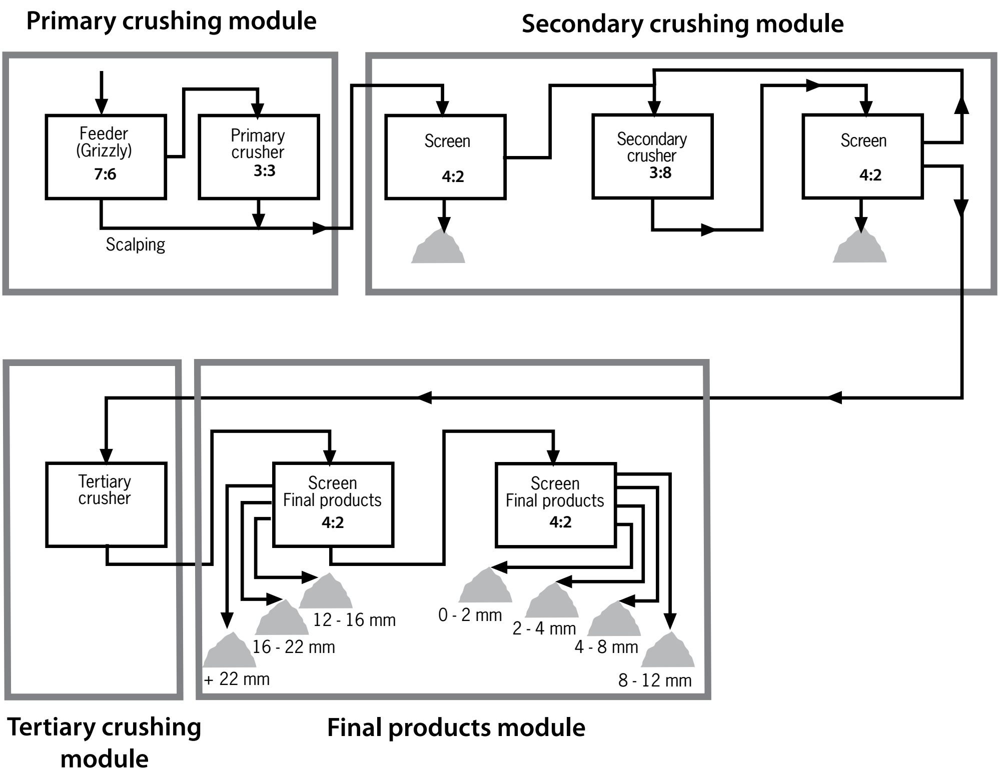
Process system – Railway ballast



Process systems – Asphalt / Concrete ballast



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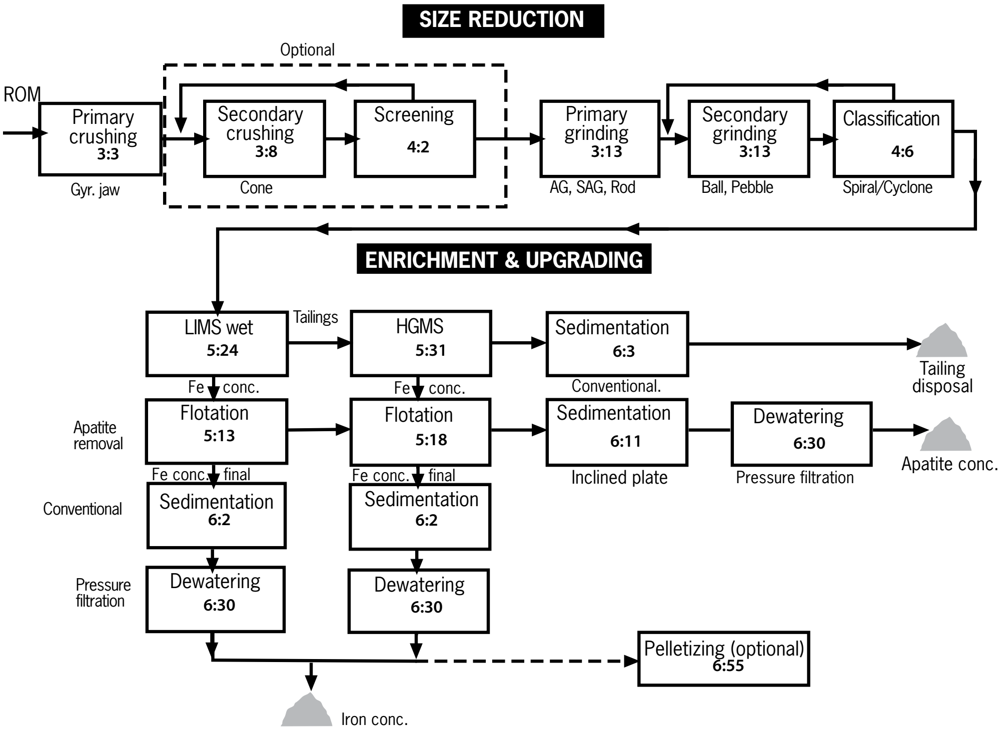
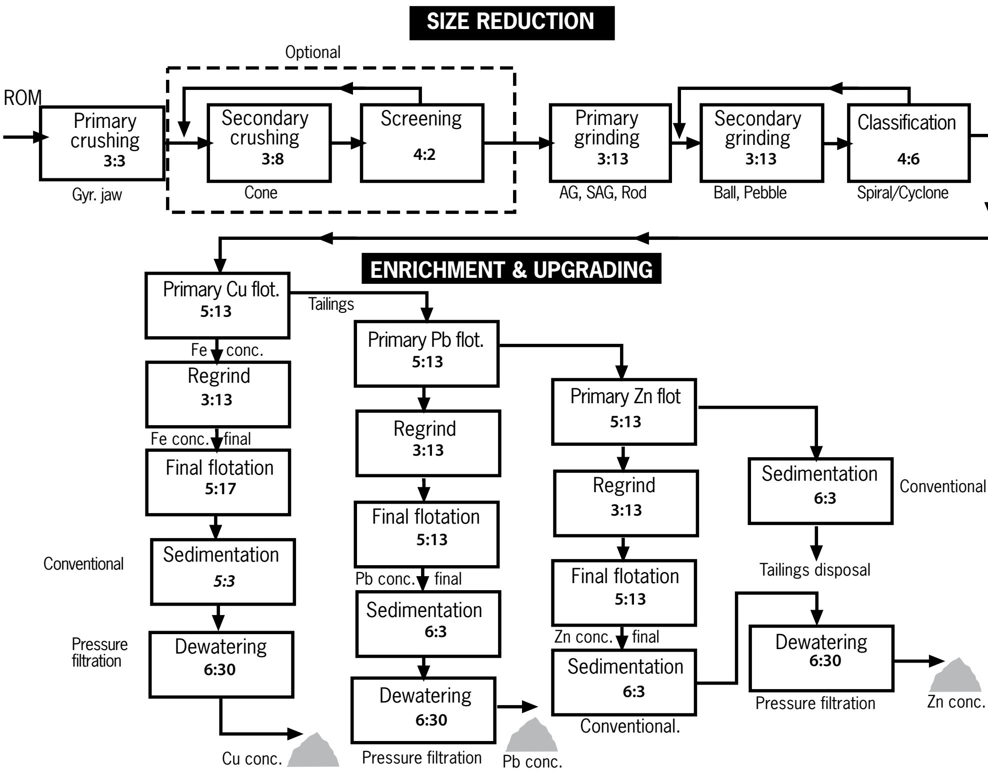
Process system – Ferrous ore (hosting apatite)



Process system – Base metal ore



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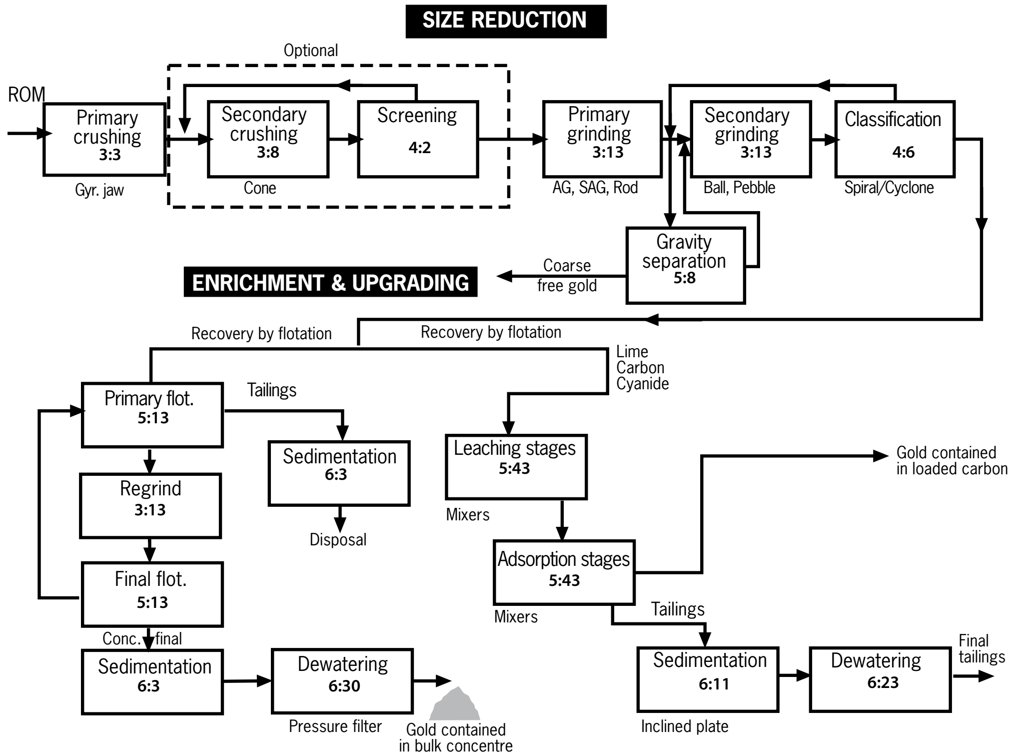
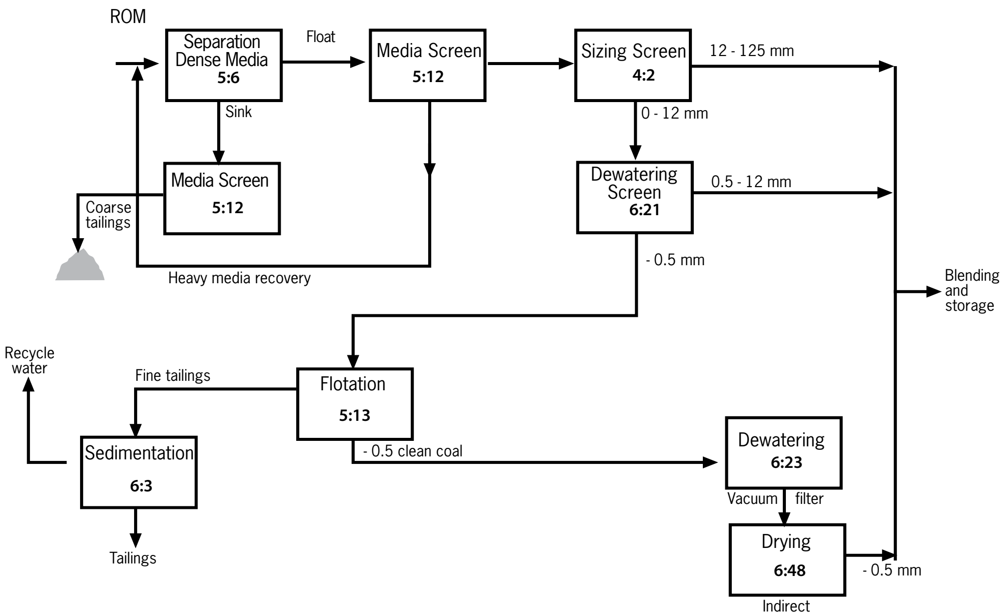
Process system – Gold bearing ore



Process system – Coal



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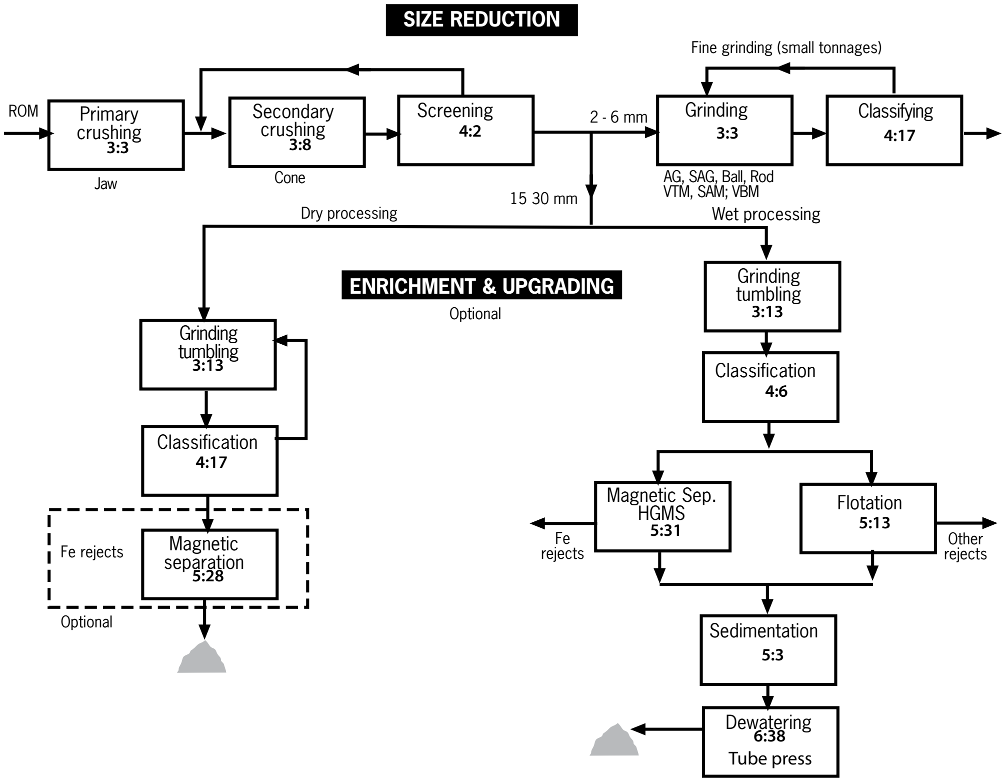
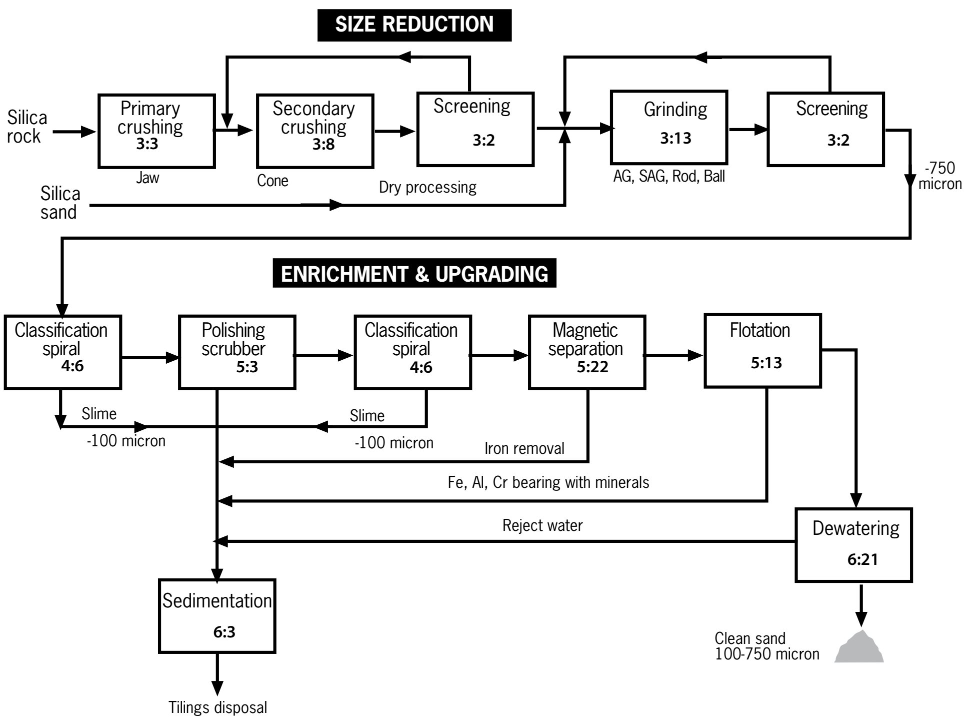
Process system – Industrial mineral fillers



Process system – Glass sand



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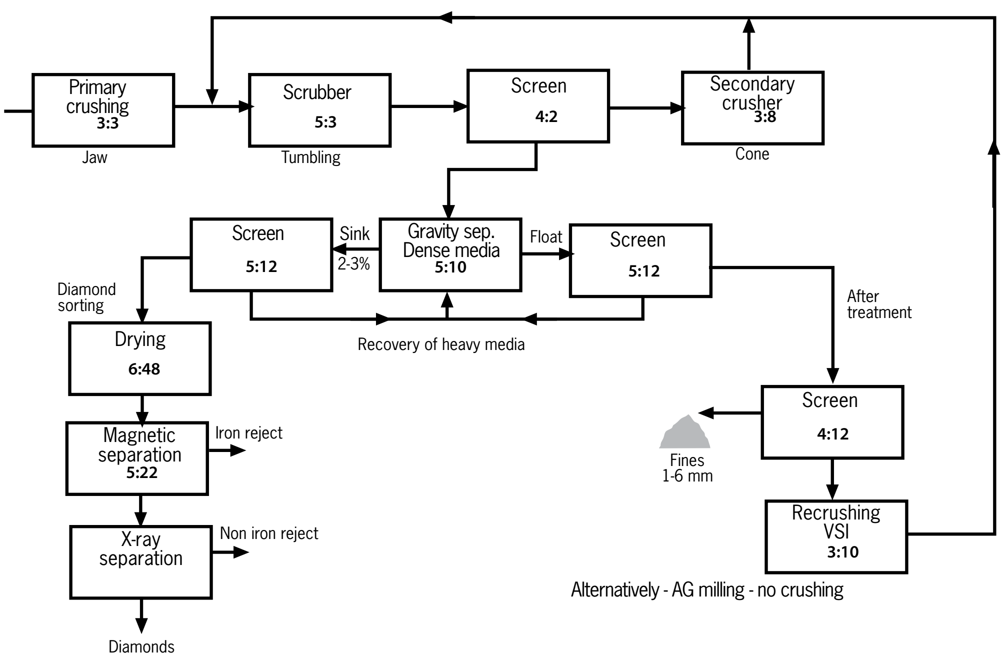
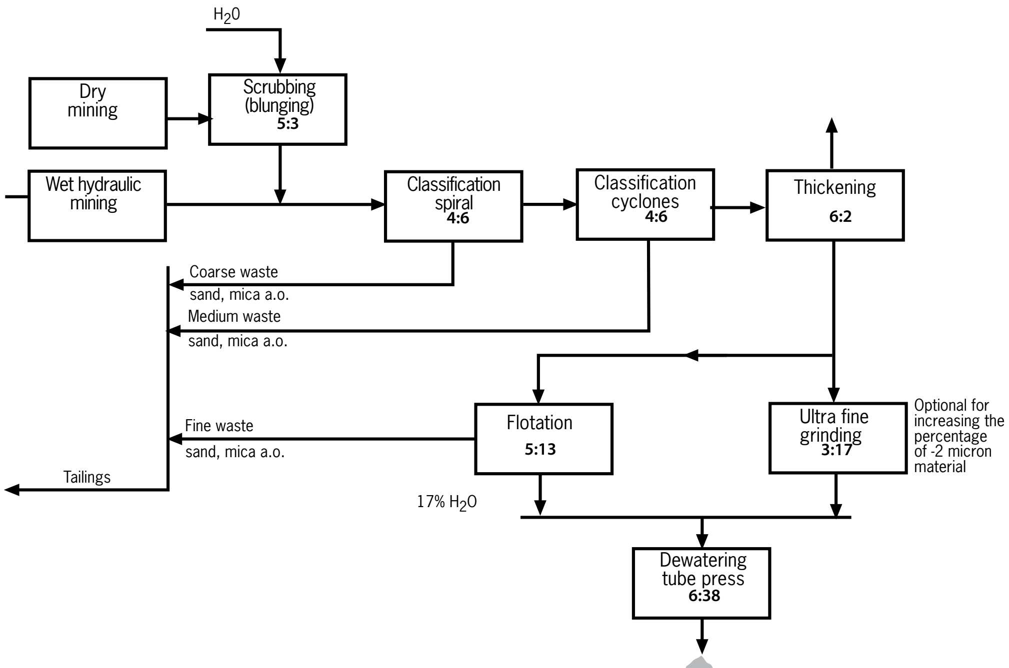
Process system – Diamonds (Kimberlite)



Process system – Kaolin



Products: Kaolin "Filler", 45% -2 micron
Kaolin "Coating", 90% -2 micron

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Mobile systems

In modern quarrying, mining, tunnelling and recycling operations the use of mobile process systems is increasing dramatically.

Particularly at rock front operations the technique of "moving the process equipment closer to the front end" using mobile crushing and screening units in many cases gives remarkable cost savings.

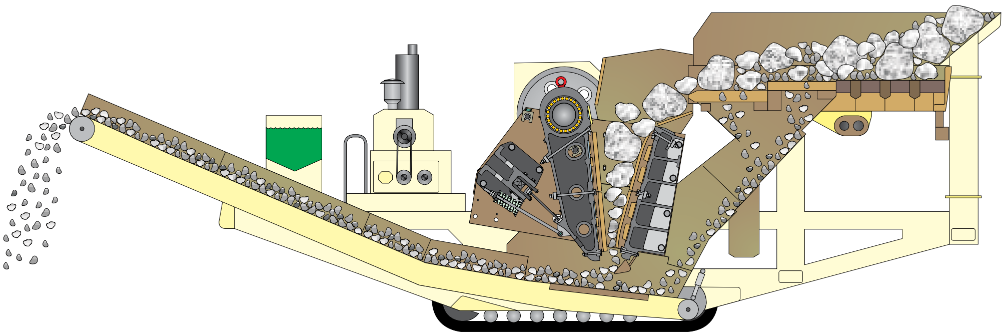
These mobile units represent one or more complete machine functions including materials handling, power supply etc. Advanced process control secures the "intelligence" of the system.

Mobile crushing and conveying system

Key arguments for mobile equipment vs stationary equipment and damp truck haulage are:

- Less hauling – less costs
- Less front road maintenance
- Less exhaust gas and dust emissions
- Improved working safety
- Improved flexibility

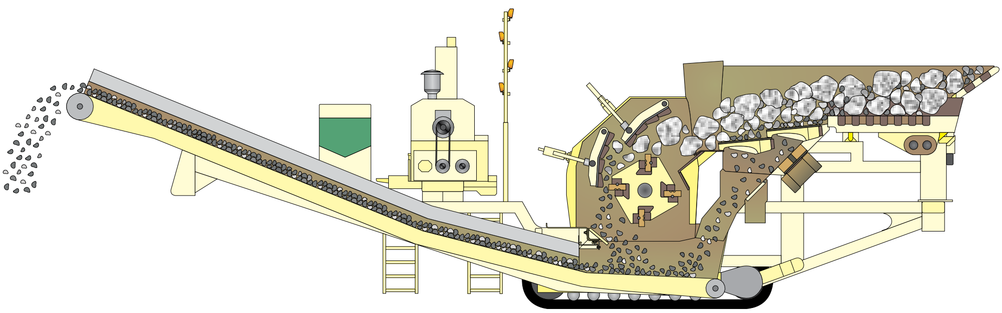
Primary jaw crusher + Grizzly (typical)



Type*	Max feed/product size mm (in)	Cap. tph	H/W/L m (ft)	Weight ton
LT110	670 / 250 (26/10)	700	4.4/3.0/17.4 (14.5/9.1/57.0)	60
LT125	800 / 300 (31/12)	800	5.7/4.0/15.8(18.6/15.2/51.1)	86
LT140	900 / 350 (35/14)	1200	6.3/4.3/16.4(20.8/14.1/53.1)	110
LT160	1040/ 400 (41/16)	2000	7.6/5.9/20.2(25.0/19.3/66.7)	220

*LT110 refers to Jaw crusher type C110, LT125 to Jaw crusher type C125 etc. see further section 3.

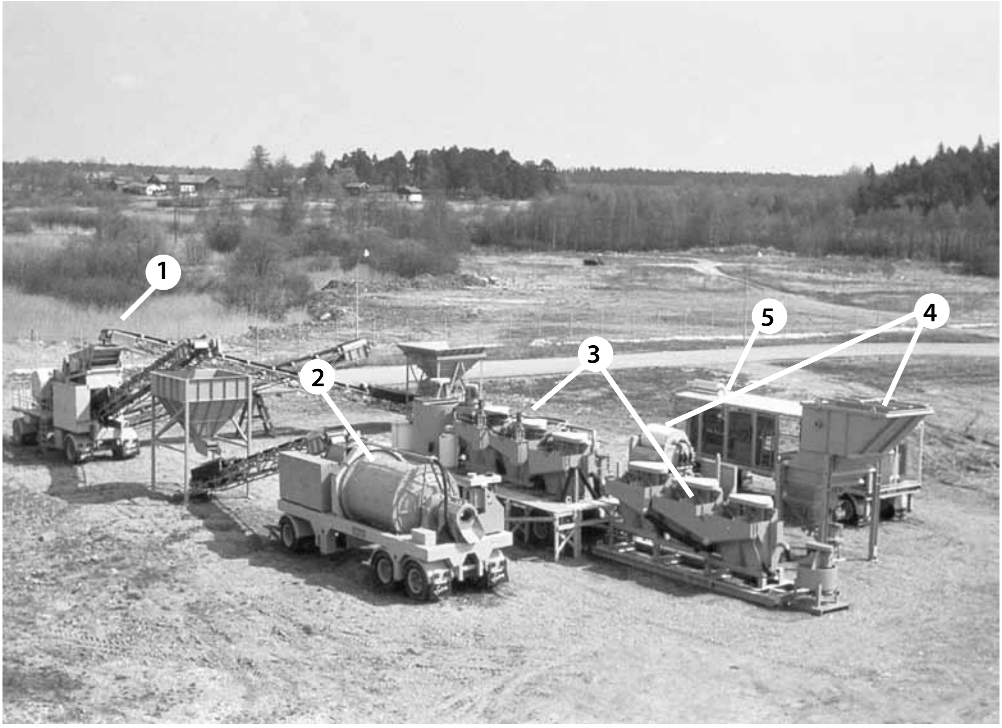
Primary impact crusher + Grizzly (typical)



Type*	Max feed/product size mm (in)	Cap. thp	H/W/L m (ft)	Weight ton
LT1415	1000/200 (40/8)	800	5.4/4.0/15.8 (17.7/13.1/51.1)	73
LT1620	1300/200 (52/8)	1200	6.5/4.8/18.5 (21.3/15.7/60.7)	170

*LT 1415 refers to Impact crusher type NP1415, LT 1620 to Impact crusher type NP1620 etc. see further section 3.

Caravan Mill – A pre-assembled ore concentrating plant



Typical units at approx. 10 t/h capacity

1. Crushing unit

Jaw- and cone crusher in closed circuit with a double deck screen

Weight app. 19 ton, transportation measures W= 2,6m, H= 4.2m

2. Grinding unit

Grinding mill (ball or rod), pump and hydrocyclone

Weight app. 25 ton, transportation measures W= 3,0m, H= 3,8m

3. Separation unit (flotation)

Rougher, scavenger and cleaner cells together with conditioners, reagent feeding systems and air blower.

Weight app.14ton, transportation measures W= 2,5m, H= 4.2m

Units for leaching and gravity separation (dense media, tables and spirals) also available

4. Dewatering unit

Compact sedimentation (lamella unit) and vacuum filter with auxiliary equipment

5. Power unit

Diesel driven generator including connection terminal

Transportation measures W= 2,5m, H= 3.8m

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 dm^3

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 troy ounce = 31,7 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 (US)

1 hp = 736 W (metric)

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

Unit Area

1 sq.ft/t/24h = 2.23 m^2/(t h)

Filtration capacity

1 lb/min/sq.ft = 293 kg/(m^2 h)

1 lb/h/sq.ft = 4.882 kg/(m^2 h)

Surface load

1 usgpd/sq.ft = 1.698 x 10^{-3} m^3/(m^2h)

1 usgph/sq.ft = 0.041 m^3/(m^2 h)

1 usgpm/sq.ft = 2.44 m^3/(m^2 h)

1 cfm/sq.ft = 0.3048 m^3/(m^2 min)

Flow

1 usgpm = 0.23 m^3/h

Velocity

1 fpm = 18.288 m/h

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	8 000	14	1 180	80	180
3	6 700	16	1 000	100	150
3 1/2	5 600	20	850	115	125
4	4 750	24	710	150	106
5	4 000	28	600	170	90
6	3 350	32	500	200	75
7	2 800	35	425	250	63
8	2 360	42	355	270	53
9	2 000	48	300	325	45
10	1 700	60	250	400	38
12	1 400	65	212	500	25

Specific gravity

Mineral	Density
A	
Albite	2.6
Almandine	4.3
Anatase	3.9
Andradite	3.8
Apatite	3.2
Arsenopyrite	5.9 - 6.2
Asbestos	2.4 - 2.5
Azurite	3.8
B	
Baddeleyite	5.6
Barite	4.5
Bauxite	2.6
Beryl	2.7 - 2.8
Biotite	3.0 - 3.1
Bismuth	9.8
C	
Calcite	2.7
Cassiterite	7.0
Celestite	4.0
Cerussite	6.6
Chalcocite	5.5 - 5.8
Chalcopyrite	4.1 - 4.3
Chlorite	2.6 - 3.2
Chromite	5.1
Crysocolla	2.0 - 2.3
Cinnabar	8.1
Cobaltite	6.0 - 6.3
Coemanite	2.4
Copper	8.9
Corundum	3.9 - 4.1
Covellite	4.7
Cryolite	3.0
Cuprite	5.8 - 6.2
D	
Diamond	3.5
Diopside	3.3 - 3.4
Dolomite	1.8 - 2.9
E	
Epidote	3.4

Mineral	Density
F	
Feldspar Group	2.6 - 2.8
Ferberite	7.5
Flint	2.6
Fluorite	3.2
Franklinite	5.1 - 5.2
G	
Gahnite	4.6
Galena	7.5
Goethite	4.3
Gold	15.6 - 19.3
Graphite	2.1 - 2.2
Grossularite	3.5
Gypsum	2.3
H	
Halite	2.5
Hematite	5.2
Hornblende	3.1 - 3.3
Huebnerite	6.7 - 7.5
Hypersthene	3.4
I	
Ilmenite	4.7
K	
Kaolinite	2.6
Kyanite	3.6 - 3.7
L	
Lepidolite	2.8 - 2.9
Limonite	2.2 - 2.4
M	
Magnesite	3.0
Magnetite	4.7
Malachite	4.0
Magnite	4.3
Marcasite	4.6 - 4.9
Martite	5.2
Microline	2.6
Microlite	5.5
Molybdenite	4.7 - 5.0
Monazite	4.9 - 5.5
Mullite	3.2
Muscovite	2.8 - 3.0

Mineral	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	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 (metric)

A = Solids by weight [%]
B = Pulp density [ton/m^3]
C = Pulp volume [m^3/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 density
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

WWater and solids - Pulp density data (metric)

A = Solids by weight [%]
B = Pulp density [ton/m^3]
C = Pulp volume [m^3/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 density
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 (metric)

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 density
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 (metric)

A = Solids by weight [%]
B = Pulp density [ton/m^3]
C = Pulp volume [m^3/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 density
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 (metric)

A = Solids by weight [%]
B = Pulp density [ton/m^3]
C = Pulp volume [m^3/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 density
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 (metric)

A = Solids by weight [%]
B = Pulp density [ton/m^3]
C = Pulp volume [m^3/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 density
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 (metric)

A = Solids by weight [%]
B = Pulp density [ton/m^3]
C = Pulp volume [m^3/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 density
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