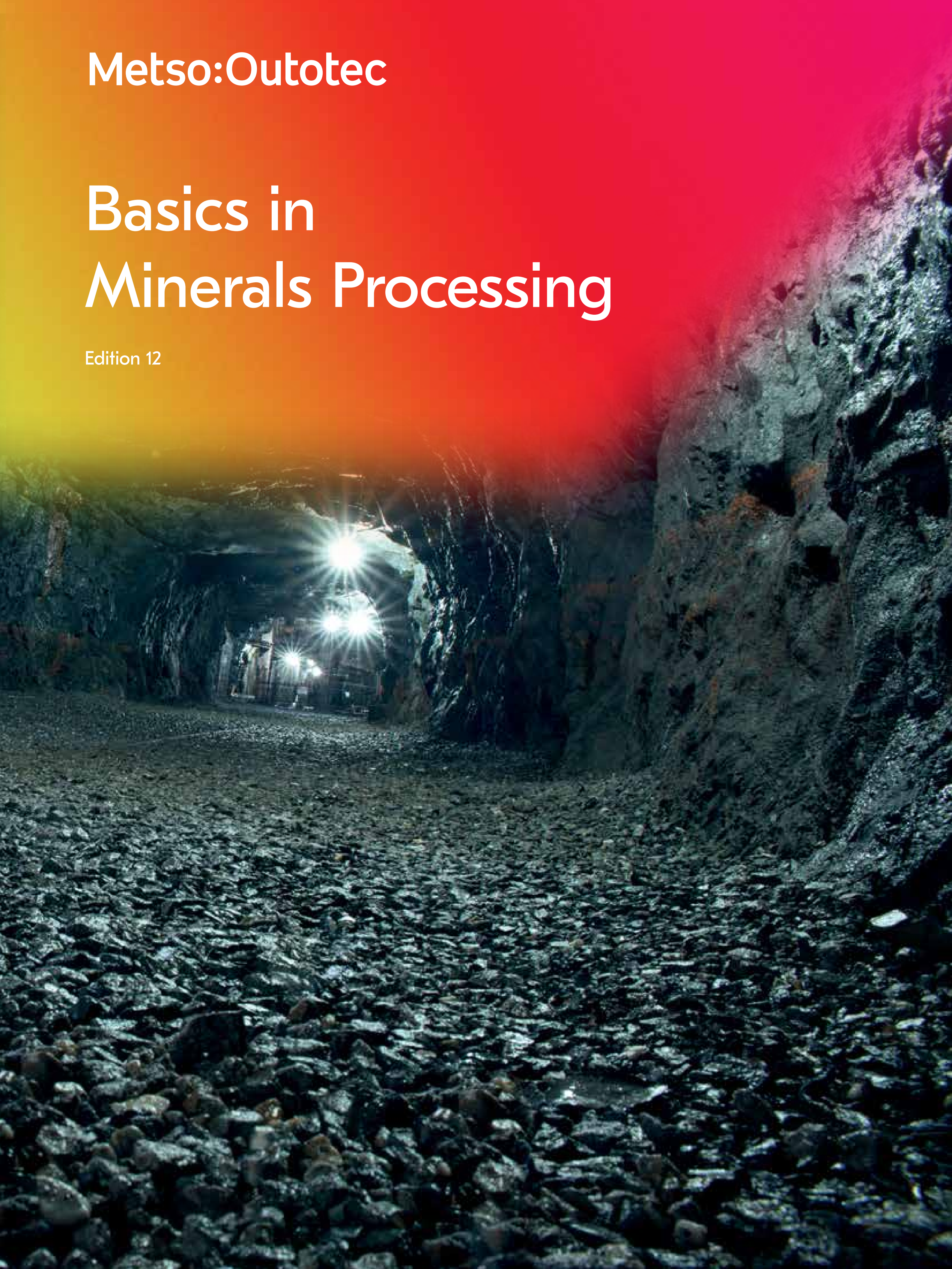
Metso:Outotec

Basics in Minerals Processing

Edition 12



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Metso Outotec mining and aggregates

Brand names in minerals processing and aggregates

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

Introduction

1. Introduction

"The practice of minerals processing is as old as human civilization. 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 Minerals Processing", is not to give a full coverage of the subject above.

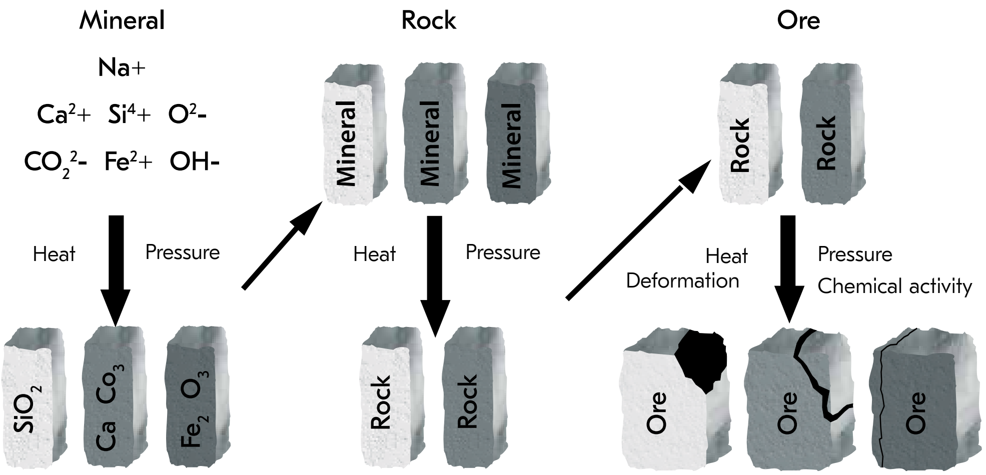
The intention is to give technicians involved in mineral operations practical and useful information about the process equipment used, their systems and operational environment.

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

Always contact Metso Outotec for information regarding specific products since the data given is subject to change without notice.

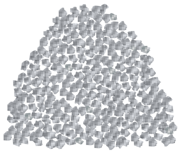
1.1 Basic definitions

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

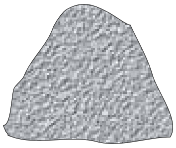


Artificial minerals

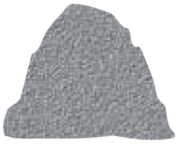
"Man made" minerals are not minerals by definitions. But from processing point of view they are similar to virgin minerals and are treated accordingly (mainly in recycling processes).



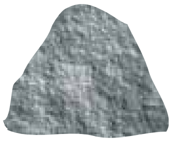
Slag



Concrete

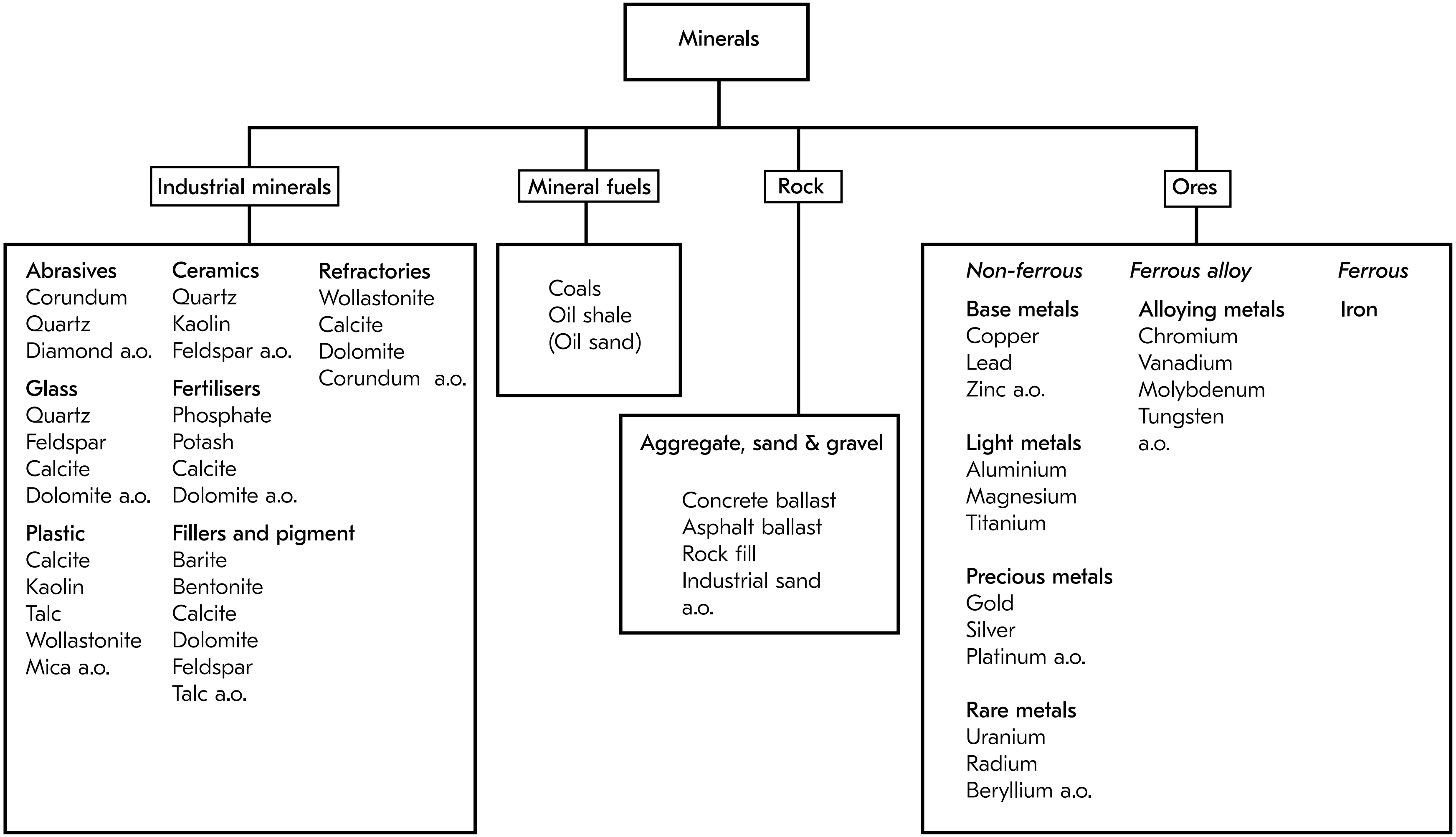


Mill scale



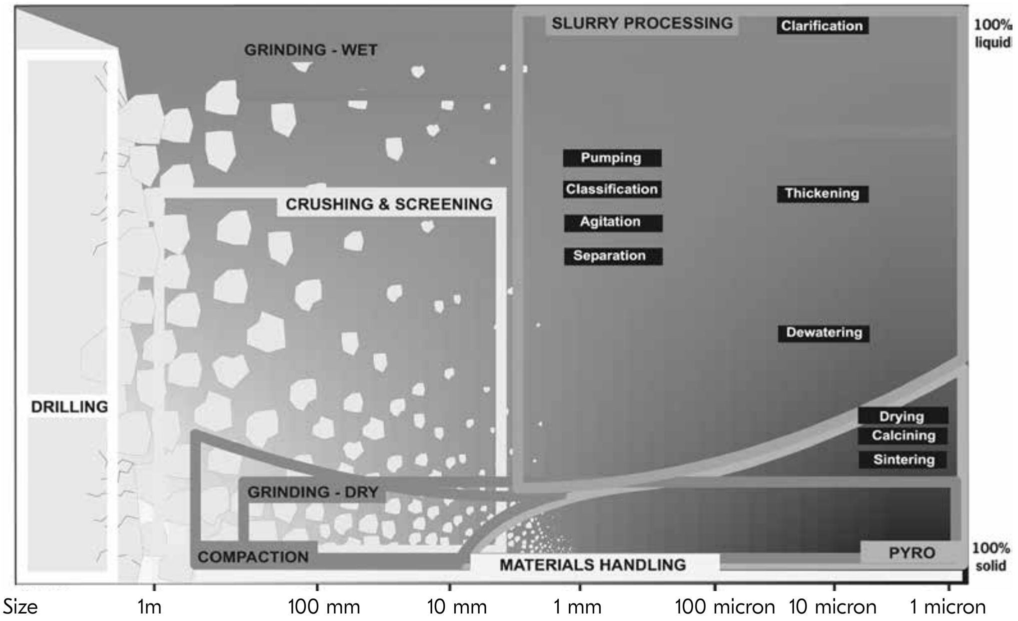
Glass & Ceramics

1.2 Minerals by value



1.3 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.

1.4 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:

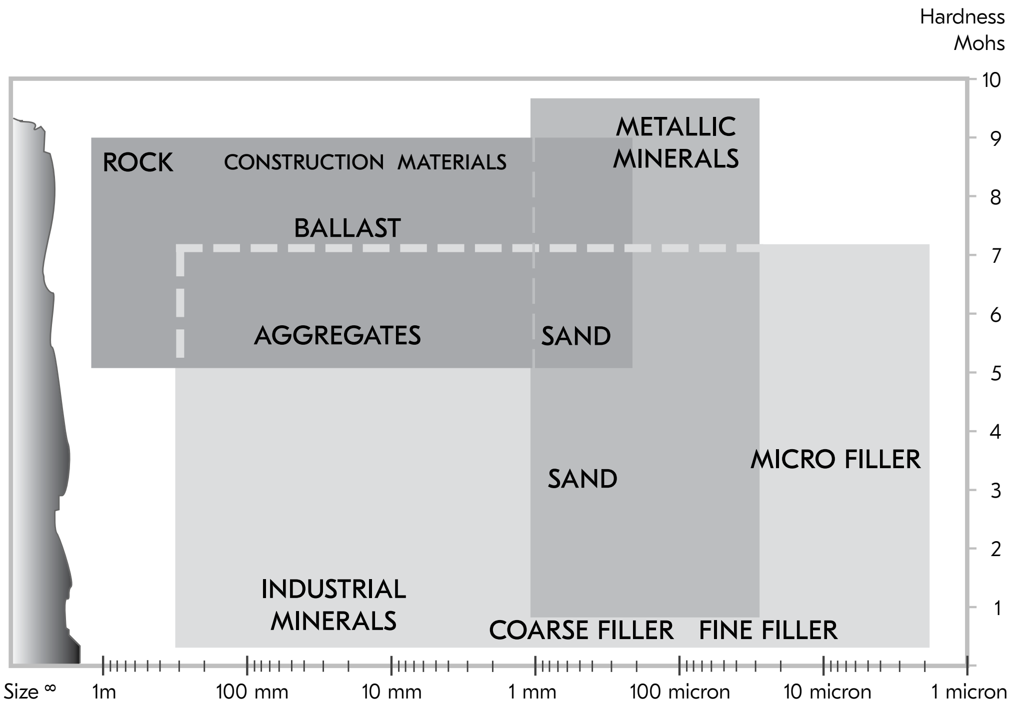
1.	Talc	Crushed by a finger nail	Graphite, Sulphur, Mica, Gold
2.	Gypsum	Scratched by a finger nail	Dolomite
3.	Calcite	Scratched by an iron nail	Magnesite
4.	Fluorite	Easily scratched by a knife	Magnetite
5.	Apatite	Scratched by a knife	Granite, Pyrite
6.	Feldspar	Hardly scratched by a knife	Basalt
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.

1.5 Size and hardness

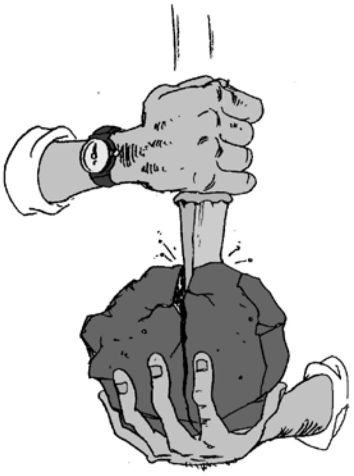
All operations have different process environments due to mineral hardness and size range. It is important to know in which "range" we are operating as this will affect many process parameters, (wear rate, uptime, operation costs etc.).
Size and hardness together give interesting information.



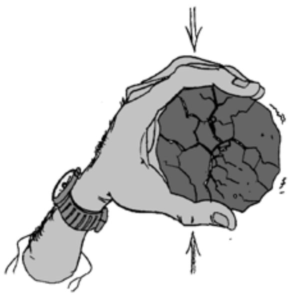
1.6 The stress forces of rock mechanics

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.

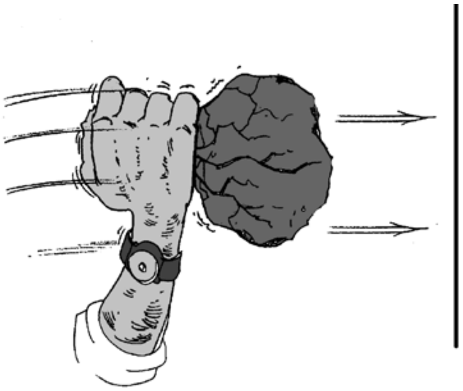
Tensile



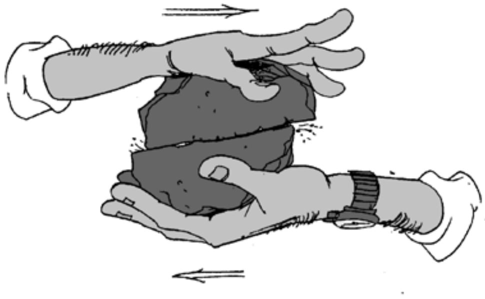
Compression



Impaction



Shearing



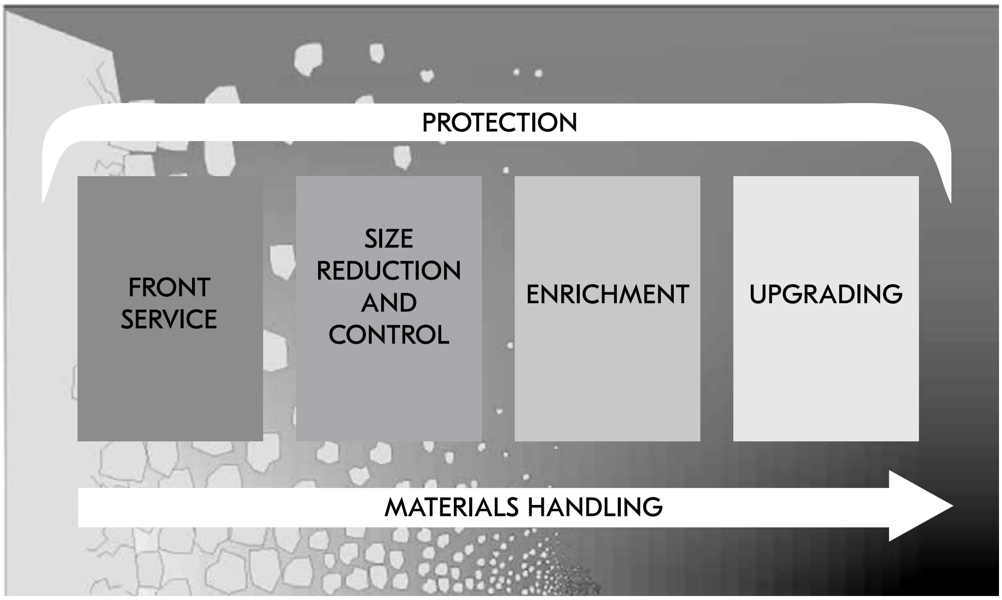
Attrition

Minerals in operation

2. Minerals in operation

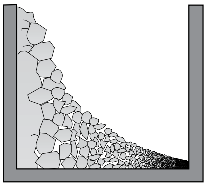
2.1 Operation stages

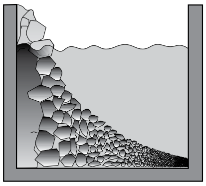
The operating stages in minerals processing have remained the same for thousands of years. Of course we have come far in development of equipment and processes since then, but the hard, abrasive and inhomogeneous mineral crystals have to be treated in special ways in order to extract maximum value out 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

2.2 Operation – Dry or wet ?





Dry processing

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

Wet processing

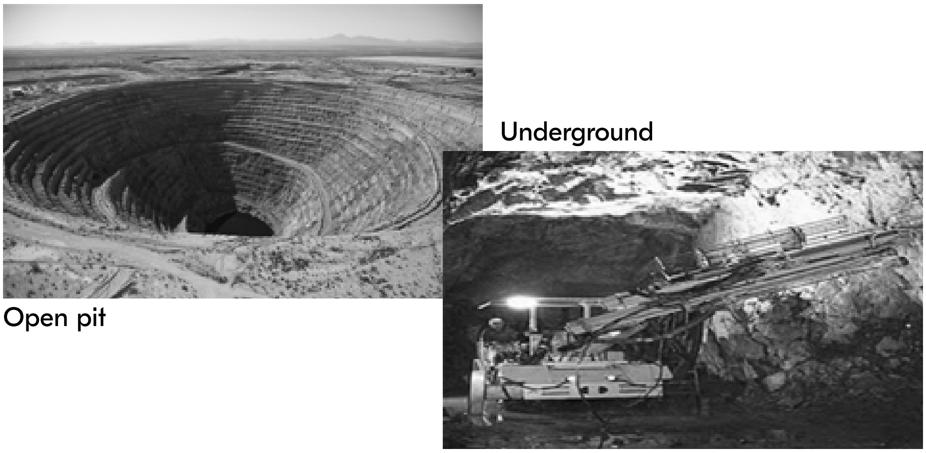
In all other cases due to:
- Better efficiency
- More compact installation
- No dusting

Note! Wear rate is generally higher in wet processing!

2.3 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



2.4 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.

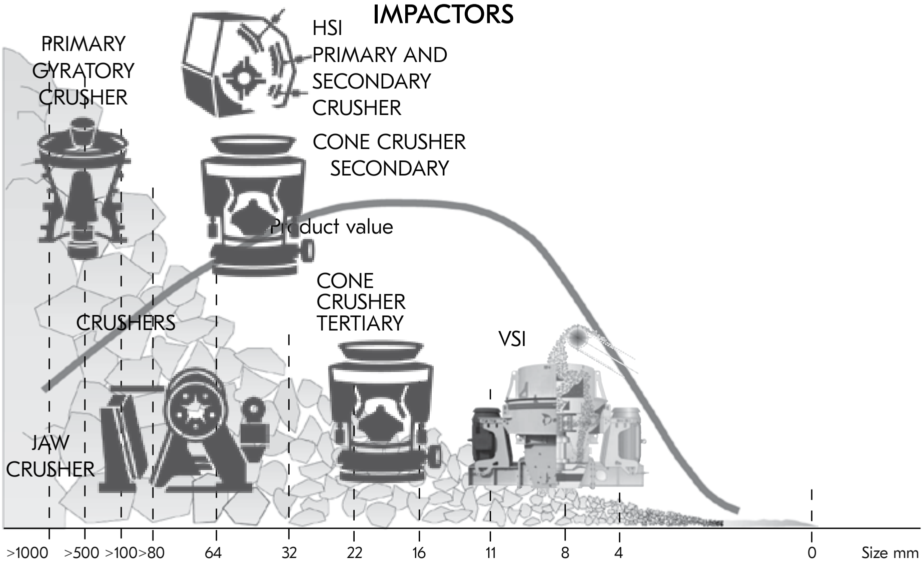
Marine

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.

2.5 Size reduction

Crushing of rock and minerals

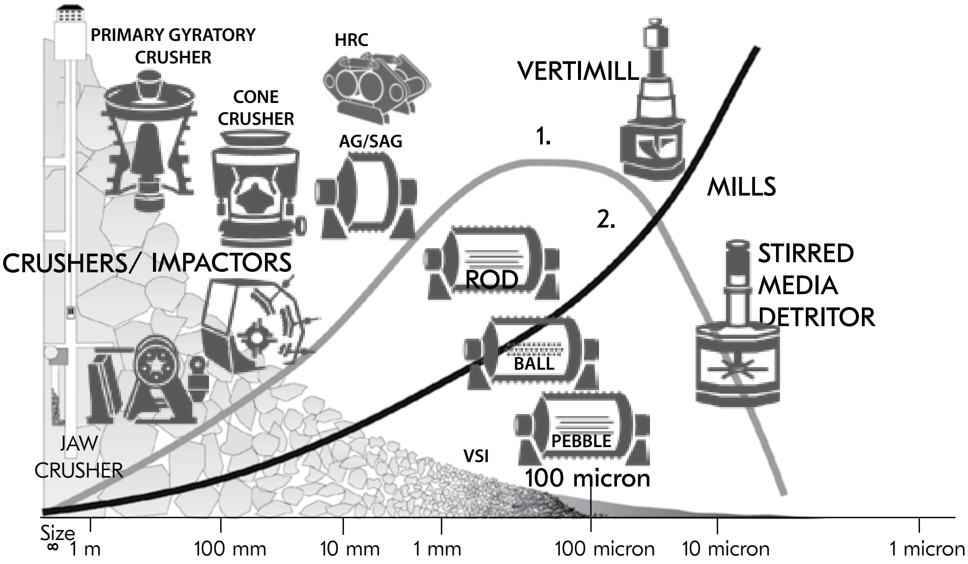
By tonnage this is by far the largest process operation in minerals processing. The goal is to produce rock or (more seldom) mineral fractions to be used as rock fill or ballast material for concrete and asphalt production. Quality parameters are normally strength, size and shape. The size fractions, 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 above.
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 below.
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.

The equipment shown below is a general application range. The actual range depends on the material properties and process requirements.



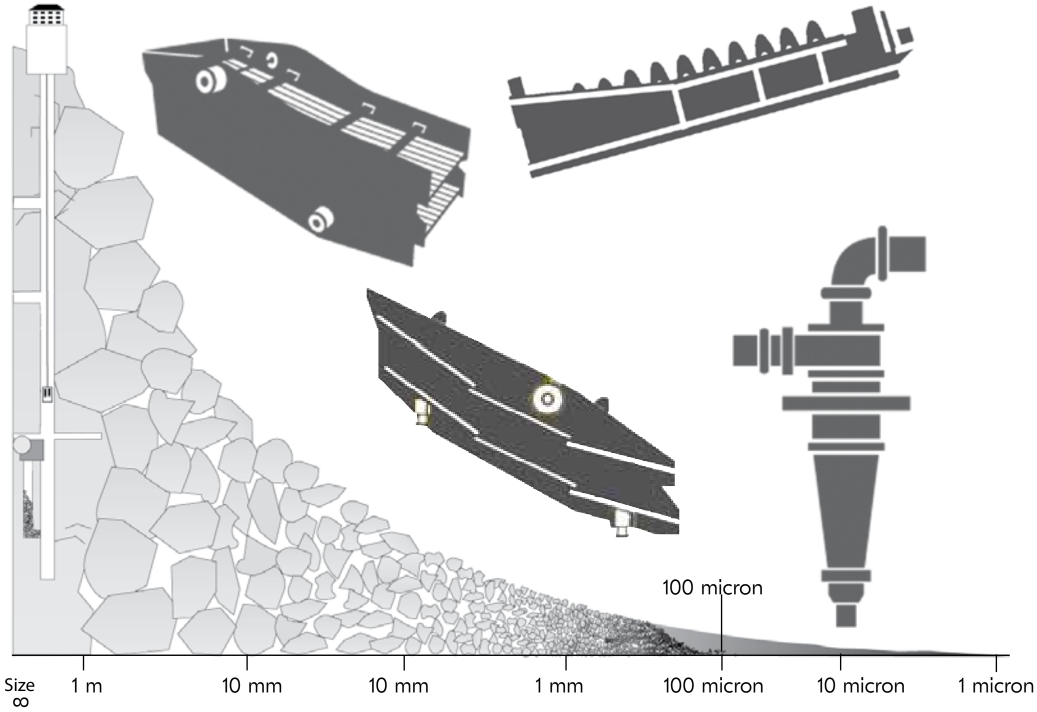
2.6 Size control

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 1-2 mm).

In the finer part we have to use classification with spiral classifiers, see section 4.



2.7 Enrichment – Washing

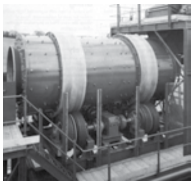
Washing is the simplest method of enrichment used to improve the value of rock and mineral fractions from sand size and upwards. Removing of surface impurities like clay, dust, organics or salts is often a must for a saleable product.

Different techniques are used depending on how hard these impurities are attached to the rock or mineral surface, see section 5.

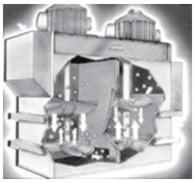
Washing using

Wet screens*

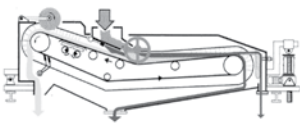
Scrubbers*



Attrition cells*



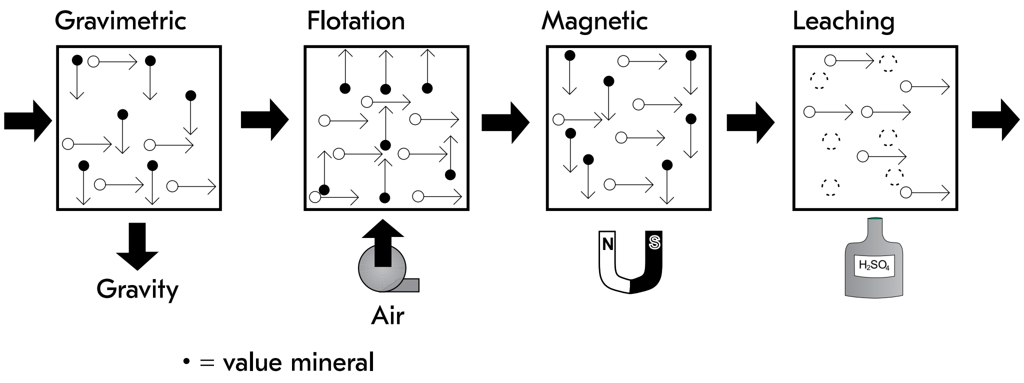
Gravity beds*



* Contact Metso Outotec for further information.

2.8 Enrichment – Separation

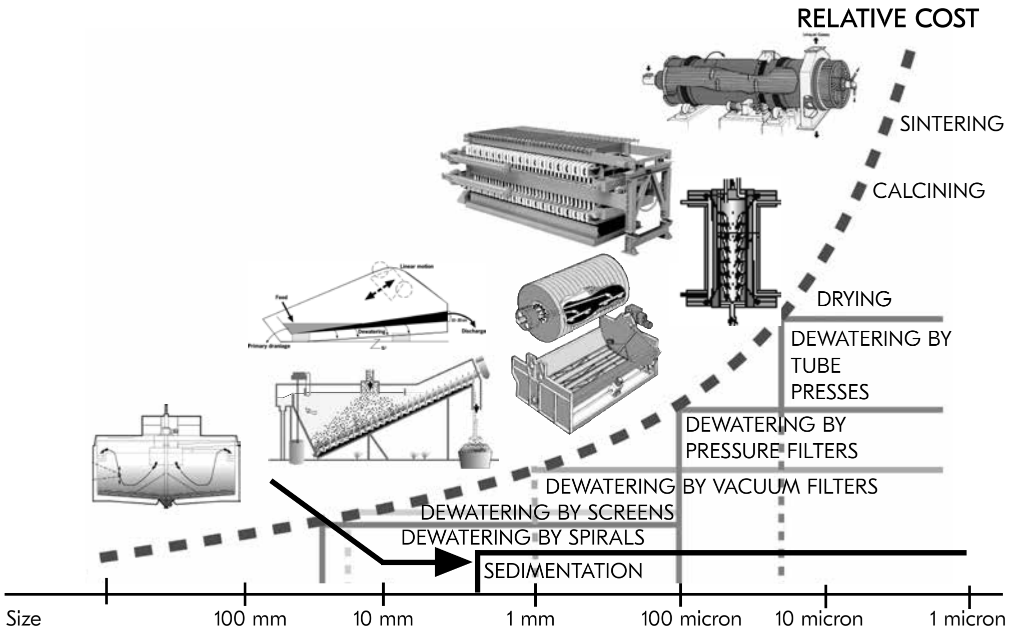
Most value minerals (both metallic and industrial) are priced by their purity. After liberation by size reduction and size control all minerals are free to be separated from each other.
Depending on the properties of the individual minerals they can be recovered by different methods of separation, see section 5.



2.9 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.

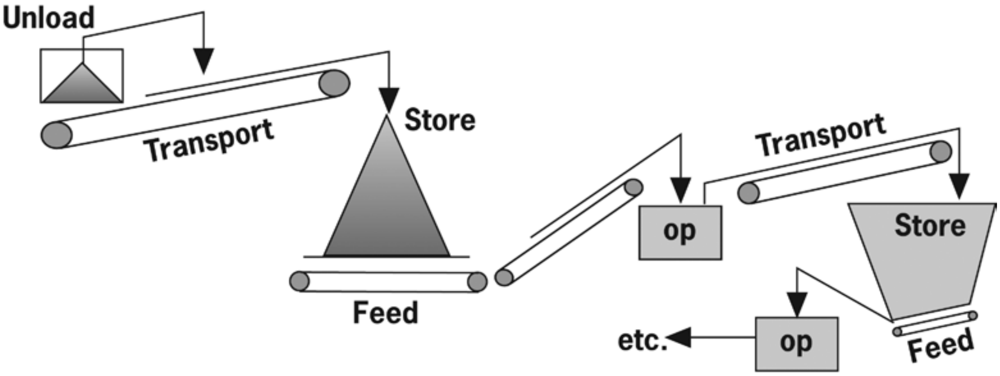
Upgrading by methods



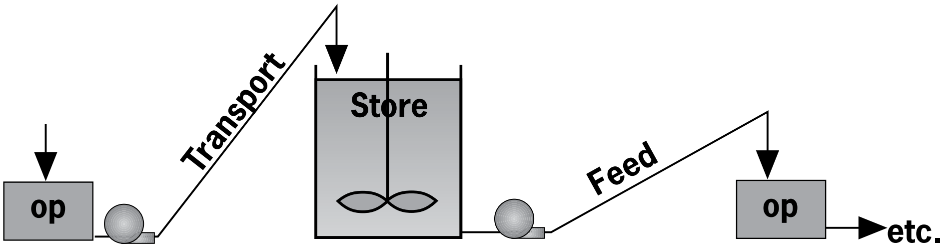
2.10 Materials handling

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

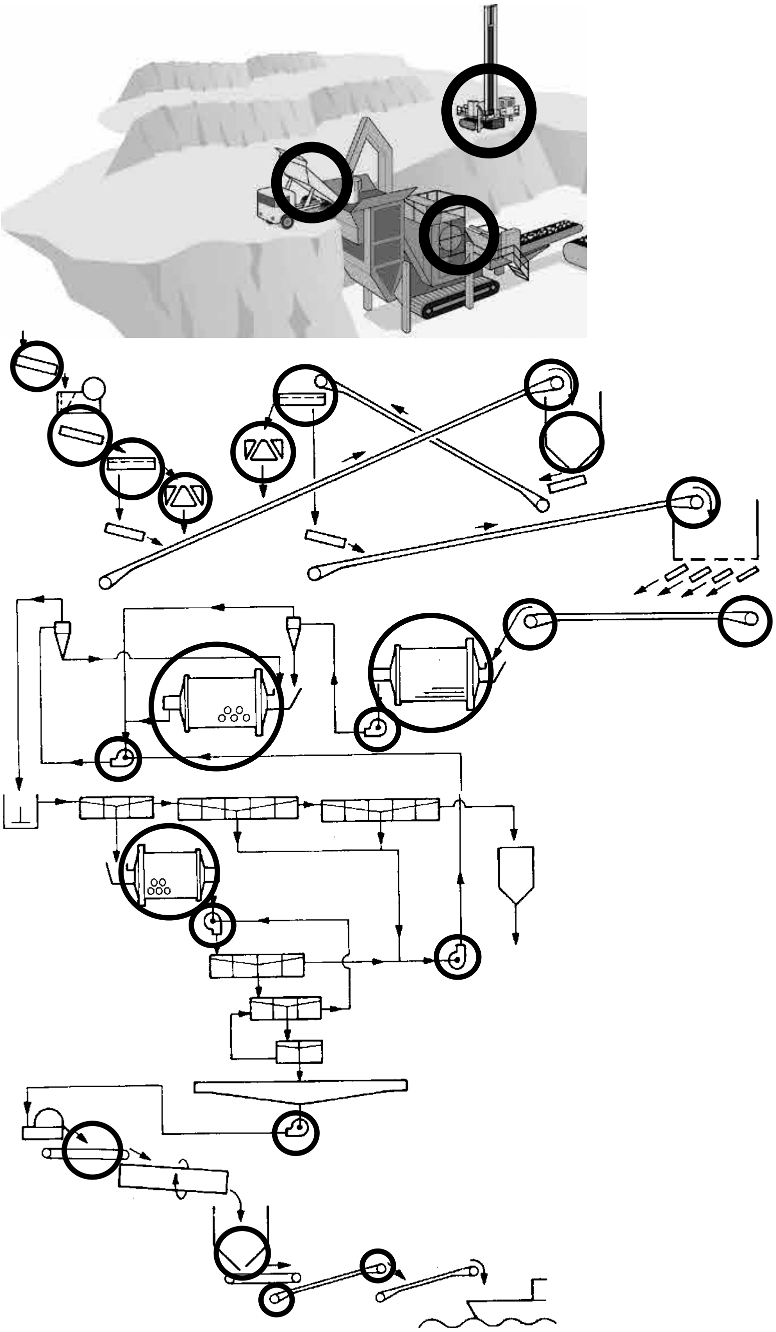


Slurry handling



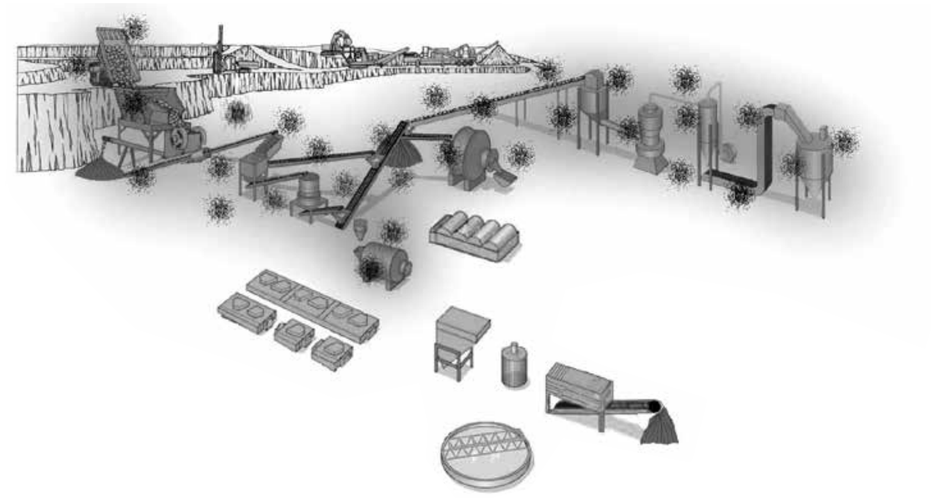
2.11 Wear in operation

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, abrasive or non-abrasive, 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.



2.12 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.



2.13 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 = $

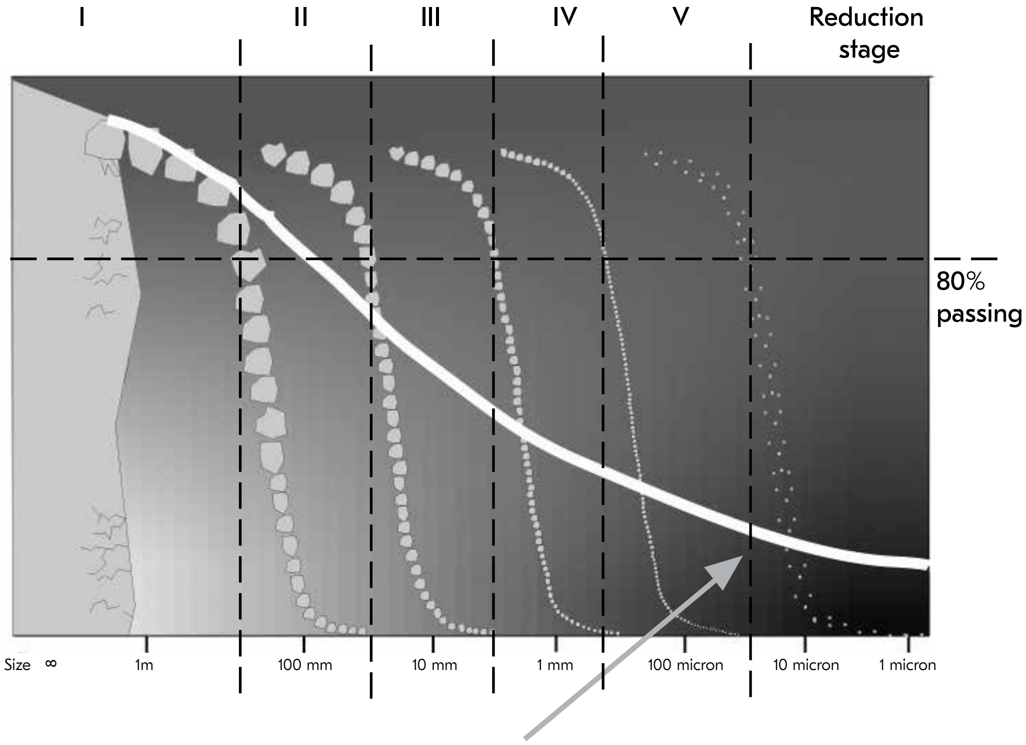
Output	Quality	Cost control	Comfort
AVAILABILITY (up time)	SIZE / SHAPE	CAPITAL	SECURITY
CAPACITY	PURITY / RECOVERY	ENERGY	ENVIRONMENT
FLEXIBILITY	COMPACTION / DENSITY	MATERIAL	RELATIONS

Size reduction

3. Size reduction

3.1 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!

There is a large benefit to flotation and separation if there is a steep size distribution of the feed to these processes. So, the trick when producing quality products from rock or minerals (fillers excepted) is to keep the size reduction curves in the later stages 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.

3.2 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 kWh/sh.ton

Material	W_i value		
Basalt Diabase Dolomite	20 19 12	± ± ±	4 4 3
Iron-ore, Hematite Iron-ore, Magnetite Gabbro	13 12 20	± ± ±	8 8 3
Gneiss Granite Greywacke	16 16 18	± ± ±	4 6 3
Limestone Quartzite Porphyry	12 16 18	± ± ±	3 3 3
Sandstone Syenite	10 19	± ±	3 4

INFLUENCING

- Size reduction
- Energy requirement
- Machine status

Abrasion index = Ai

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

INFLUENCING

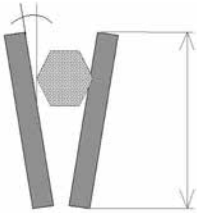
- Wear rate

Regarding Work Index (Bond) for grinding, see 3:40.

3.3 Reduction ratio

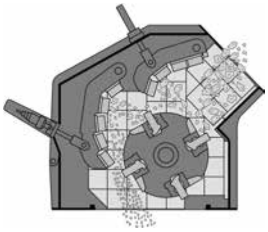
As seen above all size reduction operations are performed in stages. All equipment involved, crushers or grinding mills have different relation between feed and discharge sizes. This is called **reduction ratio.** Typical values below. **Note!** High reduction ratio is generally inefficient. For maximum energy efficiency, we recommend multiple stages of grinding

Compression crushers



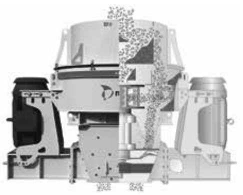
Jaw 3-4
Gyratory 3-5
Cone 3-5

Impactors (horizontal type)



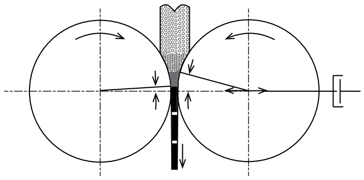
5-10

Impactors (vertical type)



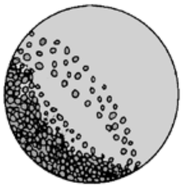
1-2

High pressure grinding rolls



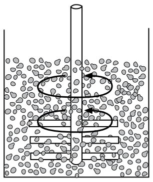
25

Grinding mills (tumbling type)



Rod 100
Ball 1000
AG & SAG 5000

Stirred grinding mills



100

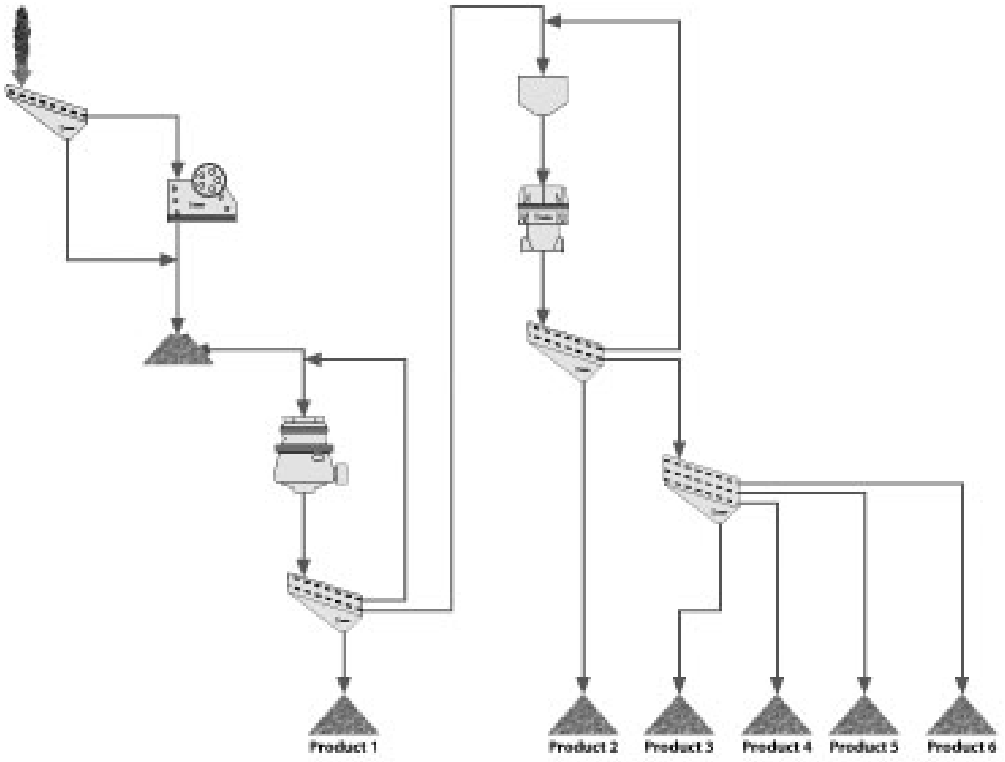
3.4 The art of crushing

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

3.5 Crushing of rock and gravel

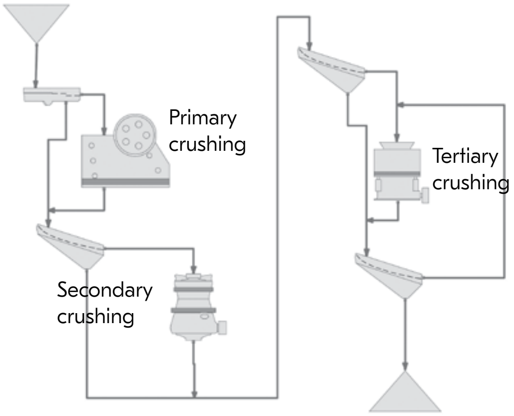
In the business you are normally paid for short fractions of relatively coarse material with the correct size and shape. Most of the ballast for concrete and asphalt is in the 4 - 18 mm (1/5 - 3/4") interval.
In order to produce the correct shape and keep over- and under sizes as low as possible this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



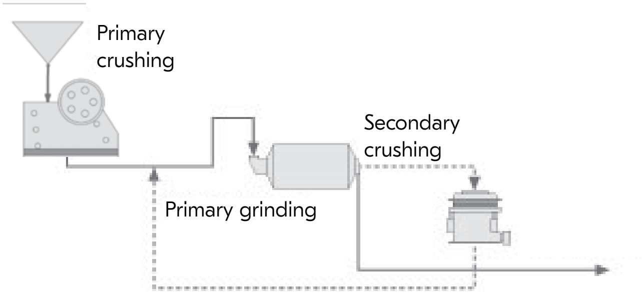
3.6 Crushing of ore and minerals

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.

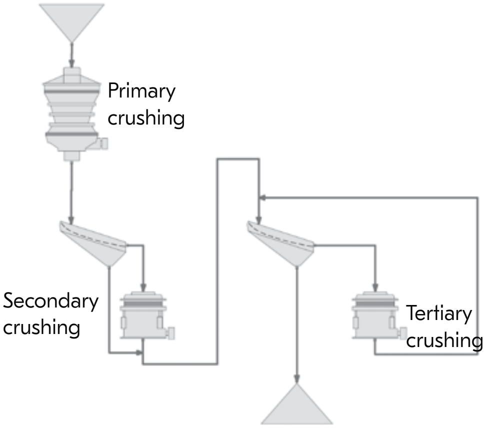
"Classical" 3-stage crushing prior to rod mill



Typical 1-2 stage ore crushing in AG-SAG circuit



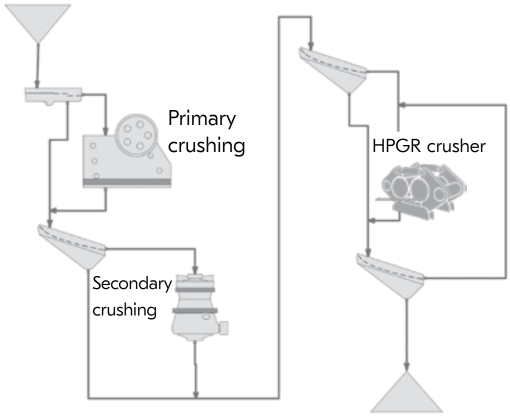
Typical 3- stage crushing prior to ball mill



3-stage crushing utilizing an HPGR prior to a rod mill or ball mill

Another option is including HPGRs in the crushing circuit.
Commons circuits include utilizing HPGRs as a:

- tertiary crusher, followed by a ball mill or VERTIMILL®
- quarternary crusher, followed by a ball mill or VERTIMILL®
- pebble crusher in a SABC circuit



3.7 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.
The same size reduction with soft feed (low Bond work index) is done with two stages of

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

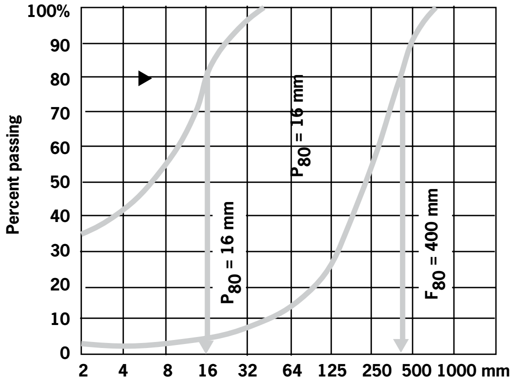
Product size: P_{80} = 16 mm
Road aggregates or rod mill feed 80% smaller than 16 mm

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**

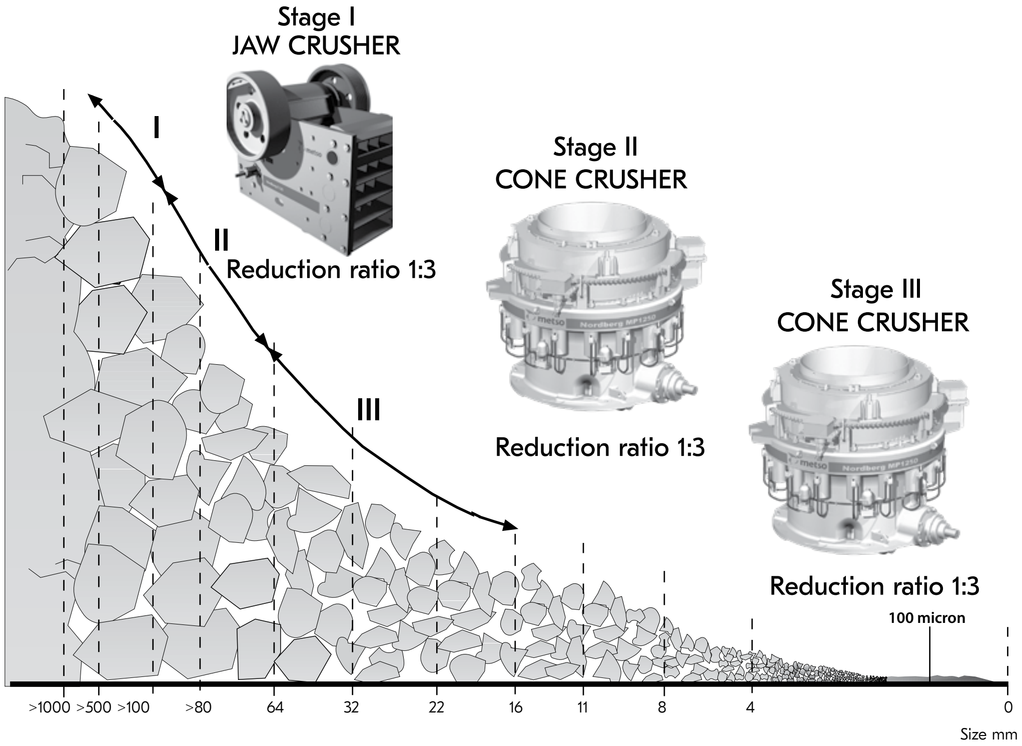
Total in 2 crushing stages gives R1xR2 = 3x4 = **12**
This is not sufficient. We need a third crushing stage.*

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



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

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



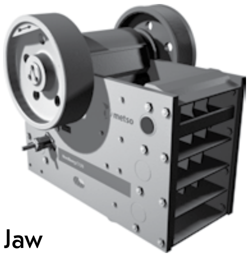
The same size reduction with soft feed (low Bond work index) is done with two stages of HSI (horizontal shaft impactors). With the increased reduction ratio capable in an impactor this process can be achieved in two stages, such as 6:1 and 5:1.

3.8 Selection of crushers

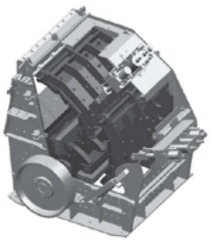
Knowing the number of crushing stages we can now start to select the correct crusher for each reduction stage. Depending on operating conditions, feed size, capacity, hardness etc, there are always some options. For primary crushers, see below.

Stationary crushers – surface and underground

Primary Gyratory

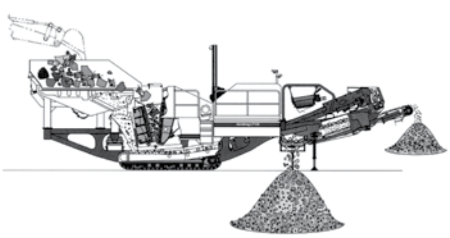


Jaw

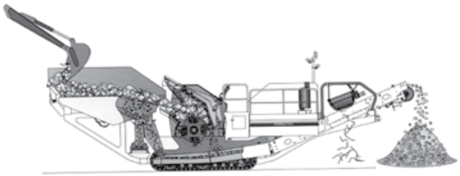


Impact

Mobile Crushers



Jaw + grizzly



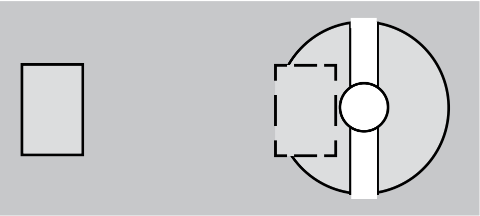
Impact + grizzly

For mobile crushers see further section 11:9

3.9 Primary crusher – Type

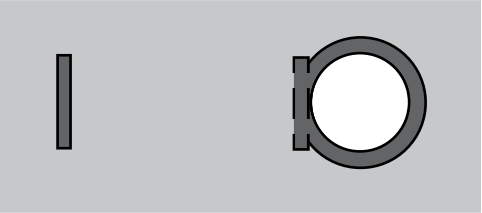
For **soft feed and non-abarasive** feed (low Bond work index) a horizontal Impactor (HSI) is an option if the capacity is not too high.

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

Note: HSI can be used only if the abrasion index is lower and the plant does not mind fines production. Otherwise, a jaw crusher is preferred for lower capacity aggregate plants.)

Rule 1: Always use a jaw crusher if you can, jaws are the least capital cost.

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

Rule 3: For high capacities (800-1500 tph)use jaw crusher with big intake opening.

Rule 4: For very high capacities (1200+ tph use gyratory crusher.

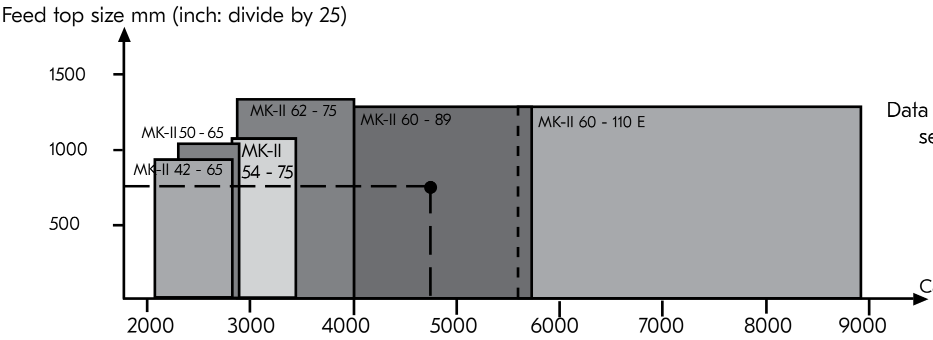
3.10 Primary crusher – Sizing

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 4750 t/h.

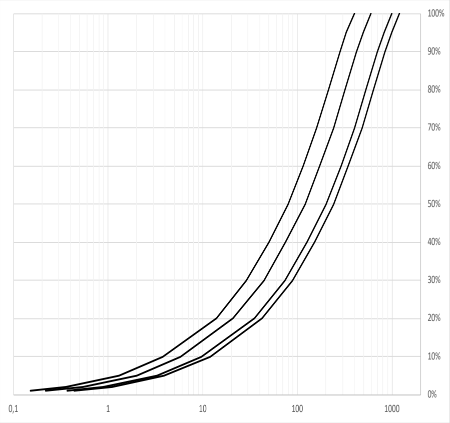
- Which primary crusher can do the job?
- Check on the two compression machines below and take out the sizing point!
- Correct selection is Superior® MK-II Primary Gyratory Crusher type MK-II 60-89

Primary gyratory – Feed size vs capacity

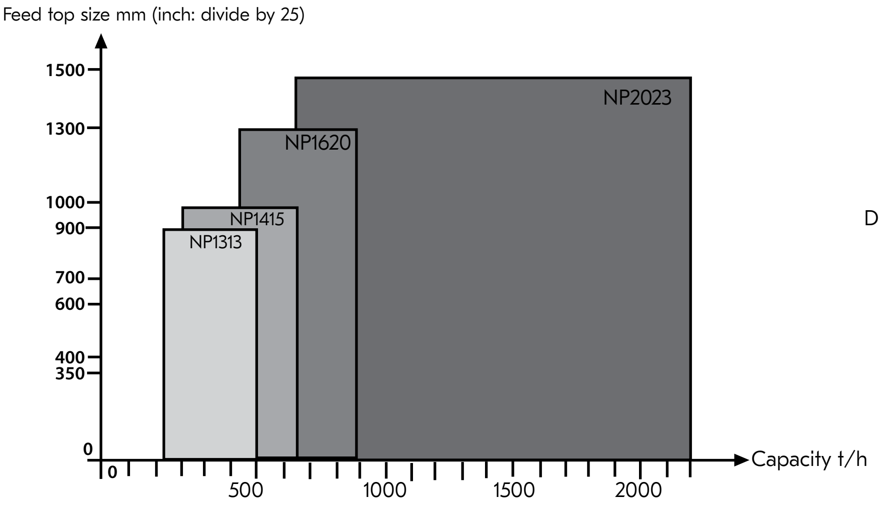


Data sheet,
see 3:15

Primary jaw crusher – Feed size vs capacity



Primary impactor – Feed size vs capacity



Data sheet,
see 3:17

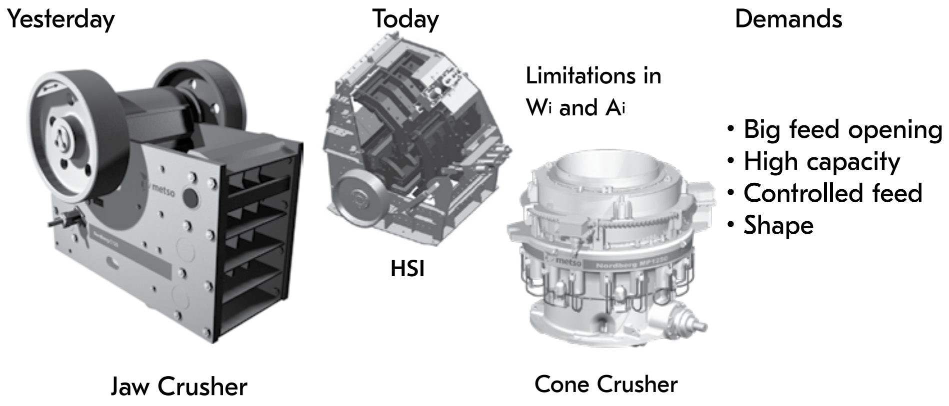
3.11 Secondary crusher – Type

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.

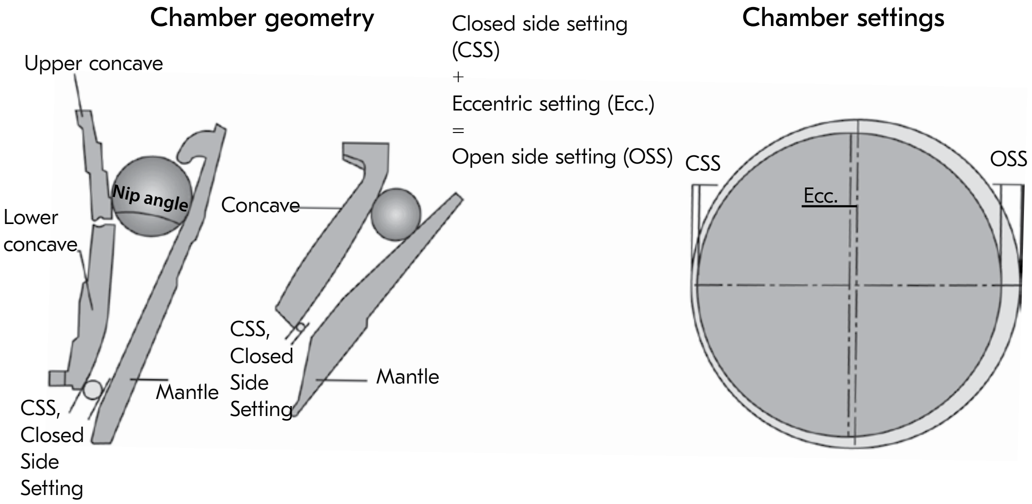
Also in comminution (crushing and grinding) circuits for ore and minerals the cone crusher is frequently used as the secondary stage, see 3:4.

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



3.12 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.



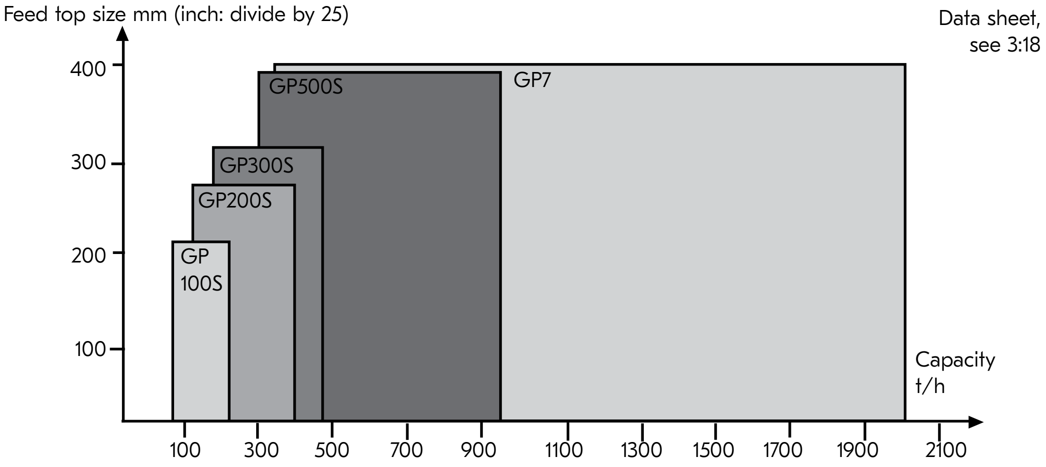
- Chamber intake to match feed size
- Each machine size has different chamber options (other crusher types have not)
- Each chamber has a certain feed size vs capacity relation
- Increased Ecc. (at the same CSS) will give higher capacity.
- Decreased CSS will improve reduction but will also reduce capacity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

Approx. size of discharge:

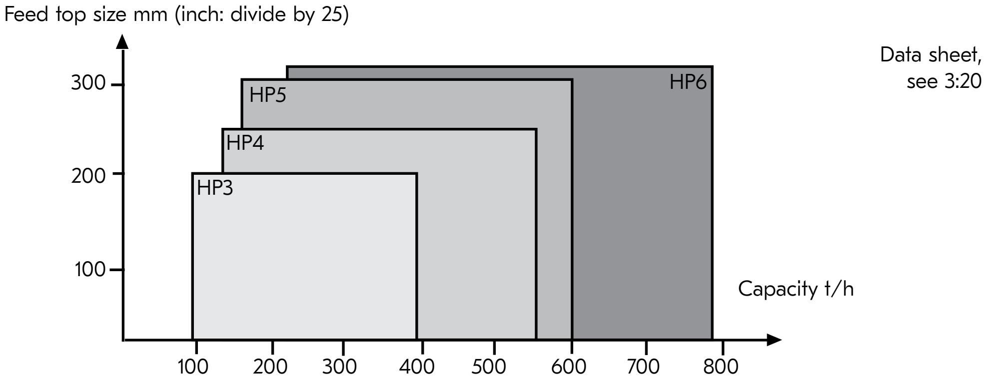
From Cone	70-80%<CSS
From Gyratory	85-95%<OSS

3.13 Secondary crushers – Sizing

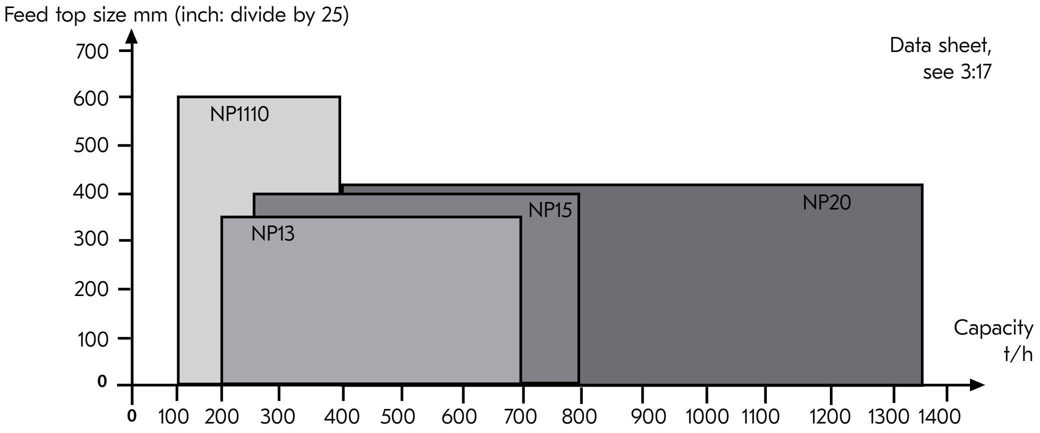
Secondary crushers – Feed size vs capacity (GPS range)



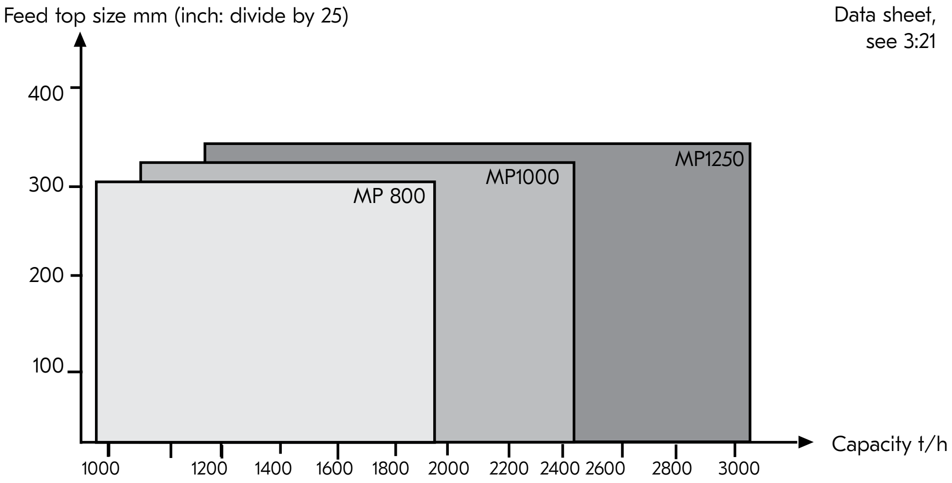
Cone crusher – Feed size vs capacity HPX range



Secondary impactor – Feed size vs capacity

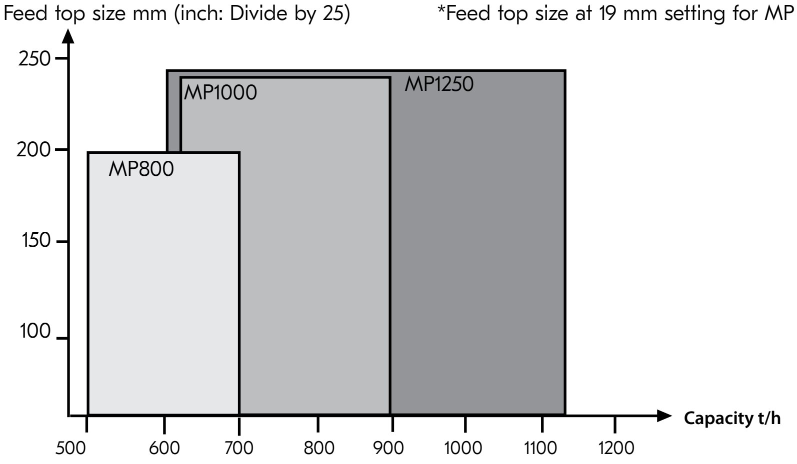


Secondary cone crusher — Feed size vs capacity MP800 - MP1250 series



Data sheet,
see 3:21

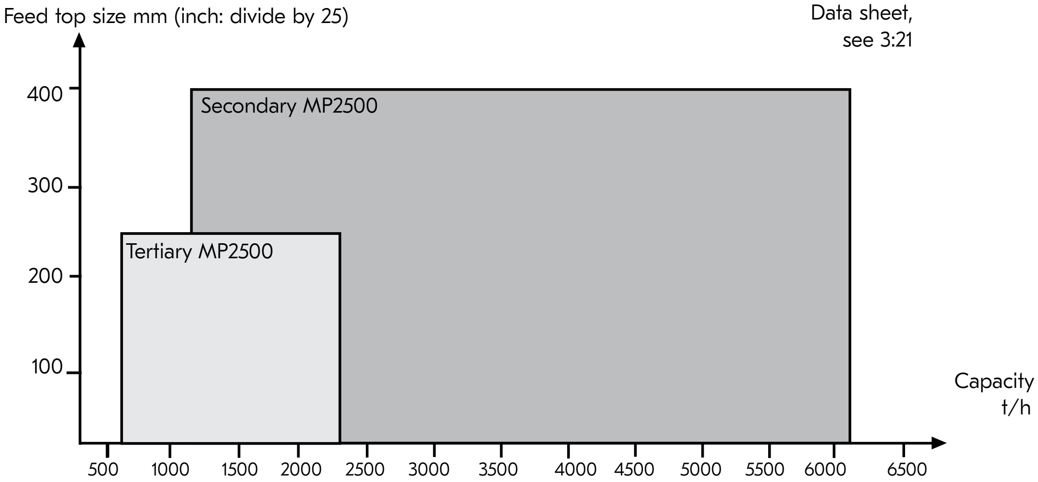
Tertiary cone crusher — Feed size vs capacity MP800 - MP1250* series



*Feed top size at 19 mm setting for MP 800 - 1250

Data sheet,
see 3:21

Secondary and tertiary cone crusher — Feed size vs capacity MP2500

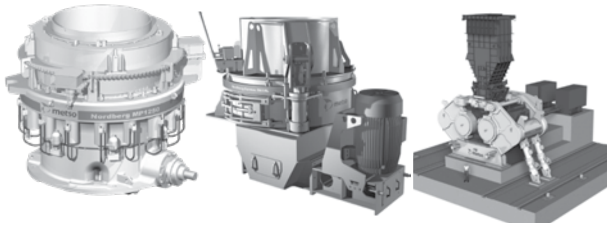


Data sheet,
see 3:21

3.14 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, abrasive rock circuits Cone crushers, Vertical Shaft Impactors (VSI) or
High Pressure Grinding Rolls (HPGRs) can be used.

Most common



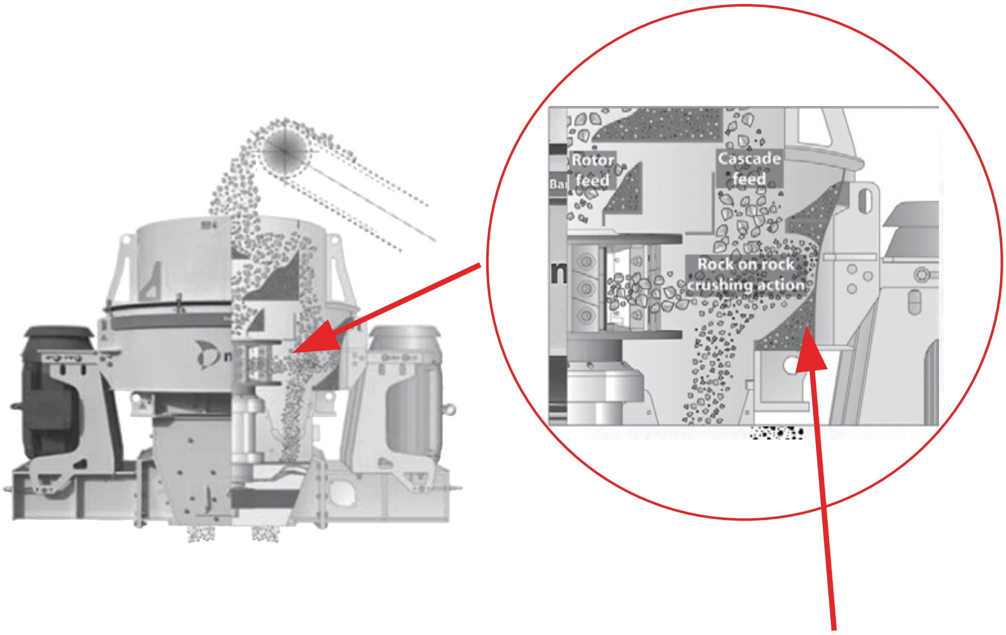
Cone crusher VSI HPGR

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

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

VSI – function



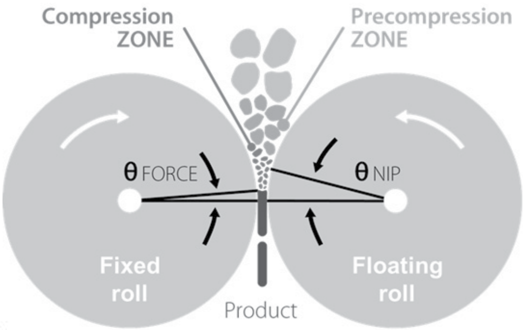
Rock protection

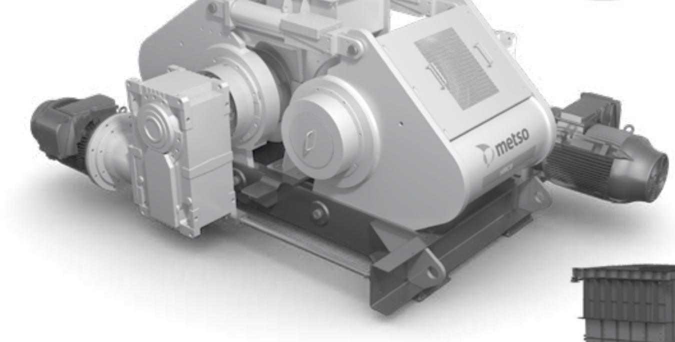
3.16 High Pressure Grinding Rolls (HPGRs) - HRC™

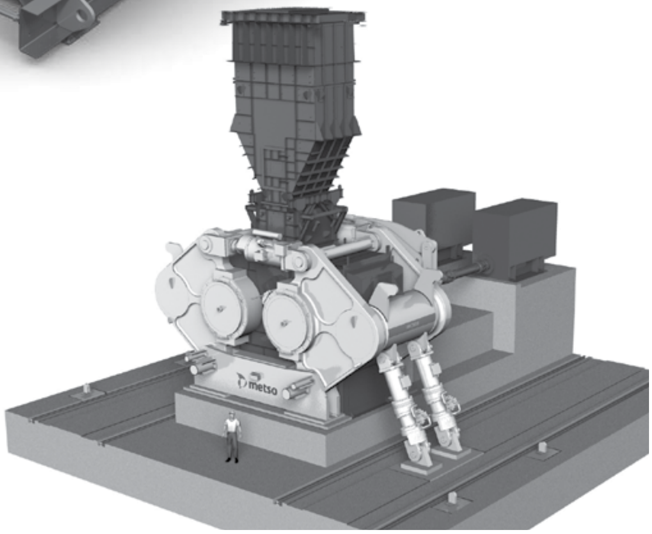
HPGRs utilize two counter-rotating rolls — one fixed and one floating — in order to effectively crush ore. Hydraulic cylinders apply very high pressure to the system, causing inter-particle comminution as the feed travels between the two rolls.
The basic operating principle behind HPGRs makes them very energy efficient:
The feed is introduced to the crushing zone, where high pressure is applied to the bed of material in a highly controlled manner.

- Dry
- Size reduction through compression, controlled application of pressure — energy efficient
- Open or closed circuit
- Flexible operating parameters (speed and pressure)
- No use of grinding media
- Short retention time
- Feed size restricted by operating gap, minus 90 mm depending on unit size
- Low noise level
- Low operating cost

Data sheet, see 3:24



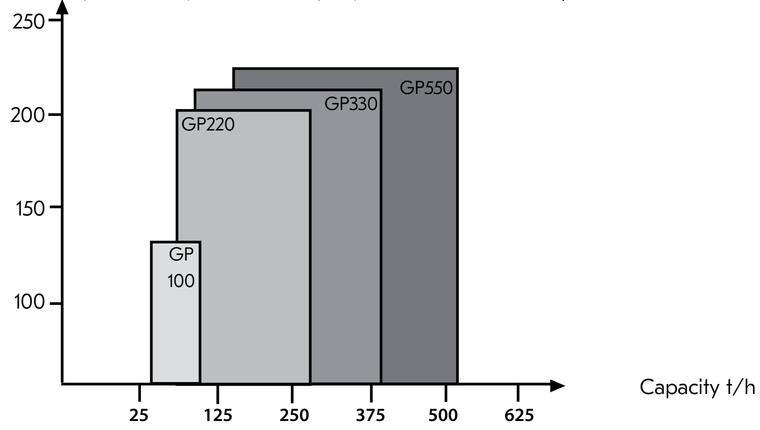




3.17 Final crusher – Sizing

Tertiary cone crushers – GP* series – Feed size vs capacity

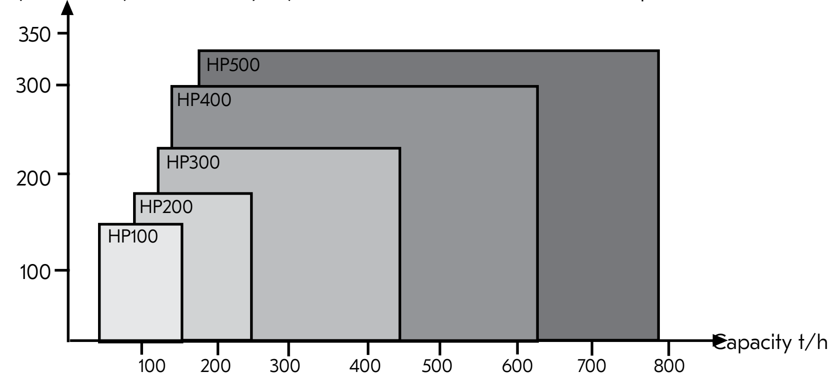
*Feed top size at minimum setting 10 mm and coarse liner profile



Data sheet,
see 3:22

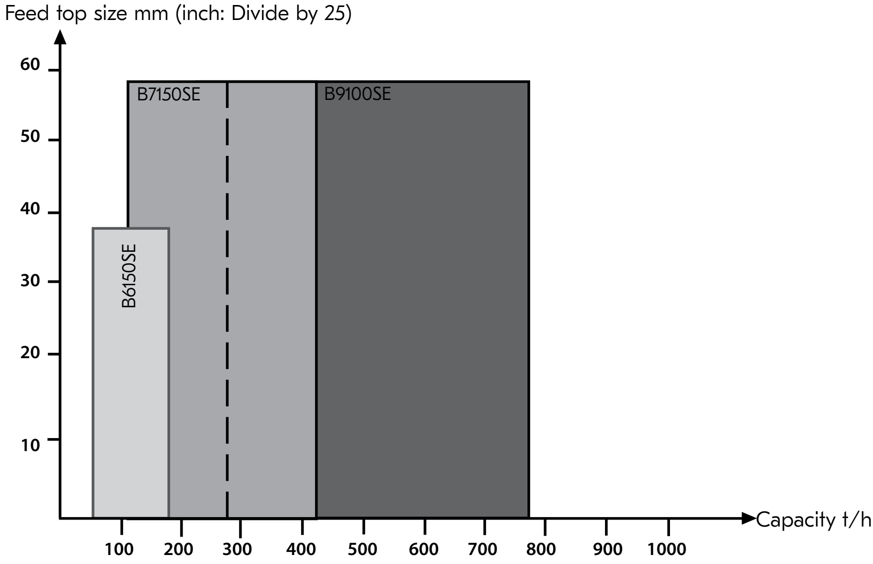
Tertiary cone crushers – HP* series – Feed size vs capacity

*Feed top size at 19 mm setting for HP 800



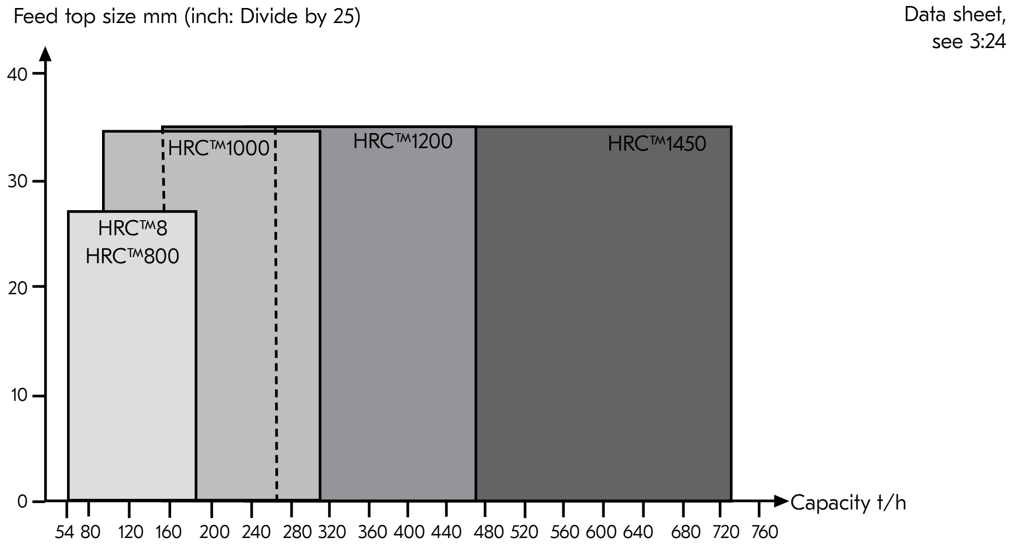
Data sheet,
see 3:19

VSI crusher – Feed size vs capacity

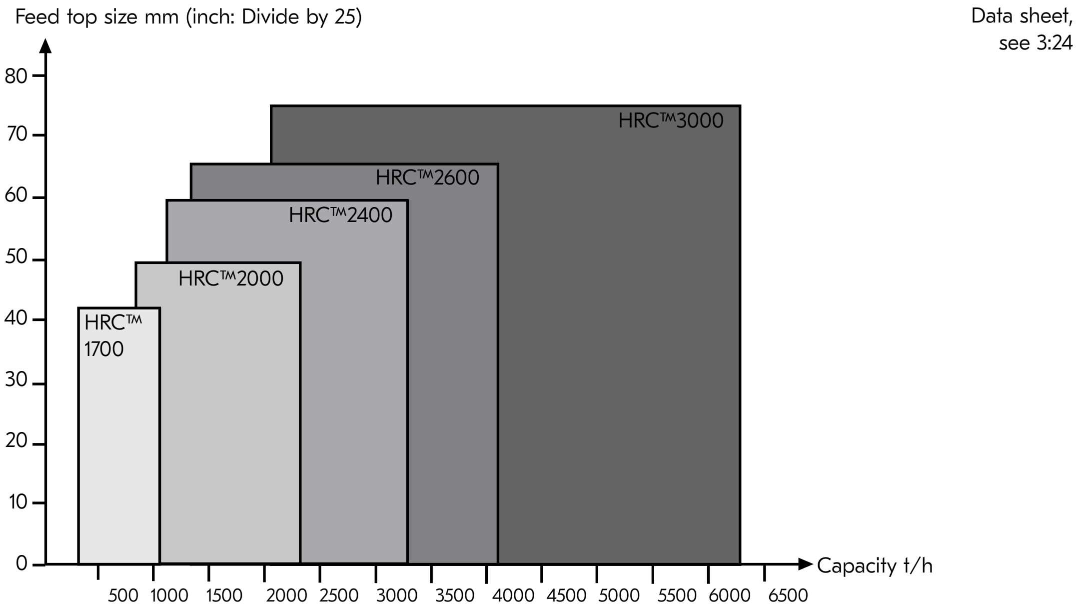


Data sheet,
see 3:23

HPGR - HRC™ 8 - 1450 — Feed size vs capacity



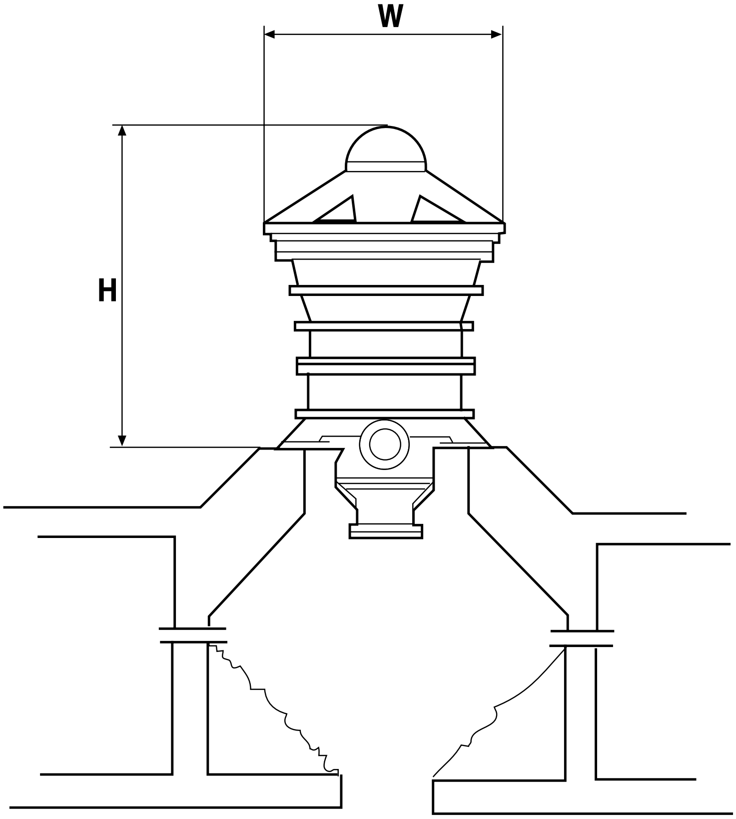
HPGR - HRC™ 1700 - 3000 — Feed size vs capacity



3.18 Wet crushing prior to grinding*

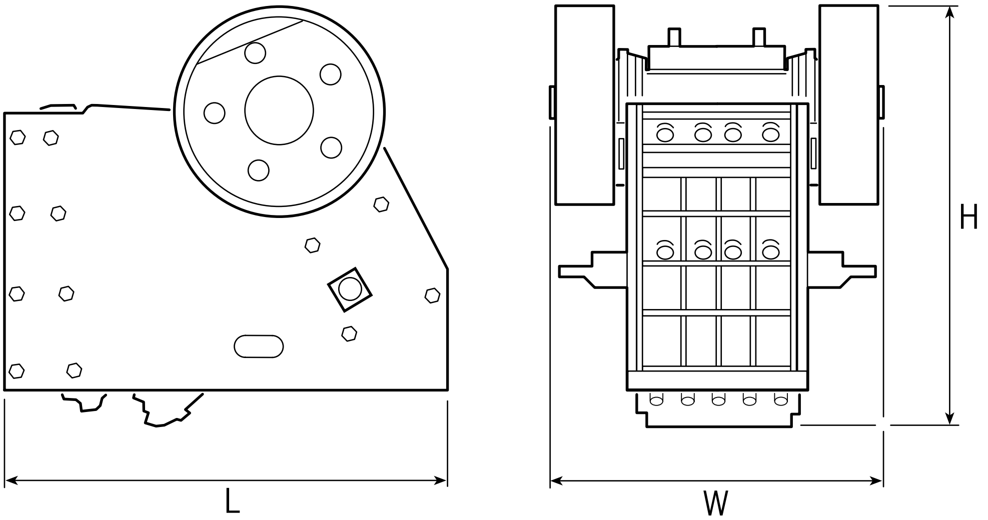
WaterFlush is a patented wet crushing process for producing a flakier finer product from specially designed cone crushers. The method is intended for mining applications comprising secondary crushing, sand manufacturing and fine crushing of ore prior to leaching. The typically crusher discharge is a 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 page 3:26-27.
*Not available from Metso Outotec

3.19 Gyratory crusher – SUPERIOR® MK-II Primary



Type	H mm (inch)	W mm (inch)	Weight mt (U.S. t)	Max. power kW (Hp)
MK-II 42-65	4807 (189.3)	3937 (155.0)	120 (132)	375 (500)
MK-II 50-65	5513 (217.0)	4458 (175.5)	153 (168)	375 (500)
MK-II 54-75	5957 (234.5)	4928 (194.0)	242 (266)	450 (600)
MK-II 62-75	6633 (261.1)	5574 (219.4)	299 (328)	450 (600)
MK-II 60-89	7474 (294.3)	5588 (220.0)	398 (438)	600 (800)
MK-II 60-110E	7518 (296.0)	6197 (244.0)	553 (609)	1200 (1600)

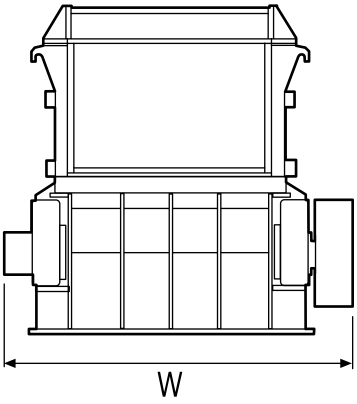
3.20 Jaw crusher — C series

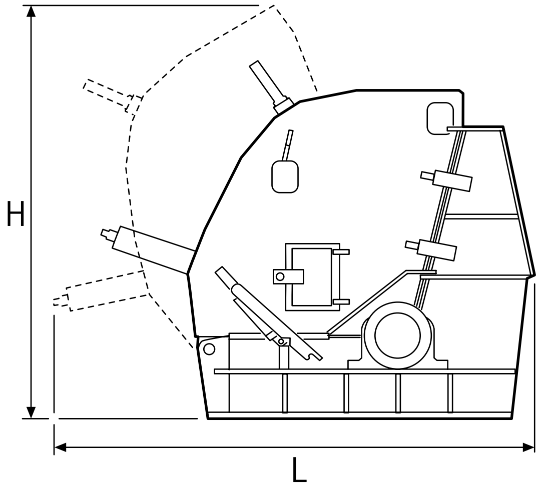


Type	H mm (inch)	L mm (inch)	W mm (inch)	Weight complete kg (lbs)	PowerkW/Hp
C 80	1700 (67)	2020 (80)	1565 (62)	9520 (21000)	75 (100)
C 96	1930 (76)	2290 (90)	1640 (65)	11870 (26170)	90 (125)
C 106	2400 (95)	2680 (106)	1930 (76)	17050 (37590)	110 (150)
C 116	2650 (104)	2890 (114)	2050 (81)	21500 (47300)	132 (175)
C 120	2950 (116)	3030 (120)	2400 (95)	29300 (64700)	160 (200)
C 130	3330 (131)	3600 (142)	2740 (108)	44000 (97000)	160 (250)
C 150	3680 (145)	3950 (156)	2890 (114)	61430 (135200)	200 (300)
C 160	3850 (152)	4200 (165)	3180 (125)	88500 (194700)	250 (350)
C 200	4220 (166)	4870 (192)	3890 (153)	137160 (302440)	400 (500)

*) complete weight including, feed chute, motor base, guards, motor

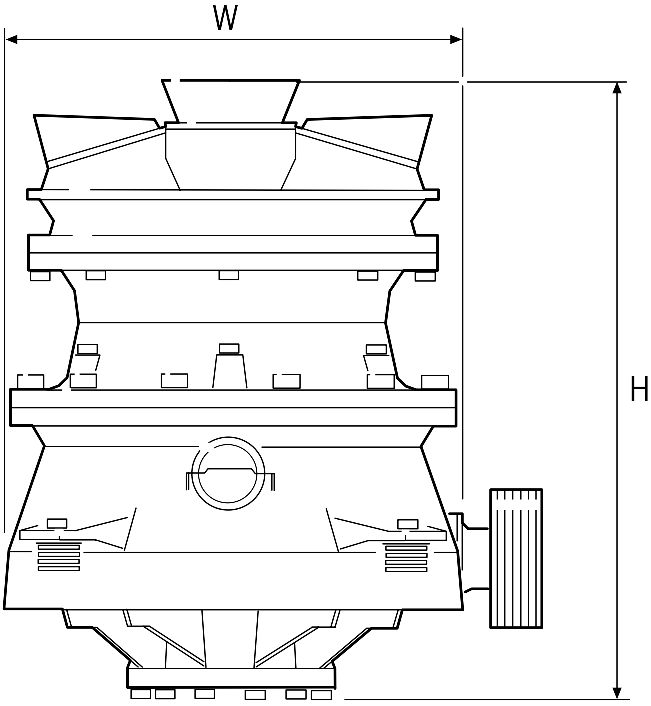
3.21 Impact crusher — NP series





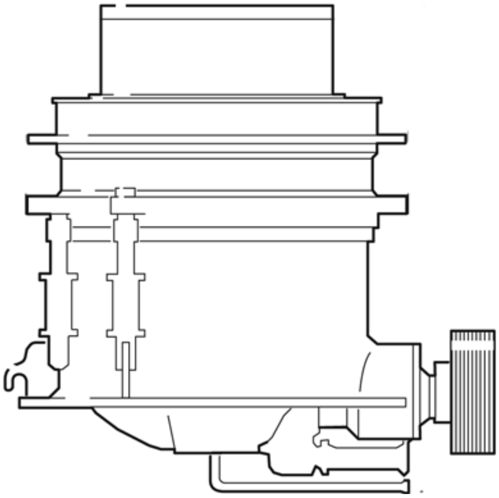
Type	H mm (inch)	L mm (inch)	W mm (inch)	Weight mt (US ton)	kW/Hp Max. power
NP 1110	2 716 (107)	3 487 (137)	2 106 (83)	8 (9)	250/350
NP13	2 491 (99)	3 974 (157)	2 531 (100)	12 (13)	315/400
NP15	2 676 (106)	4 187 (165)	2 783 (110)	16 (18)	355 (450)
NP20	3 088 (122)	4 766 (188)	3 720 (147)	27 (31)	630 (2x315) / 800 (2x400)
NP 1313	3 405 (134)	3 396 (134)	2 560 (101)	16 (18)	200/250
NP 1415	3 600 (142)	3 395 (134)	2 790 (110)	20 (22)	250/350
NP 1620	4 400 (173)	3 935 (155)	3 600 (142)	36 (40)	315/400
NP 2023	5 700 (224)	5 040 (198)	4 330 (171)	67 (74)	630 (2x315)/800 (2x400)

3.22 Cone crusher — GPS series



Type	H mm (inch)	W/L mm (inch)	Weight US tons	Power kW/Hp
GP100S	2328 (92)	1300 (51)	7 (8)	90 (125)
GP200S	2461 (97)	1745 (69)	10 (11)	160 (250)
GP300S	2546 (100)	1858 (73)	15 (16)	250 (350)
GP500S	3327 (127)	2300 (91)	29 (32)	315 (400)
GP7	5250 (207)	2810 (111)	61 (67)	560 (700)

3.23 Cone crusher — HPX00 series

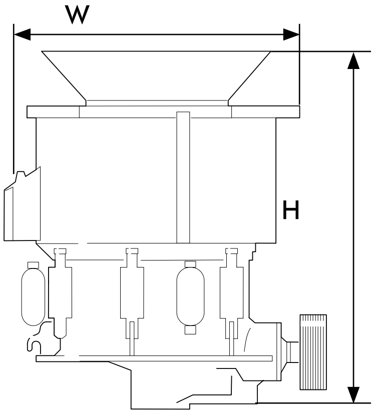


Type	Weight complete kg (lbs)	Max. power kW (Hp)
HP100	36470 (14300)	90 (125)
HP200	12160 (26800)	132 (200)
HP300	18100 (39900)	200 (300)
HP400	25600 (56400)	315 (400)
HP500	37000 (81600)	355 (500)

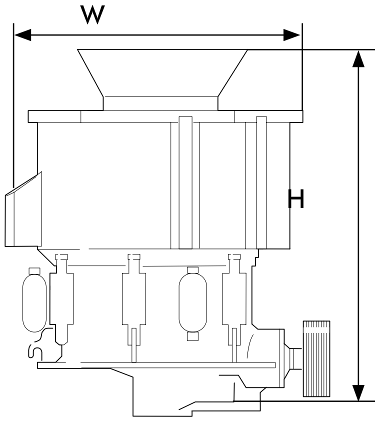
Technical data sheet

3.24 Cone crusher – HPX series

Cone crusher
HP 3 series



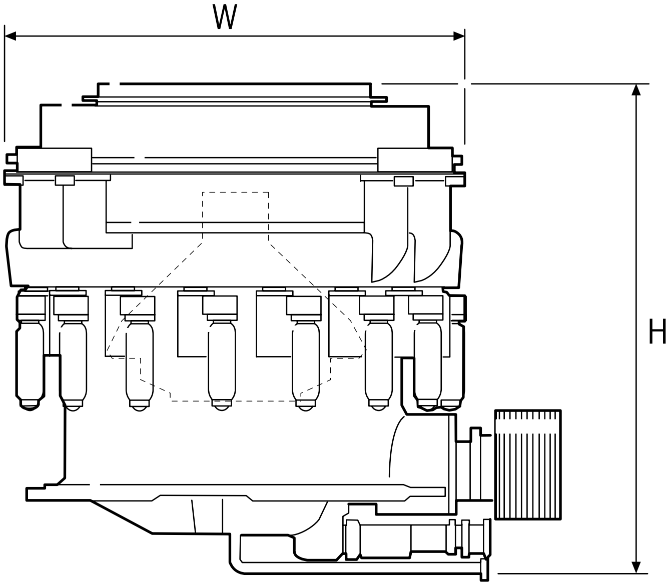
Cone crusher
HP 4, 5 and 6
series



Type	H mm (inch	W mm (inch	Complete* crusher weight kg (lb)	Max. power kW (hp)
HP3	2 817 (111)	2 778 (109)	16 100 (35 600)	220 (300)
HP4	3 147 (124)	2 955 (116)	24 200 (53 400)	315 (400)
HP5	3 295 (130)	3 438 (135)	29 000 (64 000)	370 (500)
HP6	3 953 (156)	3 854 (152)	44 500 (98 200)	450 (600)

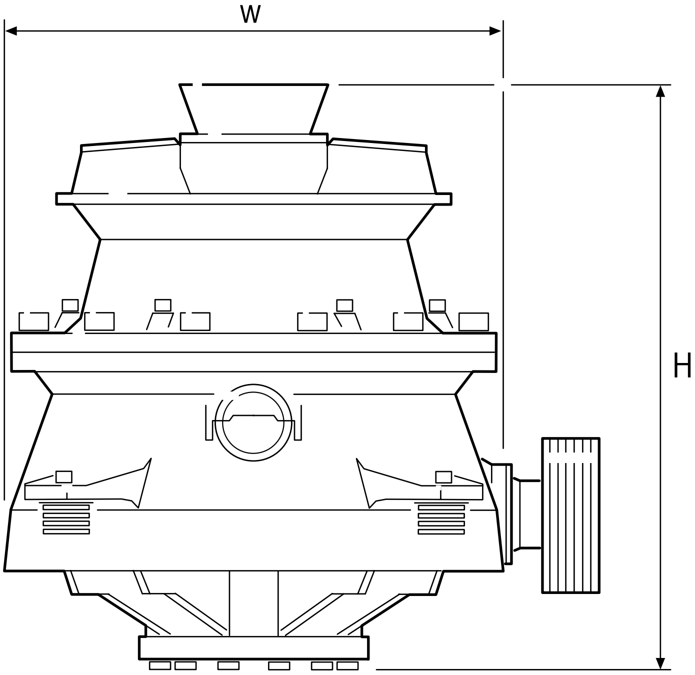
* Complete crusher weight: crusher + subframe, motor, sub frame, covers, feed and discharge arrangement

3.25 Cone crusher — MP series



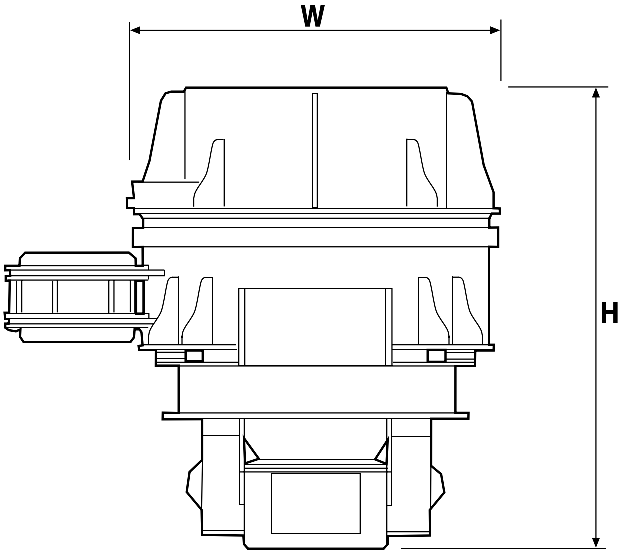
Type	H mm (inch)	W mm (inch)	Weight mt (U.S. t)	Max. power kW (Hp)
MP800	4622 (182.0)	4550 (179.1)	121 (133)	600 (800)
MP1000	4663 (183.6)	5360 (211.0)	151 (166)	750 (1000)
MP1250	4663 (183.6)	5360 (211.0)	153 (168)	933 (1250)
MP2500	6625 (260.8)	6500 (255.9)	450 (496)	2200 (3000)

3.26 Cone crusher — GP series



Type	H mm (inch)	W/L mm (inch)	Basic crusher weight kg (lbs)	Max. power kW/Hp
GP100	2038 (80)	1300 (51)	5800 (12800)	90 (125)
GP220	2170 (86)	1760 (69)	10200 (22500)	220 (300)
GP330	2380 (94)	1840 (72)	15700 (34600)	315 (425)
GP550	2860 (113)	2300 (91)	26500 (58400)	400 (500)

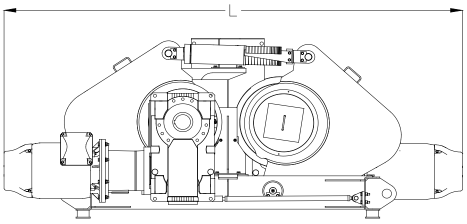
3.27 Vertical shaft impactor (VSI)

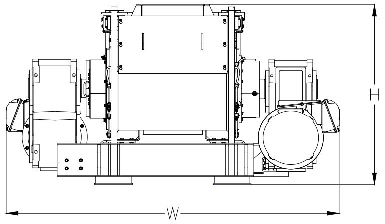


Type	H mm (inch	W mm (inch	Weight MT (US ton)	kW/Hp Max. power
B6150SE	2 189 (86)	1 870 (74)	4,5 (5)	150/20
B7150SE	2 464 (97)	2 220 (87)	10 (11)	300/400
B9100SE	2 813 (111)	2 434 (96)	12 (13)	600/800

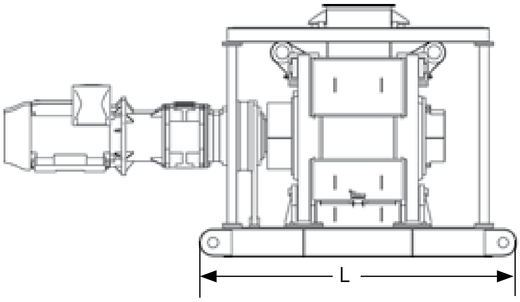
Technical data sheet

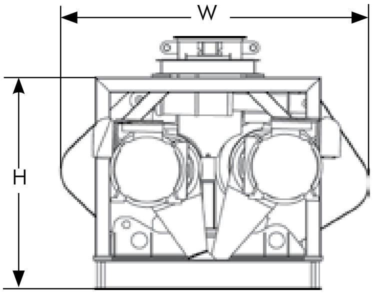
3.28 High Pressure Grinding Rolls (HPGRs) - HRC™



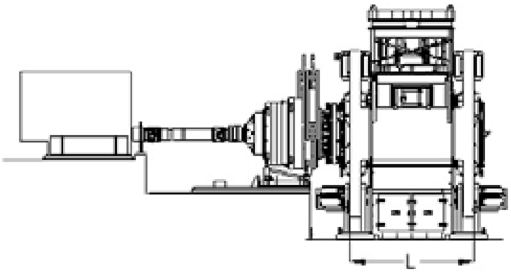


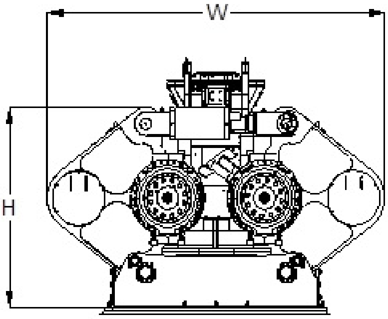
Model	Tire dimensions mm	Max. motor power kW	Max. motor power HP	H mm (inch)	L mm (inch)	W mm (inch)
HRC™8	800 x 500	2 x 75 kW	2 x 100 HP	1630 (64)	2808 (111)	3865 (152)





Model	Tire dimensions mm	Max. motor power kW	Max. motor power HP	H mm (inch)	L mm (inch)	W mm (inch)
HRC™800	730 x 500	2 x 132 kW	2 x 177 HP	2400 (94)	3700 (146)	2700 (106)
HRC™1000	1000 x 625	2 x 260 kW	2 x 349 HP	2700 (106)	3520 (139)	3500 (138)





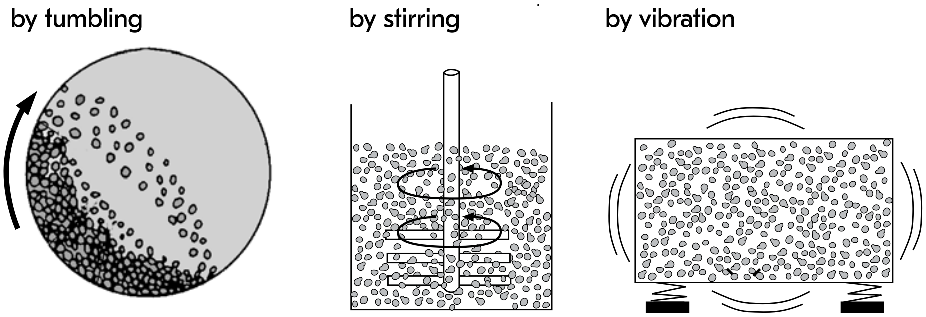
Model	Tire dimensions mm	Max. motor power kW	Max. motor power HP	H mm (inch)	L mm (inch)	W mm (inch)
HRC™1200	1200 x 750	2 x 440 kW	2 x 590 HP	2200 (87)	1610 (639)	4400 (173)
HRC™1450	1450 x 900	2 x 650 kW	2 x 872 HP	3556 (140)	2050 (81)	5196 (205)
HRC™1700	1700 x 1000	2 x 900 kW	2 x 1207 HP	3730 (147)	3690 (145)	6240 (246)
HRC™2000	2000 x 1650	2 x 2300 kW	2 x 3084 HP	5309 (209)	6079 (239)	9512 (375)
HRC™2400	2400 x 1650	2 x 3000 kW	2 x 4023 HP	6646 (262)	3630 (143)	9092 (358)
HRC™2600	2600 x 1750	2 x 3700 kW	2 x 4962 HP	6030 (237)	5660 (223)	9380 (369)
HRC™3000	3000 x 2000	2 x 5700 kW	2 x 7644 HP	6937 (273)	6480 (255)	10800 (425)

Grinding – Introduction

Size reduction by crushing has a size limitation for the final products. If we require further reduction, say below 5-20 mm, 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:

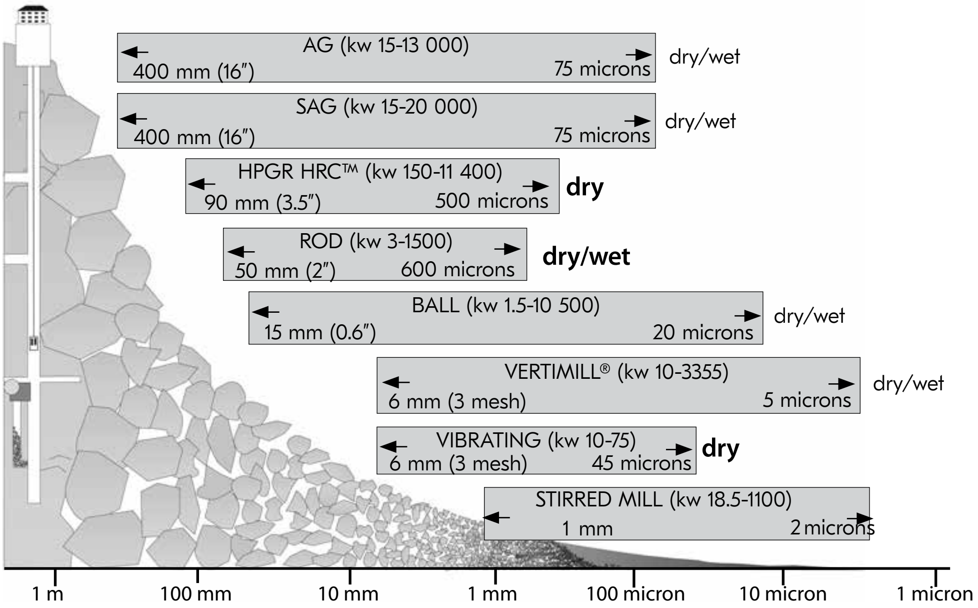
- To liberate individual minerals trapped in rock crystals (ores) and thereby open up for a subsequent enrichment in the form of separation.
- To produce fines (or filler) from mineral fractions by increasing the specific surface.

3.29 Grinding methods



3.30 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.



3.31 Grinding – Tumbling mills

Autogenous (AG) mill

High L/D

Low L/D

- 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 3:44

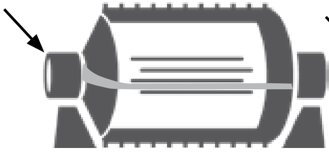
Semi – Autogenous (SAG) mill

High L/D

Low L/D

- 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 4-18% ball charge (ball dia.100-125 mm)
- High capacity (short retention time)
- Less sensitive to feed composition (critical size material), see data sheet 3:44

Rod mill



Overflow

End peripheral discharge

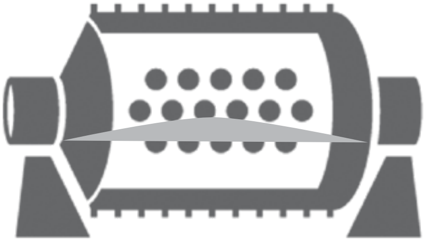
Center peripheral discharge

- 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

Note! No grate discharge

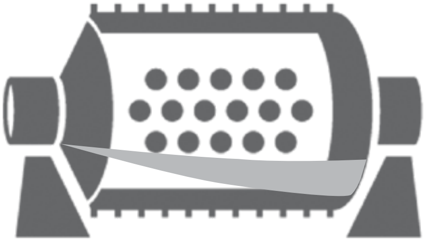
- Mostly dry
- Coarse grind and high capacity
- Special applications
- End discharge: finer product
- Centre discharge: rapid flow, less fines
- Narrow particle distribution

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 35-40%

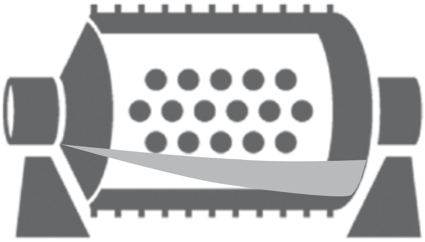


Grate discharge

- 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'

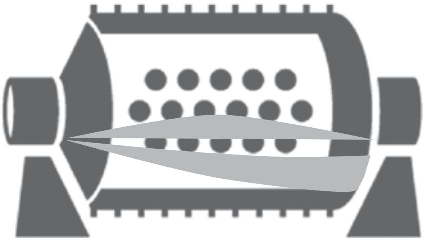
Data sheet, see 3:45-46

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
- Grinding without metallic contamination

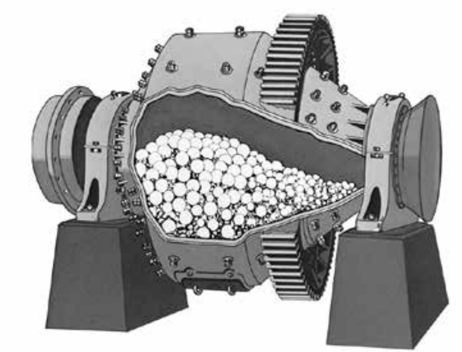
Spherical roller antifriction bearing supported mill



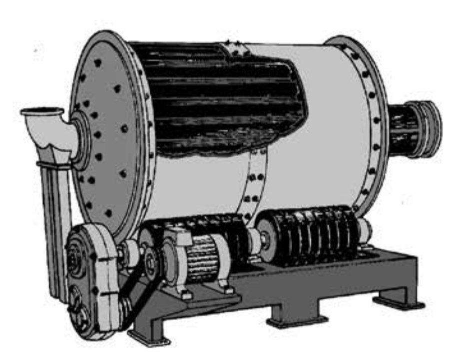
- Wet or dry
- Overflow or grate discharge
- Economic solution
- Simple design type trunnion anti- friction roller bearings and lubrication system
- Smaller capacity
- Reliable technology

Data sheet, see 3:47

Special tumbling mills



Conical ball mill



SRR (Rubber roller 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 3:48

- 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 3:49

3.33 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
- Recommended feed top size of <6 mm
- Equipment sizes from 15 to 4500 HP (11 to 3352 kW)
- Ball size max 50mm

Comparison with conventional tumbling mills

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

Data sheet, see 3:50 - *52*

Stirred media grinding mIll

Wet grinding only

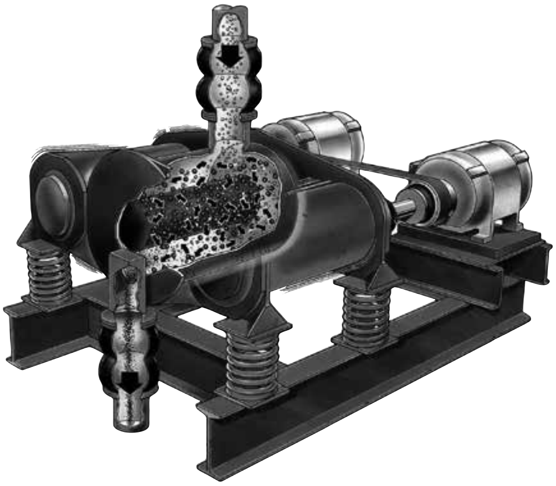
- Open or closed circuit
- Recommended feed size 100 micron and below
- Product size down to 2 micron
- Grinding media:

Ceramic or Sand Grinding Media, 1-8 mm in diameter
Ceramic media is typically recommended because of lower media consumption,l higher grinding efficiency, and lower wear rates of internal components.
1 Lab Unit, 2 Pilot Units, and 4 full size machines are available (90 kW, 185 kW, 355 kW,and 1100 kW).

Data sheet, see 3:53

3.34 Grinding – Vibrating mills

Vibrating ball mill



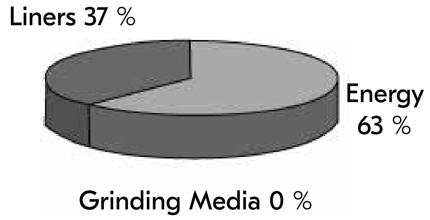
- Wet or dry
- Impact, shearing and attrition
- Open or closed circuit
- Short retention time - less overgrinding
- Feed size, minus 5 mm
- Limited in size 2x37 kW, 2x50 hp
- High noise level
- Low cost, simple installations
- Low capacity
- Specially applications

Data sheet, see 3:53

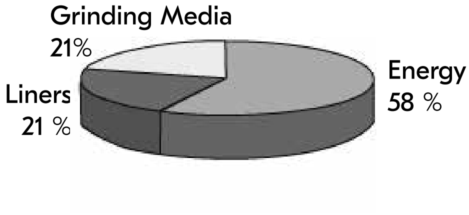
3.35 Cost of grinding – Typical

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

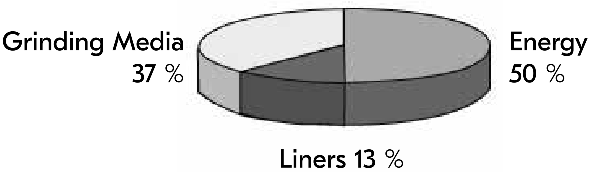
AG mills



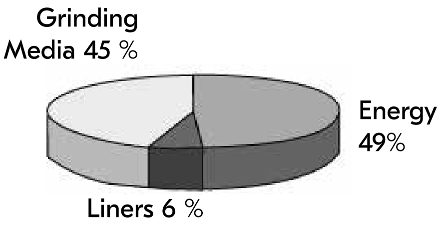
SAG mills



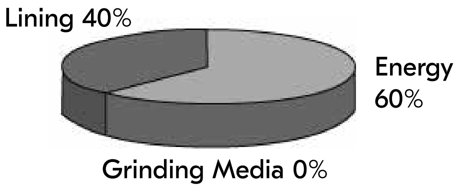
Primary ball mills



Secondary ball mills



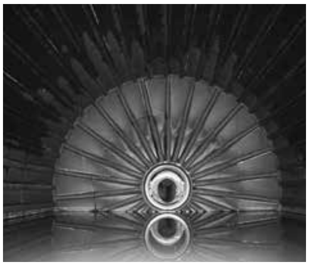
Secondary pebble mills



3.36 Mill linings and grinding media

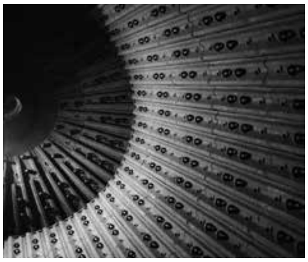
Identifying the appropriate type of mill lining and design is vital for optimizing mill throughput and total grinding cost, including costs for energy, grinding media and maintenance. Read more about wear parts for grinding on page 9:7.

Rubber linings



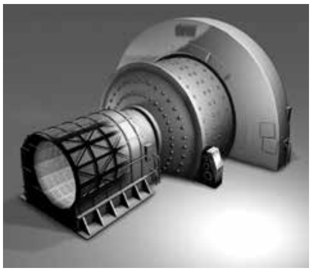
Poly-Met® linings

Metallic linings



Orebed® linings

Trommel screens



Discharge systems

3.37 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 many ways, some including:

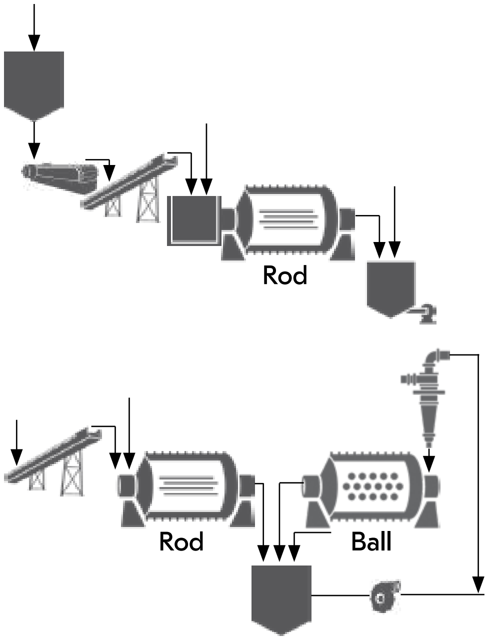
1. Operating data from existing mill circuit (direct proportioning).
2. Grinding tests in pilot scale, where the specific power consumption is determined (kWh/t dry solids).
3. Laboratory tests in small batch mills to determine the specific energy consumption.
4. Energy and power calculations based on Grind Ability Index, for example, Bond work index, (called Wi and normally expressed in **kWh/ short ton**), see 3:40.
5. Population balance modeling and other simulation techniques

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 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.

3.38 Grinding circuits

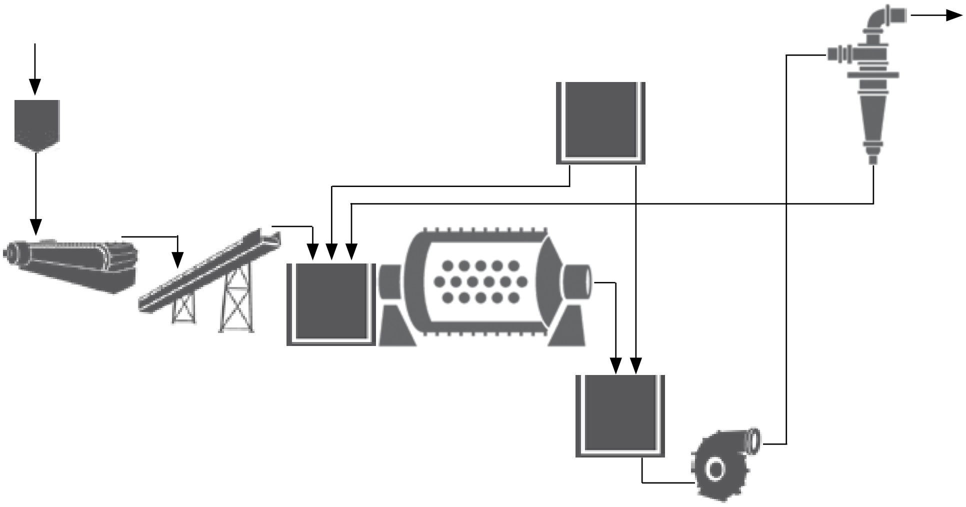
Wet grinding of feed k80 25 - 30 mm
(1" - 1 1/4") to product size k80
0.3 mm to 2 mm (8 Mesh - 48 Mesh) in open circuit.

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).



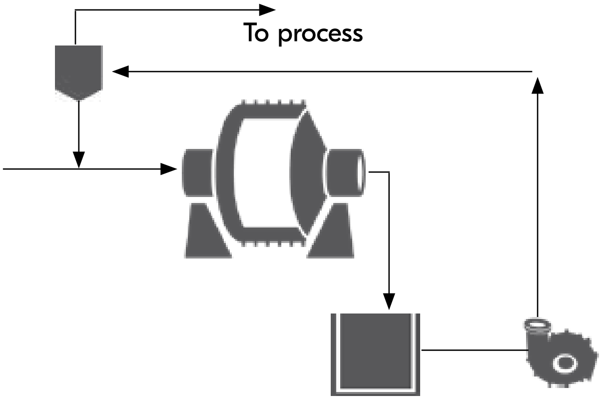
Typical duties: (Single stage ball grinding and single classification circuit)

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.



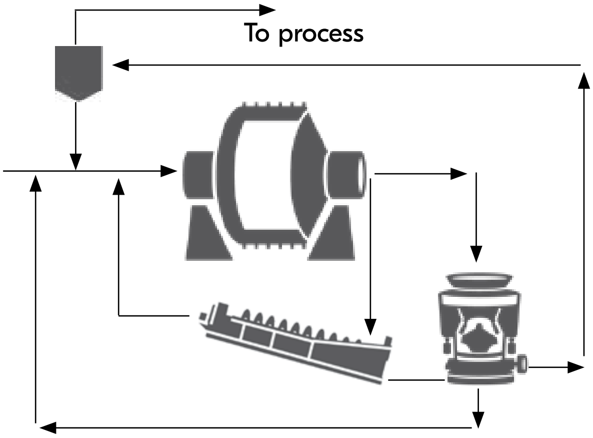
Typical duties: 1. Autogenous-Single stage

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



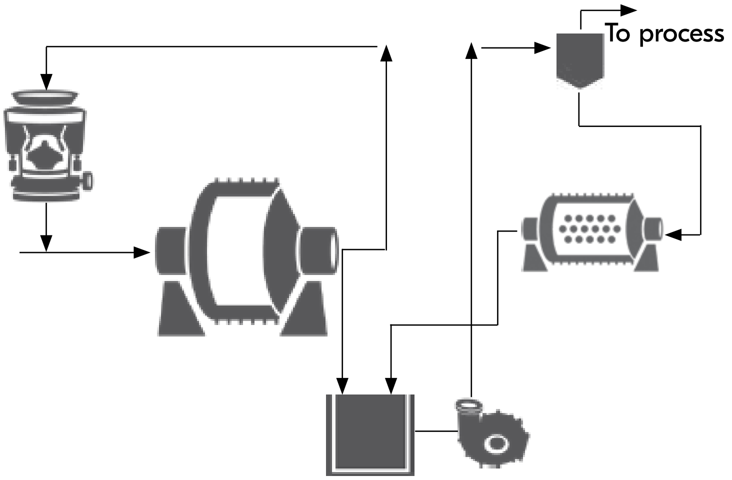
Typical duties: 2. Autogenous + Crusher

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)



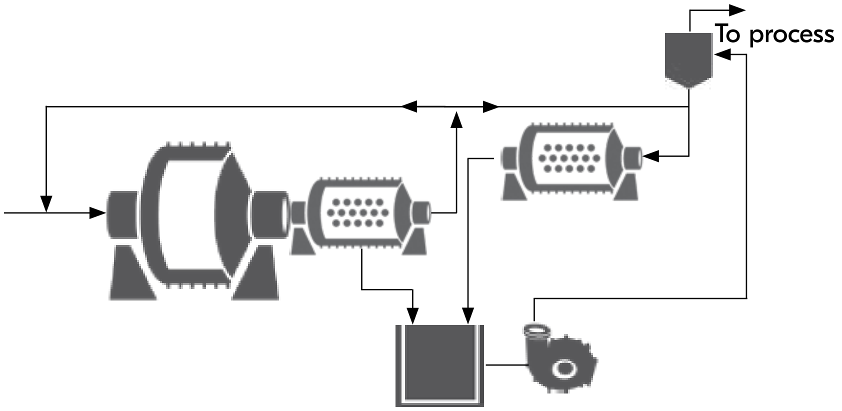
Typical duties: 3. Autogenous + Ball mill + Crusher

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.



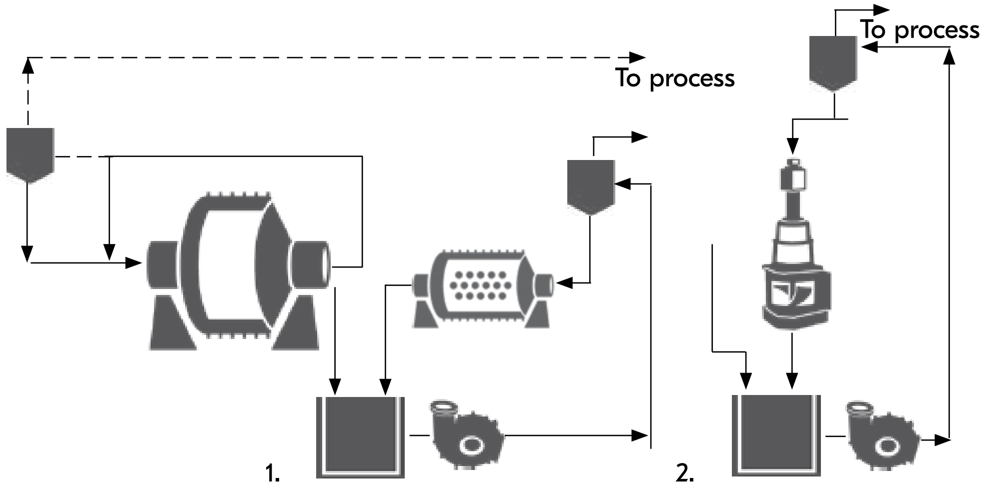
Typical duties: 4. Autogenous + Pebble mill

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.



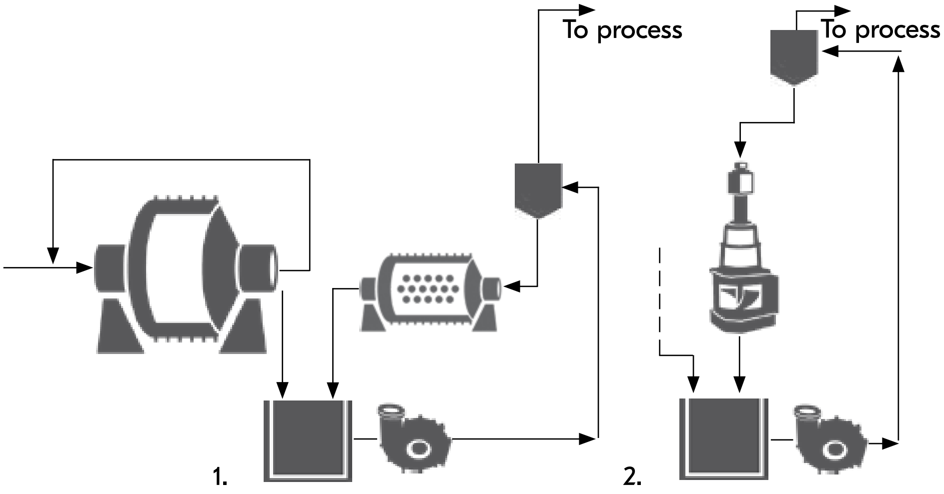
Typical duties: 5. Autogenous + Ball mill / VertiMill

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.



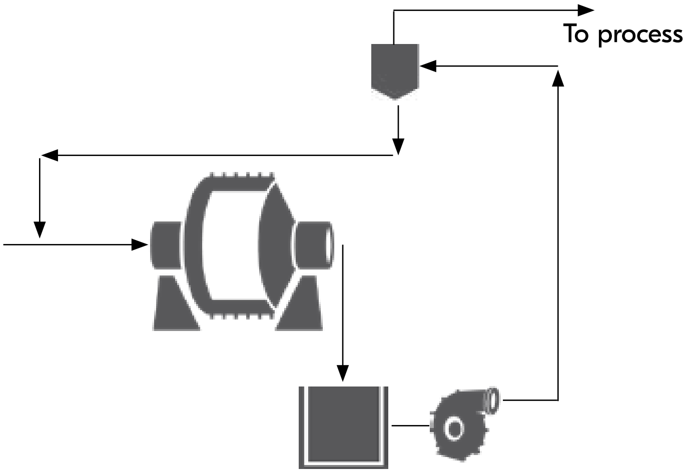
Typical duties: 6. Semi-autogenous + Ball mill / VertiMill

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.



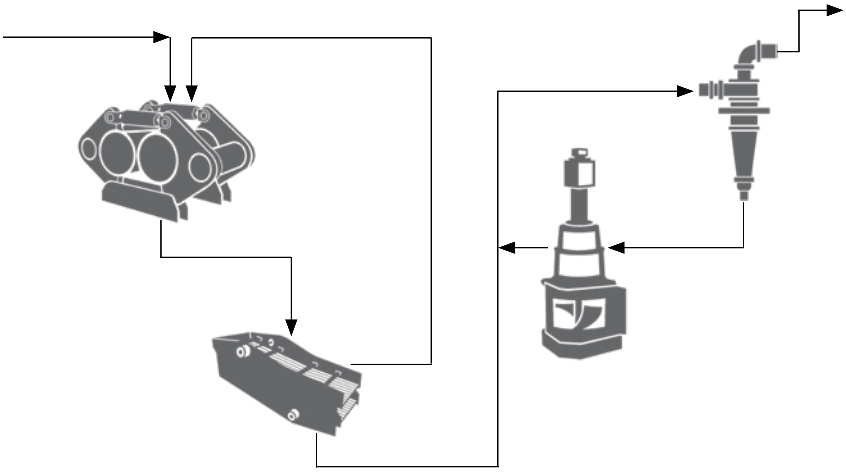
Typical duties: 7. Semi-autogenous-Single stage

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.



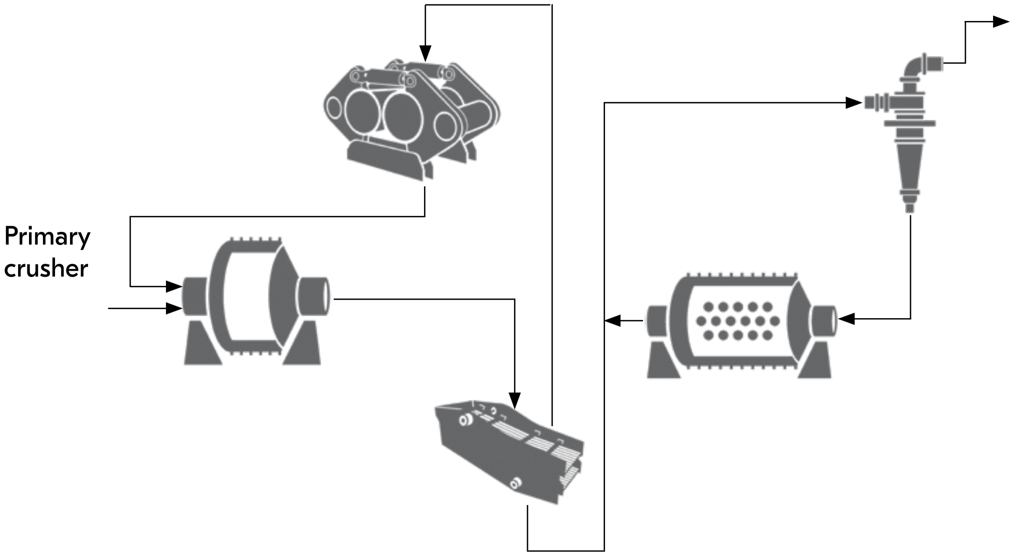
Typical duties: 8. HRC™ + Vertimill®

In this circuit, the cone crusher product is fed to the HRC™ which produces the required reduction for enrichment with the Vertimill processing the regrind. When applicable, this type of circuit can offer significant energy savings.



Typical duties: 9. AG mill + HRC™ + Ball mill

In this circuit, the AG mill is followed by a single deck screen with the oversize being recirculated through the HRC™ before returning to the AG mill. The undersize from the screen is fed to the ball mill circuit sump. The AG mill can be replaced by a SAG Mill, however special care should be used to detect and remove balls from the HRC™ feed.



3.39 VERTIMILL® Circuits

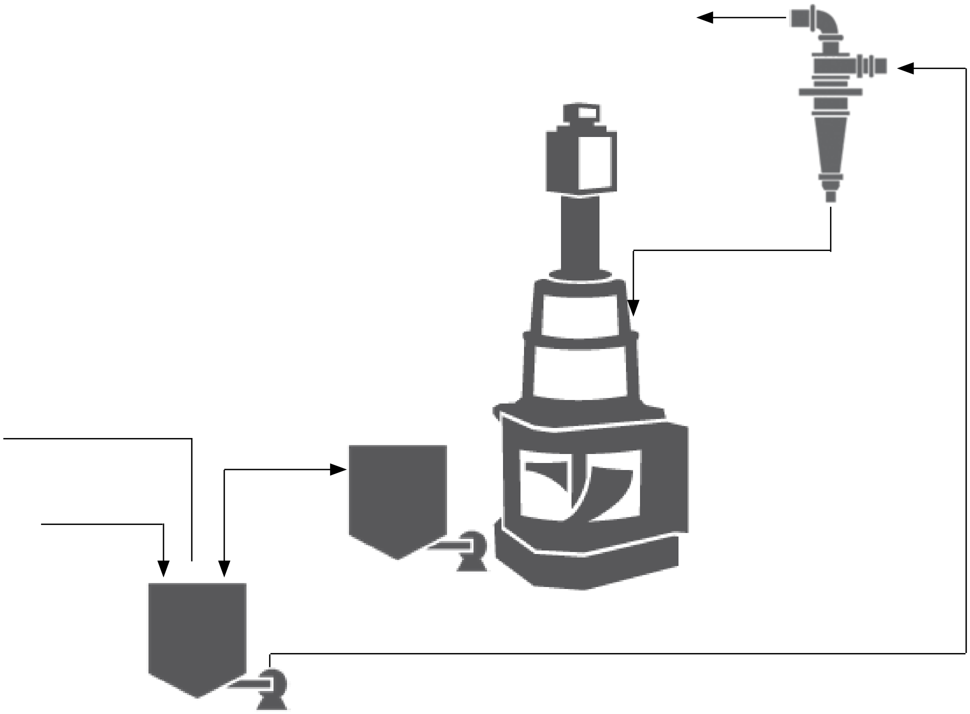
Typical duties: 10. Reversed closed circuit

Scalped or fresh feed directly into the mill

If it is desirable to use cyclones, the next decision is where in the process the cyclones should be – either closed circuit or reversed closed circuit. Typical closed circuit has the feed to the Vertimill circuit coming directly to the mill. This means that every particle regardless of size will enter the mill and may be ground. For reverse close circuit, the feed to the Vertimill circuit is introduced at the cyclone sump. The material feeding the circuit that is already at product size will have a chance to bypass the Vertimill all together, and the grinding energy will only be spent on the coarse material. This can reduce the size (and capital cost) of the Vertimill installation.

Mineralogically, there may be some benefit to direct feed in that flotation recovery may improve if all the particles surfaces, regardless of the particle size, are polished or refreshed. The reversed arrangement will minimize fines generation, which may also improve recovery. To best make a mineralogical decision, you need to have a good understand on where the losses are in the flotation circuit.

From a circuit energy perspective, in general, if the feed has very little material (<10%) that is final product size, it is better to feed it directly to the mill because the cyclone or other classifying device will send it all back to the Vertimill anyway and you would be putting undue load on the cyclone feed pumps. If there is a fair amount of fines and the classification is reasonable efficient, pre-classifying the material is beneficial.



Typical duties: 11. Direct feed

Circuit Configuration

In addition to cyclones or other external classification, there are four ways to configure a Vertimill circuit:

- Top feed with recycle system
- Top feed without recycle system
- Bottom feed with recycle system
- Bottom feed without recycle system

Bottom and top feeding configuration advantages and disadvantages are listed below and are exclusive of the use separating tank and recycle system:

Bottom feed advantages

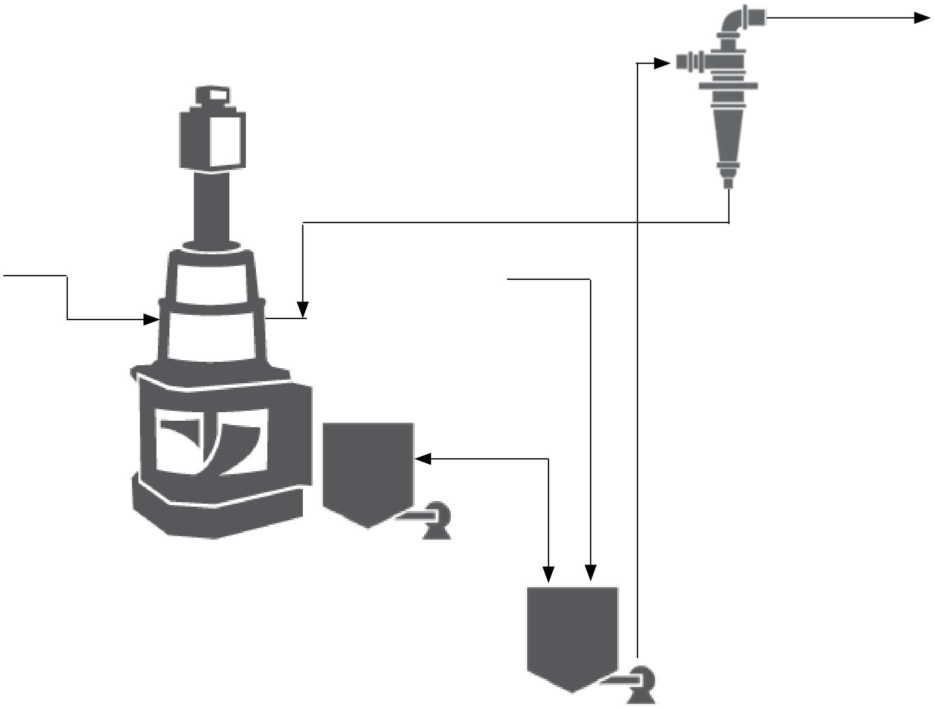
- All Particles must pass through the media, every particle surface is refreshed
- Provides additional upward classifying flow
- Can help free locked or frozen charge at start up
- Potentially more efficient because of lack of short circuiting
- Fine particles must pass through the media – potential for over grinding

Bottom feed disadvantages

- Can be bottom fed via gravity or pump
- Back flow
- need no return valves or a tall tank
- Piping must loop above ball charge height so ball to not get to the pump
- Requires variable speed pumps
- Tank requires flow split and level control
- Minimum inlet pressure requirement to prevent plugging

Top feed advantages

- Does not require a feed pump; can be feed directly from cyclones
- No inlet pressure requirement



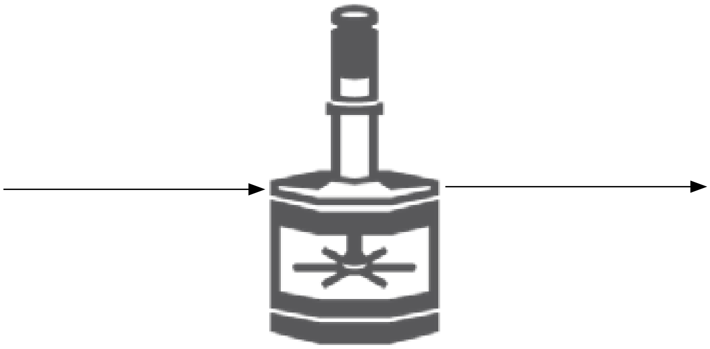
3.40 Stirred Media Detritors (SMD) Circuits

Typical duties: 12. Open circuit, whole feed

SMDs already utilize inert grinding media to improve flotation recovery, but the surface preparation of the particle may also be important for the flotation response.

The whole stream can be fed direct to the mills in open circuit so that all of the material gets some grinding to prepare the surface for flotation.

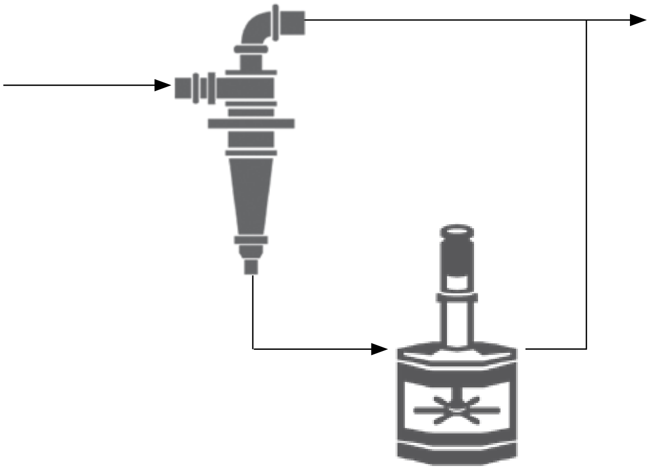
If the upstream process can provide steady feed rate and solids concentration (i.e. a thickener), the SMD can be operated in open circuit with no additional equipment required. If the feed rate or solids concentration will fluctuate periodically, then including a buffer tank to feed the mills is advised.



Typical duties: 13. Open circuit, scalped feed

If the losses in the flotation circuit are in the coarse, un-liberated material and fines generation needs to be minimized, then the SMD will be most efficient at increasing the recovery by grinding just the coarse material. Scalping cyclones can be used ahead of the mill to scalp the fines and send them straight to the next process, and the cyclone under flow feeds the SMD, and is then recombined with the cyclone overflow for the next process.

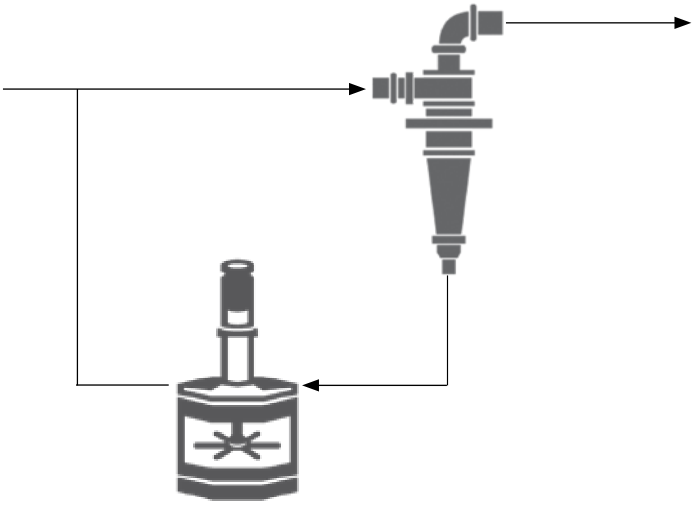
As previously stated, the SMD is best operated between 40-50% solids, and a scalping cyclone also provides a nice solution to thicken the feed to the mill.



Typical duties: 14. Closed circuit

The SMD can also be operated in closed circuit. This arrangement provides all the advantages of the Open Circuit, Scalped feed configuration, but also provides a method to control the particle size other than feed rate and mill power.

The SMD operates quite well in an open circuit configurations, and only a handful are operated in closed circuit. For ultrafine grinding, operating in closed circuit is difficult because the small diameter cyclone can easily plug. Closed circuit configuration is primarily used in coarser grinding applications and when the specific energy is low - the average residence time of the particle is short.



3.41 Grinding – Power calculation

The most common formula for this is the Bond* formula

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

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.

3.42 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

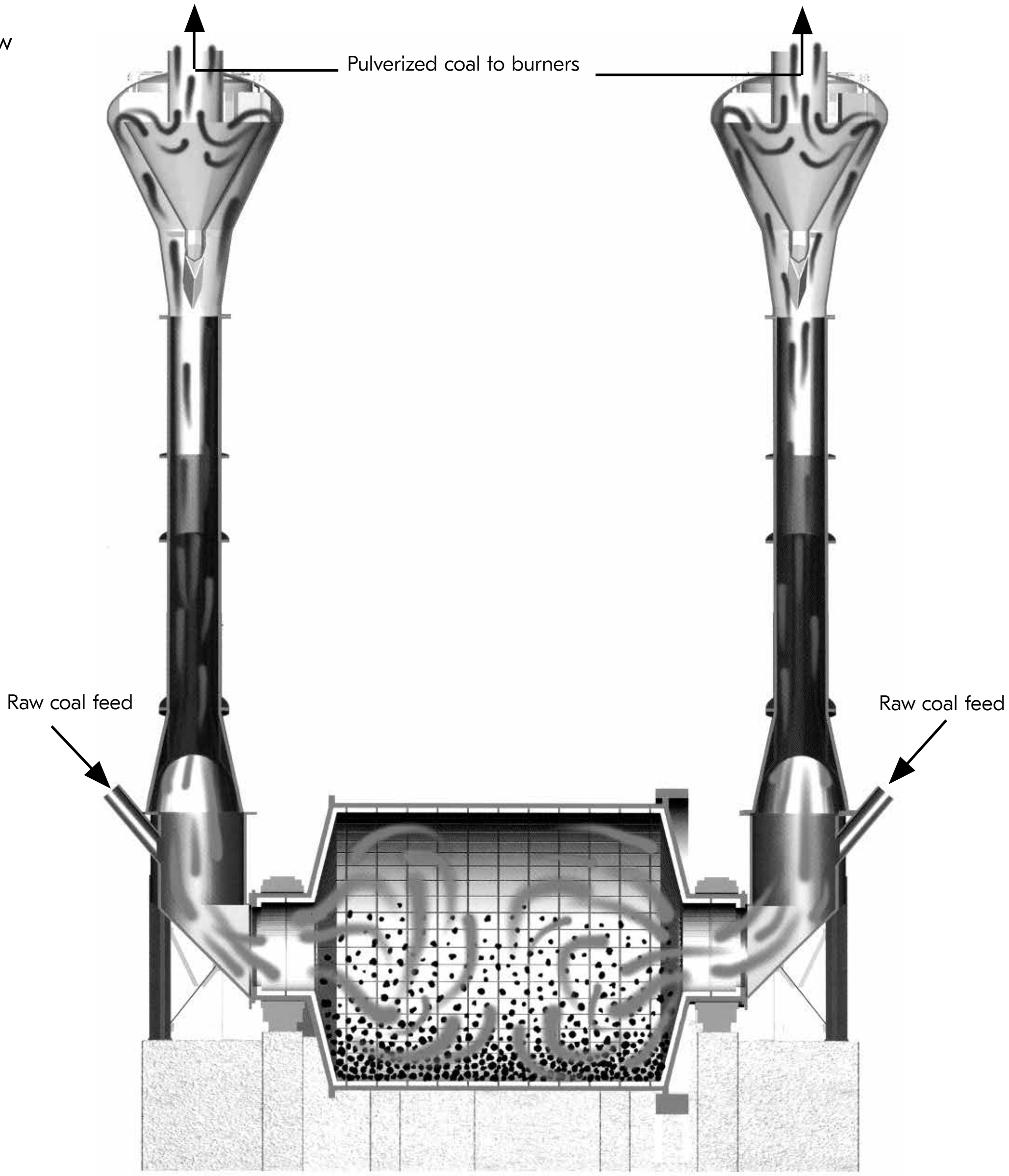
Solids [kWh/sh.ton]	Wi
Magnetite	9.97
Taconite	14.61
Lead ore	11.90
Lead-zinc ore	10.93
Limestone	12.74
Manganese ore	12.20
Magnesite	11.13
Molybdenum	12.80
Nickel ore	13.65
Oil shale	15.84
Phosphate rock	9.92
Potash ore	8.05
Pyrite ore	8.93
Pyrrhotite ore	9.57
Quartzite	9.58
Quartz	13.57
Rutile ore	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

*These values are not constant and must be used accordingly!

3.43 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



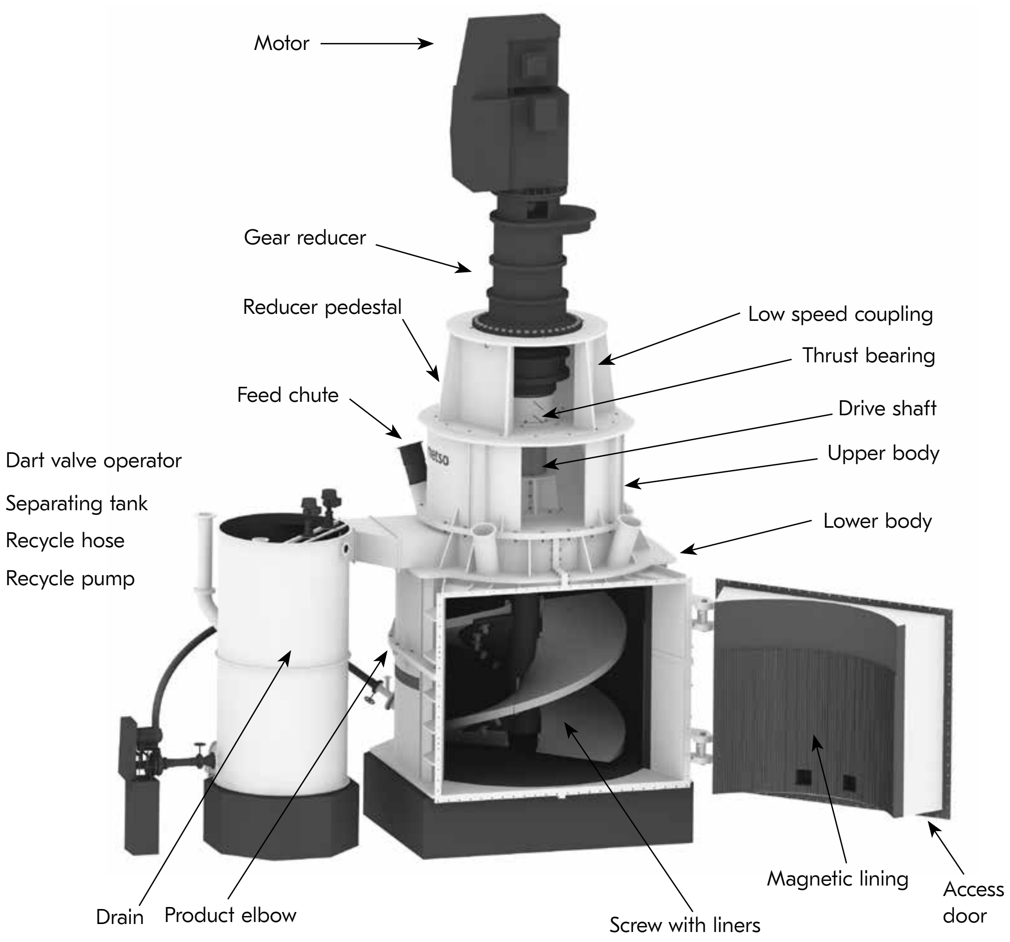
Double ended, air-swept ball mill system

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

3.44 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 3:26.



Mineral applications

- Fine / Ultra fine grinding
- Primary grinding
- Secondary grinding
- Tertiary 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
-

3.45 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	80% passing 75 microns to 90-95% passing 45 microns
Percent solids (product)	20-26%
Temperature inside mill (product)	50-82 °C (130-180°F)

Capacities vs mill sizes

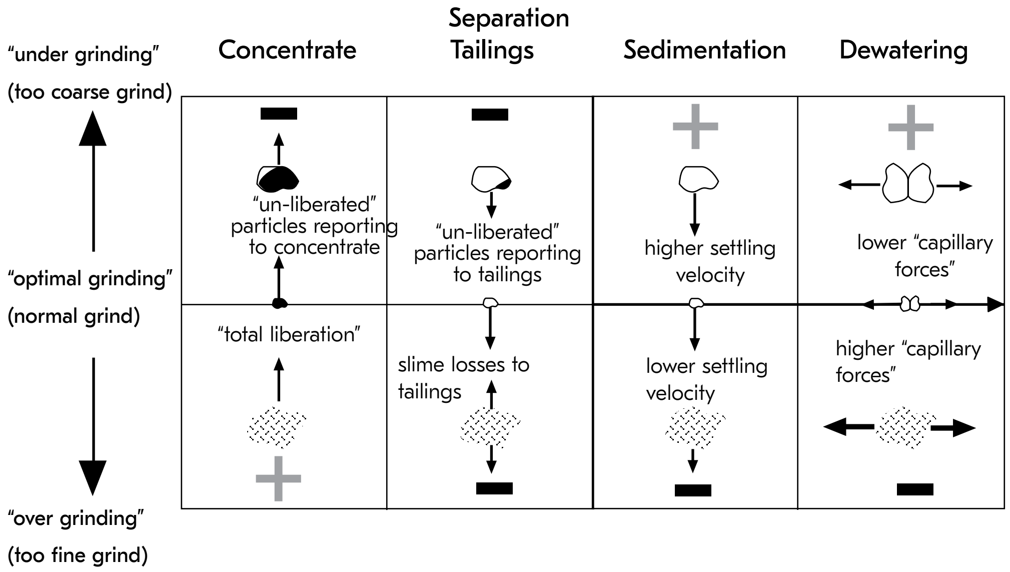
Mtph CaO	Stph CaO	Mill unit	Motor kW	Motorhp
1.4	1.5	VTM-10-LS	7.5	10
2.7	3.0	VTM-20-LS	14.9	20
3.7	4.1	VTM-30-LS	22.4	30
5.3	5.8	VTM-50-LS	37.3	50
6.6	7.3	VTM-100-LS	44.7	60
12.0	13.2	VTM-150-LS	74.6	100
13.9	15.3	VTM-200-LS	111.9	150
18.7	20.6	VTM-300-LS	149.1	200
30.0	33.0	VTM-400-LS	223.7	300

3.46 Grinding vs enrichment and upgrading

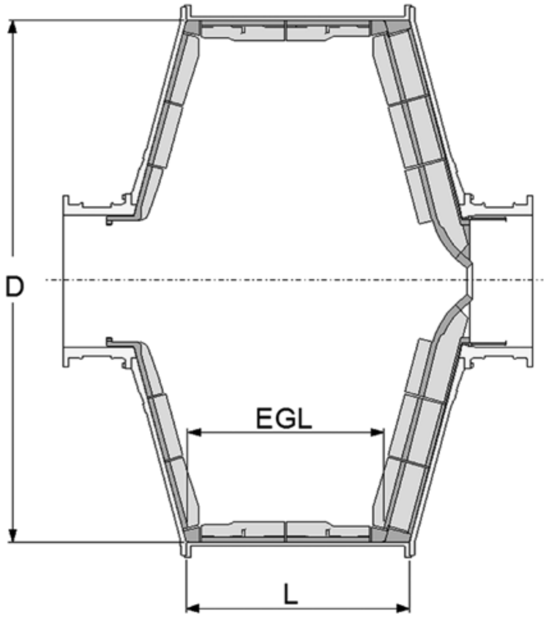
In the size reduction stages of grinding we are also creating the conditions for the following process stages of enrichment and upgrading.

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.

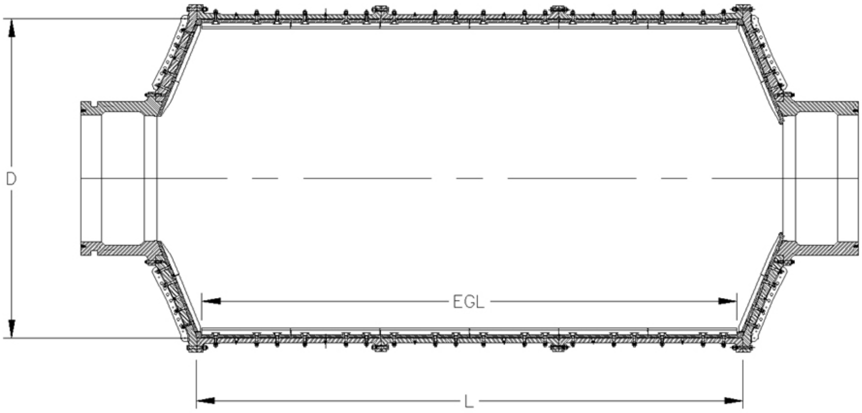


3.47 AG and SAG mills



Standard Mill size (m)	EGL (m)	Geared/Gearless	Std %TCS	Motor hp/kW (Typical)
12′ x 5′ (3,7 x 1,5)	4′ (1,2)	Geared	75	150-250/110-185
14′ x 6′ (4,2 x 1,8)	5′ (1,5)	Geared	75	300-500/220-370
16′ x 7′ (4,8 x 2,1)	6′ (1,8)	Geared	75	550-850/400-630
18′ x 8′ (5,5 x 2,4)	6.75′ (2,0)	Geared	75	900-1300/670-970
20′ x 8′ (6,0 x 2,4)	6.75′ (2,0)	Geared	75	1000-1750/745-1300
21′ x 10′ (6,4 x 3,0)	8.75′ (2,7)	Geared	75	1600-2500/1200-1860
22′ x 10′ (6,7 x 3,0)	8.75′ (2,7)	Geared	75	2000-3000/1490-2240
24′ x 10′ (7,3 x 3,0)	8.75′ (2,7)	Geared	75	2500-3500/1860-2610
26′ x 10′ (7,9 x 3,0)	8.75′ (2,7)	Geared	75	3000-4500/2240-3350
28′ x 10′ (8,5 x 3,0)	8.5′ (2,6)	Geared	75	3500-5500/2610-4100
28′ x 14′ (8,5 x 4,3)	12.5′ (3,8)	Geared	75	5000-8000/3730-5960
30′ x 12′ (9,1 x 3,7)	10.5′ (3,2)	Geared	75	5000-8000/3730-5960
32′ x 14′ (9,8 x 4,3)	12.5′ (3,8)	Geared	75	7-11000/5-8200
32′ x 16′ (9,8 x 4,8)	14.5′ (4,4)	Geared	75	8-12000/6-8950
34′ x 15′ (10,3 x 4,6)	13.25′ (4,0)	Geared	75	8-13000/6-9700
34′ x 17′ (10,3 x 5,2)	15.25′ (4,6)	Geared	75	10-15000/7-11190
34′ x 19′ (10,3 x 5,8)	17.25′ (5,3)	Geared	75	11-17000/8-12680
36′ x 15′ (11,0 x 4,6)	13.25′ (4,0)	Geared/Gearless	Variable	10-16000/7-11930
36′ x 17′ (11,0 x 5,2)	15.25′ (4,6)	Geared/Gearless	Variable	11-18000/8-13420
36′ x 19′ (11,0 x 5,8)	17.25′ (5,3)	Geared/Gearless	Variable	12-20000/9-14900
38′ x 20′ (11,6 x 6,0)	18′ (5,5)	Geared/Gearless	Variable	15-24000/11-17800
40′ x 22′ (12,0 x 6,7)	19.5′-20′ (5,9-6,1)	Gearless	Variable	19-30000/14-22370
42′ x 25′ (12,8 x 7,6)	22.5′ (6,8)	Gearless	Variable	23-36000/17-26850

3.48 Ball mills

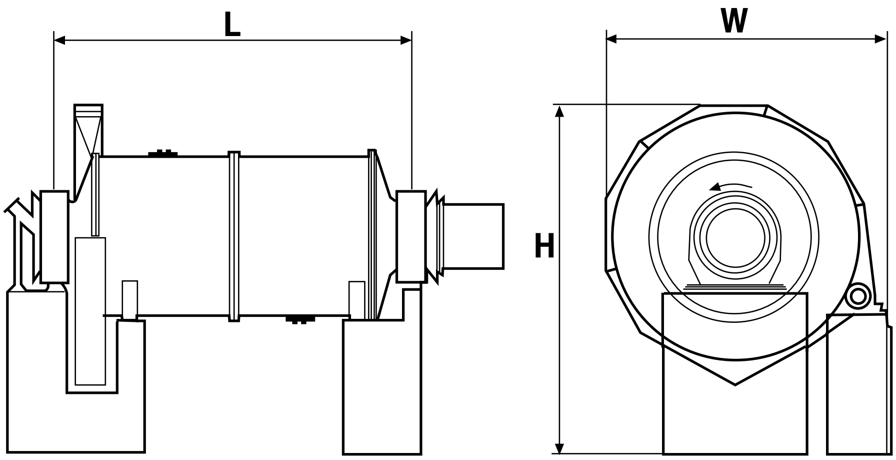


Standard Mill size (m)	Geared/Gearless	Std %TCS	Approx hp/kW	Motor hp/kW
9′ x 12′ (2,7x3,7)	Geared	76	388/290	450/335
9′ x 14′ (2,7x4,2)	Geared	76	455/340	500/373
9.5′ x 15′ (2,9x4,6)	Geared	76	564/420	600/447
10′ x 15′ (3,0x4,6)	Geared	76	596/445	700/522
10.5′ x 15′ (3,2x4,6)	Geared	76	734/547	800/597
10.5′ x 17′ (3,2x5,2)	Geared	76	836/623	900/671
11′ x 17′ (3,3x5,2)	Geared	76	944/704	1000/746
11.5′ x 18′ (3,5x5,5)	Geared	76	1125/839	1250/932
13′ x 17′ (3,9x5,2)	Geared	76	1460/1089	1500/1119
13′ x 19′ (3,9x5,8)	Geared	76	1637/1220	1750/1305
14′ x 18′ (4,2x5,5)	Geared	76	1877/1400	2000/1491
14′ x 20′ (4,2x6,0)	Geared	76	2091/1559	2250/1677
15′ x 19′ (4,6x5,8)	Geared	76	2372/1769	2500/1864
15.5′ x 21′ (4,7x6,4)	Geared	76	2861/2133	3000/2237
16.5′ x 21′ (5,0x6,4)	Geared	76	3362/2507	3000/2237
16.5′ x 24′ (5,0x7,3)	Geared	76	3854/2873	4000/2983
16.5′ x 27′ (5,0x8,2)	Geared	76	4346/3240	4500/3356
16.5′ x 30′ (5,0x9,1)	Geared	76	4838/3608	5000/3728
16.5′ x 33′ (5,0x10,0)	Geared	76	5330/3975	5500/4101
18′ x 29′ (5,5x8,8)	Geared	76	5847/4360	6000/4474
18′ x 31.5′ (5,5x9,6)	Geared	76	6360/4743	6000/4474
18′ x 33.5′ (5,5x10,2)	Geared	76	6771/5049	7000/5220

Continues on next page.

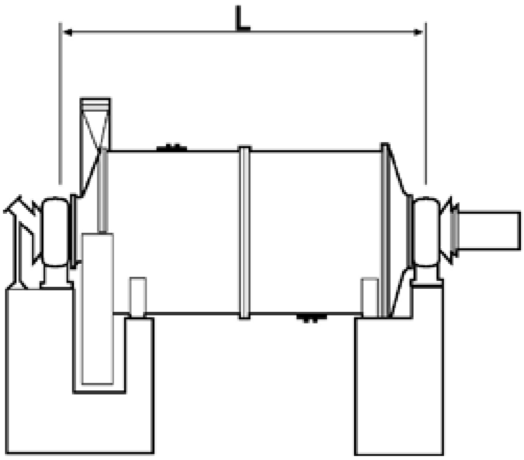
Technical data sheet

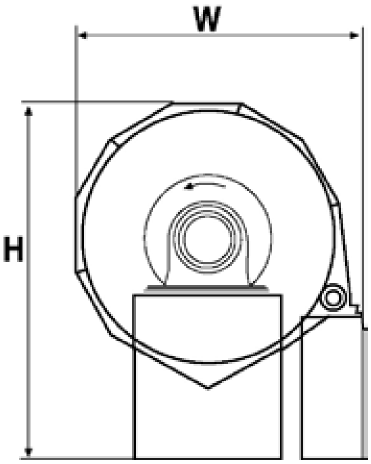
Ball mills (continued)



Standard Mill size (m)	Geared/Gearless	Std %TCS	Approx hp/kW	Motor hp/kW
20′ x 31.5′ (6x9,6)	Geared	76	8336/6212	8000/5966
20′ x 33.5′ (6x10,2)	Geared	76	8874/6617	9000/6711
21′ x 31.5′ (6,4x9,6)	Geared	76	9446/7044	10000/7457
21′ x 33.5′ (6,4x10,2)	Geared	76	10361/7726	11000/8203
22′ x 36.5′ (6,7x11,1)	Geared	76	12357/9215	13000/9694
22′ x 40.5′ (6,7x12,3)	Geared	76	13370/9970	14500/10813
24′ x 36′ (7,3x11)	Geared	76	15220/11350	16000/11931
24′ x 40′ (7,3x12,3)	Geared	76	16935/12628	17800/13273
26′ x 38′ (7,9x11,6)	Geared/Gearless	76	19720/14705	20700/15436
26′ x 40′ (7,9x12,3)	Geared/Gearless	76	20771/15489	21800/16256
26′ x 42′ (7,9x12,8)	Geared/Gearless	76	21823/16273	23000/17151
26′ x 44′ (7,9x13,4)	Geared/Gearless	76	22875/17058	24000/17897
27′ x 45′ (8,2x13,7)	Gearless	76	25763/19211	27000/20134
28′ x 46′ (8,5x14)	Gearless	76	28898/21549	30000/22371
29′ x 47′ (8,8x14,3)	Gearless	76	32291/24079	34000/25354
30′ x 46′ (9,1x14)	Gearless	76	34442/25683	36000/26845

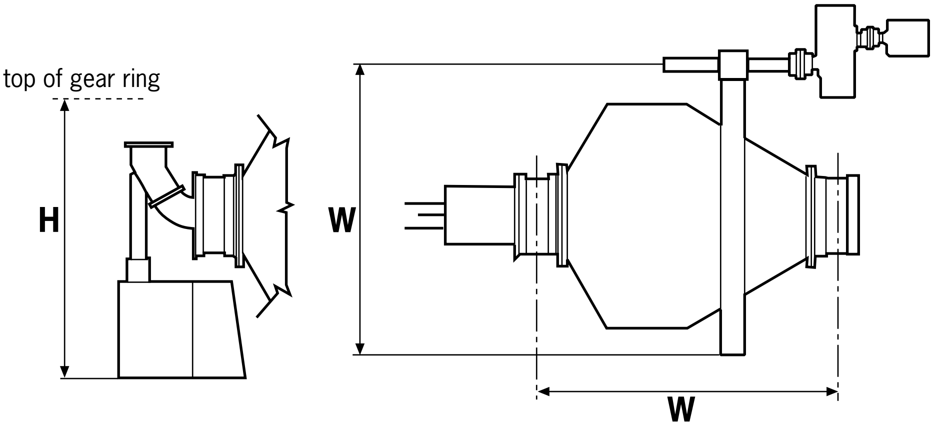
3.49 Spherical roller bearing supported ball mill





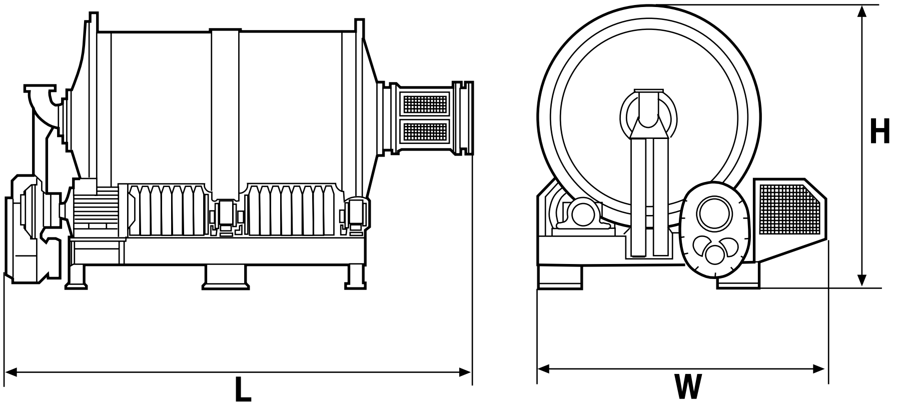
Mill size m (ft) DxL	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/HP
2.4x3.6 (8x11.8)	4350 (171)	5043 (199)	4650 (183)	232/311
2.4x4.2 (8x13.8)	4350 (171)	5643 (222)	4650 (183)	269/361
2.4x4.8 (8x15.7)	4350 (171)	6243 (246)	4650 (183)	306/410
2.8x4.2 (9x13.8)	4800 (189)	5874 (231)	5700 (225)	410/550
2.8x4.9 (9x16)	4800 (189)	6574 (259)	5700 (225)	474/636
2.8x5.6 (9x18.4)	4800 (189)	7274 (286)	5700 (225)	539/723
3.2x4.8 (10.5x15.7)	5200 (205)	6705 (264)	6790 (267)	643/863
3.2x5.6 (10.5x18.4)	5200 (205)	7505 (296)	6790 (267)	745/1000
3.2x6.4 (10.5x21)	5200 (205)	8317 (327)	6790 (267)	846/1135
3.6x5.4 (11.8x17.7)	5600 (221)	7548 (297)	7140 (281)	990/1327
3.6x6.3 (11.8x20.7)	5600 (221)	8448 (333)	7140 (281)	1145/1535
3.6x7.2 (11.8x23.6)	5600 (221)	9394 (370)	7140 (281)	1300/1743
4.0x6.0 (13x19.7)	7900 (311)	8425 (332)	9000 (355)	1452/1947
4.0x7.0 (13x23)	7900 (311)	9938 (391)	9000 (355)	1679/2251
4.0x8.0 (13x26)	7900 (311)	10425 (410)	9000 (355)	1905/2555
4.4x6.6 (14.4x21.7)	8000 (315)	9256 (364)	9500 (374)	2054/2754
4.4x7.2 (14.4x23.6)	8000 (315)	9856 (388)	9500 (374)	2229/2989
4.4x7.7 (14.4x25.3)	8000 (315)	10356 (408)	9500 (374)	2374/3184
4.4x8.2 (14.4x27)	8000 (315)	10856 (427)	5 700 (224)	2519/3379

3.50 Conical ball mill



Mill size m (ft) DxL	H) mm (inch	L mm (inch	W mm (inch	Power motor kW/Hp
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

3.51 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 *	

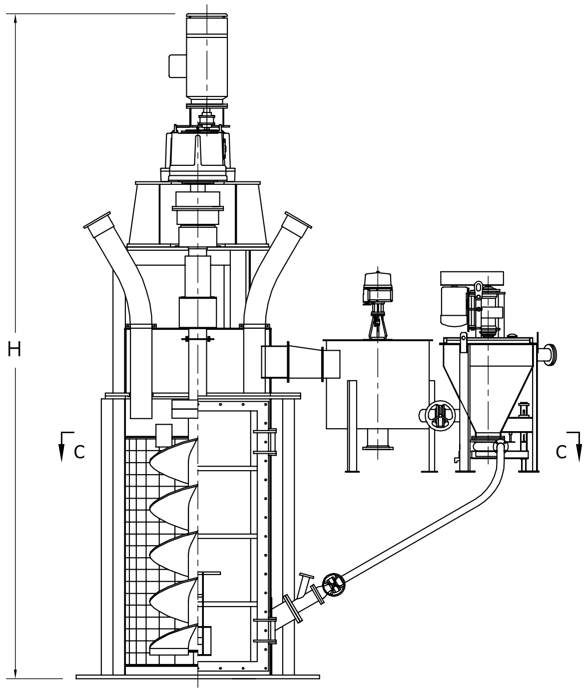
SRR Rod mill Mill size m (ft) DxL	H mm (inch)	L mm (inch	W mm (inch	Power motor kW/Hp	Weight (empty) ton
0.6x0.9 (2x3)	1 110 (44)	1 830 (72)	1 220 (48)	2.2/3	1.0
1.0x1.5 (3.3x5)	1 635 (64)	2 700 (106)	1 850 (73)	11/15	3.0
1.2x2.4 (4x8)	1 970 (78)	3 670 (144)	2 740 (108)	30/40	6.2
1.5x3.0 (3.3x6.6)	2 255 (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*	

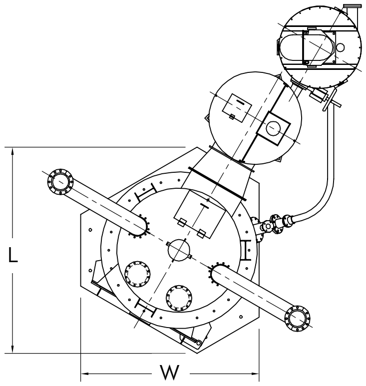
*Dual drive

Technical data sheet

VERTIMILL®

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 3:52

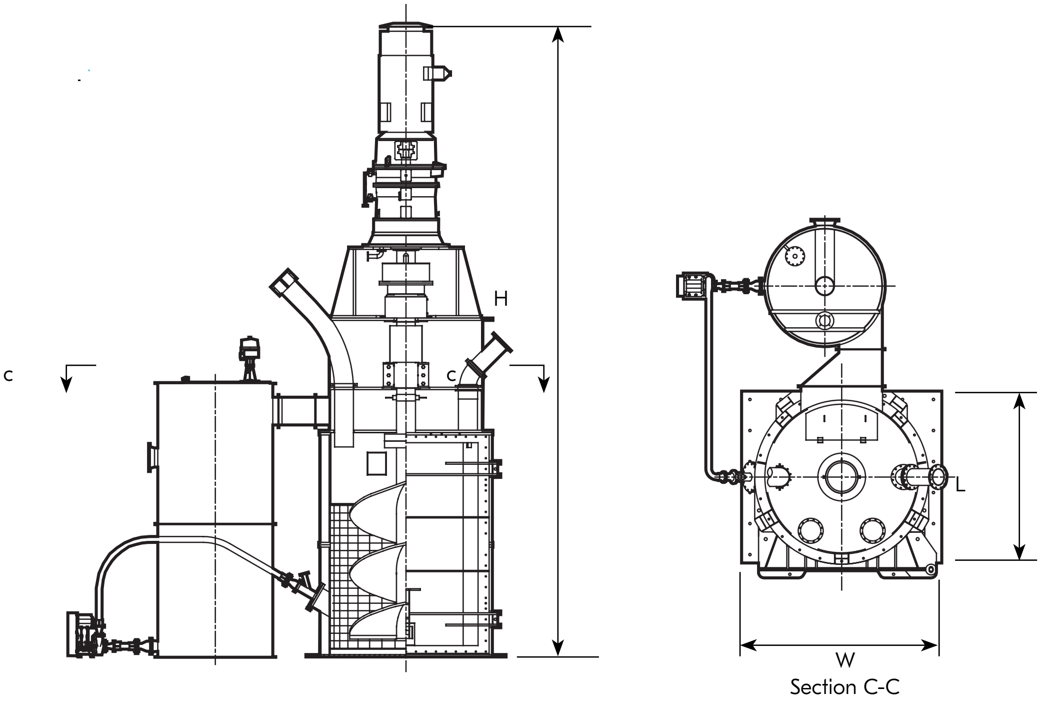




SECTION C-C

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

3.52 VERTIMILL®



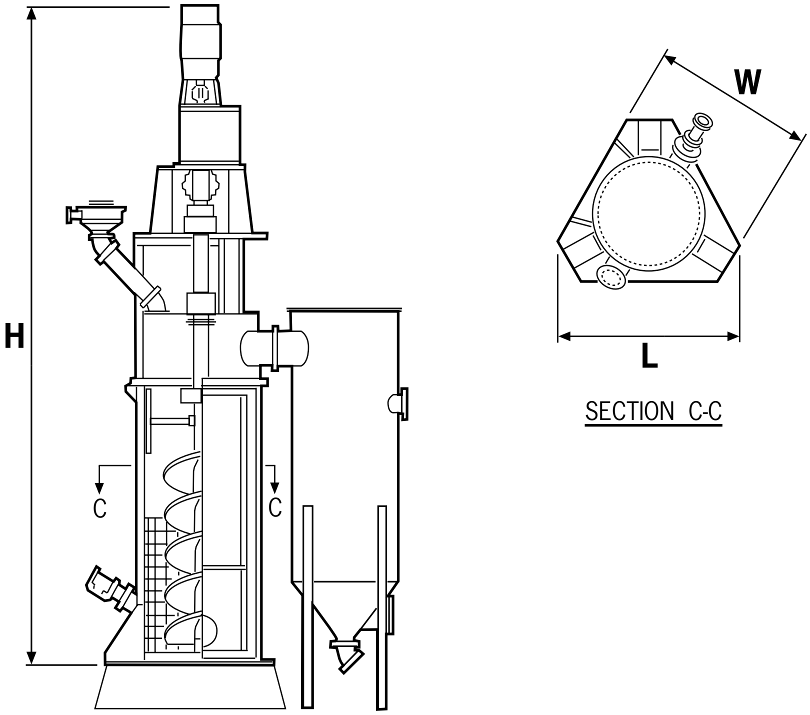
Section C-C

Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/Hp	Weight (empty) ton
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	14 220 (560)	4 370 (172)	4 570 (180)	1 118/1 500	167.0
VTM-3000-WB	17 590 (692)	6 820 (268)	6 880 (271)	2 237/3 000	343.0
VTM-4500-C	18 600 (732)	6 820 (268)	6 880 (271)	3355/4500	367.0

3.53 VERTIMILL®

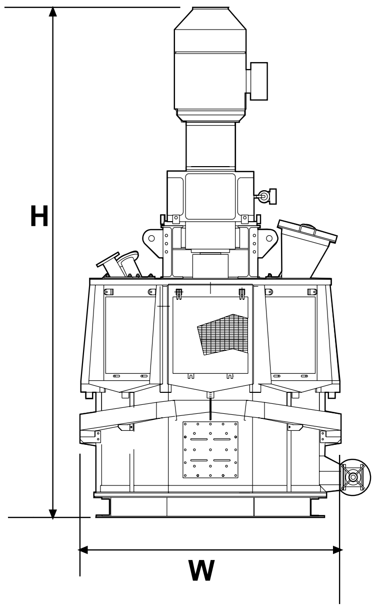
Type LS (Lime Slaking) for size reduction and slaking of lime

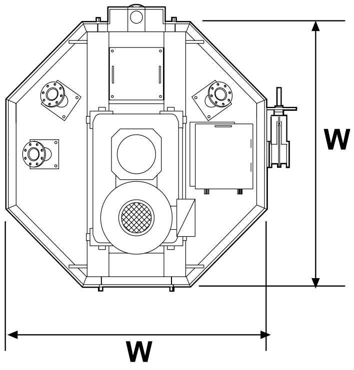
Regarding type WB (Wide body) for grinding operations only, see: 3:50-51.



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

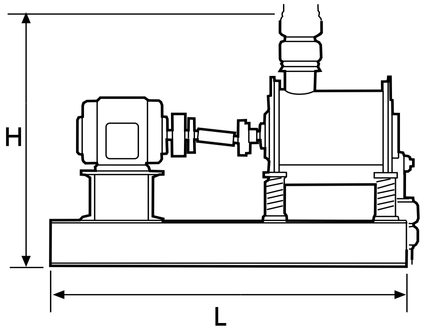
3.54 Stirred media grinding mIll

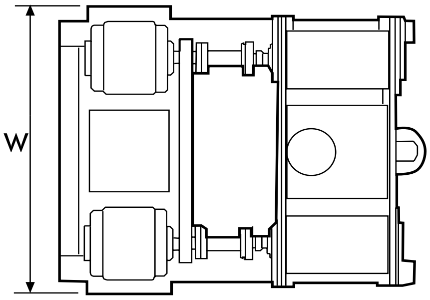




Model	Power motor kW (HP)	H mm (inch)	W mm (inch)	Weight (empty) kg (lb.)
SMD-90	90 (120)	4215 (166)	2130 (84)	4020 (8 863)
SMD 185	185 (250)	4 350 (171)	2 275 (90)	7 200 (15 875)
SMD 355	355 (475)	5 990 (236)	2 800 (110)	13 450 (29 650)
SMD 1100	1 100 (1475)	8 700 (335)	4 220 (166)	27 500 (60 630)

3.55 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

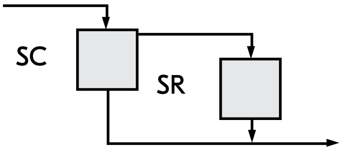
4. Size control

4.1 Size control – Introduction

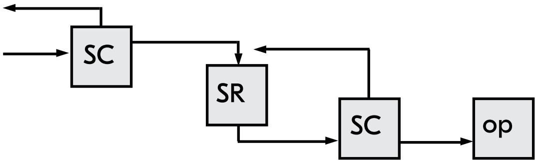
With size control we understand the process of separating solids into two or more products on basis of their size. This can be done dry or wet.
As mentioned earlier neither crushers nor grinding mills are too precise in their size reduction job and a lot of size fractions are misplaced. By using optimum size control the result can be improved both regarding capacity, size and particle shape.

4.2 Size control by duties

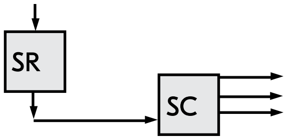
To prevent undersize in the feed from blocking the next size reduction stage (scalping)



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



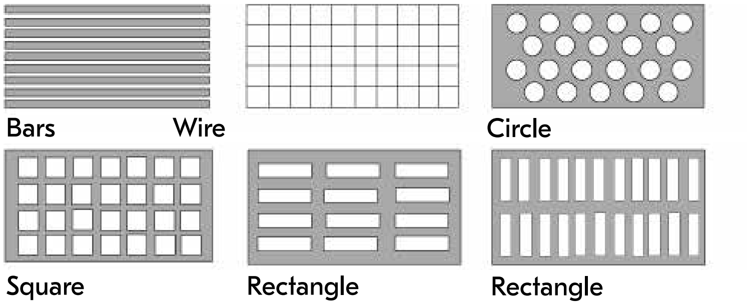
To prepare a sized product (product sizing)



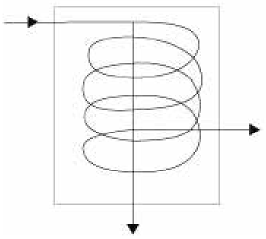
4.3 Size control by methods

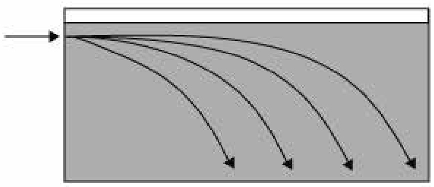
In mineral processing practices we have two methods dominating size control processes:

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



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



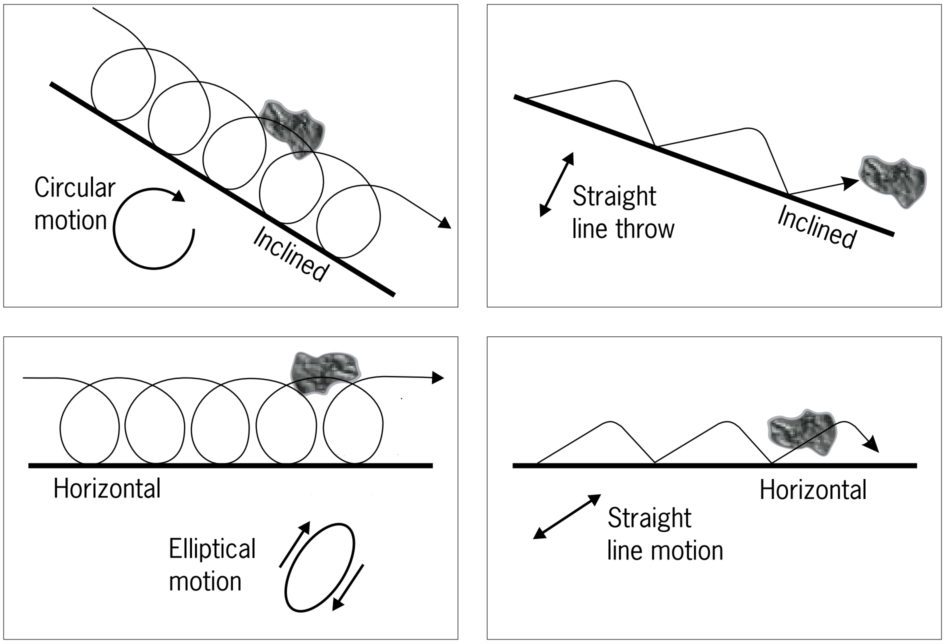


4.4 Screens

Performance of screens will fall back on three main parameters:

Motion — Inclination — Screening media

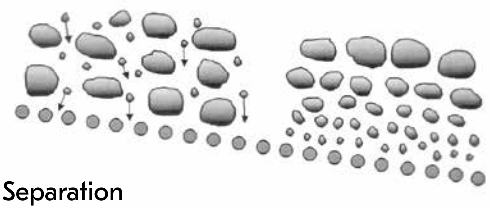
Screen motions



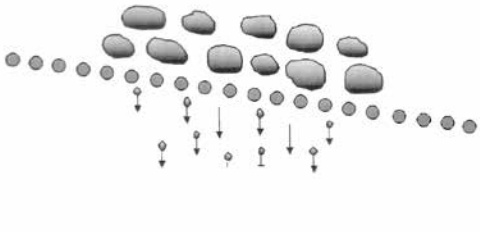
4.5 Screening by stratification

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



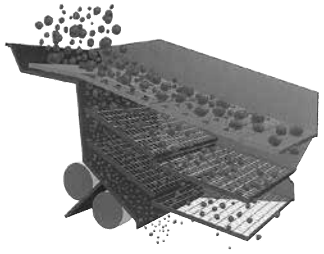
4.6 Screen types

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

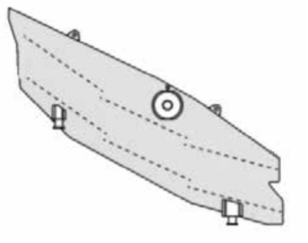
Data sheet, see 4:6



Double inclination

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

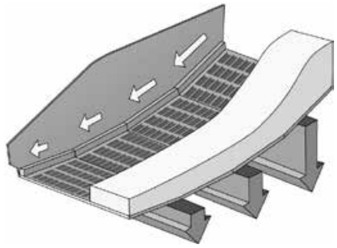
Data sheet, see 4:7



Triple inclination

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

Data sheets see 4:8



Multiple inclination ("banana screen")

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

Data sheets, see 4:8

4.7 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 m^2	7.6 m^2	10.0 m^2	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 m^2 screen deck.

4.8 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

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

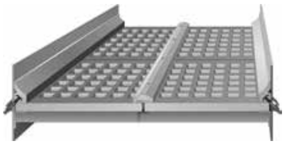
What happens if we go...?

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

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

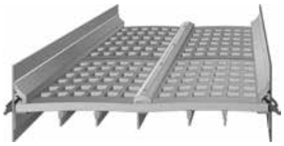
What type of panel

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



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

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

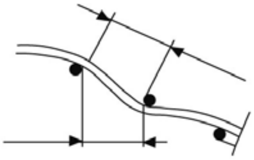


Bolt down panels, pre-tensioned for easy installation and guaranteed screening performance.

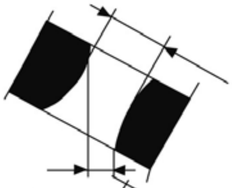
Modular systems provide flexibility in wear material/hole configuration combinations.

What hole size? (Inclined deck)

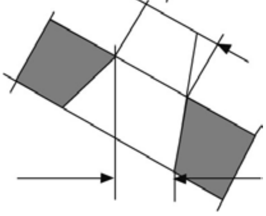
General guideline for wire mesh:
"Required product size plus 5 – 10%"



General guideline for rubber panels:
"Required product size plus 25 – 30%"

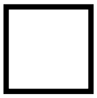


General guideline for PU panels:
"Required product size plus 15 – 20%"

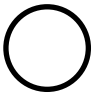


What type of hole?

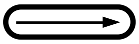
The standard choice



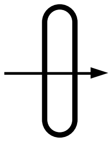
For improved service life (coarse screening)



For improved capacity



For improved accuracy and dewatering

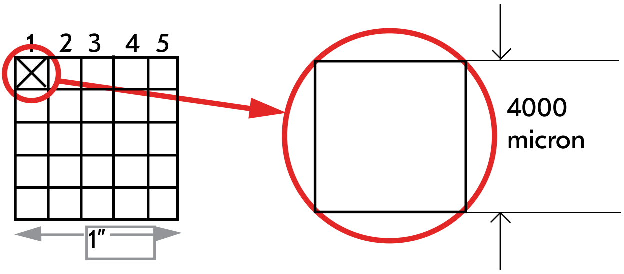


4.9 Particle size – Mesh or Micron?

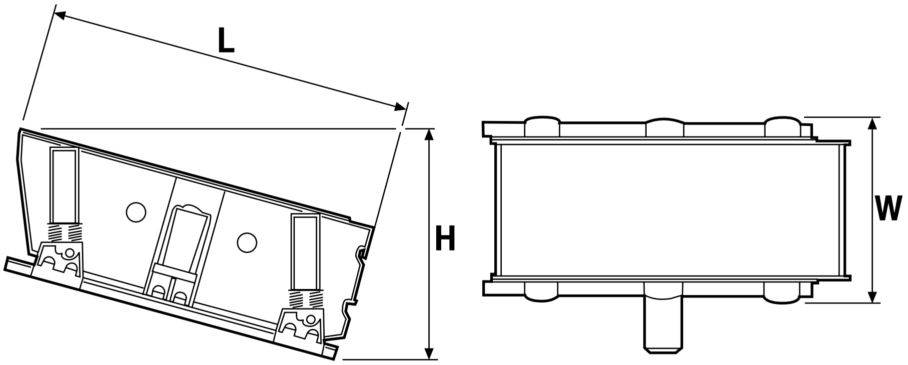
mesh*	micron	mesh	micron	mesh	micron
2½	8000	14	1180	80	180
3	6700	16	1000	100	150
3½	5600	20	850	115	125
4	4750	24	710	150	106
5	4000	28	600	170	90
6	3350	32	500	200	75
7	2800	35	425	250	63
8	2360	42	355	270	53
9	2000	48	300	325	45
10	1700	60	250	400	38
12	1400	65	212	500	25

*Taylor serie (US)

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



4.10 Single inclination screen – Circular motion

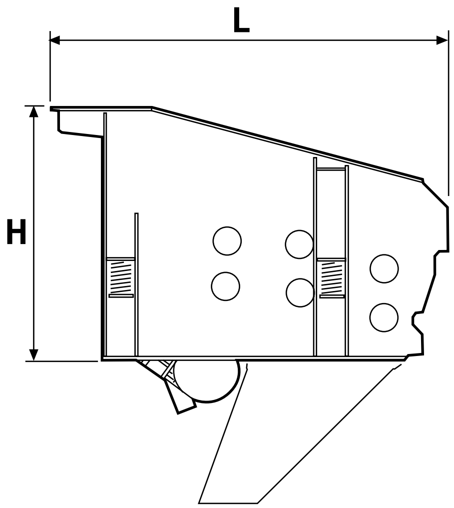


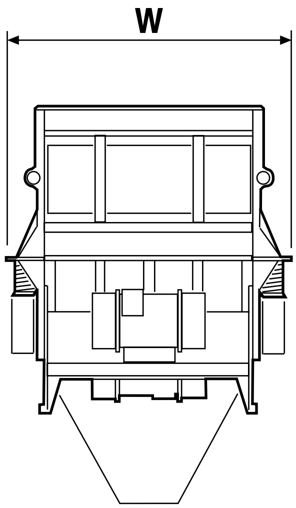
Dimensions at 15° inclination

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 m^2** x11= **82ft^2**

4.11 Double inclination screen — Linear motion

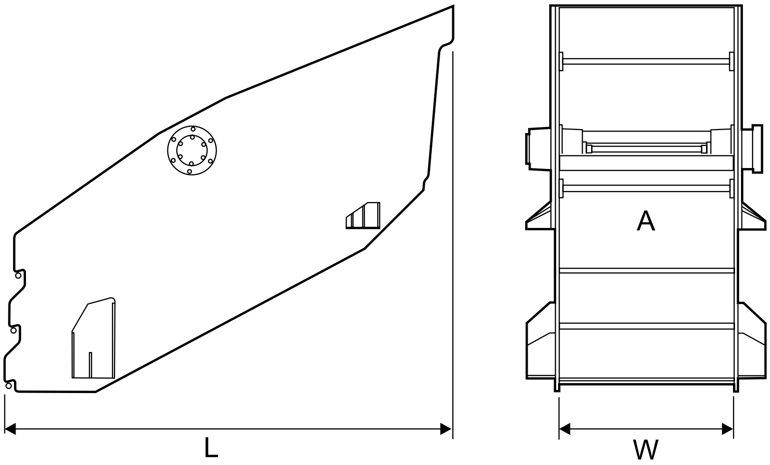




Model	H mm (inch)	L mm (inch)	W mm (inch)	Power motor kW/hp	Weight ton	Max feed mm/inch
VFO 12/10 2d	1 450 (57)	1 330 (52)	435 (17)	2x1.3/2x1.7	1.0	120/5
VFO 20/12 2d	1 515 (60)	2 380 (94)	1 700 (67)	2x2.3/2x3.1	1.6	150/6
VFO 20/12 3d	1 515 (60)	2 380 (94)	1 700 (67)	2x2.3/2x3.1	1.7	150/6
VFOM 12/10 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

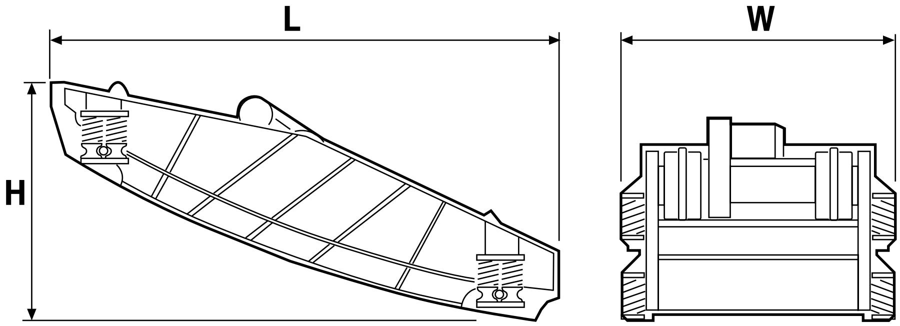
4.12 Triple inclination screen — Linear motion



Model	L mm (inch)	W mm (inch)	A m^2 (Sq. ft.)	Power motor kW /HP	Weight ton
TS 2.2*	5 830 (230)	1 530 (60)	7.5 (80)	15/20	6
TS 2.3*	5 830 (230)	1 530 (60)	7.5 (80)	15/20	8
TS 3.2	6 330 (249)	1 839 (72)	11 (116)	22/30	8
TS 3.3	6 330 (249)	1 839 (72)	11 (116)	22/30	10
TS 4.2	6 350 (250)	2 445 (96)	15 (156)	30/40	9
TS 4.3	6 350 (250)	2 445 (96)	15 (156)	30/40	12
TS 5.2	8 595 (338)	2 445 (96)	20 (215)	30/40	16
TS 5.3	8 595 (338)	2 445 (96)	20 (215)	2x22/2x30	20
TS 6.2	8 734 (344)	3 045 (120)	25 (269)	2x22/2x30	20
TS 6.3	8 736 (344)	3 045 (120)	25 (269)	2x30/2x40	24

* TS 2.2 = 2 decks and TS 2.3 = 3 decks screen

4.13 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

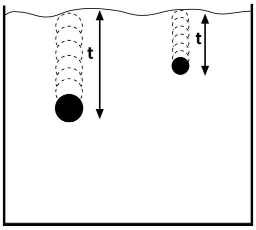
4.14 Classification – Introduction

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 behavior in air or water (liquids).

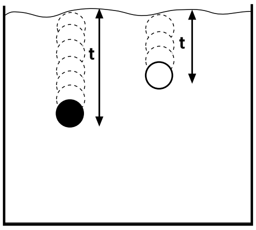
Classification methods

- **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).

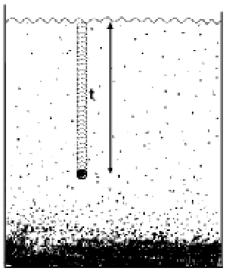
4.15 Wet classification – fundamentals



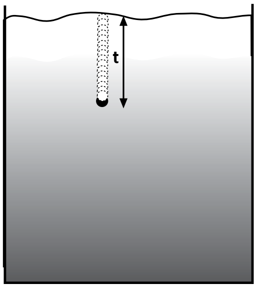
Coarse particles move faster than fine particles at equal density



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



Free movement

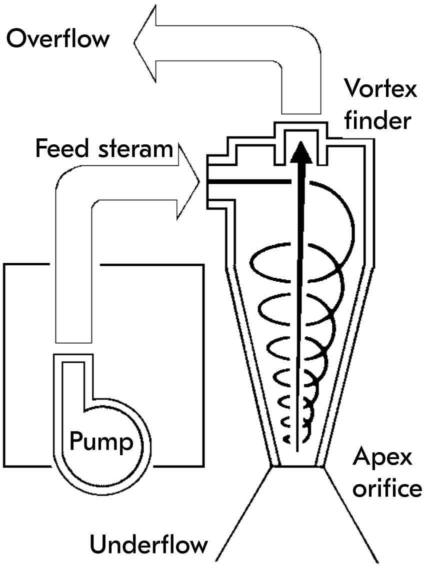


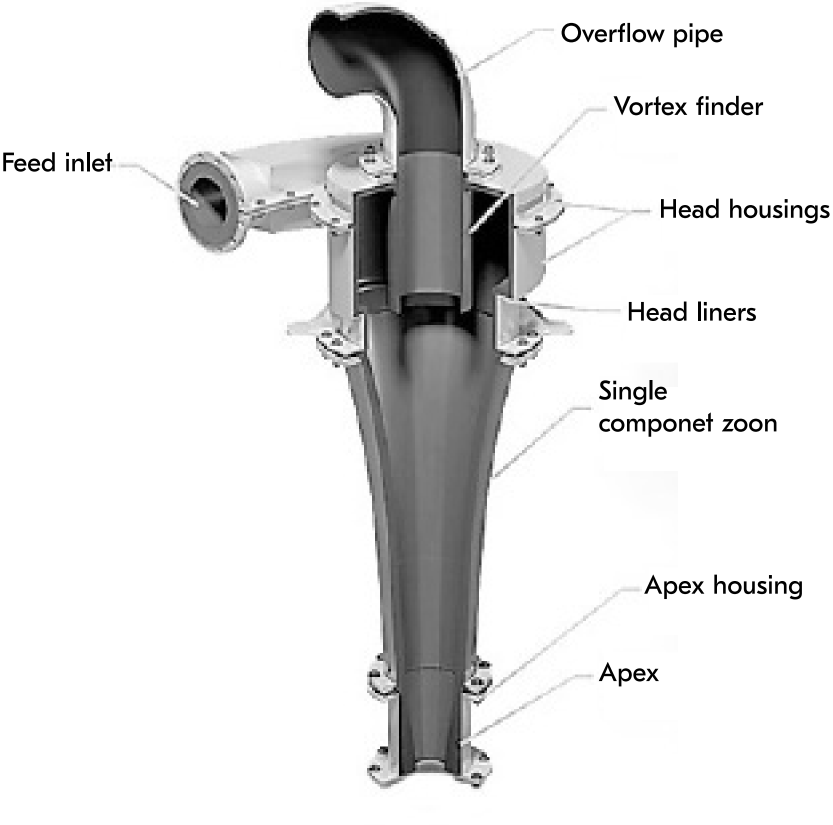
Hindered movement

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.

4.16 Hydrocyclone – Introduction

- Feed is pumped tangentially into the hydrocyclone.
- Centrifugal forces classify solids by mass (size).
- Pressure drop within the hydrocyclone creates an air core in the center.
- High mass particles closer to outer wall report to the underflow.
- Low mass particles closer to the center report to the overflow.
- Apex and Vortex Finder define the size of the air core and, therefore, the size classification



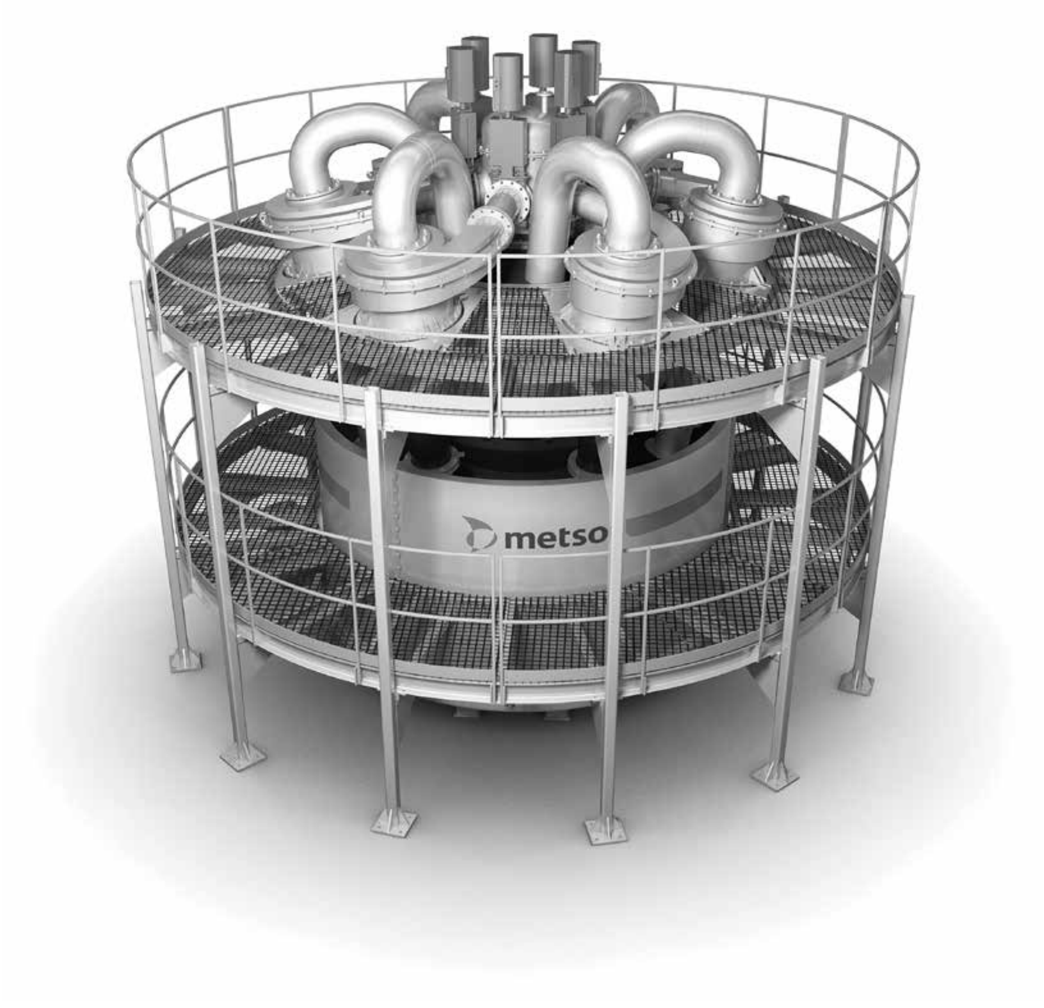


Hydrocyclone applications – more than size control

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
- Classification of multi-component ore
- Enrichment of heavy minerals (DMS)
- a.o.

4.17 Hydrocyclone cluster



Flows processed through a hydrocyclone are wide ranging in particle size distribution, slurry density, volumetric throughput, etc. Because of this, multiple hydrocyclones of a particular model are typically supplied in a larger package called a hydrocyclone cluster or hydrocyclone pack.

This hydrocyclone cluster consists of: individual hydrocyclones, hydrocyclone feed distributor, underflow launder, overflow launder, knife gate valves, and support structure. Working platforms for access are also optional for ease of maintenance tasks.

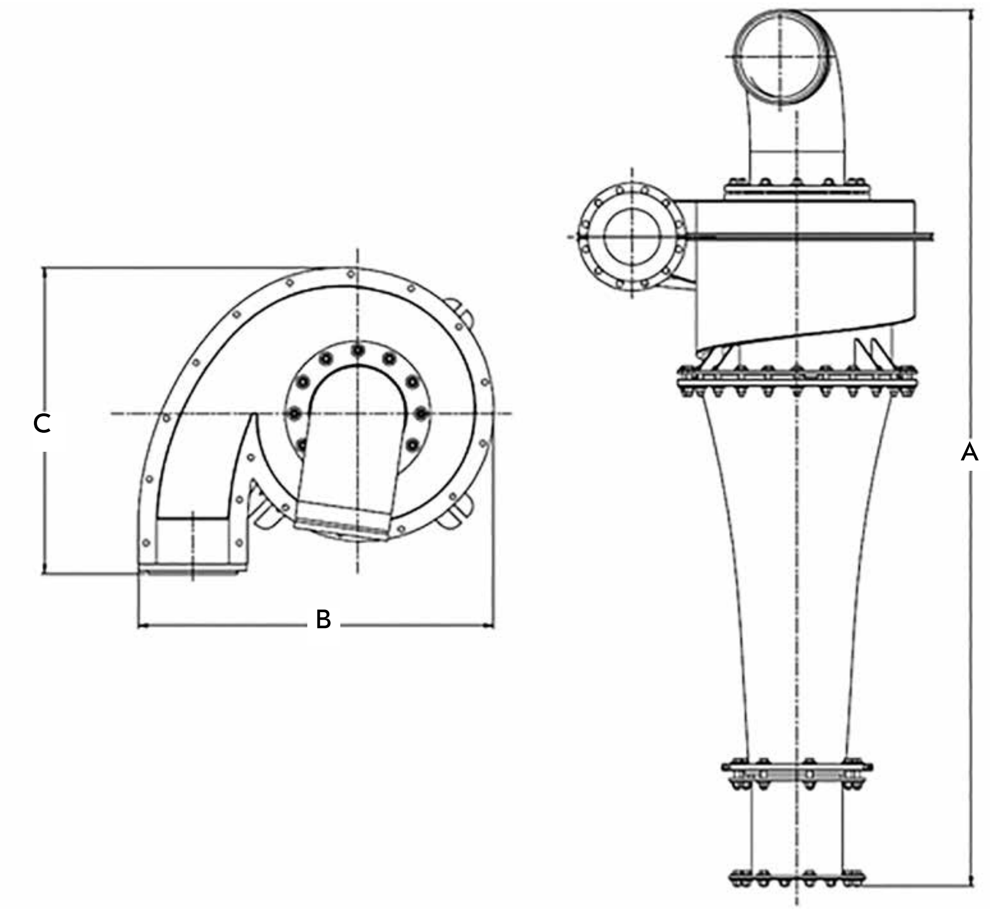
The hydrocyclone feed distributor can either be a linear or a radial design to evenly distribute feed to each hydrocyclone. A local pressure gauge and pressure transmitter can also be included for process monitoring of the hydrocyclones.

The underflow launder and the overflow launder combine the flows from the multiple hydrocyclones into one stream for each product. In classification of a grinding circuit, underflow may report back to the grinding mill while the overflow leaves the circuit as product.

To maintain high availability, many hydrocyclone clusters are supplied with one or more additional hydrocyclones than required to act in a stand-by capacity. Knife gate valves are installed to isolate each individual hydrocyclone so that maintenance tasks can be completed on stand-by hydrocyclones while the other hydrocyclones are operating.

Technical data sheet

4.18 Hydrocyclone



	A mm (inch) Cyclone Model	B mm (inch) Cyclone body height	C mm (inch) Cyclone body lenght	Weight (empty) width	Nominal operating pressure kg	Max feed slurry flow m^3/hr kPa (psi) (gpm)
MHC 100	881 (35)	220 (9)	200 (8)	7	200 (29)	24.7 (108.8)
MHC 150	1 097 (43)	308 (12)	273 (11)	12	150 (22)	47.5 (209.1)
MHC 250	1 841 (72)	580 (23)	498 (20)	125	120 (17)	114.9 (505.9)
MHC 375	2 223 (88)	827 (33)	730 (29)	201	100 (15)	239.8 (1 055.8)
MHC 500	2 626 (103)	1 063 (42)	902 (36)	375	90 (13)	398.1 (1 752.8)
MHC 650	3 295 (130)	1 337 (53)	1 152 (45)	800	80 (12)	759.0 (3 341.8)
MHC 800	2 978 (157)	1 616 (64)	1 349 (53)	1 125	75 (11)	1 171.0 (5 155.8)

4.19 Spiral classifier*

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

Spiral classifier – Nomenclature

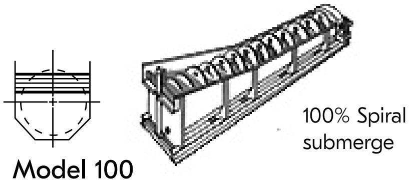
24" Model 100-MF-SP

Pitch – Single (SP) or Double (DP)
Tank Style – Straight (ST), Modified Flare (MF) and Full Flare (FF)
Spiral Submergence Model – 100%, 125% or 150%
Spiral Diameter

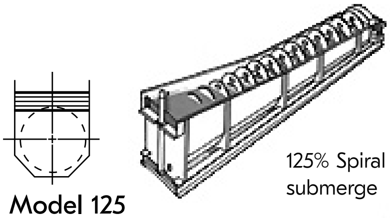
Spiral classifier – Design

By combining the proper submergence of the spiral as shown in the drawings of the three models at right with one of the three tank designs a choice of combinations are possible. Thus the selection can be tailored to suit each problem. The proper combination of pool depth, area and spiral construction, result in controlled turbulence for accurate size separations or efficient washing or dewatering as desired.

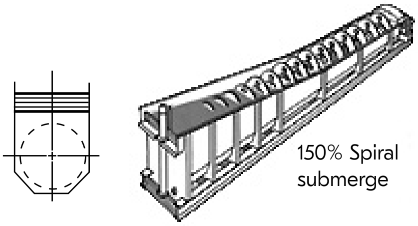
The required pool area is balanced with the sand raking capacity of the spiral by the design of the tank. Tank designs to suit specific applications are shown below.



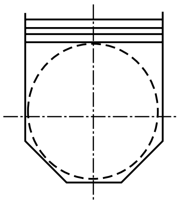
Model 100



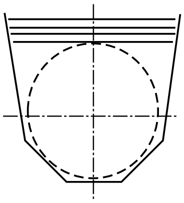
Model 125



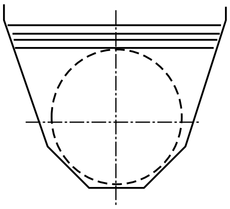
Model 150



Straight side tank



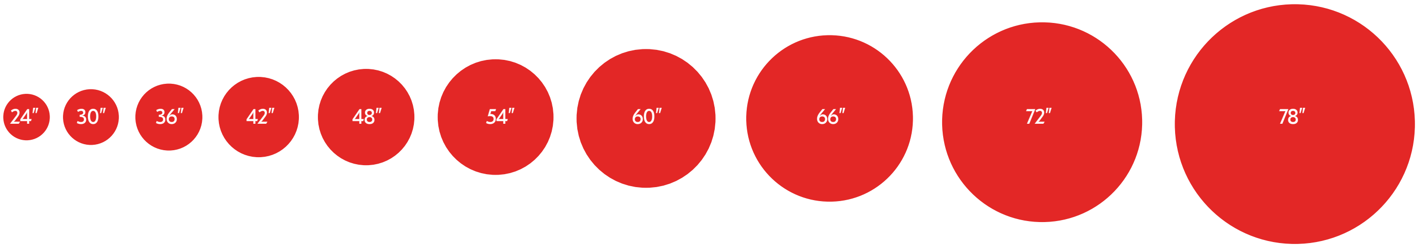
Modified flare tank



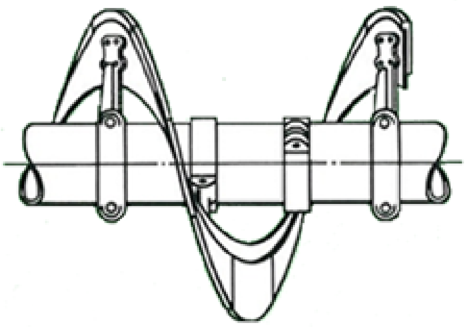
Full flare tank design

Straight side: For coarse separations.
Modified flare: Increases pool area for intermediate to fine separations and for washing and dewatering.
Full flare: Maximum pool area for fine to very fine separations and for washing and dewatering where large volumes of water are to be handled.

Sand raking and conveying is usually a major consideration in any classifier application, and the full range of spiral diameters available cover all requirements. Each of these units is designed for high efficiency and greater raking capability due to the increased lead or helix angle of the spiral. This increased lead angle results in improved conveying efficiency and greater conveying capacity.

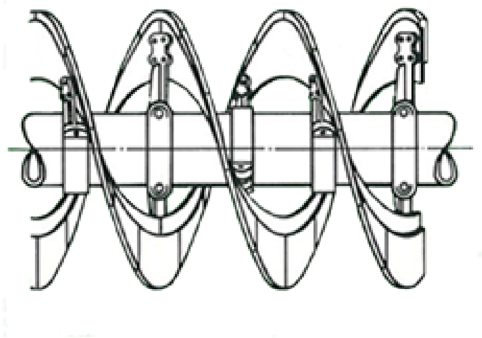


Single pitch:
Single pitch spirals are available on all sizes of classifier and consist of one continuous spiral ribbon.



Double pitch:

The double pitch spiral has twice the raking capacity of a single pitch assembly and consists of two duplicate spiral ribbons. This construction is available for all sizes of classifier.



* Contact Metso Outotec for further information about this product.

4.20 Dry classification – Introduction

General

The Static and dynamic air classifiers offer solutions in combination with ancillary equipment to meet the demands of almost any dry separation requirement. This equipment offers solutions to the mining, construction, industrial mineral and chemical industries. A wide range of separations are available from 1.4mm (12#) down to 10µm (#1250) with separation efficiencies of up to 95%. Full, flexible engineering design and support is available to ensure full integration.
Classifier throughputs range from lab size units to applications processing hundreds of tones per hour. Application, feed type, fineness of classification and classification accuracy required influence the allowable moisture in the feed which typically ranges from 2.5% to below 1% dependant on the process.
The static and dynamic classifiers offer tailored solutions for a wide range of applications Machine sizing and selection is normally done in consultation with the product line to ensure correct application and matching with required ancillary equipment.

Typical applications

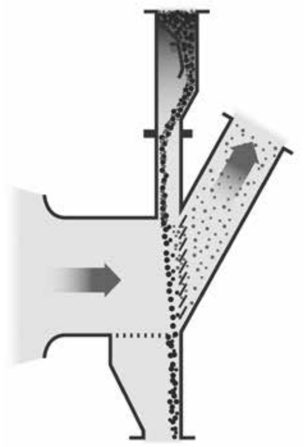
Mining
Dry grinding
Arid zone mining
Construction
Concrete sand
Asphalt sand
Mineral filler
Industrial Minerals
Silicates
Graphite
Glass
Ceramics
Salts
Feldspar
Talc
Chalk
Diatomaceous earth
Gypsum
Betonite
Cement and Pozzolan
Fly Ash
Slag
Cement
Other pozzolan
Chemical
Soda Ash
Metallurgical processing additives
Cosmetics
Stearate (salts)
Fertilizer
Bicarbonate (FGD)

4.21 Static classifiers

Static air classifiers achieve accurate separations from 1.4 mm (12 mesh) to 20µm (635 mesh). The static air classifiers are designed to achieve extremely accurate separations even though they contain no moving elements in the airstream.
This is achieved through airflow design and use of recirculating, secondary airflow on finer separations to scrub the coarse product before it is discharged. The re-circulating airflow is adjustable so the amount of undersize retained is also adjustable. This provides fine tuning of the end products so exact product specifications can be achieved. The design of the recirculating systems mean that adjustments can be done during production and results are instant.
The static design of these classifiers offers excellent wear characteristics through the use of ceramic linings whose lifetimes are measured in years, low maintenance requirements and low power draw.

Gravitational classifiers

The gravitational classifiers are designed for coarser separations in the range of 1.4mm/150µm (12/100#). The feed material is spread over the width of the classifier and drops as a continuous feed curtain through the top of the classifier. Low velocity air enters the classifier through the front inlet and is drawn through the feed curtain which is dropping in front of the angled vanes on the air outlet.
The air stream enters the feed curtain perpendicularly and draws the finer particles from the curtain of material. The air current then draws the particles up almost vertical through the vane rack. Gravitational classifiers are suitable for closing grinding circuits, de-dusting of coarser feeds, reducing a high feed loading rate to a finer classifier and it can also be used as a density separator if the specific gravity difference of the product : waste ratio is > 5:1.



Gravitational classifier

Gravitational inertial classifiers

These units combine gravitational, inertial, centrifugal and aerodynamic forces to achieve separations from 300 µm /63µm (50/230#). The feed material is spread over the width of the classifier and drops as a continuous feed curtain through the top of the classifier. The primary air also enters the top of the classifier in a downward direction with the feed. The air is drawn through the feed curtain and then through a 120° change in direction and exits through the vanes carrying undersize particles with it.
The coarser particles that are not drawn away drop down to where a secondary air flow is drawn into the classifier. The coarse particle curtain is scrubbed by this secondary air with the finer fraction being drawn by the secondary airflow back into the primary feed curtain. By making simple adjustments to the secondary air damper the end products can be modified. As there are no moving parts within the material flow stream significantly reduces maintenance requirements. Use of ceramic lining throughout the classifier gives impressive wear resistance.

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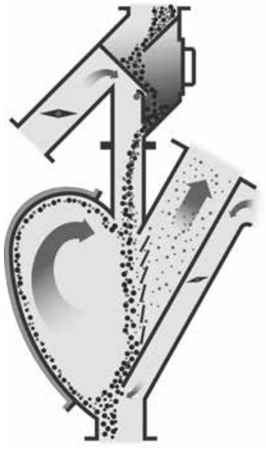
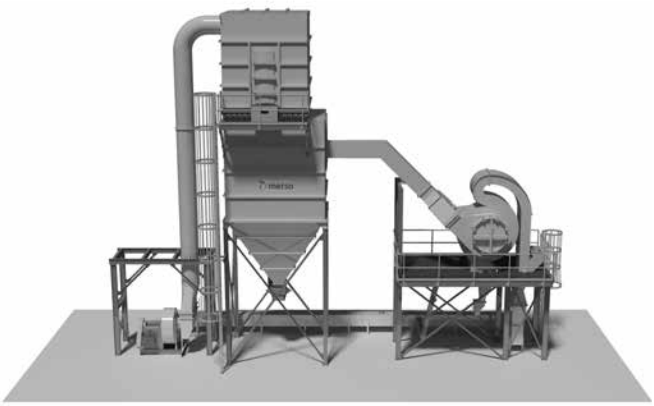
Gravitational inertial classifier



Centrifugal classifiers

The centrifugal classifier utilizes centrifugal forces in a similar way to cyclones to induce fine particle separation. The classifier is capable of separations in the range of 100/15µm (140/800#). The classifier has widespread acceptance in industrial minerals, cement and fly ash applications where its high degree of separation accuracy and exceptionally low maintenance requirements exceeds operator expectations. The classifier is used in conjunction with a dust collector and system fan. Systems can have an open or closed loop dependant on application and numerous dust collector and silo storage options.



Centrifugal classifier, dust collector and fan

Cyclonic ultrafine classifiers

Specially designed high efficiency cyclonic classifiers with controllable reverse air flow systems can achieve adjustable ultrafine classifications. The cyclonic ultra-fine classifier is a hybrid air cyclone that combines cyclone and classifier designs to separate very fine particles. In conventional air cyclones, the aim is to remove as much of the particulate from the airstream as possible. However the cyclonic ultrafine classifier is designed to allow the finest particles to be removed in the ascending vortex.

This separation is achieved by introducing a reverse airflow into the specially designed disengaging hopper that weakens the descending vortex and creates a stronger entraining force in the ascending vortex that draws the required particles away to the fines collector. Control of the separation point is achieved by varying the percentage of reverse airflow relative to the total air.

The cyclonic ultrafine classifier is designed to achieve separations in the region of 50µm (#270) to 10µm (#1250) with a top feed size of 5mm (#4). The cyclonic ultrafine classifiers are very low maintenance even on highly abrasive feeds. The unit contains no moving parts and adjustments can be made on-line. The range of manufacturing materials available includes abrasion resistant, stainless and mild steels and aluminum. For abrasive applications, ceramic lining is available which give exceptional sliding wear resistance.

4.22 Dynamic classifiers

The dynamic air classifiers are built to suit a range of applications and systems and have been often installed on air swept mills circuits. The gyrotor, a rotating vane air classifier, separates dry, solid, homogenous particles by size. Delta-sizers are designed for accurate separation of dry feeds at high efficiency and low power consumption on a continuous basis.

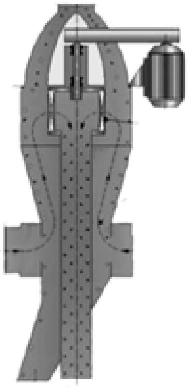
Gyrotors

Utilizes a rotating vane to separate dry solid particles by size for separations for 500/45µm (35/325 mesh). Gyrotors can be integrated into a conventional closed or open dry grinding circuit. Gyrotors can also be utilized in a classifi-cation only system complete with cyclone, fan, dust collector and rotary air locks.

Gyrotor

Delta-sizers

Delta-sizers are designed for accurate separation of dry feeds at high efficiency and low power consumption on a continuous basis. The Metso Outotec Delta-sizer can be integrated into a conventional closed or open dry grinding circuit; or utilized in a classification only system complete with cyclone, fan, dust collector and rotary air locks.



Delta-sizer

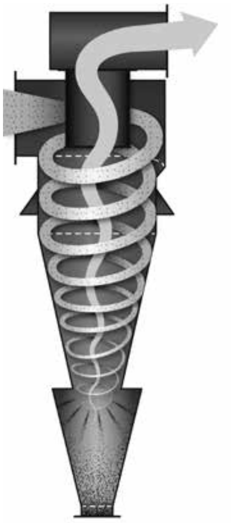
4.23 Ancillary air solutions

Ancillary air solutions provide the systems required for the correct operation of the classifier equipment as well as offering other dry solution capabilities.

High efficiency cyclones

High efficiency cyclone technologies are specifically tailored to the needs of the mining, industrial mineral and construction industries.

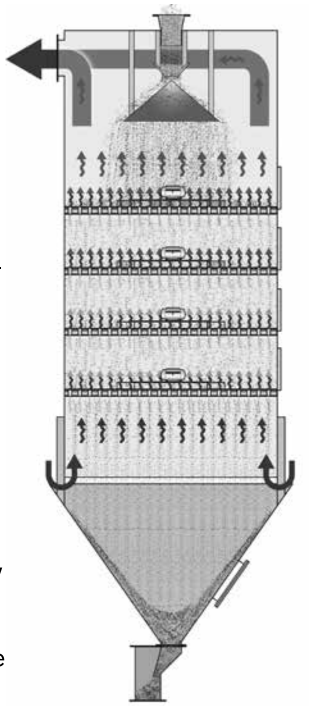
The high efficiency cyclones are the product of signi-ficant development with the aim of achieving extremely high levels of particle removal from the airstream. The unique inlet scroll is designed with a smooth flow elbow to eliminate currents perpendicular to the main direction of gas flow that is present in standard conventional rectangular entrance cyclones. Custom designed disengaging hoppers give high efficient separations by creating a void that hosts the bottom section of the descending vortex and allows the particles to disengage from the airstream before it ascends the gas outlet tube.



High efficiency cyclone

Multi-stage fluid bed coolers

Direct particle cooling and cleaning technologies are designed to process granular feeds. Multi-stage fluid bed coolers have been developed to offer simple practical solutions for cooling and cleaning granular feeds. These coolers are designed to work in conjunction with a dust collector and system fan to create a drop in pressure that draws in atmospheric air.
The feed enters the cooler through an airlock and is then evenly distributed onto the first perforated plate tray. Each tray has specifically designed apertures and is individually vibrated by an electric activator mounted above the plate. The rising airflow passes through the tray apertures and creates a fluidized bed of particles whilst carrying the ultrafine particles away to the dust collector. The fluidized bed dictates the particles residence time before dropping down to the next level plate. The individual particles eventually pass into the collection hopper where they exit the cooler through the sample valve airlock.



Multi-stage fluid bed cooler

Smart package dust collectors

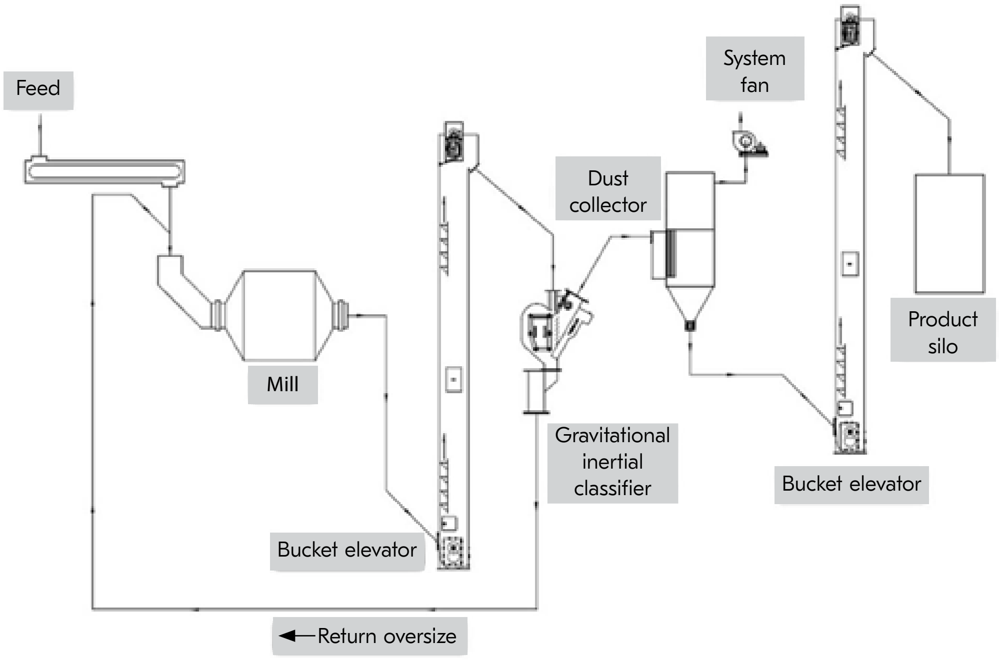
To fully support the classification solutions offering, the ancillary equipment requirement must be considered. To fully support this offering, the ancillary equipment requirement must be considered. The smart package was developed to offer a quality dust collecting solution without unnecessary transportation costs while ensuring quality solutions. Dust collectors tend to be large, bulky pieces of equipment that are expensive to transport due to their significant volume. The smart package is designed as an easily transportable solution that offers a simple, local manufacturing solution to customers requiring pulse jet dust collectors. The smart package consists of the tube sheet, solenoids, pulse pipes and air manifold. The Smart Package is supplied with Metso Outotec's pulse jet dust collector engineering design to ensure successful installation. Smart package designs are available to meet the capacity requirements of the air classifier range and are also suitable for other dust collection duties.

The smart package dust collector.

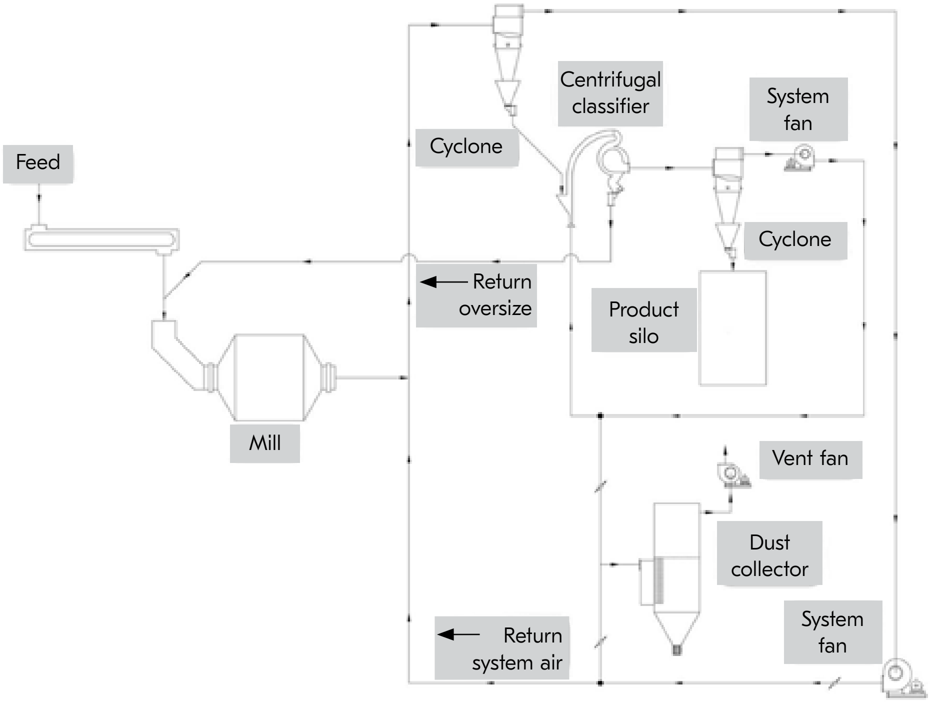
Close up of the smart package tube sheet, solenoids, pulse pipes and air manifold.

4.24 Dry Grinding

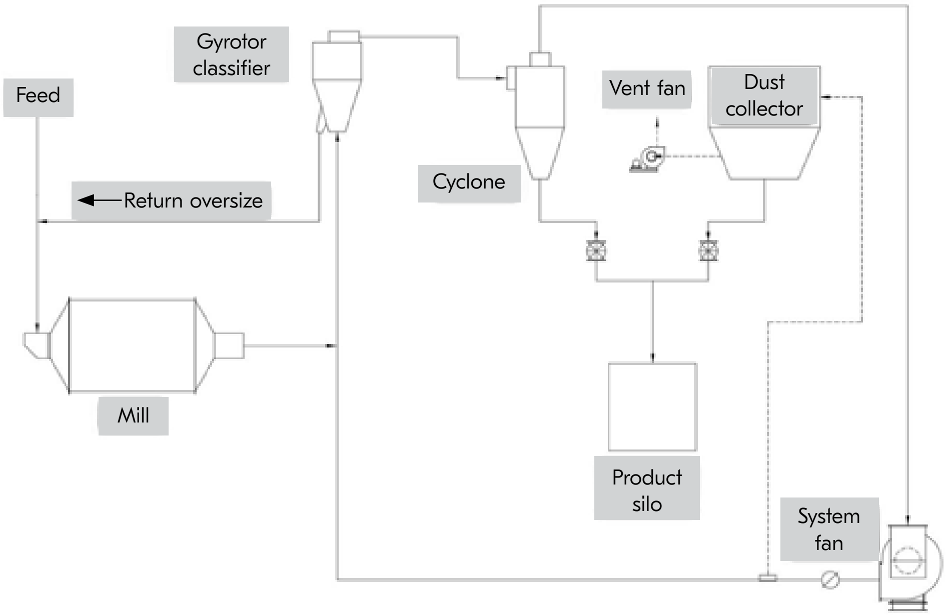
There are a wide variety of dry grinding layouts. The design of which are dependent on multiple factors which include: open/closed circuit, tonnage, material flow properties, separation size required, space available, storage and transportation and mill discharge type. Below are a few examples of classifiers in closed circuit dry grinding operations.



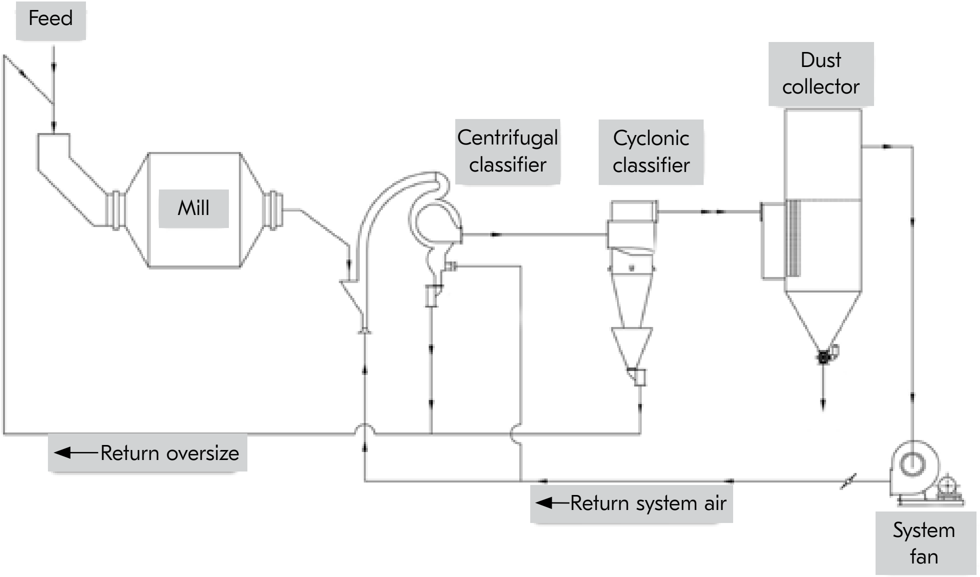
Grate discharge mill in closed circuit with a Gravitational Inertial classifier producing products in the range of 300/63µm (#50/230)



Air swept mill feeding a cyclone disengaging the throughput into Centrifugal classifier with the oversize returning to the mill and producing products in the range of 100/20µm (#140/635)

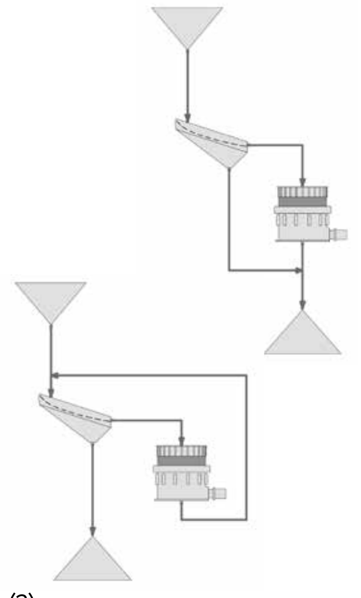


Grate discharge mill in closed circuit with a Gyrotor Classifier to produce products in the range of 500/45µm (#35/325)



Grate discharge mill in closed circuit with both a Centrifugal classifier and a Cyclonic Classifier to produce products in the range of 50/10µm (#270/1250)

4.25 Size control in crushing and grinding circuits



Crushing circuits – Open screening

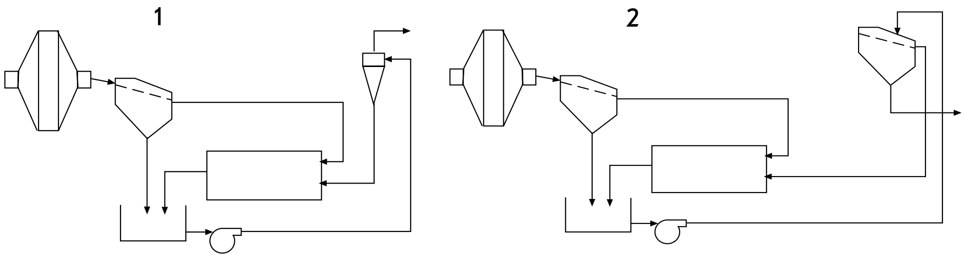
- Screening ahead of a crusher avoids packing
- Less wear in the crusher
- Higher total capacity
- The screening media is "controlling" the product in two dimensions. No "flaky shortcuts".

Crushing circuits – Closed screening

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

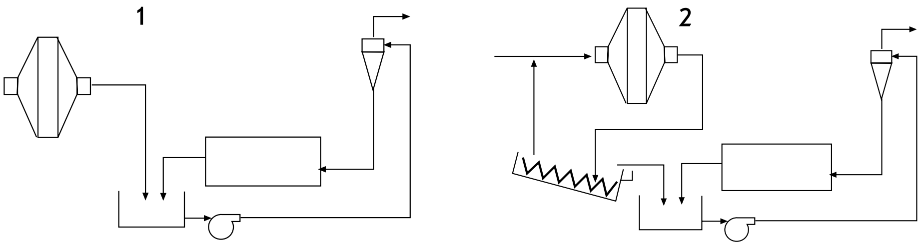
Grinding circuits – Screening

- 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.



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 300 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)



Enrichment

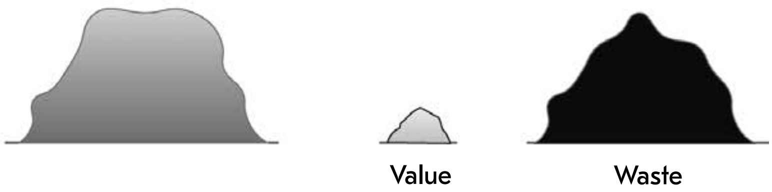
5. Enrichment

5.1 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)



5.2 Enrichment – Processes

Washing by using

Log washers (not covered)
Wet screens
Aquamator separators (not covered)
Tumbling scrubbers
Attrition scrubbers
(all wet processes)

Separation by

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

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 minimum 2 bar

Sand and gravel	1.0
Aggregates - hard rock	0.5
Mining - raw ore	0.5
Recycling (concrete)	0.2

Capacities typical, see 4:3.

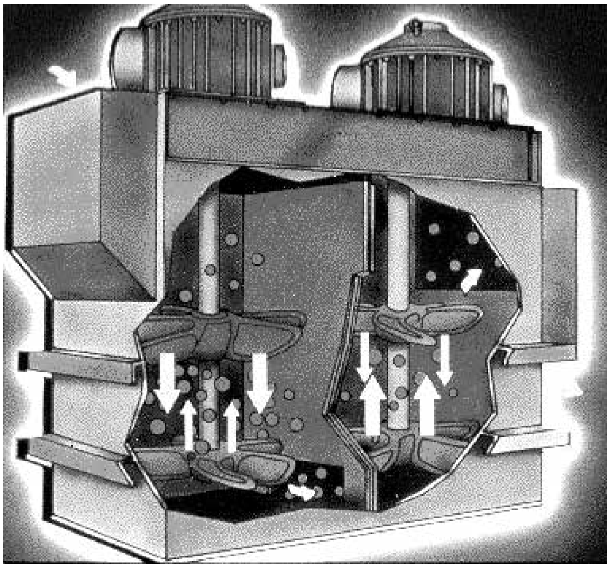
*Not available from Metso.

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 slaking, see further page 8:31.



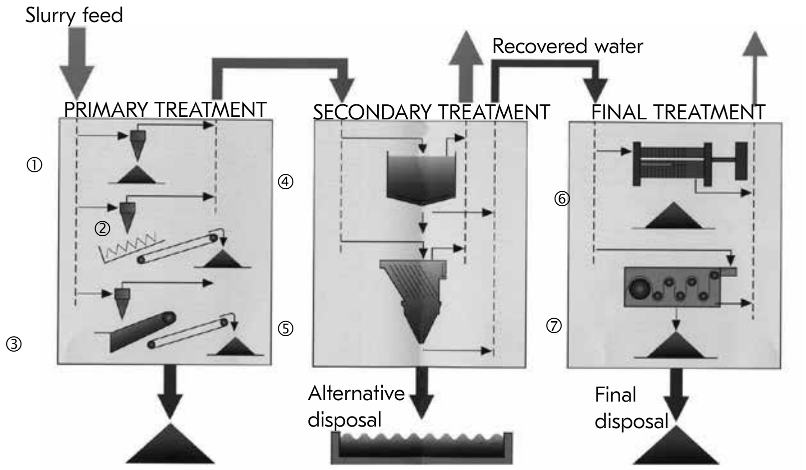
*** Contact Metso for further information about this product. Wash water treatment**

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.

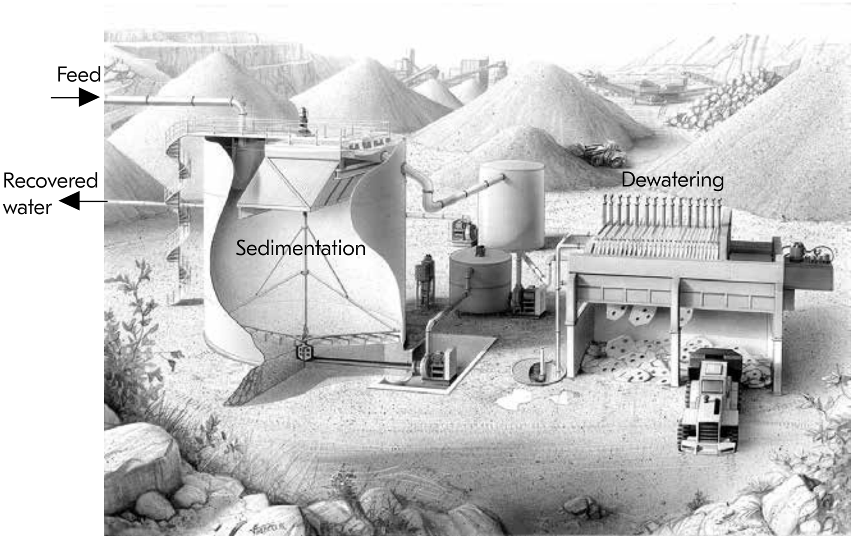


1. Hydrocyclone
2. Dewatering spiral
3. Dewatering screen
4. Conventional clarifier
5. Compact clarifier
6. Simple Pressure filter*
7. Belt press*

*Not covered in this handbook

Wash water treatment – closed system

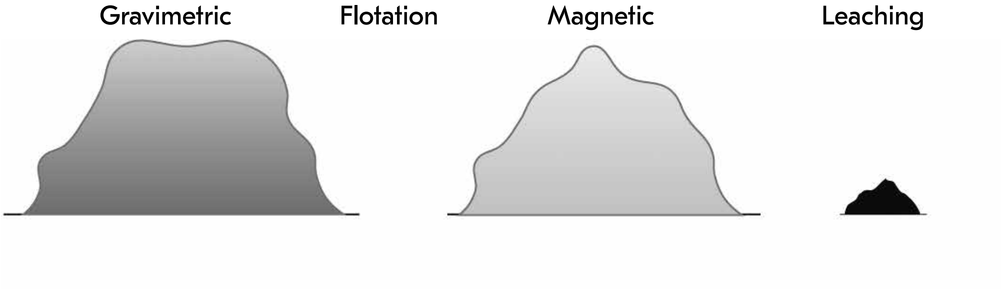
After recovery of coarser material the fines can be treated in a closed system recovering all process water and bringing the fine solids into a transportable form.



For more information see section 6!

5.3 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 behavior, different technologies are applied. We will cover the classical methods of separation as per below.



5.4 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, not covered)

The formula for Separation in water is:

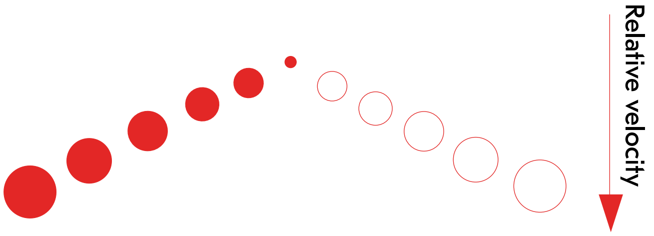
Density difference (Dd) = (D (heavy mineral)-1) / (D (light mineral)-1)

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	

5.5 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) 75 µm – 0.5 mm heavy, (32 mesh)	Coal, Beach sands, Iron Cassiterit
Shaking tables	50 µm – 2 mm (9 mesh)	Tin, Copper, Gold, Lead, Zinc, Tungsten

5.6 Separation by jigs*

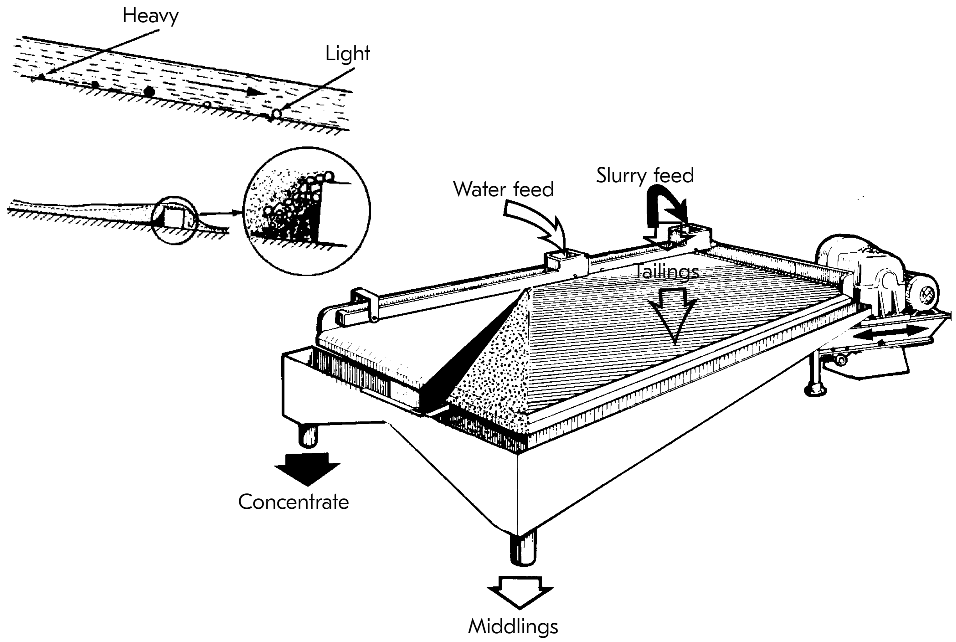
The jig operation consists of two actions. One is the effect of **hindered settling** meaning that a heavier particle will settle faster than a light particle. The other one is the separation process in an **upward flow of water** which will separate the particles by their density.
These two actions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

5.7 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.

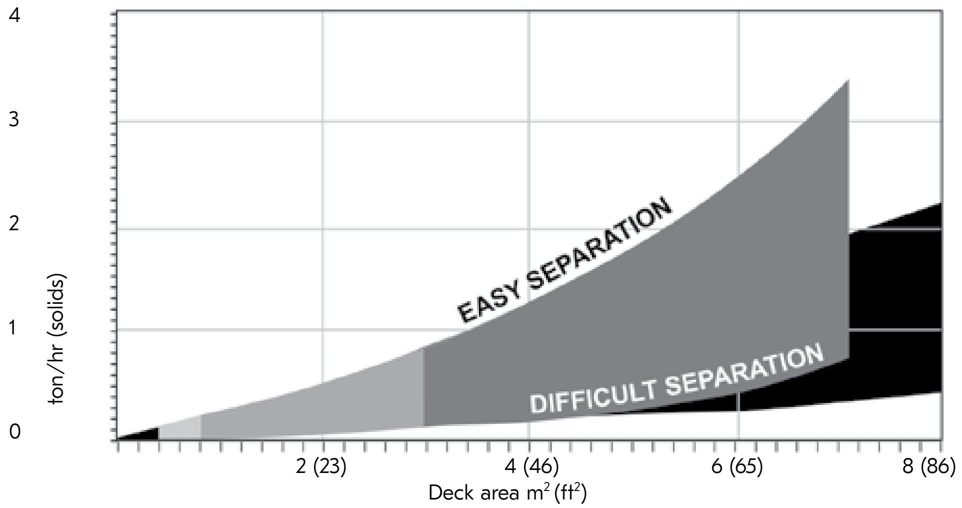
5.8 Separation by shaking tables*

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.



*Not available from Metso

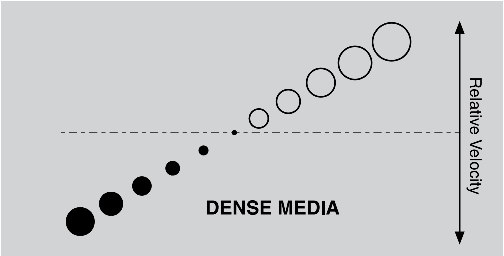
Sizing



5.9 Separation in dense media

Gravity separation utilizes 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

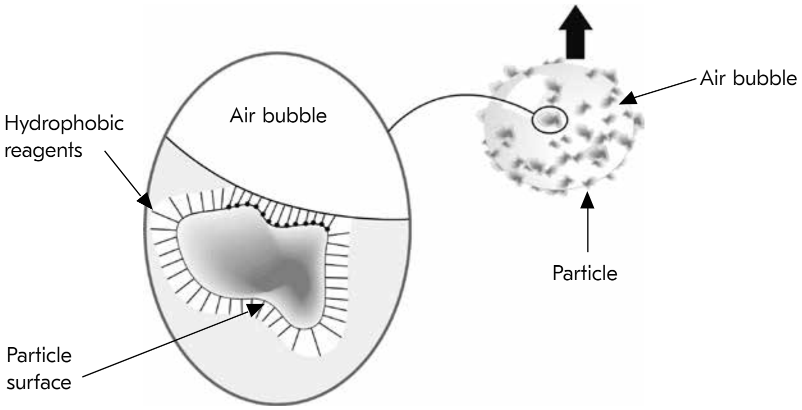


DMS – fluid media

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

5.10 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 short-circuiting**
- **Improved on line analyzers will maintain good metallurgical control**
- **Less mechanical maintenance**
- **Less energy input per volume pulp**
- **Lower total cost**

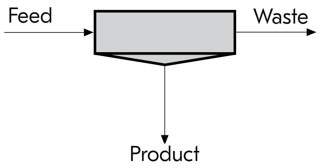
Selection of cell size is made on the basis of the largest individual cell volume that will give the required total flotation volume with an acceptable number of cells per bank. Typical figures for different minerals are given later in this section.

5.11 Flotation circuit layout

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

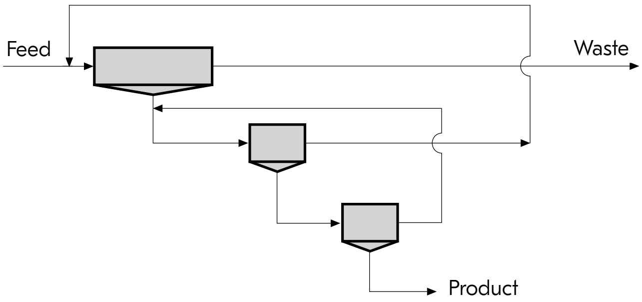
Simple circuit (e.g. coal)

Single stage flotation, with no cleaning of the froth.



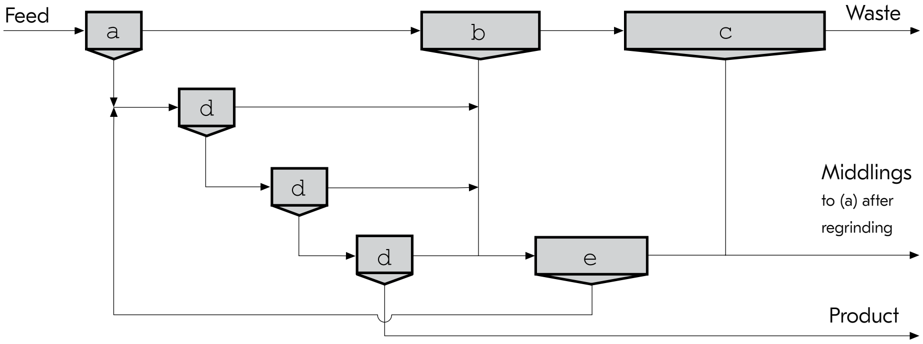
Commonly used circuit (e.g. lead)

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.



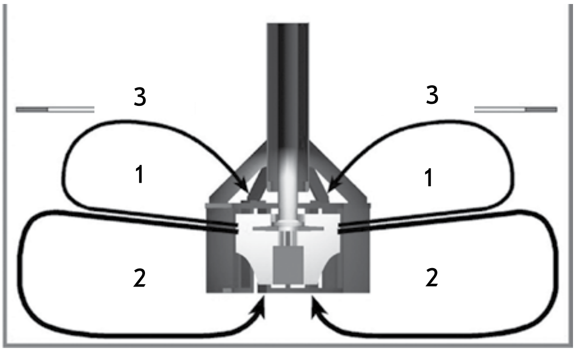
Typically the **first rougher stage** would comprise 10 – 40 % of the total rougher volume and will produce a good grade concentrate with but only medium recovery. **The second rougher stage** comprises 60 – 90 % of the total rougher volume and is designed to maximize recovery.

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 maximize 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.

5.12 Reactor cell flotation system (RCS)

The RCS™ (Reactor Cell System) flotation machine utilizes 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 minimize particle re-entrainment.
- Circular tank with low level slurry entry and exit to minimize slurry short circuiting.
- Cell size 3 – 600 m^3 (28 – 21190 ft^3)
- V-belt drive up to 70 m^3. Gearbox drive for 100 m^3 and above.
- Automatic level control by dart valves.
- Separate source of low pressure air.
- Internal peripheral launders (central crowder optional).
- Application: The majority of mineral flotation duties.

See data sheet 5:13.

5.13 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 test work.

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 number 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:

Model	Volume (m^3)	Maximum bank feed rate (m^3/h)	Maximum cells per section (1)
RCS 0,8	0,8	25	4
RCS 3	3,0	120	5
RCS 5	5,0	200	5
RCS 10	10,0	400	4
RCS 15	15,0	600	4
RCS 20	20,0	800	4
RCS 30	30,0	1120	3
RCS 40	40,0	1360	3
RCS 50	50,0	1650	2
RCS 70	70,0	2040	2
RCS 100	100,0	2550	2
RCS 130	130,0	3050	2
RCS 160	160,0	3450	1
RCS 200	200,0	3990	1
RCS 300	300,0	5250	1
RCS 600	600,0	9000	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 number of cells in one section is 3. So, to have 9 cells choose bank arrangement.

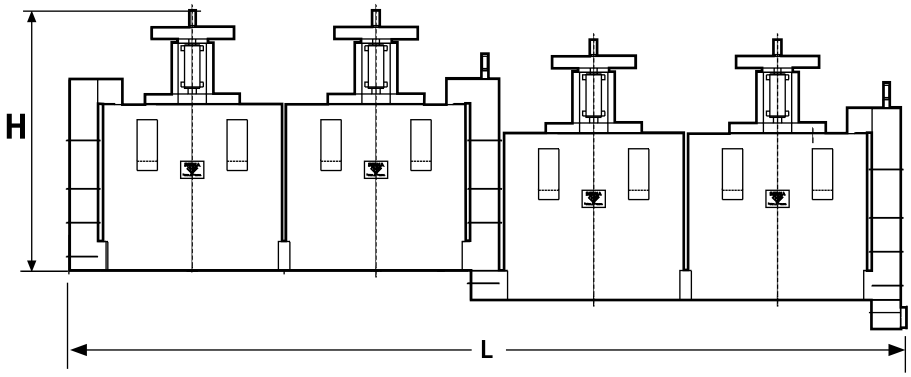
RCS 50 F-3-I-3-I-3-D

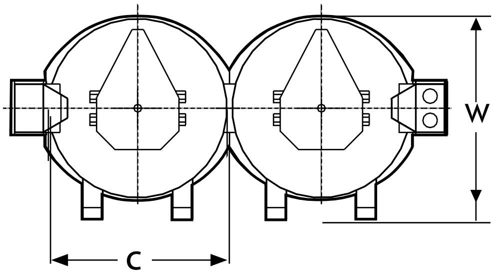
5.14 RCS specifications

Model	Standard Drive (1)	Cell volume (2)		Connected motor (3)		Air requirements (4)			
		m3	ft3	kW	HP	Am3/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	GB	100	3530	110	150	19	47	670	6,8
RCS 130	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
RCS 300	GB	300	10595	250	335	38	67	1342	9,8
RCS 600	GB	600	21190	450	600§	50	85	1765	12,4

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

5.15 Flotation machine – RCS



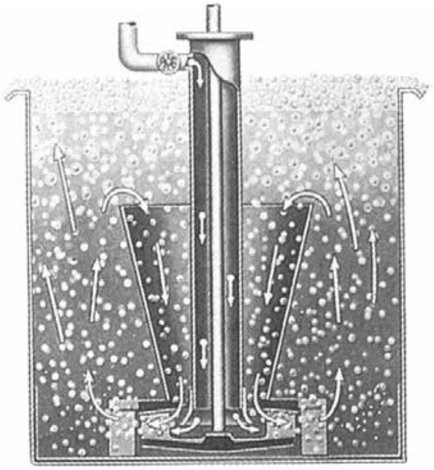


Model	H (1) mm (inch)	L (2) mm (inch)	W mm (inch)	C mm (inch)	Bank weight (2) tonnes (s tons)
RCS 0,8	1 790 (70)	5 550 (219)	1 320 (52)	1 100 (43)	2,73 (3,01)
RCS 3	2 790 (110)	8 250 (325)	1 900 (75)	1 700 (67)	8,4 (9,26)
RCS 5	3020 (119)	9850 (388)	2230 (88)	2000 (79)	10.53 (11.58)
RCS 10	3610 (142)	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)
RCS 300	*For specifications please contact your local Metso sales office*				

(1) RCS 3 to RCS 70 v-drive, RCS 100 to RCS 600 gearbox drive
(2) 4-cell bank arranged F-2-I-2-D, empty

5.16 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 applications, particularly where de-slimed coarse particles must 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 5:16-17.

DR – Specifications

Model	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	0,4	7	15	1.0
DR 18Sp	0,71	25	4,0	5,0	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	11,0	15,0	2,3	10	80	1.6
DR 180	5,10	180	15,0	20,0	3,1	14	110	2.0
DR 300	8,50	300	22,0	30,0	4,5	18	160	2.6
DR 500	14,16	500	30,0	40,0	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

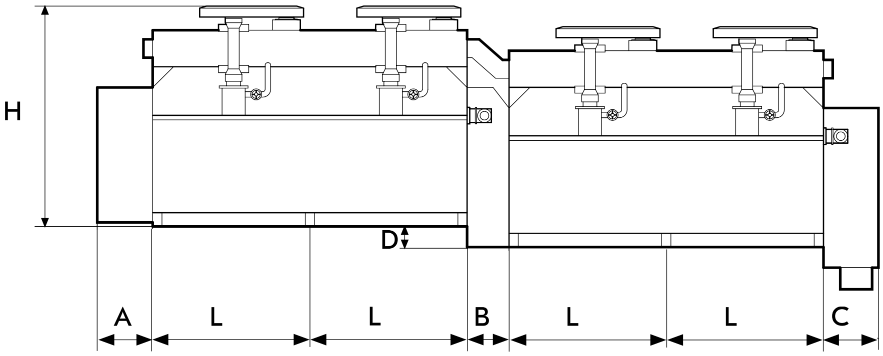
DR – Cell volumes and hydraulic capacities

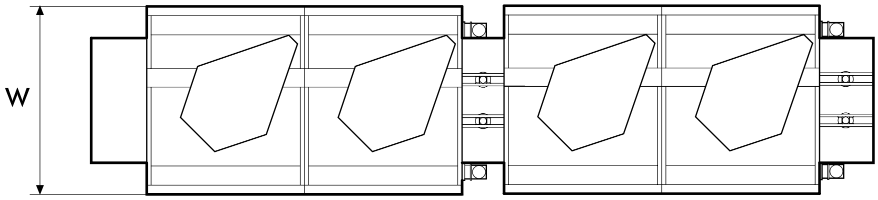
Model	Maximum Bank Feed Rate		Maximum cells per bank section (1)
	m^3/h	USGPM	
DR15	25	110	15
DR18 sp	55	240	12
DR24	110	485	9
DR100	215	945	7
DR180	415	1 825	6
DR300	580	2 550	5
DR500	760	3 345	4

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

Technical data sheet

5.17 Flotation machine – DR, Metric





Model (1)	Volume/ cell m^3	Cells/ unit (2)	A mm	B mm	C mm	D (min) mm	L (5) mm	W mm	H mm	Motor size (3) kW	Motor size (4) kW
8	0.09		152	279	279	152	483	406	1118	1.1	2.2
15	0.28	15	203	381	381	152	711	610	1626	3.0	5.0
18	0.71	12	305	457	457	203	914	813	1829	5.0	10.0
24	1.40	9	305	457	457	203	1219	1092	2362	5.5	15.0
100	2.80	7	457	457	457	203	1575	1575	2718	7.5-11	-
180	5.10	6	508	610	762	254	1829	1829	2946	11-15	-
300	8.90	5	610	762	914	305	2235	2235	3302	18-22	-
500	14.20	4	762	914	914	305	2692	2692	3404	25-30	-
1500	36.10	3	1219	1067	1372	406	4267	4267	4369	55	-

(1) From size 18 and above Single or Double side overflow.

(2) Number of cells without Intermediate box.

(3) Single cell drive.

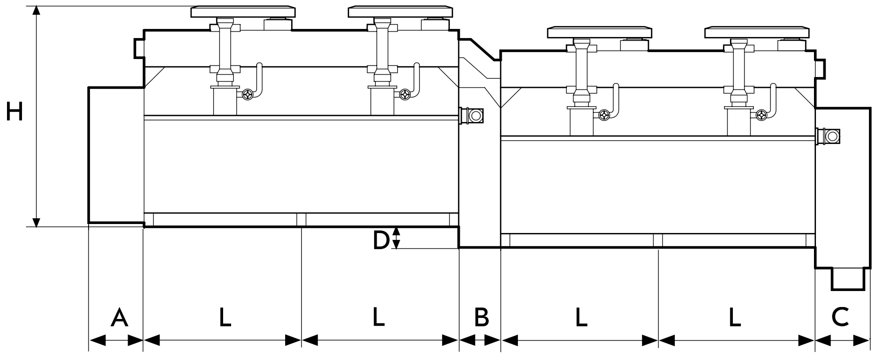
(4) Dual cell drive.

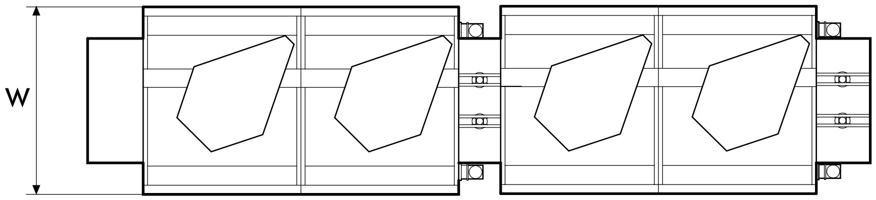
(5) Length per cell.

For dimensions in inch, see next page

Technical data sheet

5.18 Flotation machine – DR, US





Model (1)	Volume/ cell ft^3	Cells/ unit (2)	A inch	B inch	C inch	D (min) inch	L (5) inch	W inch	H inch	Motor size (3) hp	Motor size (4) hp
8	3		6	11	11	6	19	16	44	1 ½	3
15	12	15	8	15	15	6	28	24	64	4	7
18	25	12	12	18	18	8	36	32	72	6½	14
24	50	9	12	18	18	8	48	43	93	7	20
100	100	7	18	18	18	8	62	62	107	10-15	-
180	180	6	20	24	30	10	72	72	116	15-20	-
300	300	5	24	30	36	12	88	88	130	25-30	-
500	500	4	30	36	36	12	106	106	134	30-40	-
1500	1500	3	48	42	54	16	168	168	172	74	-

(1) From size 18 and above Single or Double side overflow.

(2) Number of cells without Intermediate box.

(3) Single cell drive.

(4) Dual cell drive.

(5) Length per cell.

For metric dimensions see previous page

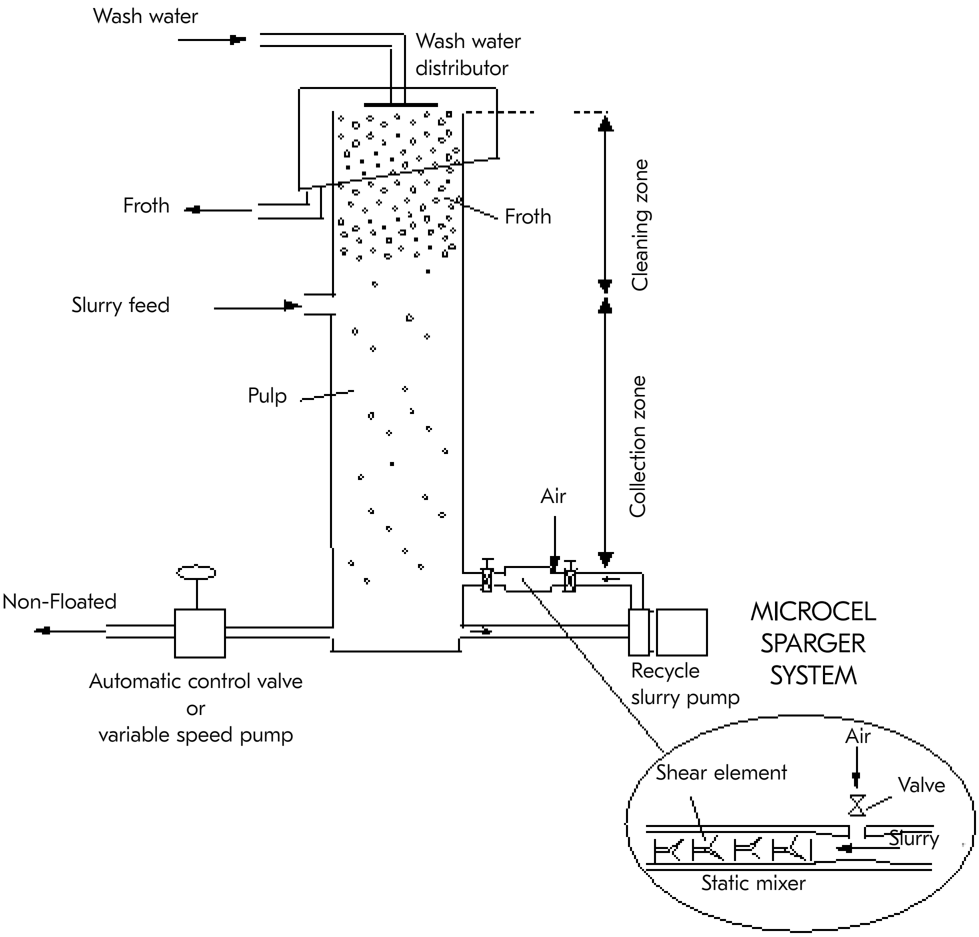
5.19 Column flotation cells system

Column flotation cells, like mechanical cells, are used to perform mineral separations. Column cells do not use mechanical agitation (impellers). Instead, mixing is achieved by the turbulence provided by the rising bubbles. Columns are mostly used to produce final grade concentrates because they are capable of high selectivity. Other features which distinguish them from mechanical cells are their shape, bubble generation system and the use of wash water. An optimum flotation circuit is a combination of mechanical cells and column cells.

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

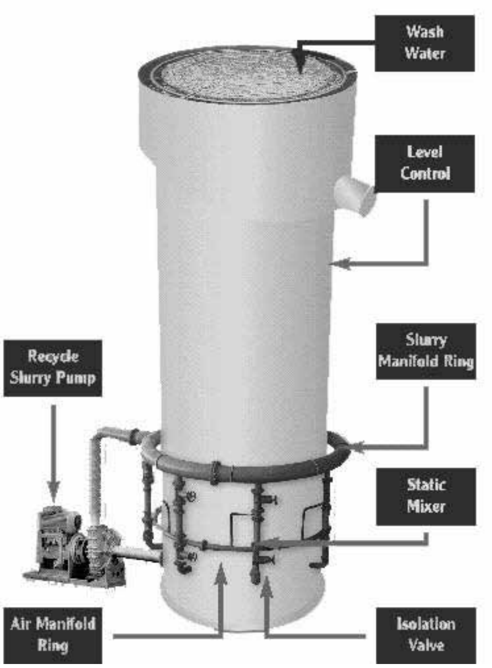
- Improved metallurgical performance
- Low energy consumption
- Less floor area
- Less maintenance
- Improved control

Schematic of Microcel flotation column



5.20 Column flotation – Microcel sparger features

The Microcel 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 ultrasonic sensor or differential pressure transmitters to automatically adjust the tailings flow 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 6 m in diameter. Flotation column cells are custom designed for each application.
- Typical superficial slurry velocity: 0.2 – 1.2 cm/s
- Typical froth carrying capacity: 2 t/h/m^2
- Typical superficial air velocity: 1.5 – 1.8 cm/s
- Height of column selected to give slurry retention time in range 10 – 20 min.
- Typical superficial wash water velocity: 0.05 – 0.2 cm/s

Applications

Applications for flotation columns include:

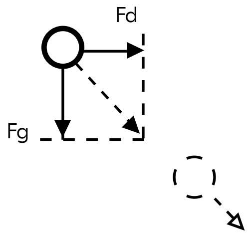
- Sulfides
- Iron ore
- Phosphate
- Coal
- Industrial minerals
- Potash

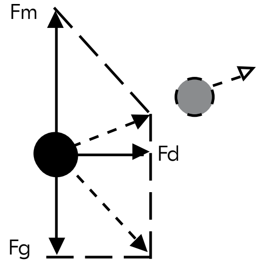
Standard column options

Column size diameter	Height m	Sparger pipe size in	Sparger quantity	Air only sparger port quantity
1,0 m	9, 10, 11, 12, 13	3, 4	1	1
1,5 m	9, 10, 11, 12, 13	4	1,2	3
3,0 m	9, 10, 11, 12, 13	4	6, 7, 8	12
3,6 m	9, 10, 11, 12, 13	4	8, 10	16
4,5 m	10, 11, 12, 13	4	12, 14	24
5,0 m	10, 11, 12, 13, 14	6	6, 7, 8	30

5.21 Magnetic separation – Introduction

By creating an environment comprising a **magnetic force** (Fm), a **gravitational 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 χ x H x grad H
V = **particle volume** (determined by process)
χ = **magnetic susceptibility** (see table below)
H = **magnetic field** (created by the magnet system design) in mT (milliTesla) or kG (kiloGauss) 1 kG = 100 mT = 0.1 T
grad 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** (F_g) is determined by particle size and density.
- **Drag force** (hydrodynamic, aerodynamic), F_d, is determined by particle size, shape, fluid density, viscosity, turbidity and velocity.
- **Centripetal force** (F_c).
- **Adhesion**
- **Electrostatic forces etc.**

5.22 Magnetic separation – Methods

Low Intensity Magnetic Separation, LIMS

- Dry and wet methods
- For separation of ferromagnetic particles
- Magnetic field intensity up to 300 mT
- Particle sizes up to 300 mm

Medium Intensity Magnetic Separation, MIMS*

- Dry and wet methods
- For separation of ferromagnetic particles
- Magnetic field intensity up to 800 mT

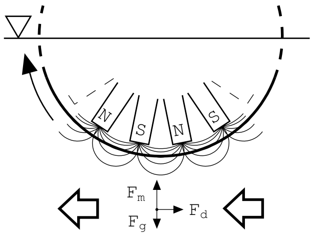
*N B At present MIMS is not available from Metso. When MIMS becomes available the above data may alter.

High Gradient Magnetic Separation, HGMS

- Cyclic and continuous methods
- For separation of paramagnetic particles
- Magnetic field intensity up to 2 T
- Limited to processing of particles finer than about 1 mm

5.23 Magnetic separation – Separator types

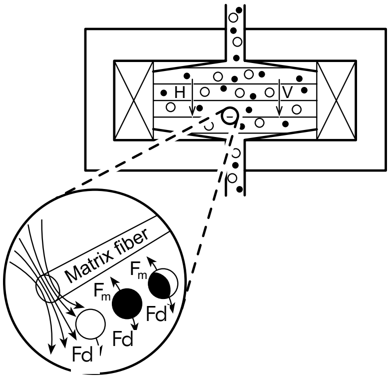
Wet LIMS = Low intensity magnetic separators



- Wet separation of ferromagnetic particles
- Magnetic field in separation zone * up to 1.2 kGauss

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

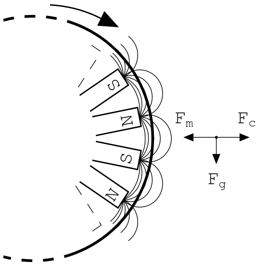
Wet HGMS = High gradient magnetic separators



- 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 in* separation zone up to 1.2 kGauss

* approx. 15 mm (5/8 inch) from magnet surface

5.24 Magnetic separation equipment

All LIMS models, wet and dry versions, comprise magnetic drum assemblies mounted in either tanks or dust housings. The magnetic assembly comprises a stationary magnetic array installed in a rotating outer drum. The drum rotation speed and direction are selected for the application in question.
Generally coarse material is processed by dry LIMS and fine material by either dry or wet LIMS. The upper particle size limit for wet processing is about 8 mm but with special arrangements coarser material can be processed by wet methods.

5.25 Dry LIMS – Belt drum separator, BS

The belt drum separator, BS, is generally used in iron ore beneficiation to either produce coarse final products or for reducing feed mass to following process stages. It is also used for steel slag and pyrite cinder treatment.

Features

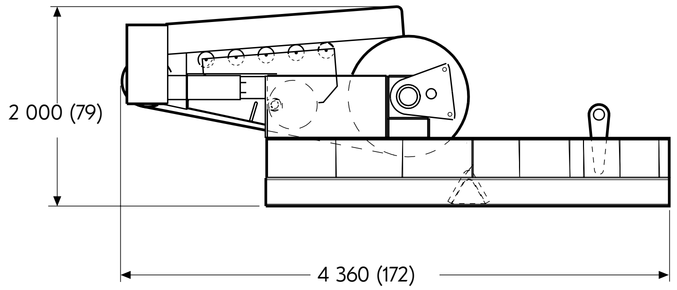
- Magnetic system with three different pole pitches with alternating polarity (models BSA)
- Special pole design with fixed polarity in rotating direction for coarse material, (model BSS)
- For low to high Fe grade feed
- Belt speeds up to 3 m/s (20 ft/min)
- Belt feed for even distribution of feed material
- Adjustable product splitter for product quality control
- Coarse particle tolerant, up to 250 - 300 mm
- Basically used in primary stages
- Can be arranged in single stage or multistage processing
- Very large unit capacity

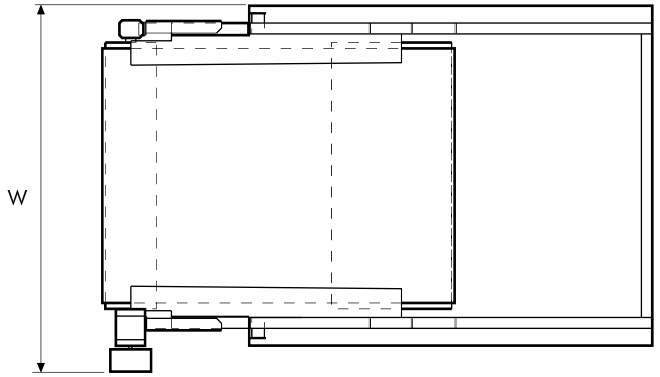
Recommended pole pitch and capacity ranges

Model	Pole pitch (pp)	Feed size mm	Feed size inch	Capacity t/h / m, st/h/ft, up to
BSA1200-112	112	5 – 75	3/16 – 3	150, 50
BSA1200-174	174	5 – 100	3/16 – 4	200, 70
BSA1200-258	258	5 – 200	3/16 – 8	200, 70
BSS1200-300	300	5 – 300	3/16 – 12	400, 140

Capacities vary with grade as well as particle size

5.26 Dry LIMS – Belt separator (BSA and BSS)





Model	Drum DxL mm (ft)	W mm (inch)	Power kW/hp*	Weight ton
BSA1206	1200 x 600 (4x2)	1800 (71)	5,5/7,5	2,1
BSA1212	1200x1200 (4x4)	2400 (95)	7,5/10	3,8
BSA1218	1200x1800 (4x6)	3000 (118)	7,5/10	5,6
BSA1224	1200x2400 (4x8)	3600 (142)	7,5/10	7,5
BSA1230	1200x2400 (4x10)	4200 (172)	11/15	9,3
BSS1212	1200x1200 (4x4)	2400 (95)	7,5/10	4,7
BSS1218	1200x1800 (4x6)	3000 (118)	7,5/10	6,9
BSS1224	1200x2400 (4x8)	3600 (142)	7,5/10	9,2

*) At peripheral drum speed 2 m/s (400 ft/min)

5.27 Dry LIMS – Drum separator, DS

The Dry Drum Separator, DS, is generally used in iron ore beneficiation to either produce coarse final products or for reducing feed mass to following process stages. It is also used for steel slag and pyrite cinder treatment. The metal powder industry uses the separator for final product control.

Features

- Magnetic system with four different pole pitches
- For low to high Fe grade feed
- Drum speeds up to 8 m/s (1600 ft/min)
- Top feed
- Coarse particle tolerant, normally up to 20 – 25 mm (3/4 – 1 inch)
- Basically used in primary stages as cobber and rougher
- Can be arranged in single stage or multistage processing
- Can be connected to dust control systems
- Large unit capacity

Recommended pole pitch

Pole pitch (pp)	Feed size mm	Feed size inch
(25) 45	0 – 5	0 – 3/16
45	0 – 10	0 – 3/8
65	0 – 15	0 – 9/16
112	0 – 20	0 – 3/4
174	0 – 25	0 – 1

Note pp 25 is intended only for special application

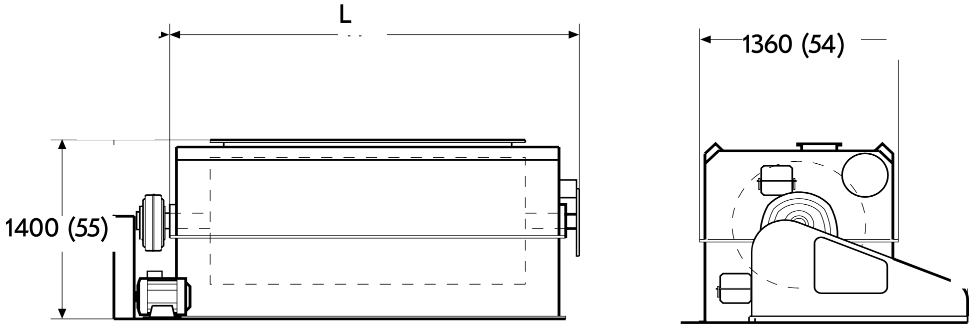
DS – Capacities

Type	Capacity t/h and m drum width	Capacity st/h /ft drum width
DS900 series	50 – 150	15 – 45
DS1200 series	50 – 200	15 – 60

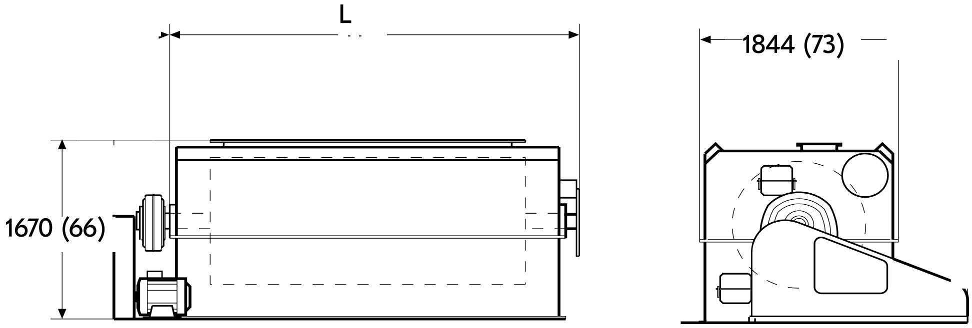
Capacities vary with grade and particle size

Technical data sheet

5.28 Dry LIMS – Drum separator – (DS)



Model	Drum dimensions DxL mm (ft.)	L mm (ft.)	Power kW/HP*	Weight empty Ton
DS906	916 x 600 (3x2)	1550 (61)	4/5	1,6
DS912	916 x1200 (3x4)	2170 (85)	5,5/7,5	2,5
DS918	916 x1800 (3x6)	2780 (109)	7,5/10	3,2
DS924	916 x2400 (3x8)	3400 (134)	7,5/10	4,0



Model	Drum dimensions DxL mm (ft.)	L mm (ft.)	Power kW/HP*	Weight empty Ton
DS1206	1200 x 600 (4x2)	1550 (61)	4/5	2,2
DS1212	1200 x1200 (4x4)	2170 (85)	5,5/7,5	3,1
DS1218	1200 x1800 (4x6)	2780 (109)	7,5/10	3,9
DS1224	1200 x2400 (4x8)	3400 (134)	7,5/10	4,8
DS1230	1200 x3000 (4x10)	4020 (158)	7,5/10	5,6

*) At drum peripheral speed of 2 m/s (400 ft/min)

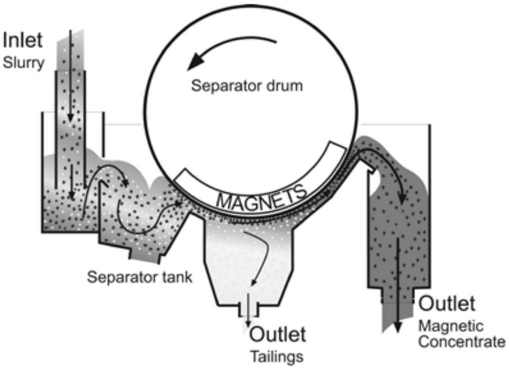
5.29 Wet LIMS – Wet magnetic separators

The wet magnetic separators are generally used in the iron ore industry in several stages of the process from coarse separation to fine concentration of magnetite ore, in single concentration means or in combination with other methods (e.g. flotation, gravity concentration, screening).
Wet LIMS are also used in other mineral industries for e.g. preparation of dense media, reduction of pyrrhotite content in base metal concentrates, removal of ferromagnetic contaminants etc.

Please always check with Metso for final selection!

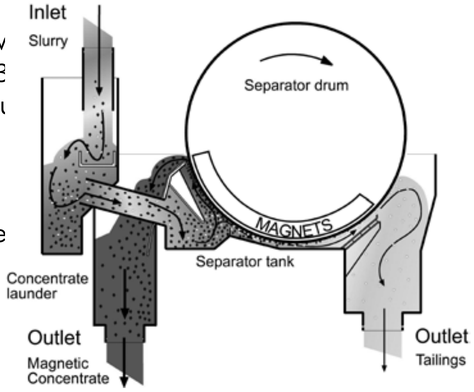
5.30 Wet LIMS – Concurrent CC

- Medium lenght magnetics pick up zone
- Standard magnetic system
- For low to high Fe grade feed
- Concurrent operation
- Tank bottom spigots for tailings flow control
- Coarse particle tolerant, normally up to 8 mm
- Used in primary stages as cobber and rougher
- Can be arranged as single stage or multistage units on same level for reprocessing of the magnetic product
- Large unit capacity
- Feed density acceptable in a wide range, normally 35 to 45 percent solids by weight



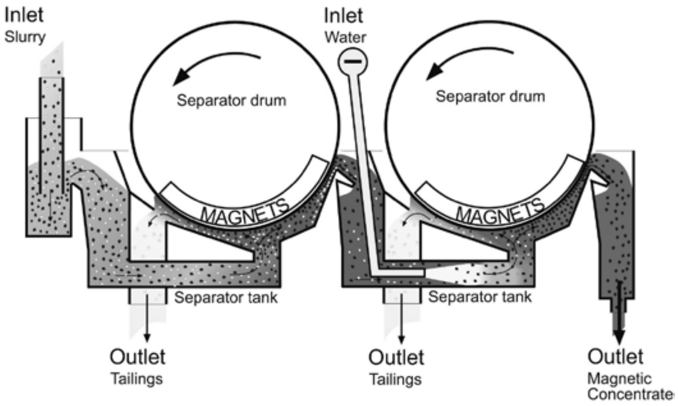
5.31 Wet LIMS – Counter rotation CR and CRHG

- Extra long magnetics pick up zone
- Available with either standard or High Gradient magnetic systems
- For low to high Fe grade feed
- Counter rotational operation
- Manually adjustable weir for tailings flow
- Coarse particle tolerant, normally up to 3
- Used in primary stages as cobber or rou
- Also used for dense media recovery
- Large unit capacity
- Mostly used in single unit operation but
- Feed density acceptable in a wide range



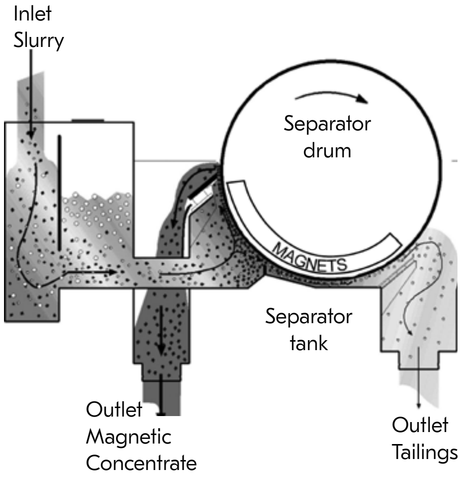
5.32 Wet LIMS – Countercurrent CTC and CTCHG

- Long magnetics pick up zone
- Available with either standard or High Gradient magnetic systems
- Countercurrent operation
- Commonly arranged as multistage units on same level for reprocessing of the magnetic product
- Fixed overflow weir for tailings flow control
- Medium particle tolerant, normally up to 0,8 mm
- Used in cleaning or finishing stages
- Feed density acceptable in a wide range, normally up to 40 percent solids by weight



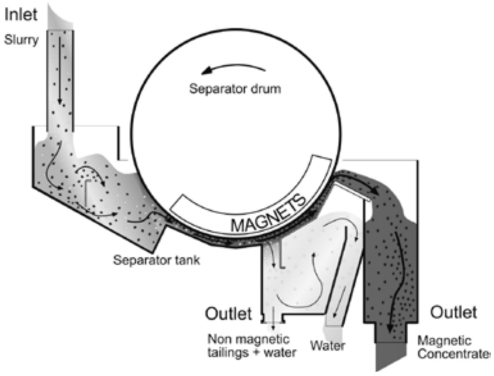
5.33 Wet LIMS – Counter rotation froth DWHG

- Long magnetics pick up zone
- High Gradient magnetic systems
- Counter rotational operation
- Extra large feed box for deaeration of feed slurry
- Normally installed as a single stage unit
- Manually adjustable weir for tailings flow control
- Coarse particle tolerant, normally up to 3-4 mm
- Designed to improve recovery from aerated (frothy) slurries
- Used for recovery of magnetics in slurries emanating from flotation
- Feed density acceptable in a wide range, normally up to 45 percent solids by weight



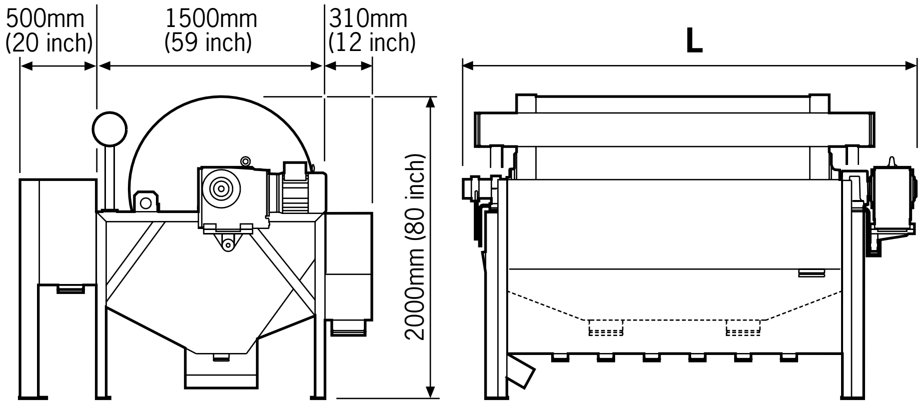
5.34 Wet LIMS – Dense media recovery DM and DMHG

- Very long magnetics pick up zone
- Standard and High Gradient (HG) magnetic systems available
- For low to high Fe grade feed
- Concurrent operation with long magnetics pick-up zone
- Bottom spigots combined with effluent weir overflow for tailings flow control
- Coarse particle tolerant, normally up to 8 mm
- Used in both primary and secondary stages in single stage units



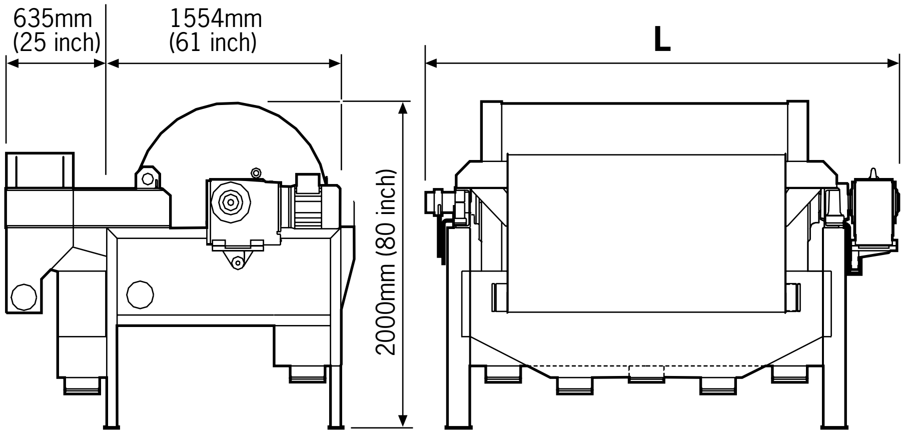
Technical data sheet

5.35 Wet LIMS – Concurrent (CC)



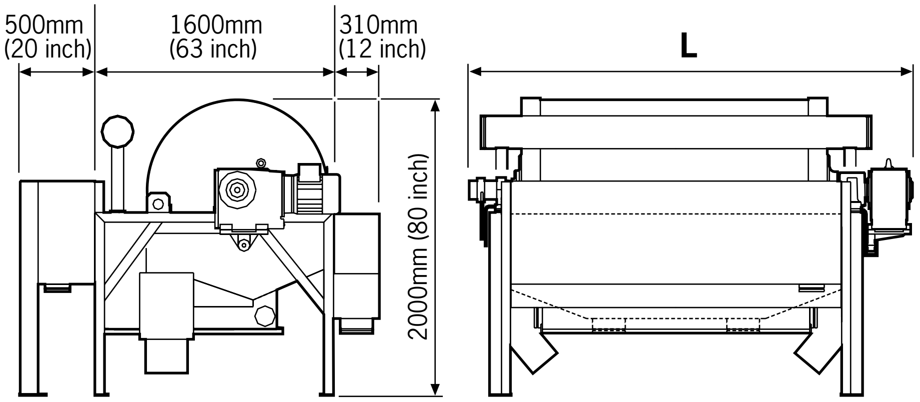
Model	Drum dimensions DxL mm (ft)	L mm (inch)	Power kW/HP	Weight (empty) ton
WS1206CC	1200 x 600 (4x2)	1810 (71)	4 (5)	1,9
WS1212CC	1200x1200 (4x4)	2410 (95)	5,5 (7,5)	2,8
WS1218CC	1200x1800 (4x6)	3010 (119)	7,5 (10)	3,6
WS1224CC	1200x2400 (4X8)	3610 (142)	7,5 (10)	4,7
WS1230CC	1200x3000 (4x10)	4218 (166)	7,5 (10)	5,6
WS1236CC	1200x3600 (4x12)	4818 (190)	11 (15)	6,6

5.36 Wet LIMS – Counterrotation CR and CRHG



Model	Drum dimensions DxL mm (ft)	L mm (inch)	Power kW/hp	Weight (empty) ton
WS1206CR	1200 x 600 (4x2)	1810 (71)	4/5	1,9
WS1212CR	1200x1200 (4x4)	2410 (95)	5,5/7,5	2,8
WS1218CR	1200x1800 (4x6)	3010 (119)	7,5/10	3,6
WS1224CR	1200x2400 (4X8)	3610 (142)	7,5/10	4,7
WS1230CR	1200x3000 (4x10)	4218 (166)	7,5/10	5,6
WS1236CR	1200x3600 (4x12)	4818 (190)	11/15	6,6

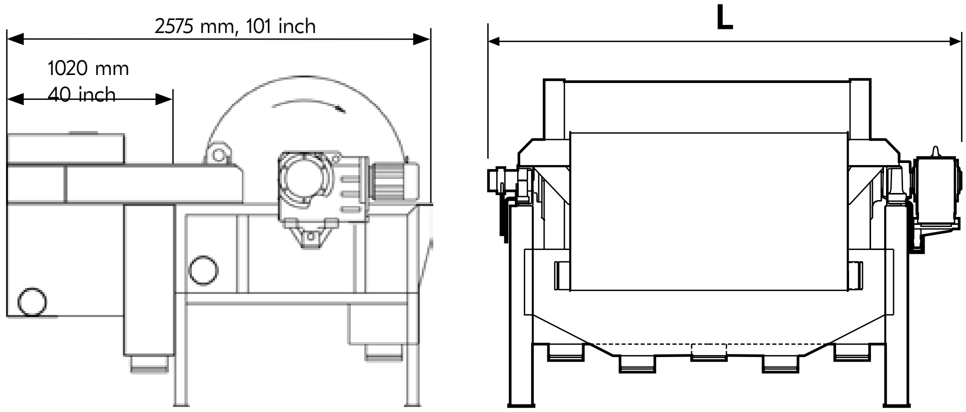
5.37 Wet LIMS – Countercurrent CTC and CTCHG



Model	Drum dimensions DxL mm (ft)	L mm (inch)	Power kW/hp	Weight (empty) ton
WS1206CTC	1200 x 600 (4x2)	1810 (71)	4/5	1,9
WS1212CTC	1200x1200 (4x4)	2410 (95)	5,5/7,5	2,8
WS1218CTC	1200x1800 (4x6)	3010 (119)	7,5/10	3,6
WS1224CTC	1200x2400 (4X8)	3610 (142)	7,5/10	4,7
WS1230CTC	1200x3000 (4x10)	4218 (166)	7,5/10	5,6
WS1236CTC	1200x3600 (4x12)	4818 (190)	11/15	6,6

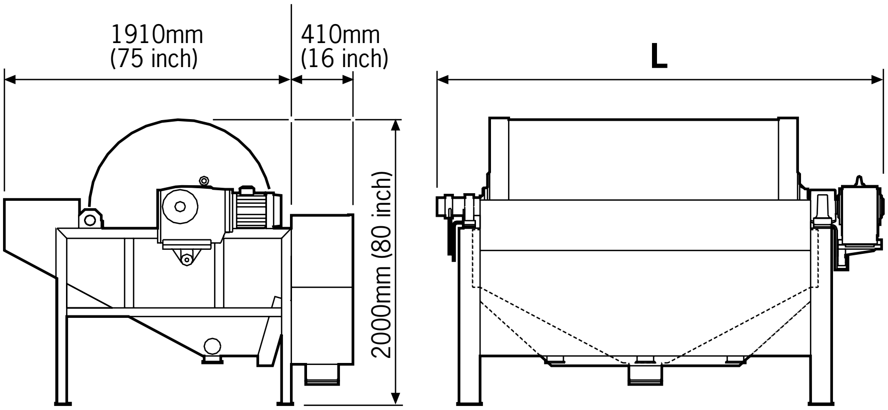
WS1200CTC and WS1200CTCHG carry identical dimensions

5.38 Wet LIMS – Counter rotation froth DWHG



Model	Drum dimensions DxL mm (ft)	L mm (inch)	Power kW/hp	Weight (empty) ton
WS1206DWHG	1200 x 600 (4x2)	1810 (71)	1,5/2,0	1,9
WS1212DWGH	1200x1200 (4x4)	2410 (95)	2,2/3,0	2,8
WS1218DWHG	1200x1800 (4x6)	3010 (119)	3,0/4,0	3,6
WS1224DWHG	1200x2400 (4X8)	3610 (142)	3,0/4,0	4,7
WS1230DWHG	1200x3000 (4x10)	4218 (166)	4,0/5,0	5,6
WS1236DWHG	1200x3600 (4x12)	4818 (190)	4,0/5,0	6,6

5.39 Wet LIMS – Dense media DM and DMHG

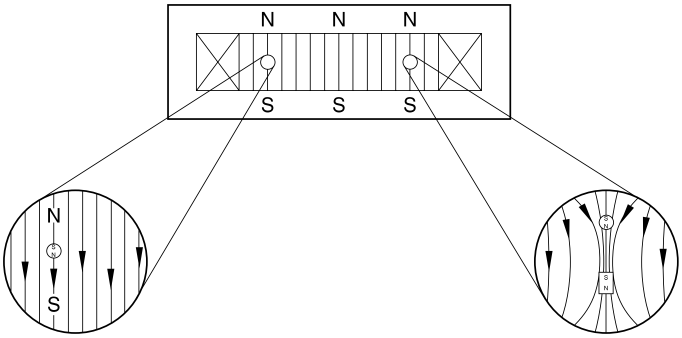


Model	Drum dimensions D x L mm (ft)	L mm (inch)	Power kW/hp	Weight (empty) ton
WS1206DM	1200 x 600 (4x2)	1810 (71)	1,5/2,0	1,9
WS1212DM	1200x1200 (4x4)	2410 (95)	2,2/3,0	2,8
WS1218DM	1200x1800 (4x6)	3010 (119)	3,0/4,0	3,6
WS1224DM	1200x2400 (4X8)	3610 (142)	3,0/4,0	4,7
WS1230DM	1200x3000 (4x10)	4218 (166)	4,0/5,0	5,6
WS1236DM	1200x3600 (4x12)	4818 (190)	4,0/5,0	6,6

WS1200DM and WS1200DMHG carry identical physical dimensions

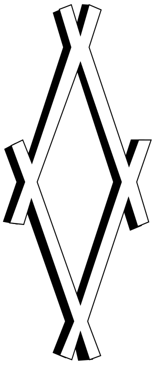
5.40 Wet HGMS/F – Magnet design

The HGMS and HGMF magnet design provides a uniform magnetic field in the canister (separation vessel). The uniform field in itself cannot alone achieve selective separation but by inserting a sharply edged ferromagnetic material, a matrix, in the void the magnetic field is greatly disturbed and the required magnetic field gradient is generated in the separation space.

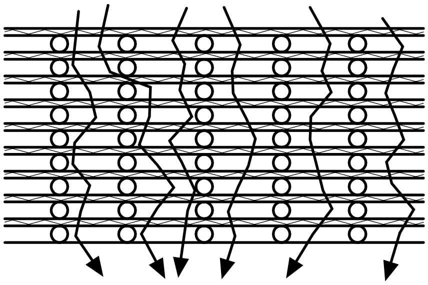


Homogeneous field (Fm=0)

Inhomogeneous field (Fm>0)



Filament



Filament matrix

Facts about Matrix

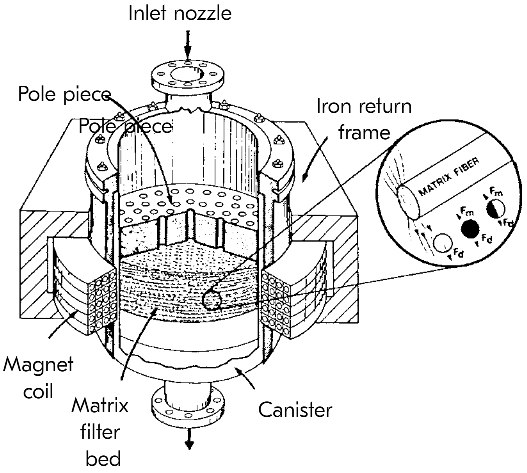
- Made of ferromagnetic stainless steel as expanded metal (X) or as steel wool (W)
- Matrix grade (opening size) is selected to suit particle size and properties
- The gradient generating material, constitutes 15 to 20 % by volume in the process space.
- Due to the controlled pulp velocity through the matrix, the matrix material wear rate is extremely low.

5.41 Wet HGMS, HGMF – Separator types

Cyclic separators, HGMS	For applications with low magnetic content in the feed, normally less than 4 - 5 %
Cyclic separators, HGMF	Also called magnetic filter, designed similar to cyclic HGMS but specially outfitted for removal of magnetic content of effluents.
Continuous Separators	For mineral separation with magnetic content in feed higher than 4 %.

5.42 Wet cyclic HGMS

- Robust and simple design
- No moving parts except for valves
- Magnetic field intensity up to 2T (20kG)
- Extremely long wear life of matrix
- Extremely low maintenance requirement
- Generally fully automated operation
- See data sheet page 5:36.



Models and dimensions

The cyclic unit models are defined by canister diameter, matrix height and magnetic field.

HGMS canister size — matrix area

Model	Canister OD mm	Canister OD inch	Matrix area m^2
HGMS10	36	1,4	0,00099
	86	3,4	0,0057
HGMS22	168	6,6	0,019
HGMS38	324	12,8	0,078
HGMS46	406	16	0,118
HGMS56	508	20	0,187
HGMS66	660	26	0,323
HGMS76	763	30	0,433
HGMS107	1 067	42	0,862
HGMS152	1 524	60	1,778
HGMS214	2 134	84	3,511
HGMS305	3 084	120	7,175

Matrix heights

Matrix heights nomination	Matrix heights mm	Matrix heights inch
15	150*	6*
15	178	7
30	305	12
50	503	20

*) available only with model HGMS10

Standard magnetic field designs

The available magnetic field designs have been limited to 3, 5, 10, 15 and 20. The available magnetic field can always be adjusted to a lower rating. The highest available rating appears as the last digit(s) in the HGMS model name.

Model definition

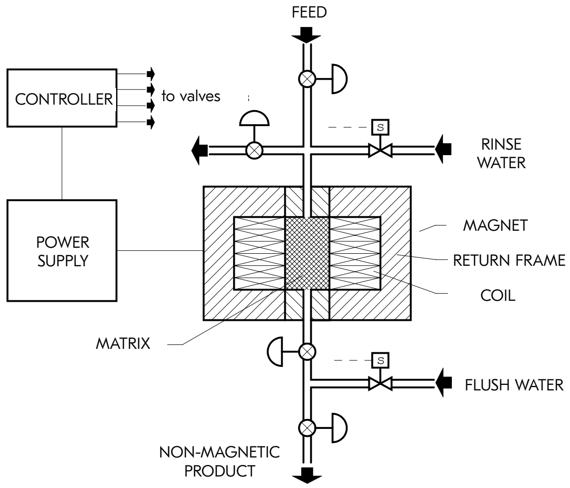
In the model name canister diameter, matrix height and nominal magnetic rating are appearing, e.g. HGMS107-15-10 had a diameter of 1067mm a matrix height of 178 mm and a magnetic rating of 10 kG.

Matrix grades for cyclic HGMS units

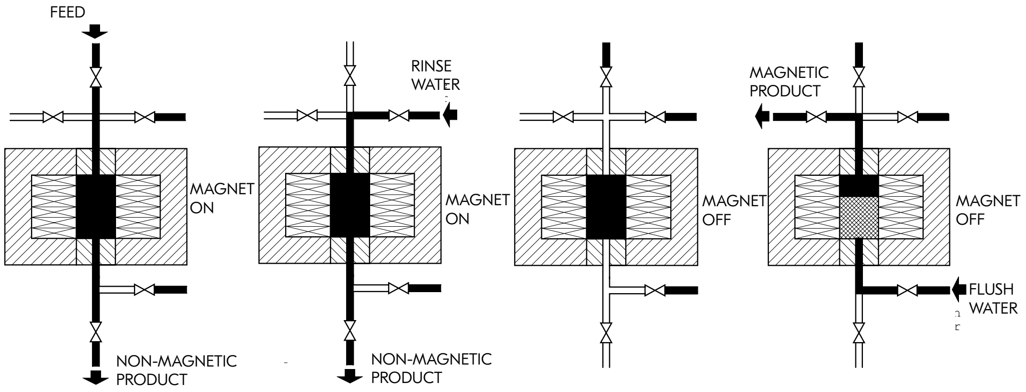
Matrix grade	Type of matrix	Maximum particle size, µm	Maximum particle size, mesh
XR1.1	Expanded metal	1000	16
XR	Expanded metal	800	22
XM1.1	Expanded metal	450	35
XM	Expanded metal	350	42
XMG0	Expanded metal	300	48
XF1.1	Expanded metal	150	106
XF	Expanded metal	100	150
WC	Steel wool	20	
WM	Steel wool	10	
WF	Steel wool	7	

5.43 Wet cyclic HGMS – Process system

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



5.44 Wet cyclic HGMS – Operation



Cycle 1
Separation

Magnet activated
Feed on

Cycle 2
Rinse

Magnet activated
Feed off
Washing on

Cycle 3
Demagnetizing

Magnet off
Feed off
Washing off

Cycle 4
Flushing

Magnet off
Feed off
Washing on

Typical cycle times (Kaolin separation):

Separation	4 min.
Rinse	1.5 min.
Magnetizing / Demagnetizing	< 1 min.
Flush	< 1 min.

5.45 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
- Testing and research (Laboratory unit HGMS10-15-20)

5.46 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.*

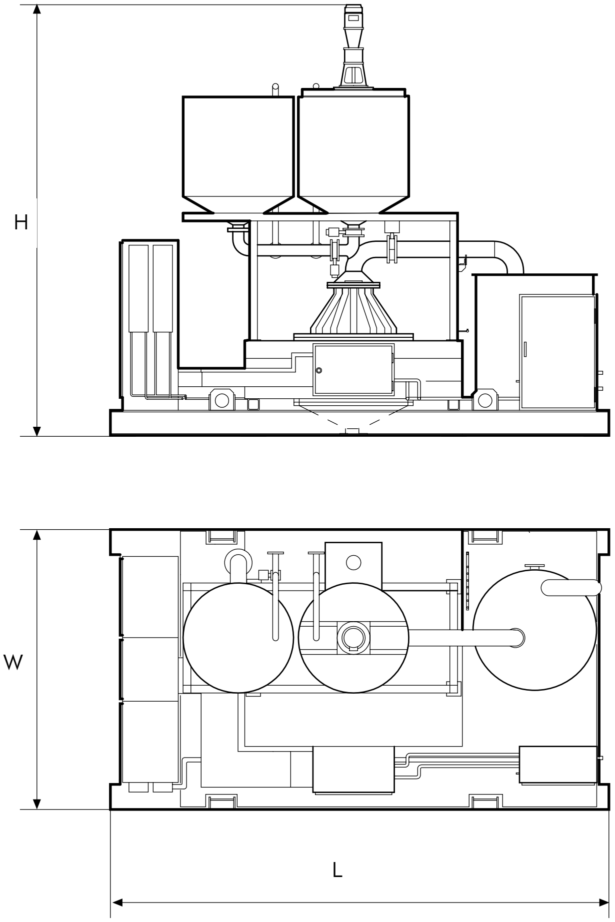
2. Calculate the actual separation time (feed) from 1. above
   4 / (4 + 1,5 + 1 + 1) = 4 / 7,5 = 0,53 (53%)
3. Calculate the volume flow of 4.0 t/h (at say 25% solids and S.G. 2.5) which gives 13.6 m^3/h (0.75 ft / min)
   As actual separation time is 53% of total time, separator volumetric capacity 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

5.47 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

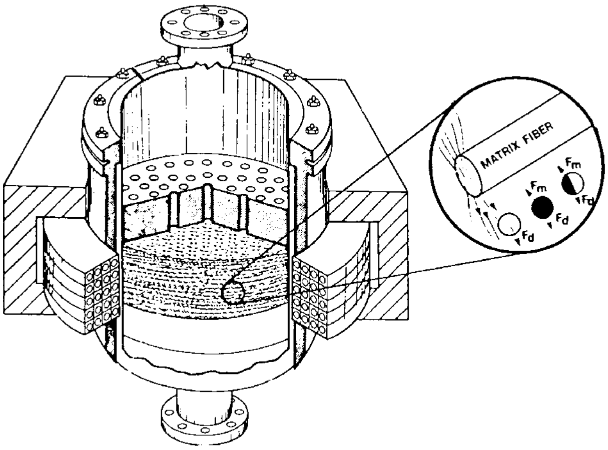
5.48 Wet cyclic high gradient magnetic filter HGMF

The Cyclic HGMF is in principle based on the cyclic HGMS but arranged to work as filter instead of as separator. It is normally used for magnetic filtration of liquids and effluents.

Features

- Robust and simple design
- No moving parts except for valves
- Magnetic field intensity up to 2T (20kG)
- Extremely long wear life of matrix
- Extremely low maintenance requirement
- Generally fully automated operation
- Can be arranged for special process requirements like high pressure and temperatures

See data sheet page 5:41.



Models and sizes

The cyclic HGMF units are defined by canister diameter, matrix height and magnetic field.
The laboratory model is available as HGMS10-15-20 and is used for both HGMS and HGMF investigations.

HGMF – Canister diameters and matrix areas

Model	Canister OD mm	Canister OD inch	Matrix area m^2
HGMS10	36	1,4	0,00099
	86	3,4	0,0057
HGMF22	168	6,6	0,019
HGMF38	324	12,8	0,078
HGMF46	406	16,0	0,118
HGMF56	508	20,0	0,187
HGMF66	660	26,0	0,323
HGMF76	763	30,0	0,433
HGMF107	1 067	42,0	0,862
HGMF152	1 524	60,0	1,778
HGMF214	2 134	84,0	3,511
HGMF305	3 084	120,0	7,175

Matrix heights

Matrix heights nomination	Matrix heights mm	Matrix heights inch
15	150*	6*
15	178	7
30	305	12
50	503	20

*) available only with model HGMS10

Standard magnetic field designs

The available magnetic field designs have been limited to 3, 5, 10, 15 and 20. The available magnetic field can always be adjusted to a lower rating. The highest available rating appears as the last digit(s) in the HGMS model name.

Model definition

In the model name canister diameter, matrix height and nominal magnetic rating are appearing, e.g. HGMF107-15-10 has a diameter of 1067mm a matrix height of 178 mm and a magnetic rating of 10 kG.

Matrix grades for cyclic HGMF units

Matrix grade	Type of matrix	Maximum particle size, µm	Maximum particle size, mesh
XR1.1	Expanded metal	1000	16
XR	Expanded metal	800	22
XM1.1	Expanded metal	450	35
XM	Expanded metal	350	42
XMG0	Expanded metal	300	48
XF1.1	Expanded metal	150	106
XF	Expanded metal	100	150
WC	Steel wool	20	
WM	Steel wool	10	
WF	Steel wool	7	

5.49 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.)

5.50 HGMF – Process data

Solids in feed	Normally low ppm levels
Particle size in feed	Restricted by matrix type
	Matrix type XF will allow particles – 100 microns

5.51 HGMF – Sizing

Sizing similar to conventional clarification sizing, see section 6:3.
Surface load $(m^3/h)/m^2$ and $(ft^3/h)/ft^2$ is the flow velocity through the matrix for optimal clarification.

Application *	Surface load $(m^3/h)/m^2$	Surface load $(ft^3/h)/ft^2$	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 $(m^3/h)/m^2$ 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:

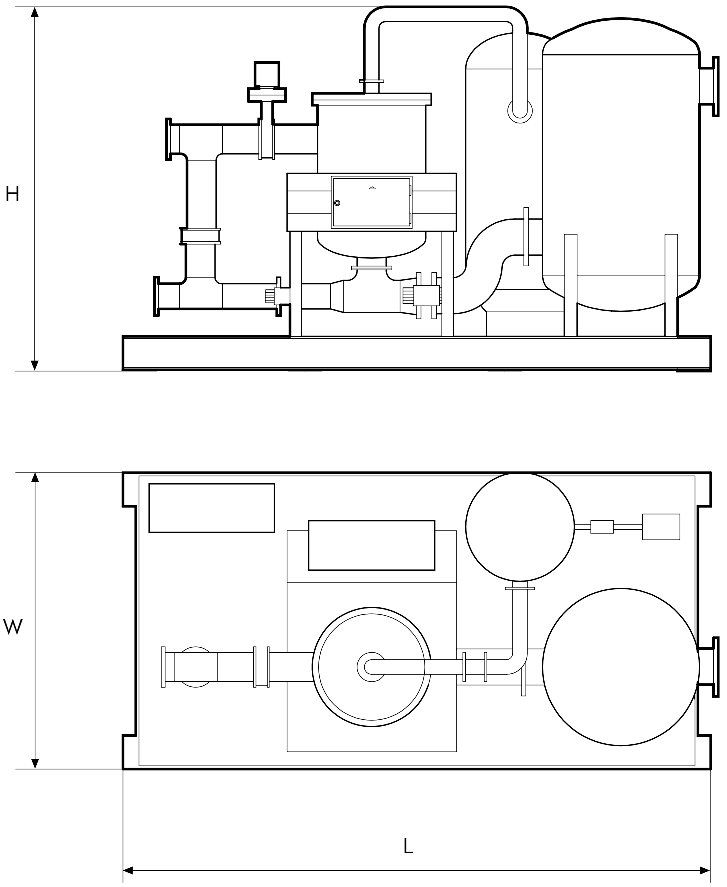
Paper mill Condensate water can be treated with a surface load of approx. 500 GPMPSF (Gallon per minute per square foot)

Flow is 3000 GPM

HGMF model 107 has an area = 9.1 ft^2

3000 / 9.1 = 330 GPMPSF (OK!)

5.52 Wet cyclic 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)

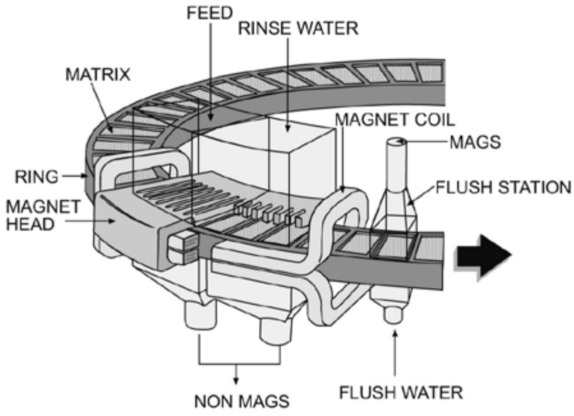
Magnetic field available 3,5,10,15 and 20 kGauss

** Site specific

5.53 Wet continuous HGMS

Features

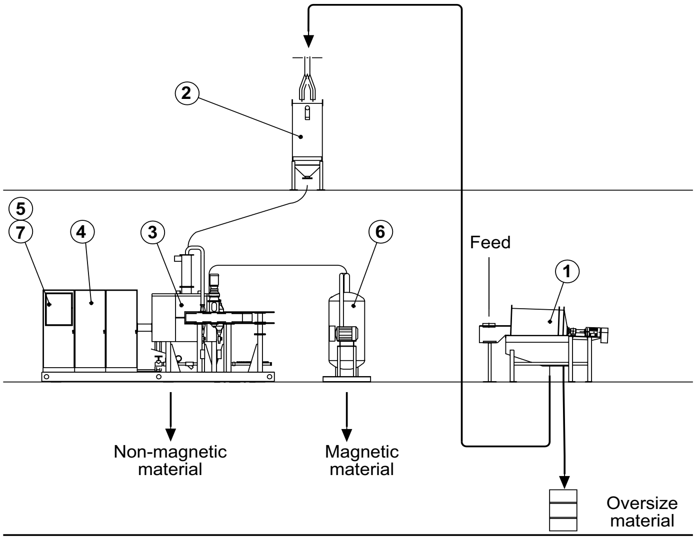
- Continuous operation
- Fully automatic processing
- Broad range of applications
- Fine particle processing
- High separation efficiency
- Reliable design
- Low specific power consumption
- Large process capacity
- Long component life



See data sheet page 5:44

5.54 Wet continuous HGMS – Process system

1. Oversize control
2. Passive matrix
3. Separator
4. Power supply
5. Cooling system
6. Vacuum system
7. Control system



5.55 Wet continuous 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 (desulphurization and de-ashing)
5. Separation of base metal minerals such as:
    - Cu-Mo
    - Cu-Pb
    - Zn-Pb

5.56 Wet continuous HGMS — Sizing and selection

Note: The sizing and selection of the equipment should be carried out by authorized personnel.
Matrix loading (ML) = Allowable feed solids (dry weight) per matrix volume, g/cm3.
Pulp flow velocity (PFV), mm/s
The factors feed density, Magnetic field, ML and PFV are determined by laboratory testing.
The data in the tables below are only indicative.

Matrix grades for continuous HGMS units

Matrix grade	Type of matrix	Maximum particle size, µm	Maximum particle size, mesh
XR1.1	Expanded metal	1000	16
XR	Expanded metal	800	22
XM1.1	Expanded metal	450	35
XM	Expanded metal	350	42
XMG0	Expanded metal	300	48
XF1.1	Expanded metal	150	106
XF	Expanded metal	100	150

Wet continuous 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
250	200	250	27	6
350	350	450	40	9

* One magnet head 7 kGauss

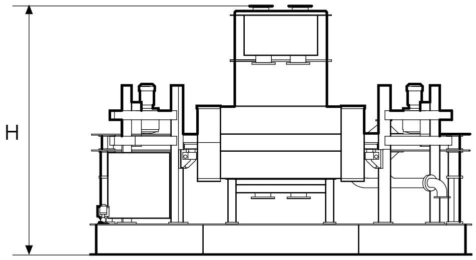
Size	Rinse/mag head (USGPM)	Flush/mag head (USGPM)	Seal water/unit (USGPM)	Cooling water* (USGPM)
120	65	90	35	15
185	310	395	50	20
250	880	1 095	120	25
350	1 535	1 975	175	40

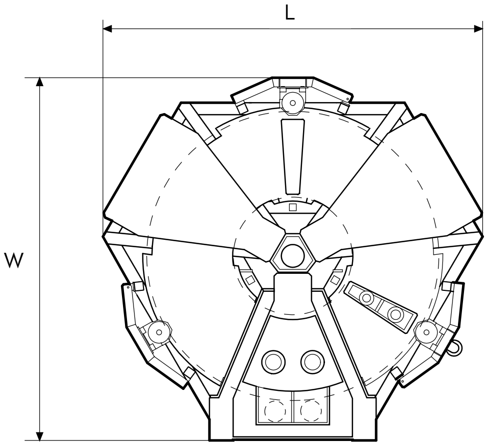
* One magnet head 7 kGauss

Application	Magnetic field T	Matrix loading g/cm3	Flow velocity mm/s
Hematite	0,3 – 0,7	0,3 – 0,65	180 – 250
Martite	0,3 – 0,7	0,3 – 0,6	180 – 250
Ilmenite	0,5 – 0,7	0,3 – 0,45	180 – 200
Chromite	0,5 – 0,7	0,3 – 0,5	150 – 200
Manganese	1,0 – 1,5	0,3 – 0,5	100 – 200
Apatite	0,7 – 1,5	0,3	100 – 150
Kyanite	1,5	0,3	100 – 150
Wolframite	1,0	0,3	100 – 150
Nepheline Syenite	1,2 – 1,5	0,3	60 – 90
Glass sand	1,5	0,3 – 1,0	60 – 90
Mica	0,8 – 1,0	0,3 – 0,8	60 – 90
Retreatment of current tailings and exist. deposits	Varying	Varying	Varying

Technical data sheet

5.57 Wet continuous HGMS





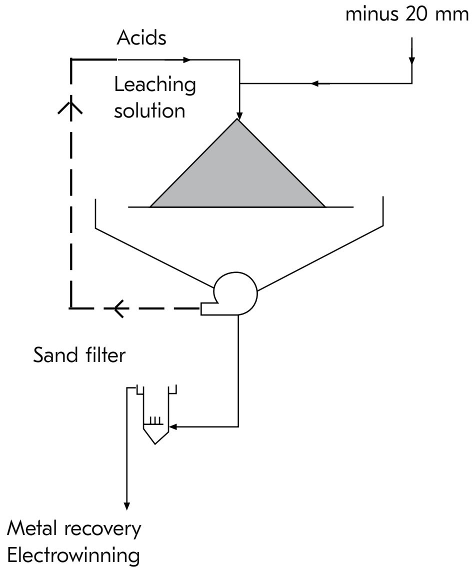
Model	H mm (ft)	L mm (ft)	W mm (ft)	Power/head* kW	Weight/frame ton	Weight/head ton
120-10 (2)*	2 800 (9)	2 600 (9)	2 200 (7)	75	6	3
120-15 (2)	2 800 (9)	2 600 (9)	2 200 (7)	175	5	5
185-7 (2)	3 600 (12)	4 100 (13)	3 700 (12)	65	10	9
185-10 (2)	3 600 (12)	4 100 (13)	3 700 (12)	85	10	18
185-15 (2)	3 600 (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

* power required for ring drive, cooling systems lubrication etc is additional.

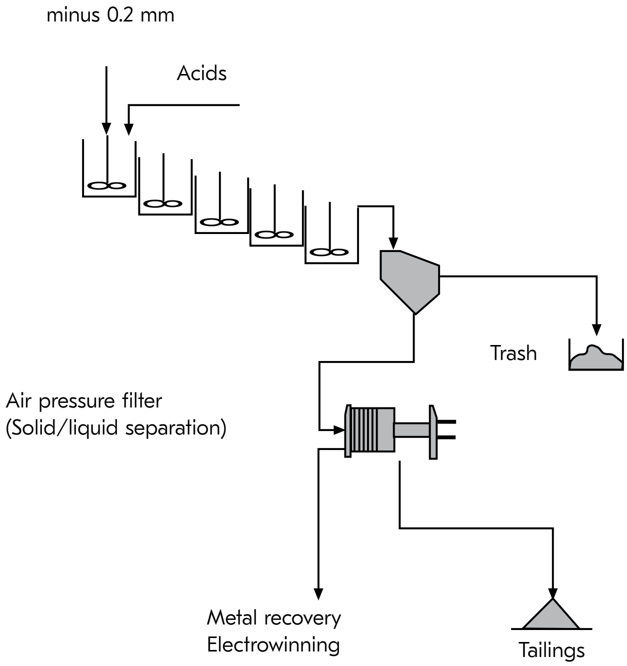
5.58 Leaching of metals

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.



5.59 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.

5.60 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).

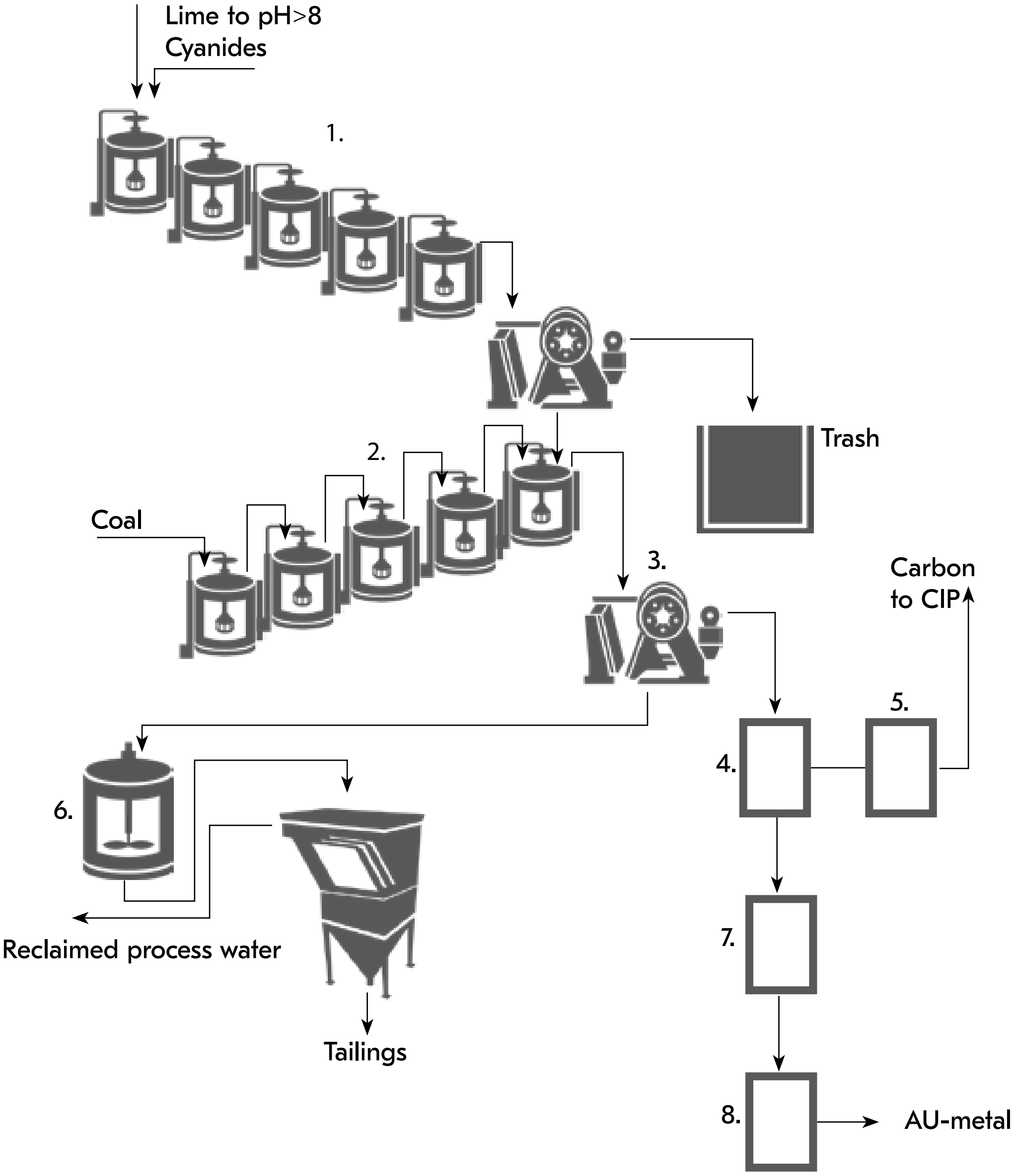
5. **Carbon reactivation** is needed after the washing to restore the active surface of the granules. This is done in a kiln at 125° C

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).

5.61 Gold leaching – CIP

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



Agitation, see 8:31.
Sedimentation, see 6:2.
Mechanical dewatering, see 6:24.

Upgrading

6. Upgrading

6.1 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 valuables.

6.2 Upgrading by methods

Sedimentation

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

Mechanical dewatering

Gravity
Low pressure
Medium pressure
High pressure

Thermal drying

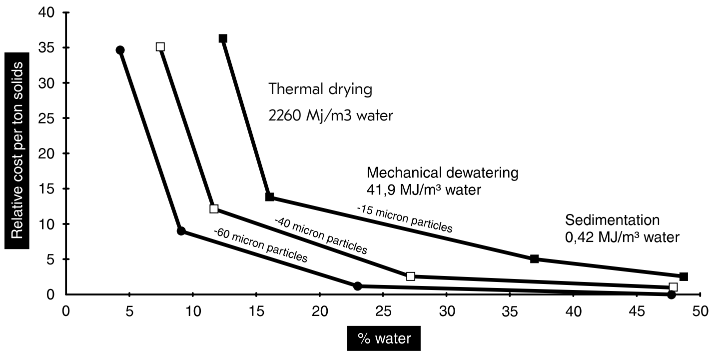
Direct
Indirect

Thermal processing

Calcining
Sintering (pelletizing)

6.3 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?

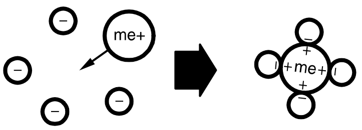
6.4 Sedimentation

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

6.5 Flocculation

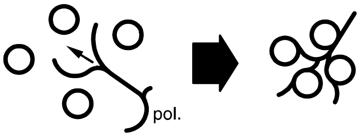
All sedimentation technologies are related to particle size. One way of improving the settling speed generally is therefore to increase the size of the particles.
Fine particles can be connected together by coagulation or flocculation. The settling rate of the combined particles will be higher than that of each individual particle. This can also be applied prior to mechanical dewatering.
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).

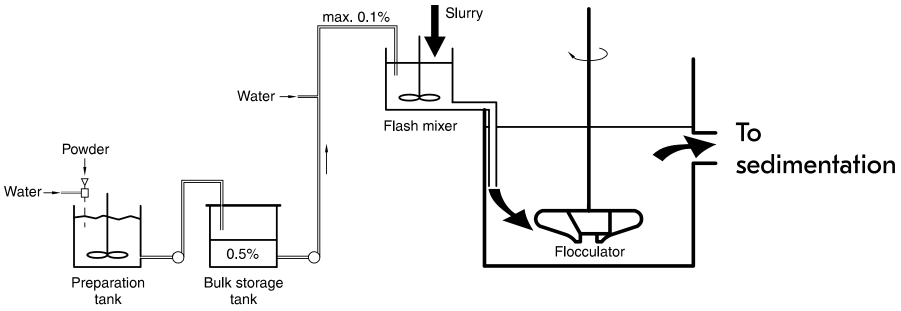
Flocculation: Polymers with molecule chains which physically link the particles together (mechanical bridging).



A flocculated aggregate will not reform after breaking.

Flocculation system

A handling system is needed for flocculent 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.

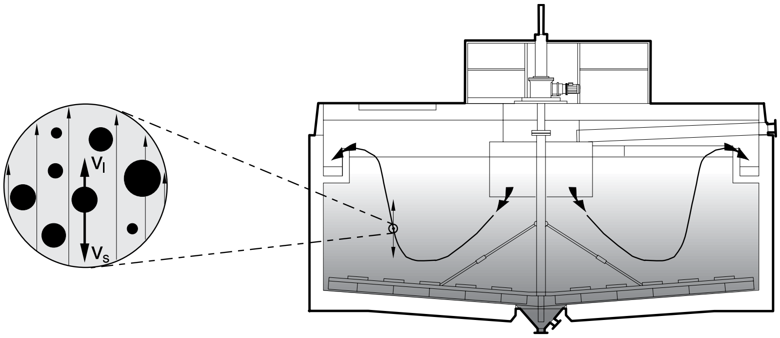


Flocculation - addition and mixing time

Application	Flocculant charge	Mixing time min	Addition rate g/m^3
Sand wash water	an- or non-ionic	0.5 – 1	0.5 – 5
Scrubber water (gas cleaning)	an-ionic	0.5 – 2	0.5 – 2
Coal tailings	non- and cat.ionic	0.5 – 1	2.0 – 10
Mineral tailings	an-ionic	0.5 – 1	1.0 – 5 (40-80 g/t)

6.6 Conventional clarifier

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



6.7 Conventional clarifier – sizing

Clarifier diameter is selected to give a suitable upstream velocity (m/h). Sizing is usally done using "Surface Load", meaning the volume of slurry m^3/h fed per m^2 of clarifier surface. Typical surface loads 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 – 5	0.5 – 1.7	0.03 – 0.07	
Coal refuse	0.5 – 6	0.7 – 1.7	0.04 – 0.09	
Clean coal fines	1.0 – 5	1.0 – 1.9	0.06 – 0.10	(with flocculation)
Heavy media magnetite	20 – 30	6 – 7.5	0.32 – 0.41	
Gas cleaning	0.2 – 2	1.5 – 3.7	0.08 – 0.20	(with flocculation)
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 $m^3/h/m^2$.

Select clarifier diameter.

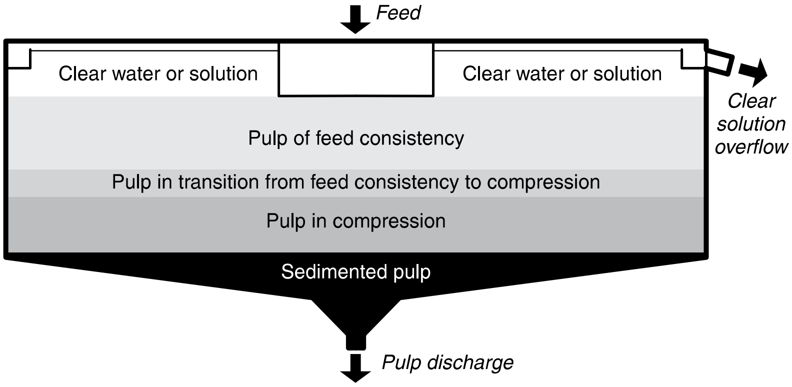
Required area is: $100/0.5 = 200\ m^2 = \frac{\pi d^2}{4} = 200$ where d is required diameter = 15.9.

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.

6.8 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.



6.9 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	
Industrial minerals conc.	k80 150 µm	15-25	50-60	3-6	1-3
Industrial minerals conc.	k80 100 µm	15-25	45-55	4-8	2-4
Industrial minerals conc.	k80 50 µm	15-25	40-50	6-12	1-5
Industrial minerals conc.	k80 30 µm	15-25	30-40	8-15	4-7
Mineral tailings	k80 90 µm	10-20	50-60	5-6	2-3
Mineral tailings	k80 50 µm	10-20	40-50	6-10	3-5
Metallic mineral conc.	k80 130 µm	20-30	60-70	1-2	0,5-1
Metallic mineral conc.	k80 80µm	20-30	55-65	2-3	1-2
Metallic mineral conc.	k80 50 µm	20-30	50-60	3-5	2-3
Metallic mineral conc.	k80 30 µm	20-30	45-55	4-7	2-3
Metallic mineral conc.	k80 20 µm	20-30	40-50	5	3-4

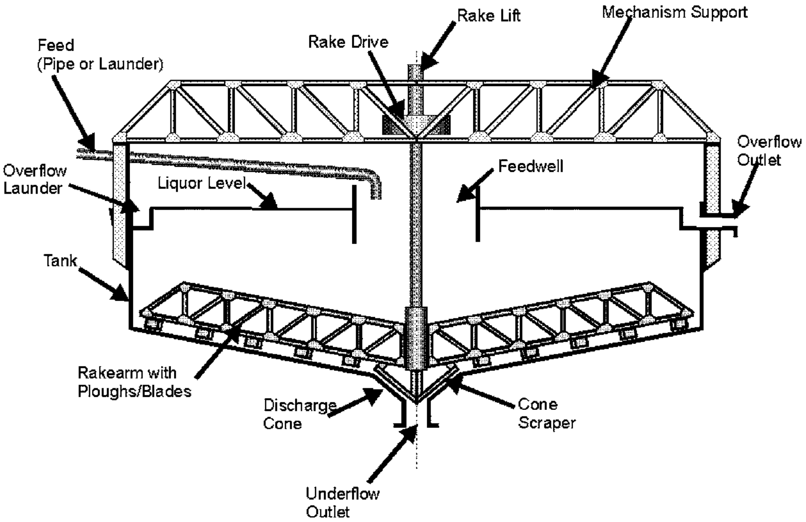
Heavy minerals are easier to treat. Mo and Zn are more difficult than i.e. Cu and Fe.

6.10 Conventional clarifier/thickener – Design*

Bridge type

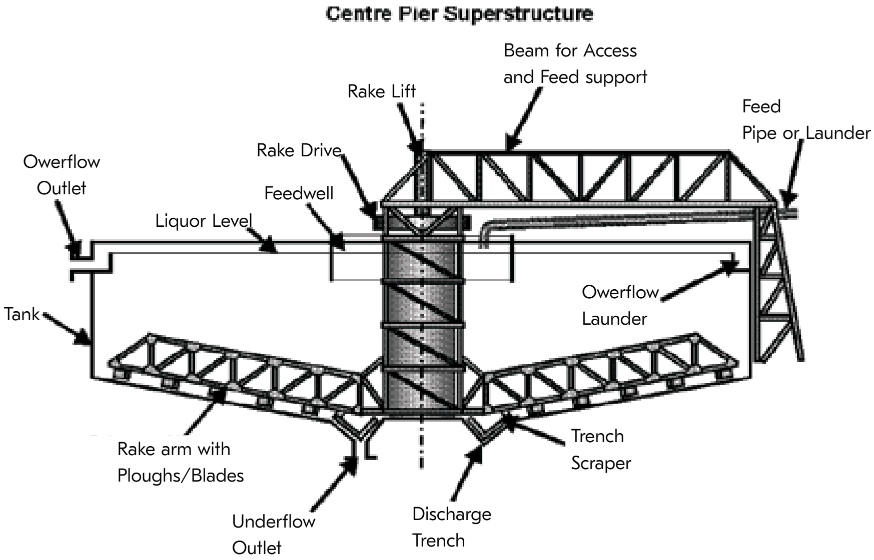
For smaller thickeners, up to 30 – 40 m diameter, the rakes and drive mechanism are supported on a bridge superstructure, which straddles the tank as shown.

See data sheet 6:10.



Centre pier type

For tanks over 30 – 40 m diameter a bridge structure will be impractical. 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.



Design options

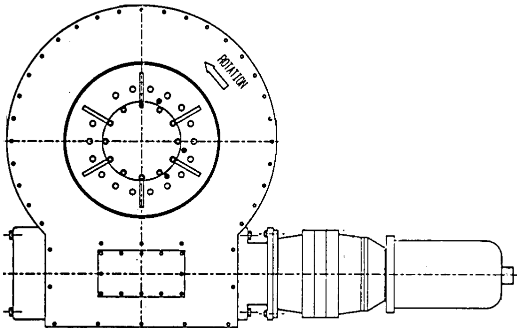
Up to 20 m elevated tank with underflow at ground level. Above 20 m tank at ground level with underflow in a tunnel.

***Contact Metso Outotec for further information about this product.**

6.11 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 toaccommodate out of balance loads on rakes
Worm and wheel and multistage epicyclic gearbox drive

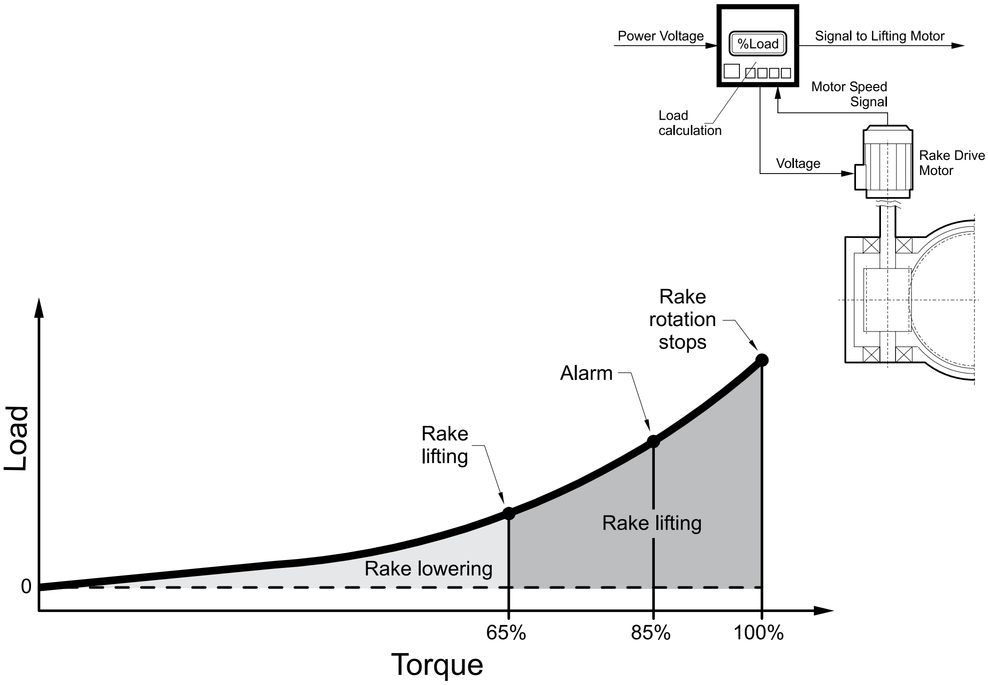


Conventional clarifier/thickener drives — torque definitions

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.
Peak torque	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.



*Contact Metso Outotec for further information about this product.

6.12 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.

Typical drive head torque rating

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

*Contact Metso Outotec for further information about this product.

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	150-200
Lime sludge	210
Pulp and paper sludge	250
Metall works process water	200-250
Gas cleaning water	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).

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

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

6.13 Inclined plate sedimentation – Introduction

Metso Outotec's inclined plate principle uses several parallel inclined plates to maximise the available area for any floor area. In this way, the size and cost of the gravity settler can be minimised by matching the thickening and clarifying requirements more closely.

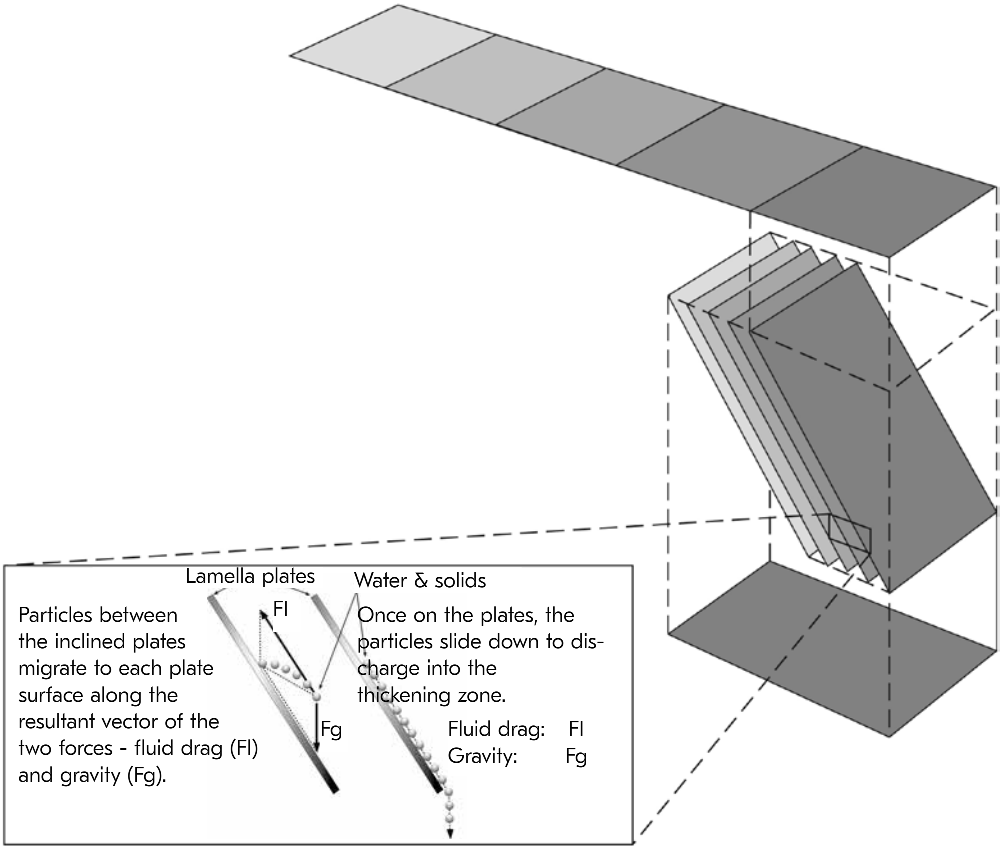
The two basic criteria for gravity settling equipment are good clarity of the over flow liquid and maximum density of the underflow solids discharge.

The area required to clarify a suspension is often greater than that needed for thickening.

This means that in a cylindrical thickening tank, the lower section with rakes and drive mechanism can be oversized.

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

Inclined plate thickening is achieved as primary thickening on the lamella plates and secondary thickening and compression in the lower inclined plate tank.

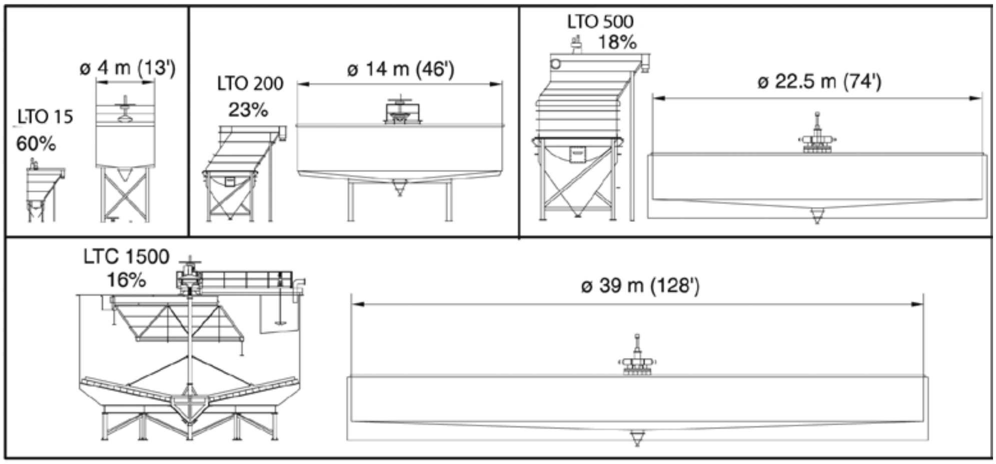


Particles between the inclined plates migrate to each plate surface along the resultant vector of the two forces - fluid drag (Fl) and gravity (Fg).

Once on the plates, the particles slide down to discharge into the thickening zone.

Inclined plates – principle

The clarifiers and thickeners are utilising the "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 (for clarification applications):



The inclined plate concept offers many practical advantages:

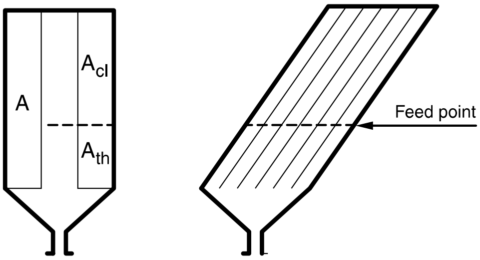
- Reduced plant area requirements
- Reduced retention time
- Possibility to optimize the ratio of clarification & thickening area
- Low heat losses – easy to insulate
- Low water losses due to evaporation – easy to cover
- Transport of the unit is more practical
- More suitable for indoor installation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

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

- High surface loads (above approx. 5.0 m3/m2h (0.28 ft3/ft2min)
- Feeds with very high solids content / sludge volumes
- High froth content (flotation concentrates)

Inclined 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.



6.14 Inclined Plate Settler – IPS

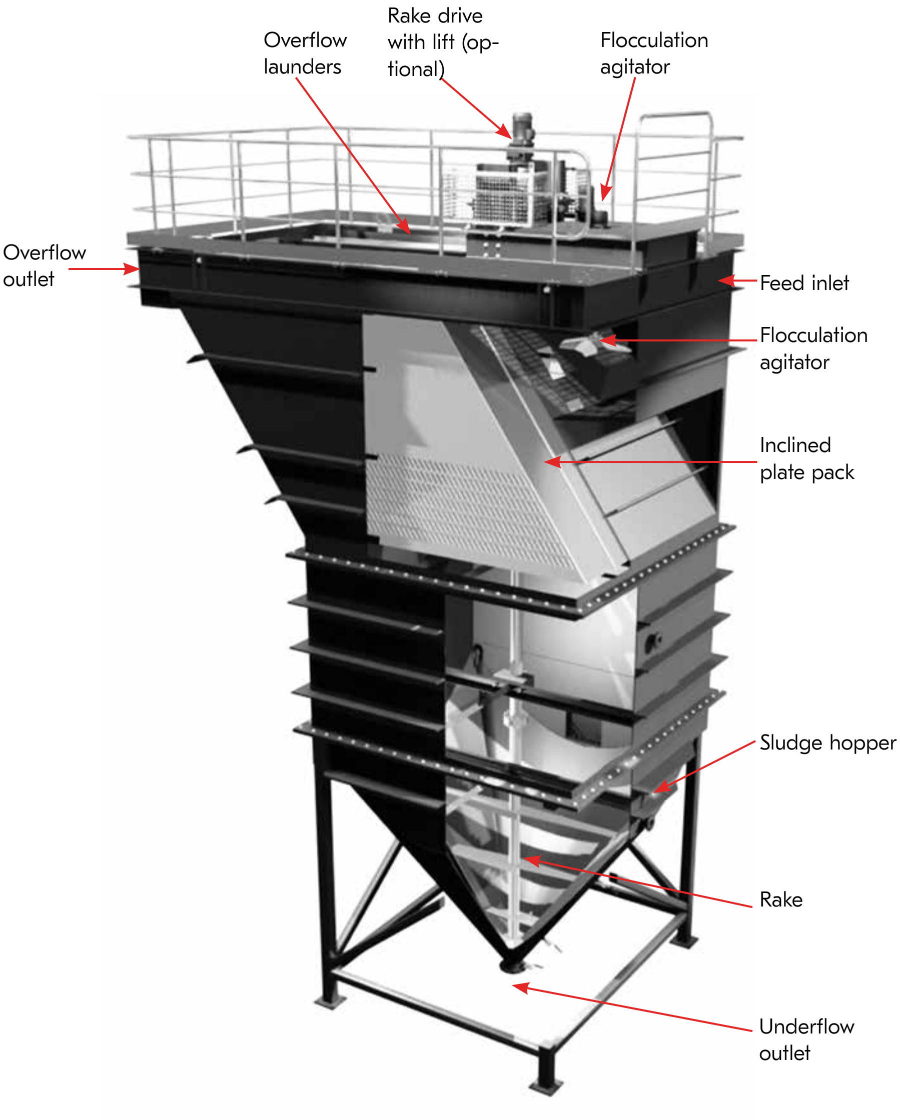
Design

The inclined plate settler consists of two main components, the upper tank containing the inclined 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 plate 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 inclined plate chambers with minimum turbulence at the entry points.

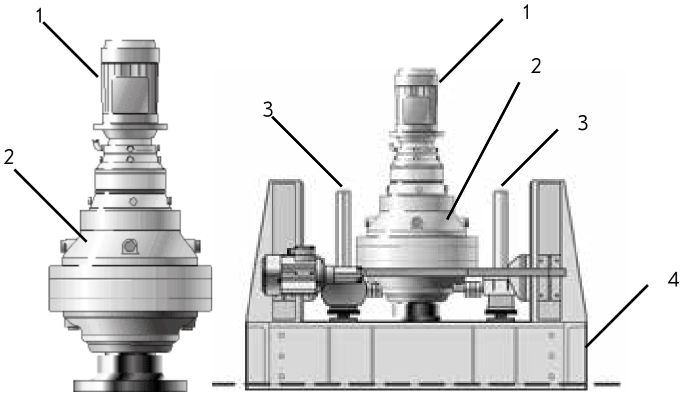
The solids settle onto and slide down each plate to the sludge container where the solids are further thickened and compressed with the assistance of the raking system.



6.15 Inclined Plate Settler — Drives

Design

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



Sizes

Drive unit	Max. operating torque		Cut - out torque		Power range		Lifting capacity	
size	(Nm)	(ft lbs)	(Nm)	(ft lbs)	(kW)	(hp)	(kN)	(lbf)
SFL 02	2 000	1 475	2 700	1 990	0.18 — 0.75	$^1/_4$ — 1	50	11 240
SFL 05	5 000	3 690	6 750	5 000	0.37 — 2.2	$^1/_2$ — 3	50	11 240
SFL 10	10 000	7 380	13 500	9 956	0.37 — 5.5	$^1/_2$ — 7$^1/_2$	50	11 240
SFL 20	20 000	14 760	27 000	19 900	0.55 — 4.0	$^3/_4$ — 5	50	11 240
SFL 30	30 000	22 140	40 500	29 900	0.75 — 5.5	1 — 7$^1/_2$	50	11 240
SFL 60	60 000	44 255	80 000	59 005	0.75 — 5.5	1 — 7$^1/_2$	100	22 480
SFL 80	80 000	59 000	108 000	79 655	3-5,5	4-7,5	100	22 480
SFL 100	100 000	73 755	135 000	99 550	3'-4	4-5,5	100	22 480
SFL 130	130 000	95 885	175 500	129 440	4-5,5	5,5-7,5	150	33 720

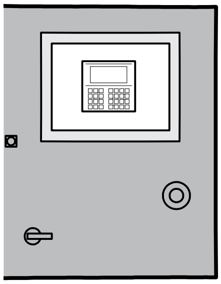
Lifting sequences

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

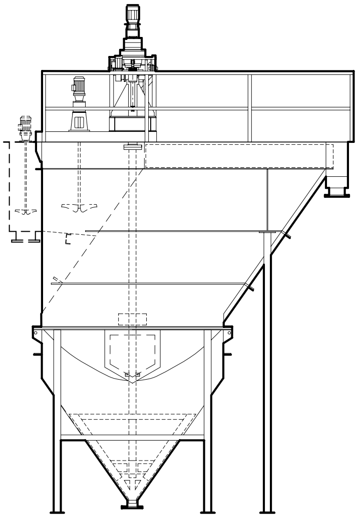


6.16 Inclined Plate Settler – Product range

Type LTO

- Sizes up to 400 m^2 (4 305 ft^2) effective clarification area (500 m^2 total projected area)
- Effective also with coarser material
- Limited solids content in feed
- Extension of lower part as option
- Lifting device as option

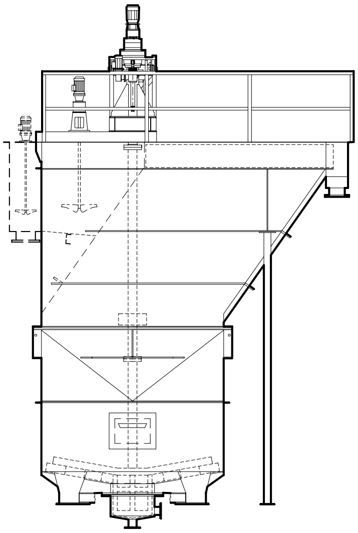
See also data sheet 6:16.



Type LTS

- Sizes up to 400 m2 (4 305 ft2) effective clarification area (500 m^2 total projected 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

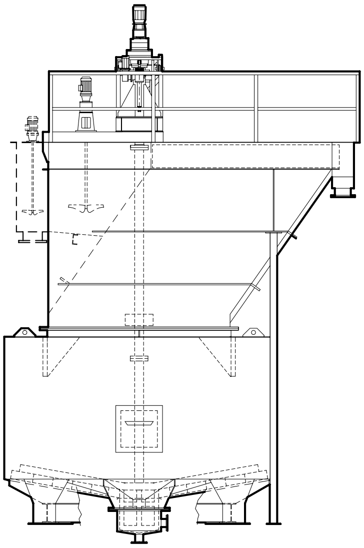
See also data sheet 6:17.



Type LTK

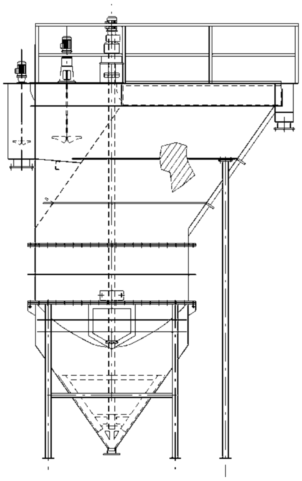
- Sizes up to 400 m2 (4 305 ft2) effective clarification area (500 m^2 total projected area)
- For higher solids load
- Used when storage and thickening is critical
- Extension of lower part as option
- Lifting device as standard

See also data sheet 6:18.



Type LTO, LTS, LTK with extended tank

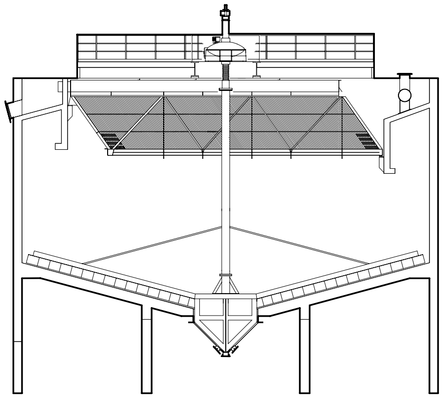
- By lower tank extensions the volume can be increased giving better storage and improved thickening.



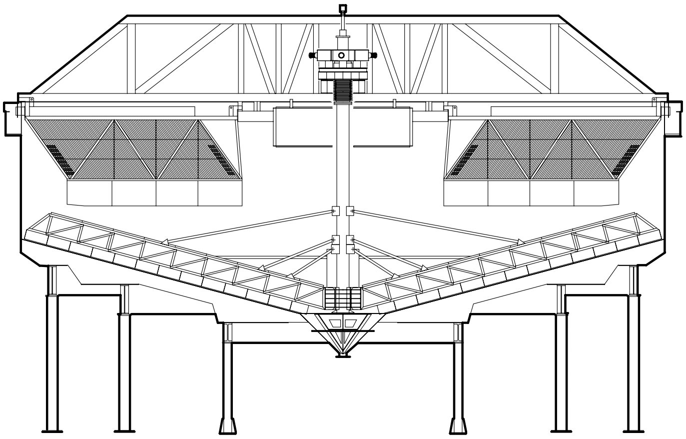
Type combi LTC

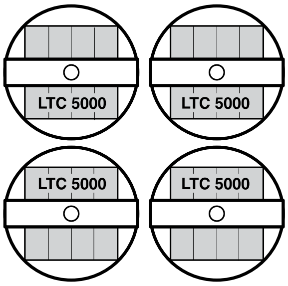
- Sizes up to tank dia 24 m (78.7 ft) = 400 m2 (53 800 ft2)
- For light and heavy duties
- High storage capacity
- Improved thickening
- Plate or concrete tank
- Conventional thickener drives

See also data sheet 6:21.



"Combi IPS" built up by using inclined plate packs in circular tanks have principally no limitation in sizes. From design point, however, max. practical area for each plate pack unit is approx. 5 400 m^2. These sizes can then be combined in modules 5 400 m^2 + 5 400 m^2 + ... (58 125 ft ^{2}+ 58 1250 ft ^{2} + ...)

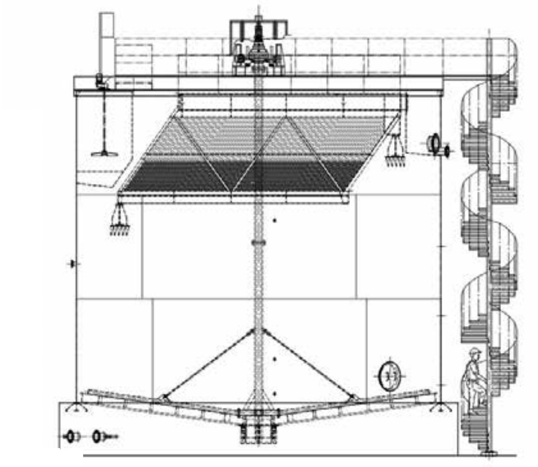




Type LTE

- Sizes up to 1 140 m2 (12 270 ft2) projected area.
- Increased solids storage capacity, e.g. for installation prior to a batch process such as a filter press.

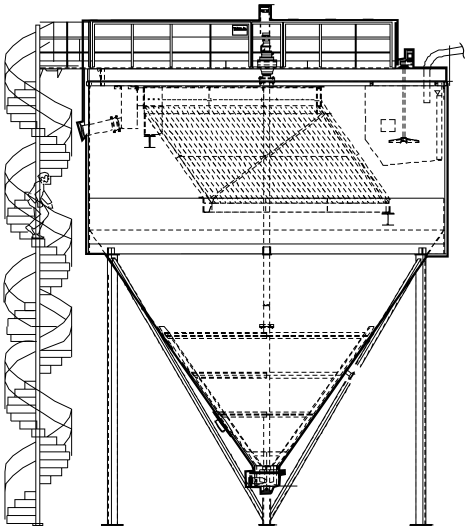
See also data sheet 6:19.



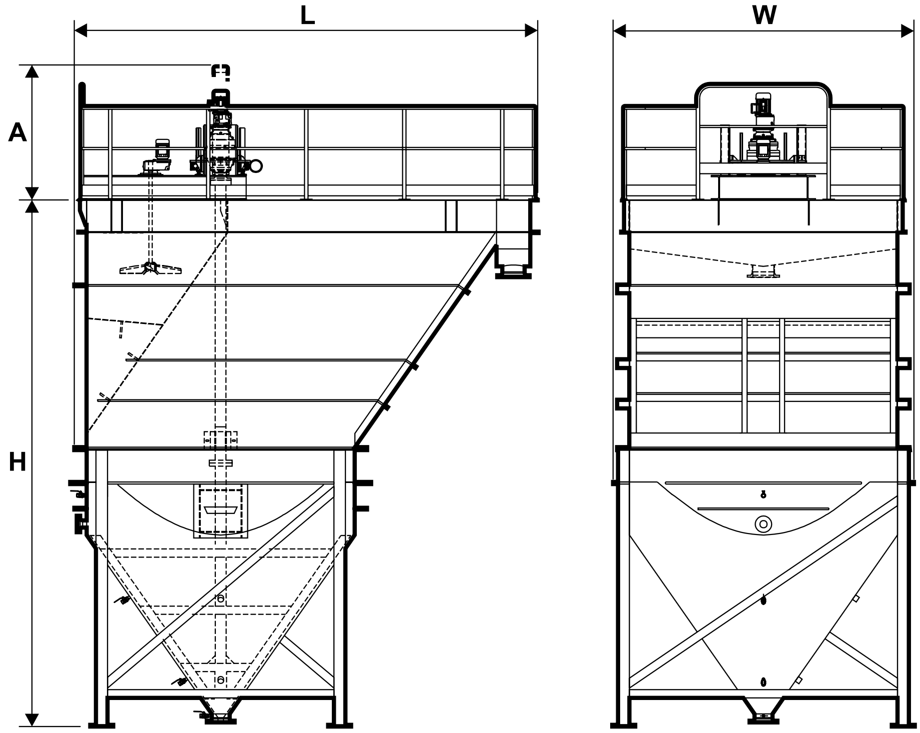
Type LTE/C

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

See also data sheet 6:20.

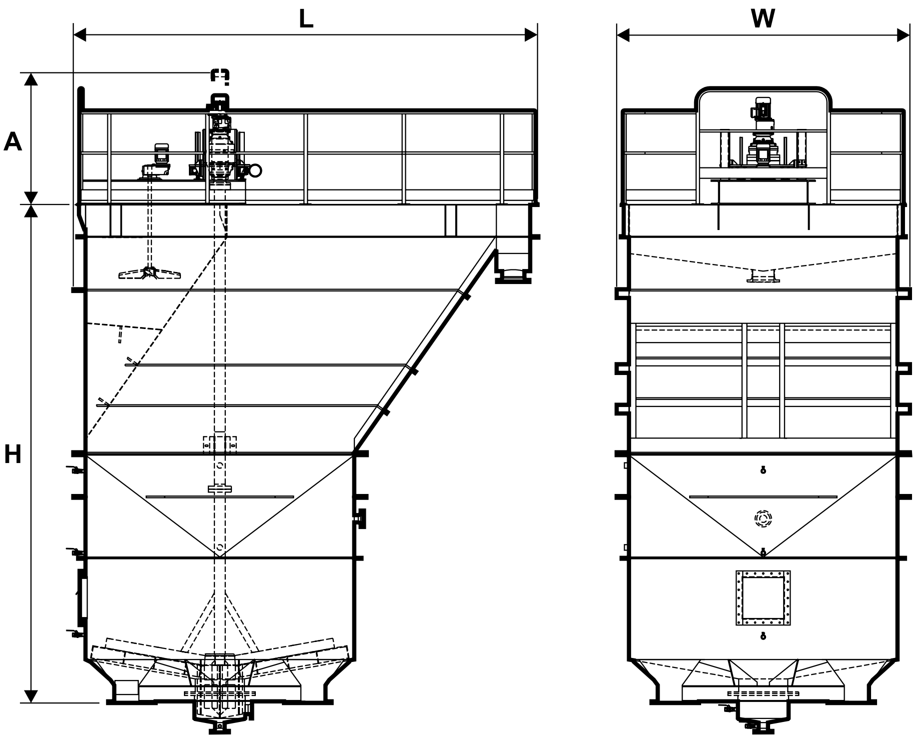


6.17 Inclined Plate Settler – LTO



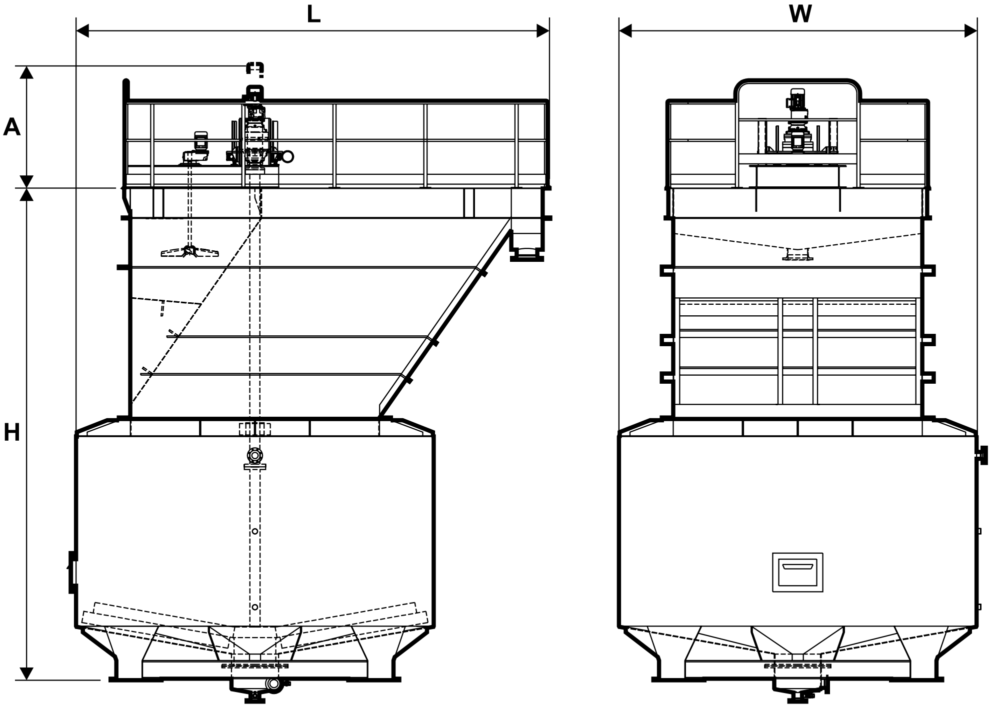
Model	H (max) mm (ft)	L mm (ft)	W mm (ft)	A mm (ft)	Total volume mm^3 (ft^3)	Sludge volume m^3 (ft^3)	Flocculator volume m^3 (ft^3)	Weight empty kg (lbs)
LTO 15	3 485	2 640	1 345	1 800	4.6	1.1	0.8	1 800
	(11.4)	(8.7)	(4.4)	(5.9)	(162)	(39)	(28)	(3 968)
LTO 30	4 300	3 430	1 830	1 800	9.2	2.3	0.8	3 500
	(14.1)	(11.3)	(6.0)	(5.9)	(325)	(81)	(28)	(7 716)
LTO 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)
LTO 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)
LTO 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)
LTO 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)
LTO 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)
LTO 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)

6.18 Inclined Plate Settler – LTS



Model	H (max) mm (ft)	L mm (ft)	W mm (ft)	A mm (ft)	Total volume mm^3 (ft^3)	Sludge volume m^3 (ft^3)	Flocculator volume m^3 (ft^3)	Weight empty kg (lbs)
LTS 15	3 750	2 640	1 345	1 800	5.2	1.7	0.8	2 000
	(12.3)	(8.7)	(4.4)	(5.91)	(184)	(60)	(28)	(4 409)
LTS 30	4 620	3 430	1 830	1 800	11.1	4.2	0.8	3 700
	(15.2)	(11.3)	(6.0)	(5.91)	(392)	(148)	(28)	(8 157)
LTS 50	4 700	3 865	2 230	1 800	18.6	6.6	2.0	5 100
	(15.4)	(12.7)	(7.3)	(5.91)	(657)	(233)	(71)	(11 244)
LTS 100	5 130	4 510	2 870	1 800	32.5	13.2	3.0	8 600
	(16.8)	(14.8)	(9.4)	(5.91)	(1 148)	(466)	(106)	(18 960)
LTS 150	5 300	5 540	3 100	1 800	45.8	18.8	4.0	11 300
	(17.4)	(18.2)	(10.2)	(5.91)	(1 617)	(664)	(141)	(24 912)
LTS 200	6 100	5 740	3 690	1 800	61.8	26.0	5.0	15 800
	(20.01)	(18.8)	(12.1)	(5.91)	(2 182)	(918)	(177)	(34 833)
LTS 350	6 200	6 910	4 500	2 000	114.0	56.0	7.0	23 000
	(20.3)	(22.7)	(14.8)	(6.56)	(4 026)	(1 978)	(247)	(50 706)
LTS 500	6 400	7 810	5 780	2 000	153.0	65.0	8.0	36 000
	(21.0)	(25.6)	(19.0)	(6.56)	(5 403)	(2 295)	(283)	(79 366)

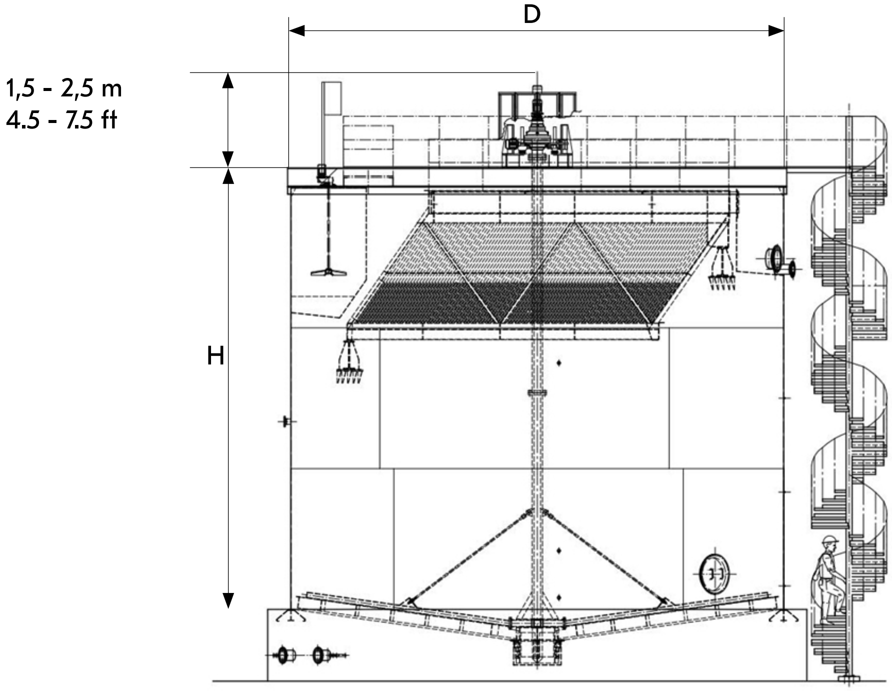
6.19 Inclined Plate Settler — LTK



Model	H mm (ft)	L mm (ft)	W mm (ft)	A mm (ft)	Total volume mm^3 (ft^3)	Sludge volume m^3 (ft^3)	Flocculator volume m^3 (ft^3)	Weight empty kg (lbs)
LTK 15	5 100	2 795	1 610	1 800	8.0	4.5	0.8	2 200
	(16.7)	(9.2)	(5.3)	(5.9)	(283)	(159)	(28)	(4 850)
LTK 30	4 550	3 690	2 310	1 800	14.5	7.6	0.8	4 500
	(14.9)	(12.11)	(7.6)	(5.9)	(512)	(268)	(28)	(9 921)
LTK 50	4 800	4 170	2 810	1 800	23.5	11.5	2.0	6 200
	(15.7)	(13.7)	(9.2)	(5.9)	(830)	(406)	(71)	(13 669)
LTK 100	5 390	5 020	3 715	1 800	45.5	26.2	3.0	10 100
	(17.7)	(16.5)	(12.2)	(5.9)	(1 607)	(925)	(106)	(22 267)
LTK 150	5 800	5 885	4 490	1 800	61.0	34.0	4.0	13 000
	(19.0)	(19.3)	(14.7)	(5.9)	(2 154)	(1 201)	(141)	(28 660)
LTK 200	6 500	6 235	4 715	1 800	87.0	51.2	5.0	16 500
	(21.3)	(20.6)	(15.5)	(5.9)	(3 072)	(1 808)	(177)	(36 376)
LTK 350	6 930	7 485	6 220	2 000	143.0	85.0	7.0	26 500
	(22.7)	(24.6)	(20.4)	(6.6)	(5 050)	(3 002)	(247)	(58 422)
LTK 500	6 940	8 705	7 520	2 000	200.0	112.0	8.0	46 500
	(22,8)	(28,6)	(24,7)	(6,6)	(7 063)	(3 955)	(283)	(102 515)

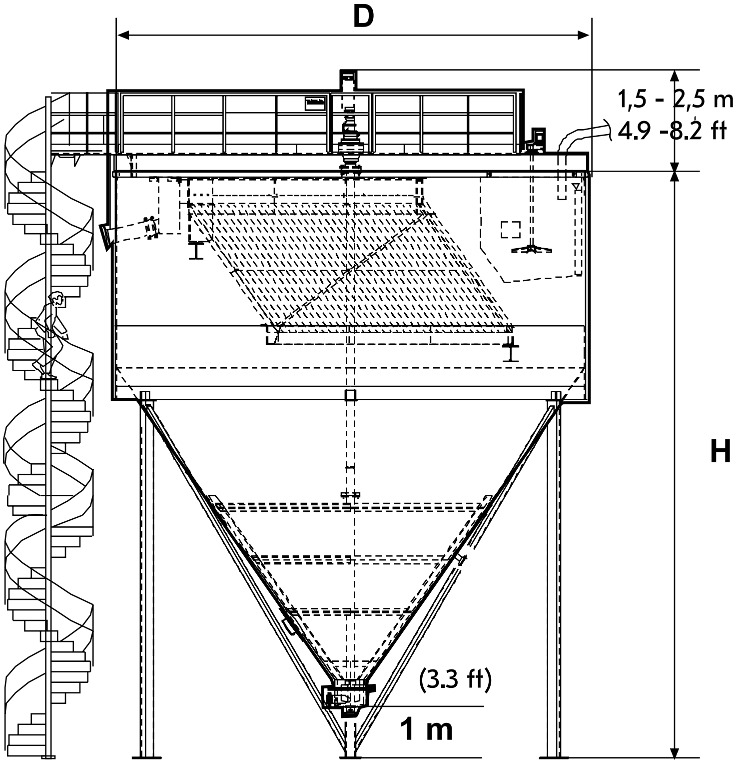
Technical data sheet

6.20 Inclined Plate Settler – LTE



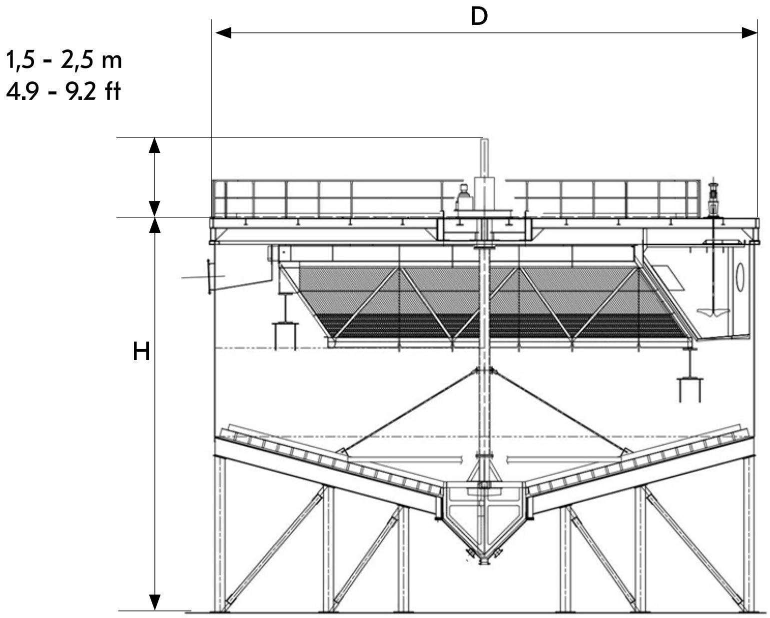
Model	Settling area m2 (ft2)	Tank dia (D) mm (ft)	Tank height (H) mm (ft)	Sludge volume m3 (ft3)	Total volume m3 (ft3)
LTE 220-6.3	220 (2 386)	6 300 (20.7)	6 000 (19.7)	86 (3 040)	192 (6 780)
			9 000 (29.5)	179 (6 320)	285 (10 065)
LTE 275-7.1	275 (2 960)	7 100 (23.3)	6 000 (19.7)	110 (3 885)	244 (8 629)
			9 000 (29.5)	228 (8 050)	363 (12 820)
LTE 440-8.3	440 (4736)	8 300 (27.0)	6 000 (19.7)	151 (5 335)	335 (11 830)
			9 000 (29.5)	314 (11 090)	497 (17 550)
			12 000 (39.4)	476 (16 810)	660 (23 310)
LTE 550-9.0	550 (5 920)	9 000 (29.5)	6 000 (19.7)	179 (6 320)	395 (13 950)
			9 000 (29.5)	370 (13 065)	586 (20 695)
			12 000 (39.4)	561 (19 810)	777 (27 440)
LTE800-10.5	800 (8 611)	10 500 (34.4)	6 000 (19.7)	246 (8 690)	541 (19 105)
			9 000 (29.5)	506 (17 870)	801 (28 290)
			12 000 (39.4)	766 (27 050)	1 060 (37 435)
LTE 1140	1 140 (12 270)	12 000 (39.4)	6 000 (19.7)	326 (11 510)	710 (25 0705)
			9 000 (29.5)	665 (23 480)	1 050 (37 080)
			12 000 (39.4)	1004 (35 4555)	1 389 (49 050)

6.21 Inclined Plate Settler – LTE/C



Model	Settling area m2 (ft2)	Tank dia (D) mm (ft)	Tank height (H) mm (ft)	Sludge volume m3 (ft3)	Total volume m3 (ft3)
LTE/C 220-6.3	220 (2 368)	6 300 (20.7)	8 500 (27.9)	66 (2 3301)	172 (6 075)
LTE/C 275-7.1	275 (2 960)	7 100 (23.3)	10 000 (33.0)	91 (3 215)	225 (7 945)
LTE/C 440-8.3	440 (4 736)	8 300 (27.2)	11 000 (36.0)	140 (4 945)	324 (11 440)
LTE/C 550-9.0	550 (5 920)	9 000 (29.5)	11 500 (37.7)	175 (6 180)	391 (13 810)
LTE/C 800-10.5	800 (8 611)	10 500 (34.4)	12 500 (41.0)	269 (9 500)	563 (19 880)
LTE/C 1040-12	1 140 (11 194)	12 000 (39.4)	13 500 (44.3)	392 (13 845)	776 (27 405)

6.22 Inclined Plate Settler – LTC



*Model	Settling area m^2 (ft^2)	Tank dia (D) mm (ft)	Tank height height (H) mm (ft)	**Sludge volume m^3 (ft^3)	Total volume m^3 (ft^3)
LTC 1140	1 140 (12 270)	12 000 (39.4)	Min. 8 050 (26,4)	345 (12 185)	710 (25 075)
LTC 1500	1 500 (161 145)	12 500 (41.0)	Min. 8 400 (27.6)	330 (11 655)	715 (25 250)
LTC 1500	1 500 (161 145)	15 000 (49.2)	Min. 9 465 (31.1)	620 (21 895)	1180 (41 670)
LTC 1900/2200	1 900/2 200 (20 450/23 680)	15 000 (49.2)	Min. 9 465 (31.1)	620 (21 895)	1180 (41 670)
LTC 2300/2700	2 300/2 700 (24 755/29 060)	16 500 (54.1)	Min. 8 400 (28)	705 (24 895)	1345 (47 500)
LTC 2300/2700	2 300/2 700 (24 755/29 060)	16 500 (54.1)	Min. 10 100 (33.1)	760 (26 840)	1445 (51 030)
LTC 3450	3 450/37 135	18 000 (59.1)	Min. 10 305 (33.8)	900 (31 785)	1 735 (61 270)
LTC 3450	3 450/37 135	18 000 (59.1)	Min. 8 600 (28.2)	875 (30 900)	1 635 (57 740)
LTC 4300	4 300 (46 285)	21 000 (98.9)	Min. 9 485 (31.1)	1 170 (41 320)	2 320 (81 930)
LTC 5250/5400	5 250/5 400 (56 510/58 125)	24 000 (78.7)	Min. 10 515 (34.5)	1 720 (60 740)	3 095 (109 300)
LTC 5250/5400	5 250/5 400 (56 510/58 125)	24 000 (78.7)	Min. 9 050 (29.7)	1590 (56 150)	2 970 (104 885)

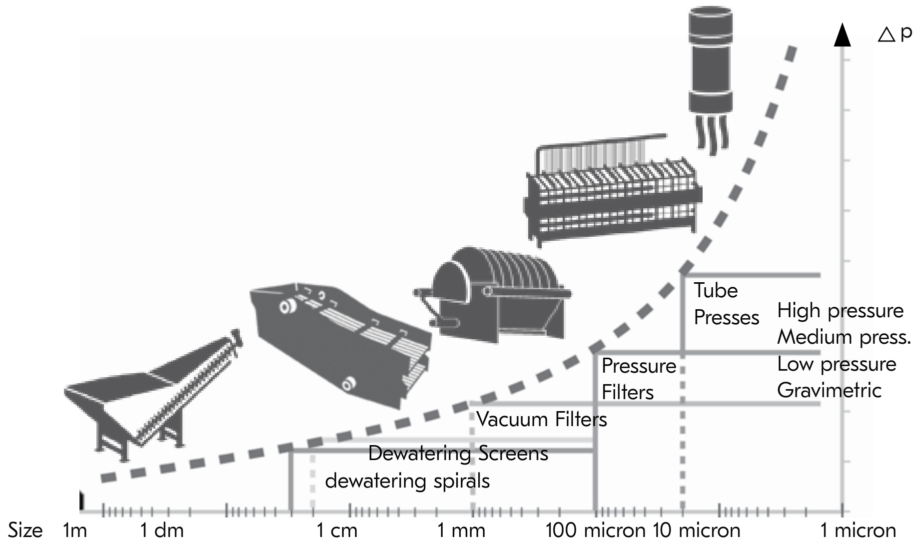
*All models except LTC 1500 with tank dia 12 500 mm has integrated flocculator chamber.

**Sludge volume from tank bottom to lamella pack lower end = max allowable.

6.23 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



6.24 Mechanical dewatering – Methods and products

Gravimetric dewatering

- Dewatering spirals (not covered)
- Dewatering screens
- Dewatering wheels (not covered)

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)

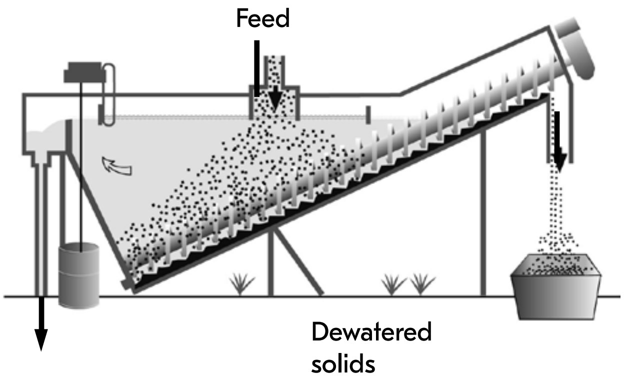
6.25 Gravimetric dewatering

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.

6.26 Spiral dewaterer

Spiral dewaterer for coarse solids
Typical application is scales removal in steel mill.

- Feed usually up to 2% solids w/w.
- 10 – 1 500 m3/h (44-6 600 USGPM)
- Remaining moisture
- 5-20% w/w.
- Large sedimentation pool
- Oil skimmer as option



See also data sheet 6:24.

Spiral dewaterer – Sizes

Model	Pool area (m^2)	Pool area (ft2)
SDC45-3	3	32
SDC45-5	5	54
SDC45-7	7	75
SDC60-10	10	108
SDC60-20	20	215
SDC60-40	40	430
SD60-100*	100	1 075
SDC60-40/100**	40-100	430-1075
SDC60-200	200	2050

* With inclined plate ** With variable inclined plate package

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 sizing use:

10 – 20 m/h (0,55 - 1,1 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.

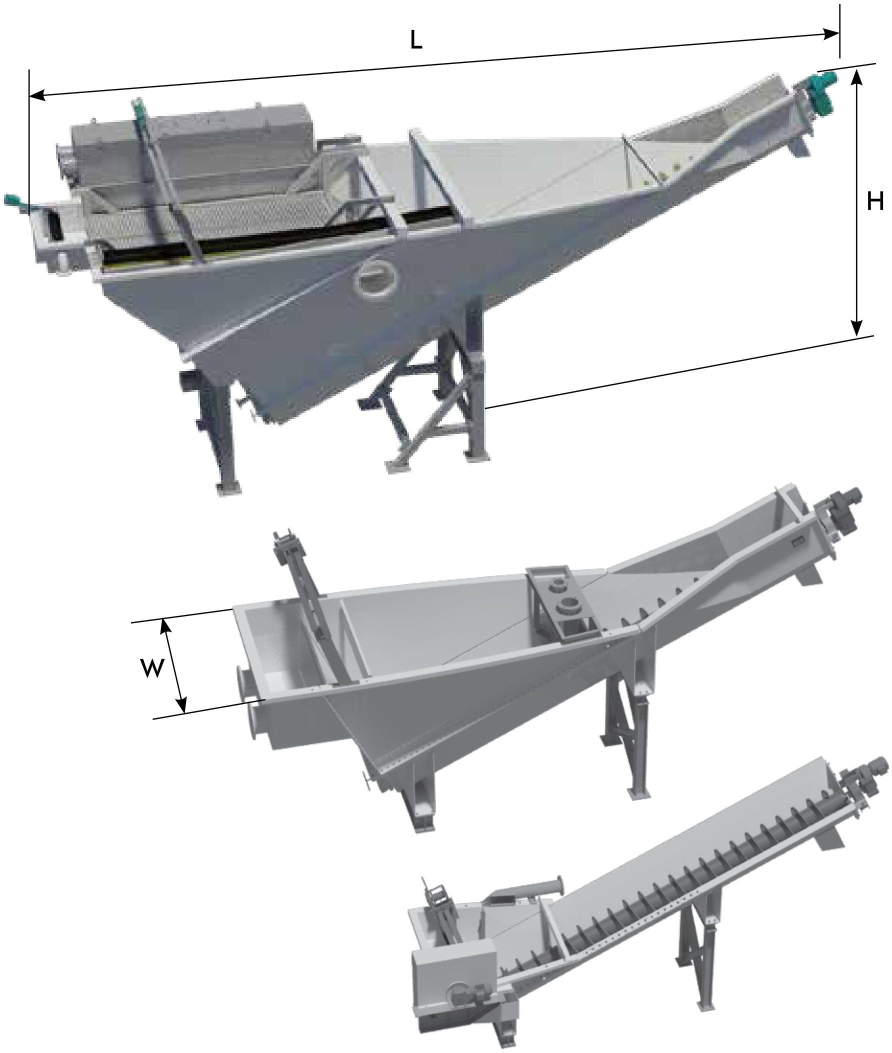
The flow is 800 m^3/h with 2 g/l mill scale.

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

Pool area: 800 / 20 =40 m^2

Select spiral dewaterer SDC 60 - 40

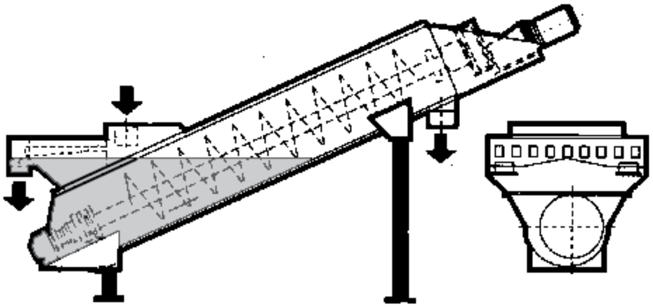
6.27 Spiral dewaterer



Model	H mm (inch)	L mm (inch)	W mm (inch)	Power kW/hp	Weight nom. flooded ton (empty)	Tank volume m^3 (ft^3)
SDC45-3	3450 (136)	6700 (264)	2000 (79)	1.5 (2)	2,3	1.4/1.8 (49/64)
SDC45-5	3450 (136)	6700 (264)	2150 (85)	1.5 (2)	2,5	3,5/4,2 (123/148)
SDC45-7	3450 (136)	6700 (264)	2200 (87)	1.5 (2)	2,7	5,9 /6,6 (208/233)
SDC60-10	4550 (179)	9200 (362)	2620 (103)	1.5 (2)	6,5	10/13 (353/459)
SDC60-20	5550 (218)	11550 (455)	3520 (139)	3 (4)	9,5	25/30 (883/1059)
SDC60-40	6450 (254)	14100 (555)	4880 (192)	4 (4)	17	60/70 (2119/2472)
SDC60-100	6450 (254)	14100 (555)	4880 (192)	4 (5)	18,5	60/70 (2119/2472)
SDC60-40/100	6450 (254)	14100 (555)	4880 (192)	4 (5)	19	60/70 (2119/2472)

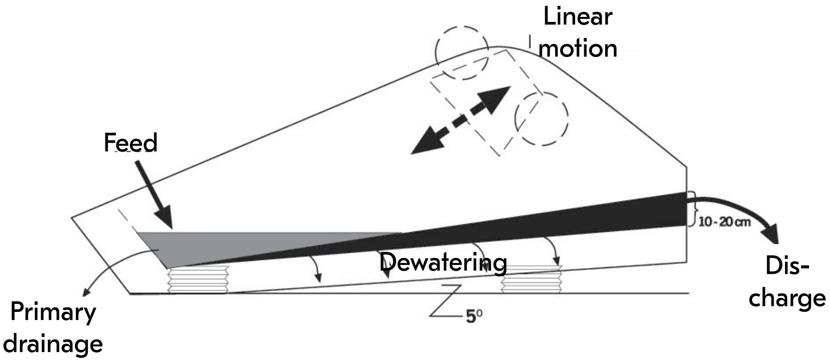
6.28 Sand screw*

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.



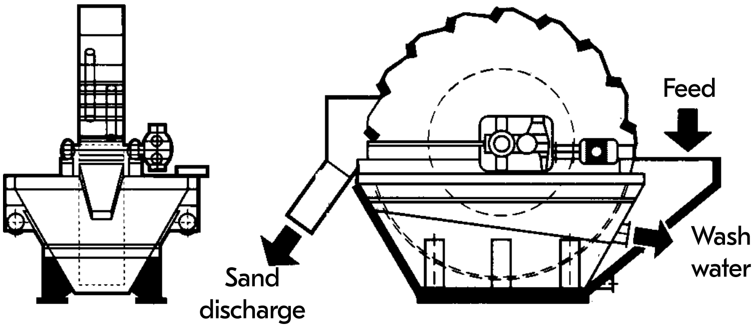
6.29 Dewatering screen*

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.



6.30 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.

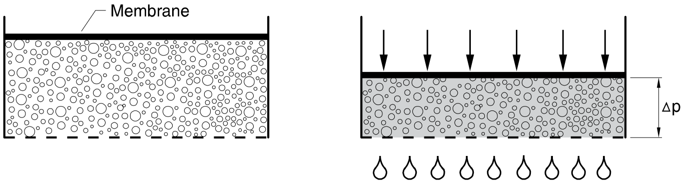


*Not available from Metso Outotec.

6.31 Mechanical dewatering by pressure – Introduction

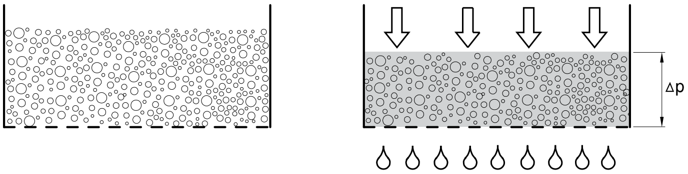
As particles get finer the resistance against removing water increases. Gravity dewatering can no longer be used. Pressure has to be applied.
By creating a differential pressure Δp across a cake of solids, liquid can be removed by

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 (air through blow) is used. The Tube Press also enables cake washing.

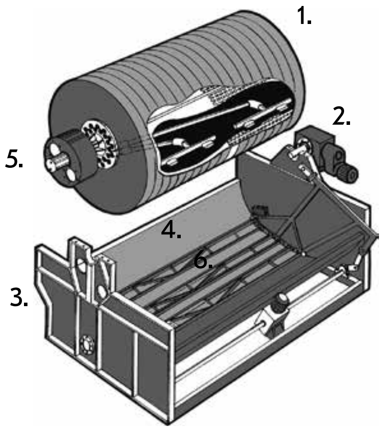
Cake wash can be applied to any of these filters

6.32 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.

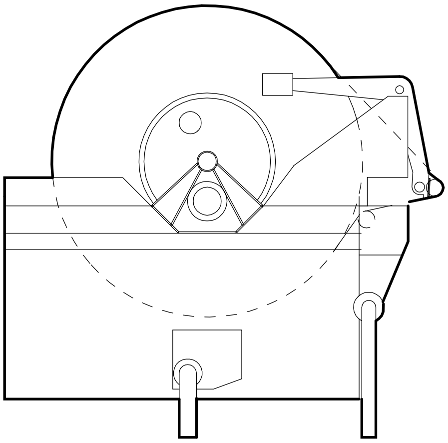
Drum filter

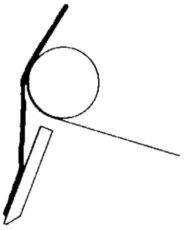
1. **Drum** – filter cloth mounted on segment grids. Internal drainage pipes.
2. **Drum drive** – variable speed
3. **Support frame**
4. **Tank**
5. **Vacuum head** – seal arrangement to connect rotating drum to stationary vacuum piping
6. **Agitator** – to suspend solid particles in tank



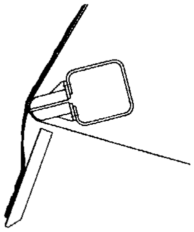
6.33 Belt drum filter*

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.

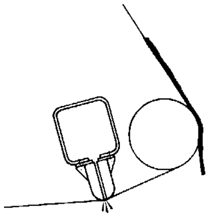




Break roller



Air knife

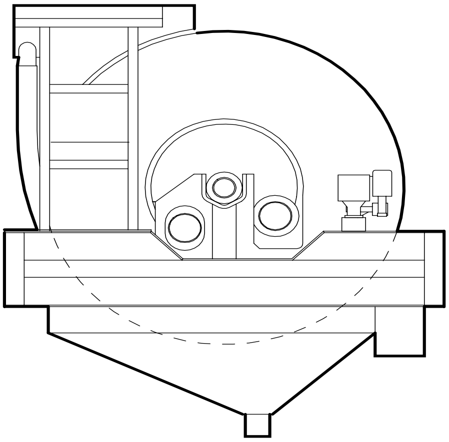


Break roller and air knife

*Contact Metso Outotec for further information about this product.

6.34 Top feed drum filter*

A top feed drum filter is designed to dewater de-slimed 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.

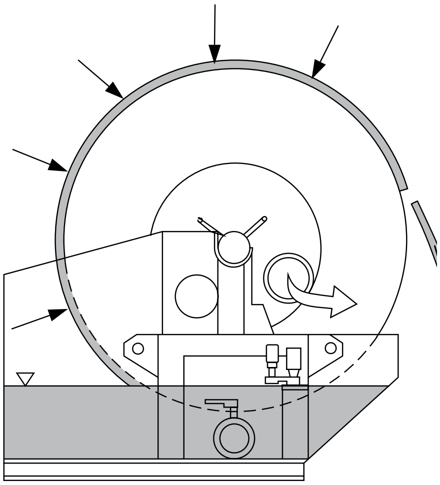


*Contact Metso Outotec for further information about this product.

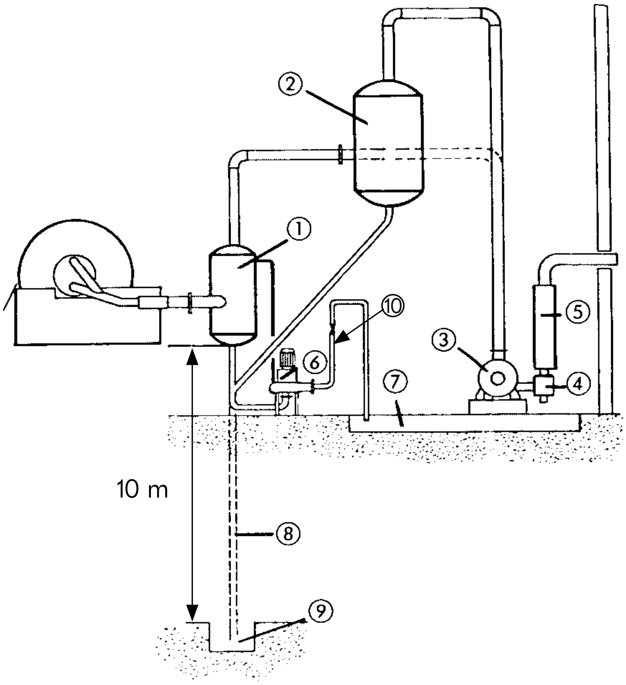
6.35 Vacuum filters – Vacuum requirement

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.



6.36 Vacuum plant – Arrangement



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

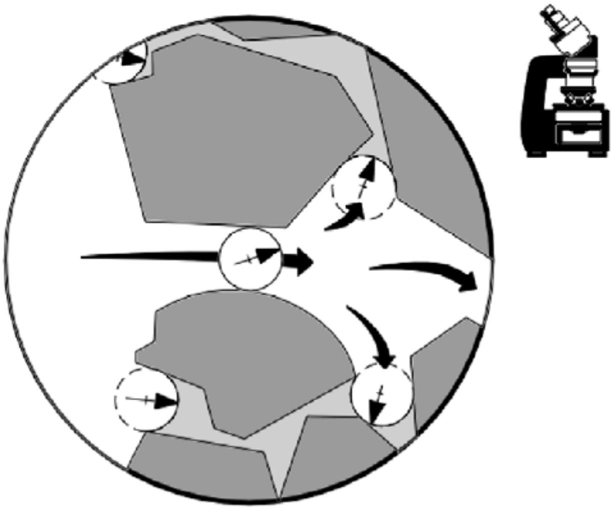
For plants without filtrate pump also:

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

* Normally used for aggressive filtrates only.

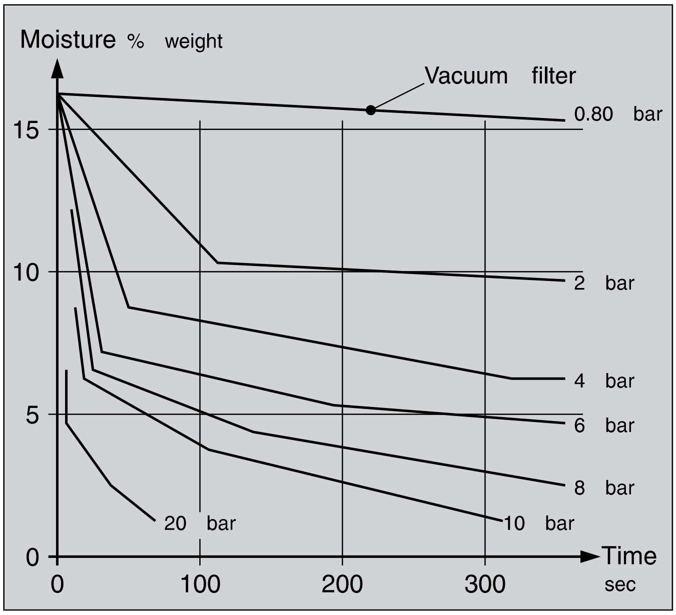
6.37 Vertical plate pressure filter – Introduction

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.

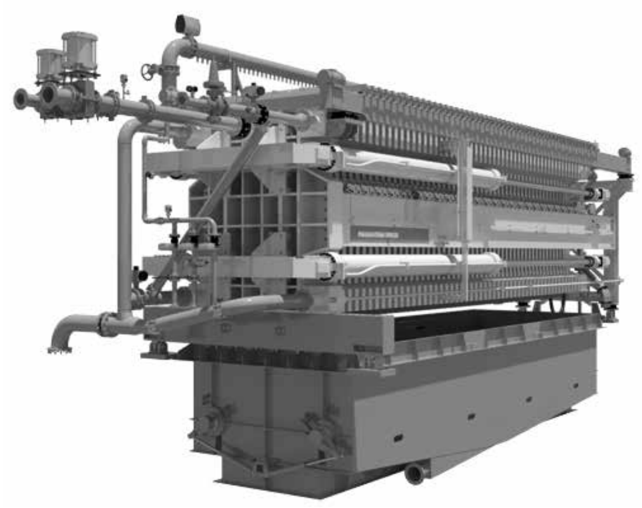


Air penetration through a pore system

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, as smaller voids are emptied from liquid.



6.38 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 8 – 10 bar (116-145 psi)

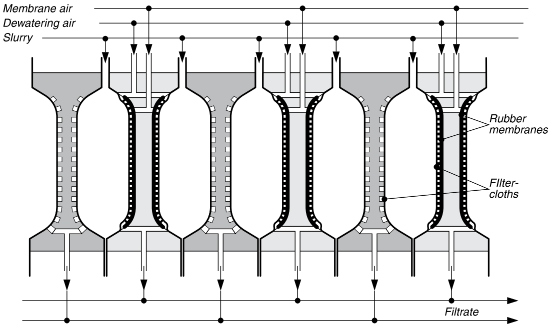
6.39 Pressure filter VPA – Operation

Pretreatment

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

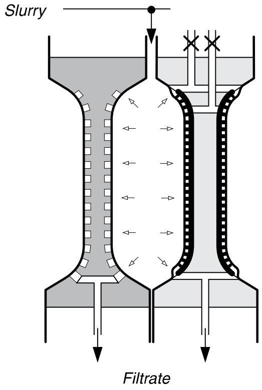
Dewatering cycle

Start position



Step 1 — Filtration

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

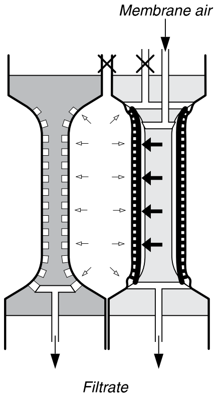


Step 2 — Compression

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.

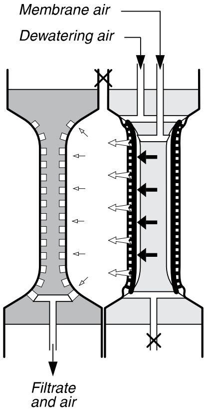
These are the dewatering steps. In cases when throughblow is not applicable and filter is used for compression, only step 1 and 2 are used.



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.



Service cycle

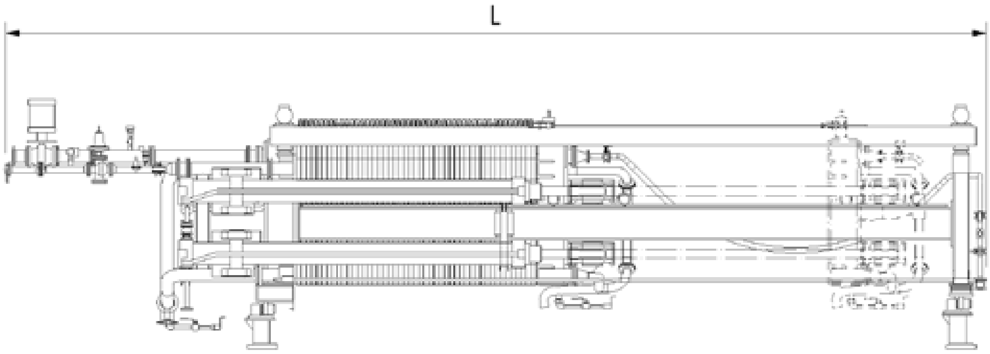
In addition to the above dewatering steps the complete process includes a number of so called technical steps.

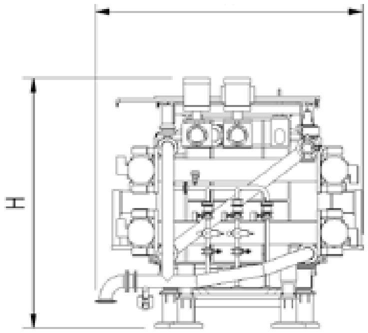
Step 4 — 9 — Service cycle

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

6.40 Pressure filter VPA – Nomenclature

Filter model	VPA 10XX-YY	VPA 15XX-YY	VPA 20XX-YY
Filter size	10	15	20
Chamber depth	XX mm	XX mm	XX mm
No. of chambers	YY	YY	YY





6.41 Pressure filter VPA – Technical data

Number of chambers		VPA 10 8 – 40	VPA 15 20 – 60	VPA 20 32 – 62
Main dimensions				
Overall length	mm	6585 – 10815	9340 – 15640	14090 – 18890
Overall width	mm	2450	3600	5250
Overall height	mm	2370	3360	4530
Installed power (hydraulics)				
High Pressure pump (in operation at all time)	kW	11	22	30
Low Pressure pumps (only in operation during opening/closing)	kW	22	55	75

The technical data is subject to change without notice

VPA 10

	Chamber depth mm	Chamber volume litre	Filtration area (feed) m^2	Filtration area (air blow) m^2
VPA 1030	30	20	1,3	0,65
VPA 1040	40	25	1,3	0,65

Filter volumes (litres)

Filter size	30 mm	40 mm
VPA 10XX-8	160	200
VPA 10XX-12	240	300
VPA 10XX-16	320	400
VPA 10XX-20	400	500
VPA 10XX-24	480	600
VPA 10XX-28	560	700
VPA 10XX-32	640	800
VPA 10XX-36	720	900
VPA 10XX-40	800	1000

Filtration areas

Filter size	Filtration area (feed) m$^{2)}$	Filtration area (air blow) m^2
VPA 10XX-8	10,4	5,2
VPA 10XX-12	15,6	7,8
VPA 10XX-16	20,8	10,4
VPA 10XX-20	26,0	13,0
VPA 10XX-24	31,2	15,6
VPA 10XX-28	36,4	18,2
VPA 10XX-32	41,6	20,8
VPA 10XX-36	46,8	23,4
VPA 10XX-40	52,0	26,0

VPA 15

	Chamber depth mm	Chamber volume litre	Filtration area (feed) m^2	Filtration area (air blow) m^2
VPA 1530	30	55	3,4	1,7
VPA 1540	40	68	3,4	1,7

Filter volumes (litres)

Filter size	30 mm	40 mm
VPA 15XX-20	1100	1360
VPA 15XX-24	1320	1632
VPA 15XX-28	1540	1904
VPA 15XX-32	1760	2176
VPA 15XX-36	1980	2448
VPA 15XX-40	2200	2720
VPA 15XX-46	2530	3128
VPA 15XX-50	2750	3400
VPA 15XX-54	2970	3672
VPA 15XX-60	3300	

Filtration areas

Filter size	Filtration area (feed) m$^{2)}$	Filtration area (air blow) m^2
VPA 15XX-20	68	34
VPA 15XX-24	82	41
VPA 15XX-28	96	48
VPA 15XX-32	108	54
VPA 15XX-36	122	61
VPA 15XX-40	136	68
VPA 15XX-46	156	78
VPA 15XX-50	170	85
VPA 15XX-54	184	92
VPA 15XX-60	204	102

VPA 20

	Chamber depth mm	Chamber volume litre	Filtration area (feed) m2	Filtration area (air blow) m2
VPA 2040	40	169	7,8	3,9
VPA 2050	50	205	7,8	3,9

Filter volumes (litres)

Filter size	40 mm	50 mm
VPA 20XX-32	5408	6560
VPA 20XX-36	6084	7380
VPA 20XX-40	6760	8200
VPA 20XX-46	7774	9430
VPA 20XX-50	N/A	10250
VPA 20XX-54	9126	N/A
VPA 20XX-56	N/A	11480
VPA 20XX-60	10140	N/A
VPA 20XX-62	N/A	12710
VPA 20XX-66	11154	N/A

Filtration areas

Filter size	Filtration area (feed) m^2)	Filtration area (air blow) m2
VPA 20XX-32	249,6	124,8
VPA 20XX-36	280,8	140,4
VPA 20XX-40	312,0	156,0
VPA 20XX-46	358,8	179,4
VPA 20XX-50	390,0	195,0
VPA 20XX-54	421,2	210,6
VPA 20XX-56	436,8	218,4
VPA 20XX-60	468,0	234,0
VPA 20XX-62	483,6,	241,8

6.42 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/liter or lb/ft^3)
Approximate cake bulk weights (ρ_{cake}) usually about 60% of specific gravity.

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
- Through blow (drying)
- Technical 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 15	7 11
Pb-conc	40 20	7 9
Zn-conc	40 20	7 9
Magnetite	40	5
Flotation tailings	36	8 - 20

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) liter

Ex. A zinc concentrate should be dewatered to 8% H2O.

The capacity is 12 t/h (dry solids) and k_{80} 35 µm.

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).
4. Cycles per hour n = 60 / 8 = 7.5
5. Filter volume V / n = (5.7 x 1 000) / 7.5 = 760 l
   Select VPA-1040-32 (800 l)

6.43 Pressure filter VPA - Moisture in filter cake

Following approximate moistures in the dewatered cakes (using 6 bar air blow pressure) can be expected.

Material	Moisture % H_2O by weight
Cu-conc medium (80% - 45 µm)	7.0 - 8.0
Cu-conc fine (80% - 15 µm)	9.0 - 11.0
Pb-conc medium (80% - 40 µm)	5.0 - 6.0
Zn-conc. medium (80% - 30 µm)	8.0 - 9.0
Pyrite conc. coarse (80% - 60 µm)	5.0 - 6.0
Hematite conc. medium (80% - 40 µm)	10 - 12
Magnetite medium (80% - 40 µm)	6.0 - 8.0
Calcite conc. fine (80% - 8 µm)	12.0 -15.0
Mineral tailings (0 - 500 µm)	15 - 20

6.44 Pressure filter VPA - Typical air flows

Compressed air for pressure filters are calculated as
"Normal cubic meters of free air at normal temperature and atmospheric pressure required per m2 of filter area per minute".
Requirement of compressed air (throughblow) at end of drying

Particle size	Compressed air	
	(Nm^3/m^2/min)	(ft^3/ft^2/min)
Mineral concentrates 80 % passing 30 µm	0.4	1.3
Mineral concentrates 80 % passing 40 µm	0.5	1.6
Mineral concentrates 80 % passing 50 µm	0.6	2.0
Mineral concentrates 80 % passing 80 µm	0.9	2.9
Mineral tailings 0-500 µm	0.4	1.3

6.45 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

6.46 Pressure filter VPA - Feed pump power (approximate)

VPA 10	55-75kW - 74-100hp
VPA 15	75-132kW - 100-177hp
VPA 20	160-200kW - 215-268hp

6.47 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)

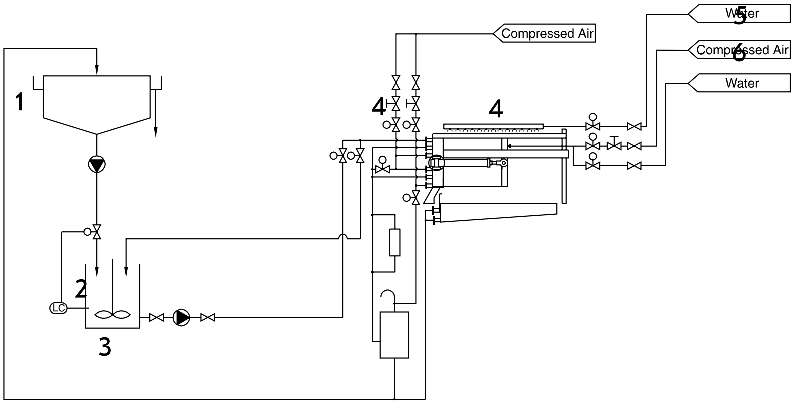
Valves for pulp, water and air. (4)

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)

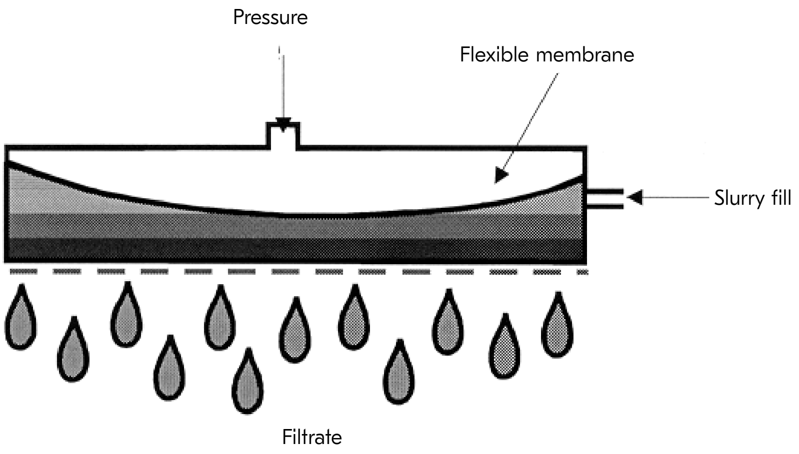
Computer based control system for operation and control of the filtration process.



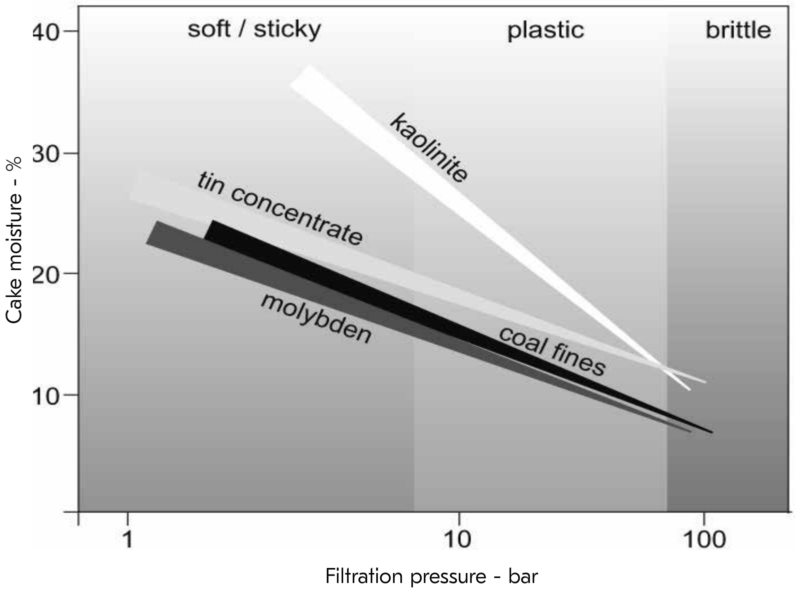
6.48 Tube press – Introduction

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 100 bar. The tube press is a variable volume filter using flexible membrane to apply high pressure mechanical compression to the slurry that is dewateried.



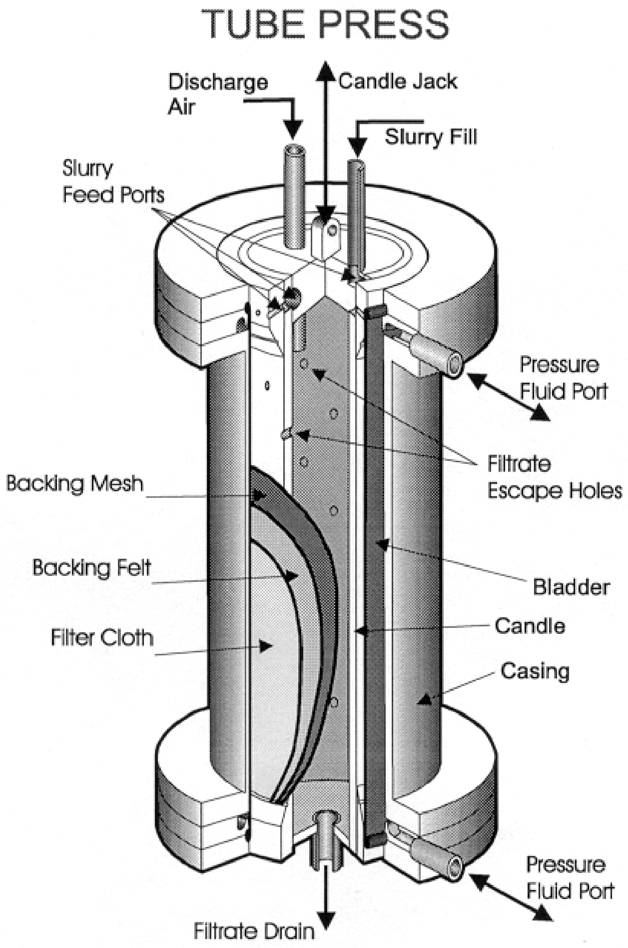
By applying a higher pressure or "driving" force to the filtration process a drier filter cake with better handling characteristics can be produced.



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.

6.49 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

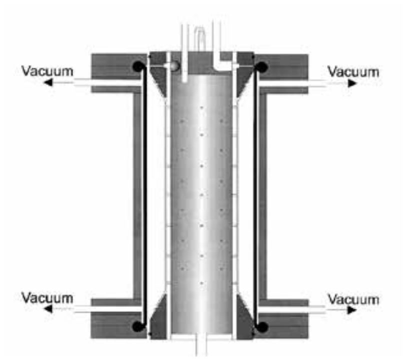


6.50 Tube press — Operation

The filtration cyle

Step 1 — Starting cycle

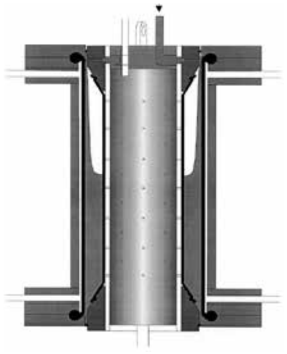
The tube press will start each cycle empty.



- The candle is in the closed position
- Hydraulic vacuum is applied
- The Bladder is pulled back against the casing

Step 2 — Slurry fill

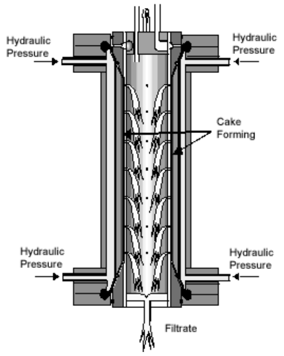
The tube press is then filled with the feed slurry.



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.

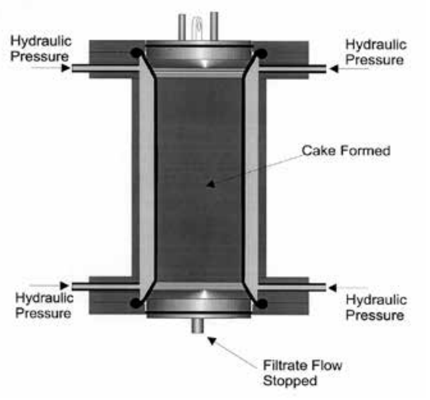


- The pressure water pushes the Bladder squeezing the slurry against the filter cloth
- The filtrate passes through the fliter cloth and runs to drain
- The solids are held by the filter cloth forming a cake

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.

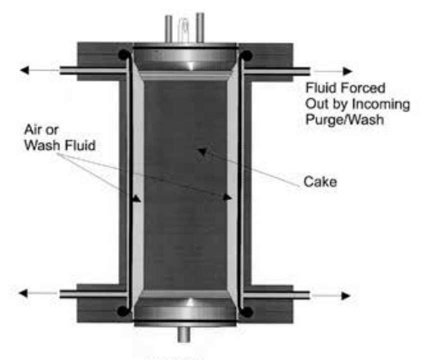


- Cake will be formed
- Filtrate will no longer flow

The next step in the process will depend on whether 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

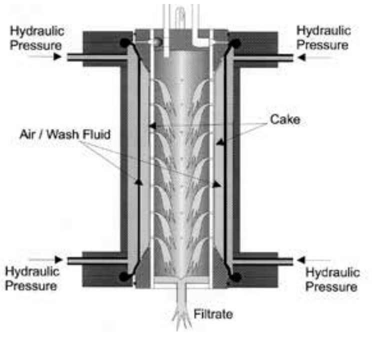
If it is necessary to treat the cake by air purging or washing, the following is carried out:



- 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.



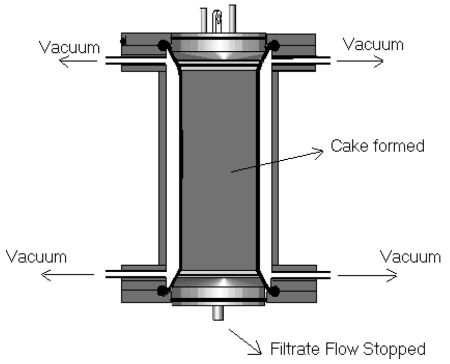
- Air purge:

— 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.

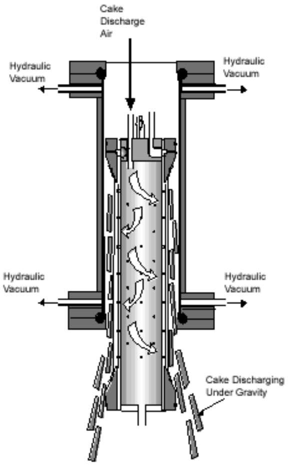


- The hydraulic vacuum draws the pressure fluid out of the tube press, pulling the Bladder away from the cake
- The bladder is pulled tight against the casing wall

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

- 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

6.51 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 (>55-60°C, 130-140°F)

6.52 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.

6.53 Tube press – Sizes

The tube press 500 series 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 (liters)	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 6:61

6.54 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.

6.55 Tube press – Cycle times and cake moisture

Typical cycle times and rest cake moisture:	time (sec)	moisture (%)
Fine coal. without air purge	220	23.0
Fine coal. with air purge	280	15.0
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

6.56 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 (% solids w/w)	Cake moisture (%)	Output/Tube 3m (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.

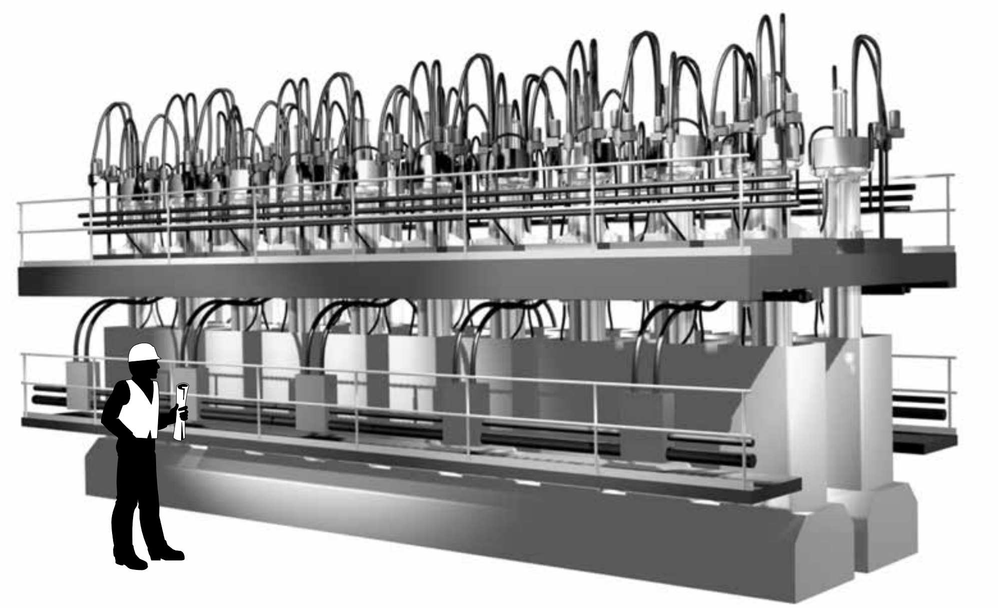
Capacity per tube = 1250 kg/h (dry)

9500/1250 = 7,6

Select 8 tube presses type 500 !

6.57 Tube press – Product systems

Pump drive

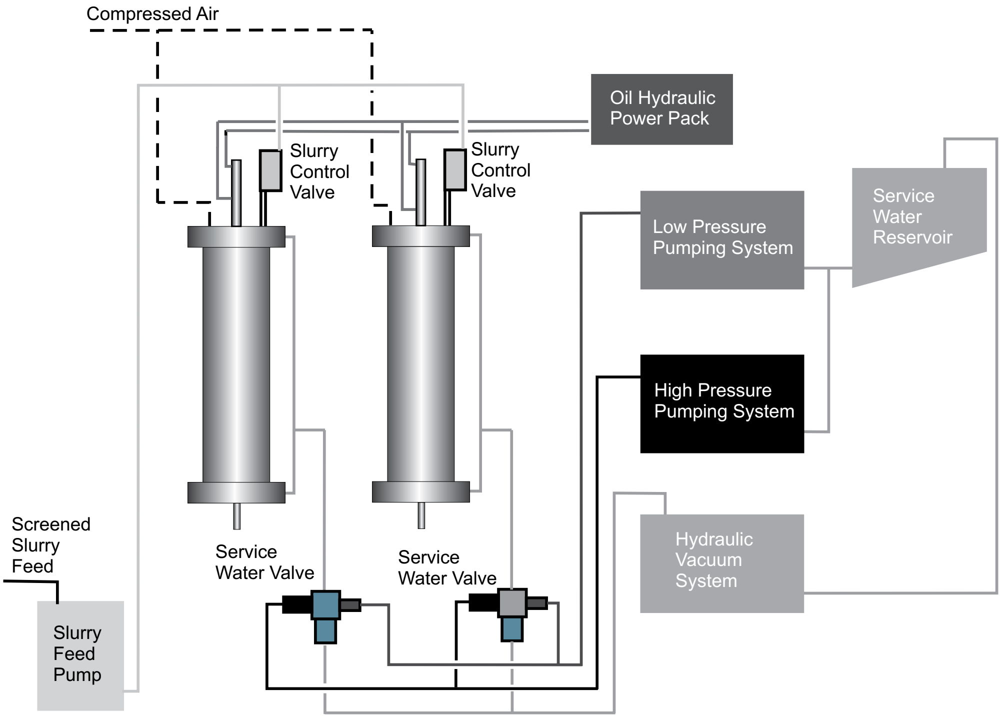


A tube press plant will contain the appropriate number of tube units according to the overall capacity required.
The units are usually supplied and installed in modules. Each module consists of a support raft to take two tube units, complete with all local valving and service header pipework. The rafts 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 ancillaries 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

6.58 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

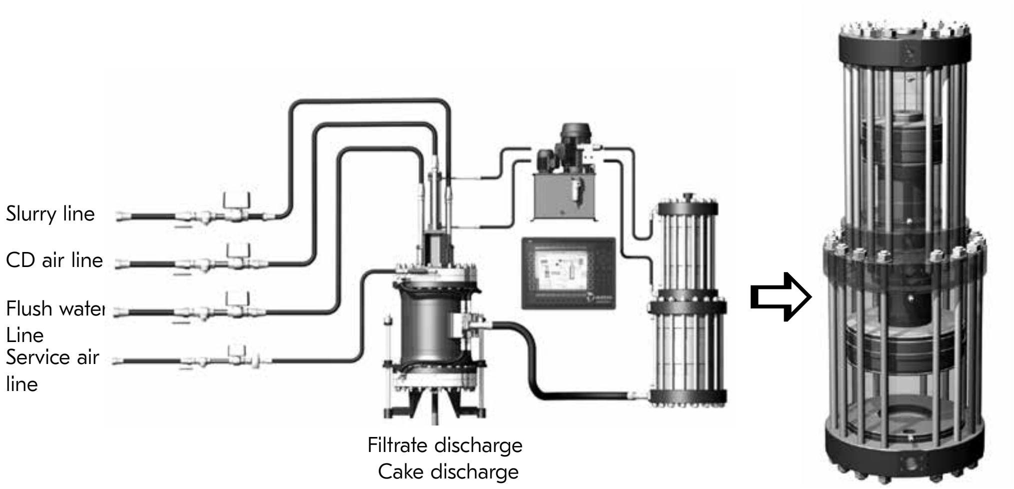
The booster is an individual drive system closely coupled with the tube press.

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.

6.59 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 booster unit into a water based pressure medium.
The pressure and dewatering speed is controlled via the control system, which is constantly receiving feedback 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

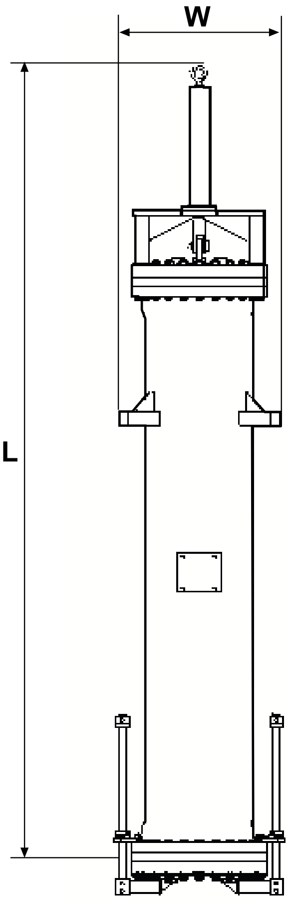
The tube press is operated from the operator's monitor located on the control panel.
The monitor is connected to a PLC that handles the control logics and interlockings.
All process specific data and parameters can be set and adjusted from the monitor in the settings menu.
Cycle time, press weight, etc., 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

6.60 Tube press



Model	L mm (inch) tube length	W mm (inch)	Weight (empty) ton	Filter area m² (ft²)	Max operating 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)	2.0	1.73 (18.6)	100 (1 450)
SC-500-3,0	5 200 (205)	860 (34)	3.0	3,45 (37.1)	100 (1 450)

6.61 Tube press booster

Model	Tube chamber volume cm³ (inch³)	Filter area m² (ft²)	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)

* Lab unit for special applications.

6.62 Thermal processing – Introduction

The level of dewatering that can be achieved through mechanical processes such as VPA's and tube presses is limited. If further upgrading is required, it must be achieved through 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®)
- Fluid bed dryers

Thermal medium (850 – 950°C)

Used for various 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 calciners

Thermal high (1300 –1400°C)

Used for vaious calcining operations
Type of equipment

- Direct heat rotary kiln
- Travelling grate and straight grate induration furnaces

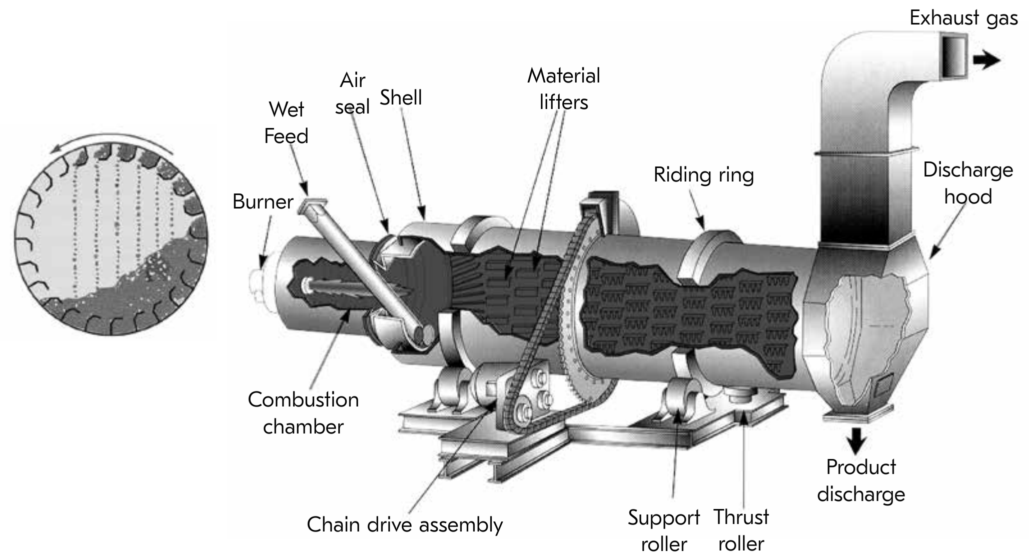
Thermal processing – basics

- Thermal processing equipment is typically 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)

For thermal processing systems, fuel consumption is one of the largest and most important Operational Expenses. It's therefore critical that systems are designed in a manner that optimizes the fuel efficiency and the overall heat balance.
As processing temperatures increase from the thermal low range to the thermal high range, there are more opportunities to conserve energy and recover heat. For instance, low temperature dryers are usually not insulated as they typically have insignificant energy losses to atmosphere. However, high temperature kilns are always refractory lined, not only to protect the mechanical parts from the high temperatures but also to reduce the energy losses through radiation to atmosphere. Additionally, the high temperatures in the product and off-gases of a kiln provide greater opportunity for heat recovery systems.

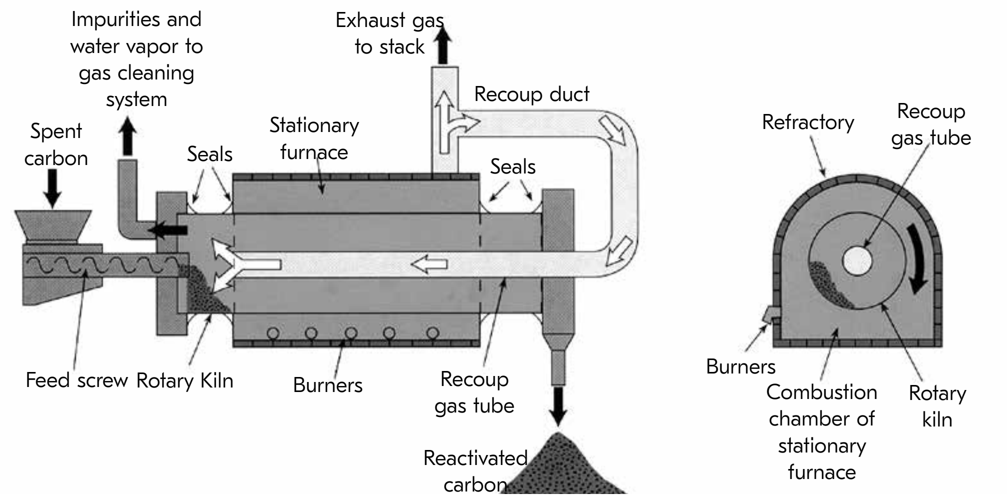
6.63 Direct heat rotary dryer (Cascade type)

- 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 <0,5-7 m (2 –23 ft), length 6 – 55 m (70 – 180 ft). Feed rates from less than 1 ton to 1000 tons per hour
- Applications in minerals, clay, sand, aggregates, heavy chemicals and fertilizers



6.64 Indirect heat rotary dryer (Kiln)

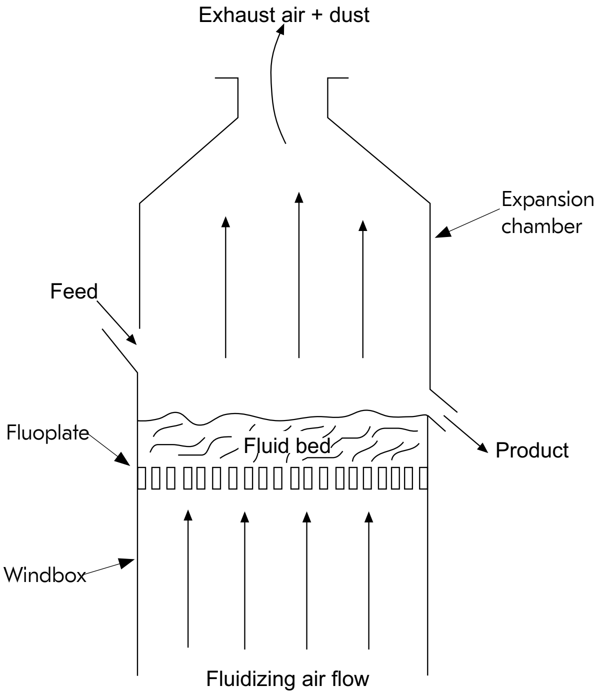
- Controlled environment interior excludes products of combustion
- Heat transfer by conduction and radiation
- Pulse-fired burners available
- Facilitates recovery of off-gases and product vapours
- Diameter 0,5m – 5,5 m (1.5-18 ft). Length 2.5 m to 28 m (8 – 90 ft).
- Applications in hazardous-, ultra fine- and combustible materials.
- Regeneration of active carbon, pyrolysis of waste rubber (car types), and plastics.



6.65 Fluidized bed

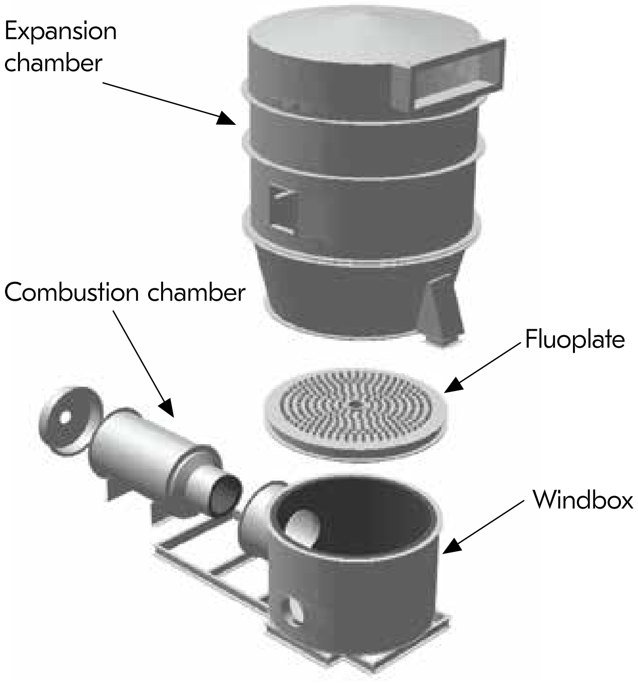
Principals

In a fluid bed, gases are forced from the windbox through a distributor plate, called the Fluoplate, which delivers the flow evenly to the particle bed and expansion chamber. As the flowrate of the gases is increased to achieve the fluidization velocity, the bed of particles expands and begins to behave very similarly to a fluid with all particles in motion.
Product is discharged from the fluid bed as it overflows a weir and spills down the product chute.



Fluidized bed — key components

- Combustion chamber
- Windbox
- Fluoplate
- Expansion chamber



Fluid bed – advantages

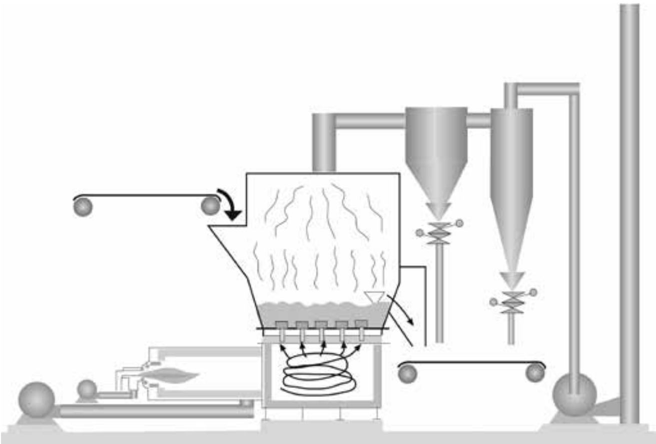
- A fluid bed behaves like a fluid allowing the use of equipment with no moving parts.
- The air/particle contact creates optimal heat and mass transfer
- Good agitation and mixing promotes consistent product quality

Fluid bed – applications

- Drying with bed temperature 100°C (212°F), (main application a)
- Cooling with bed cooled by water pipes
- Calcining with bed temperatures of 750 – 1200°C (1 382°F – 2)
- Combustion at operating temperatures of 750 – 900°C (1 382°F), (solid fuels combusted within a sand bed)

Fluid bed dryer

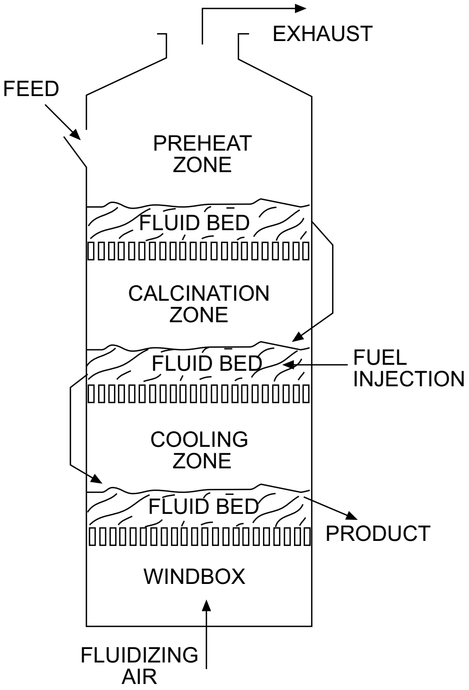
- For drying of most granular and powdery materials.
- Capacity up to 300 ton/h.
- Particle size minus 6 mm (1/4"),
- 0.25 – 1.0 mm optimal (60 – 16 mesh)
- Size range 6:1 (optimal)



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 the product zones vertically. Calcination gases preheat the feed whilst a cooling zone cools the product and preheats the fluidizing air.



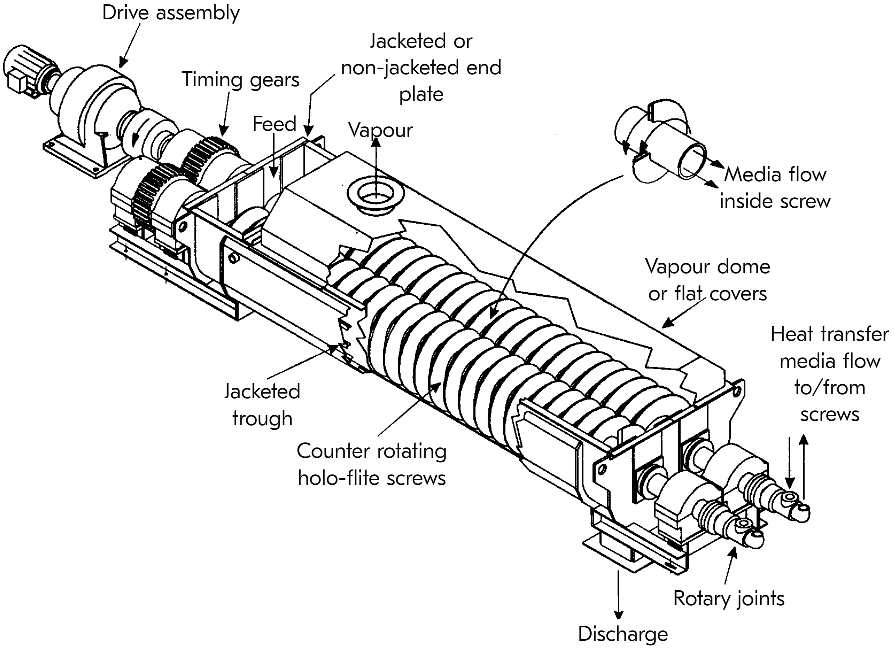
6.66 Indirect heat screw dryer (Holo-Flite®)

Operating principle

The principle for the Holo-Flite® dryer is the same as for the indirect heat rotary dryer (described earlier) 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 recirculated giving a high thermal efficiency. The design is very compact giving certain advantages in application layouts.

Holo-Flite®— design

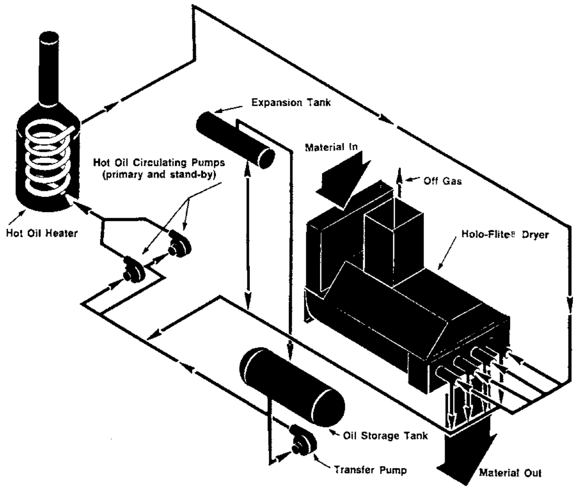
- Design can take up temperature variations 0 — 1200° C (30 — 2000° F)
- Construction material carbon steel, and various alloys as required by application for resistance to corrosion and abrasion.
- Screw diameter 178 — 915 mm
- 7 — 36"), 1,2 or 4 screws
- Concurrent or counter-current flow of heat transfer medium
- Patented twin pad design



6.67 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

Any material that can be successfully transported through a screw conveyor can also be thermally processed in a Holo-Flite®.
The only restriction is with sticky materials that adhere and build up on the surface of the transporting flights.
The maximum recommended particle size is 12mm (1/2″).
The Holo-Flite® is an excellent fit for thermally processing materials such as:

- Coal fines
- Mineral concentrates (gold, silver, molybdenum, rare earths)
- Mineral fines
- Carbon black
- Iron powder
- Other valuable granular and powdery material

Holo-Flite® — sizing

Holo-Flite® sizing is a complicated computer exercise that is normally based on laboratory 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 6:57.

Cooling technologies

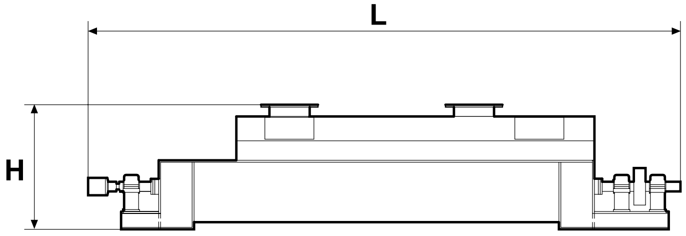
In most thermal medium and high processing applications the temperatures of discharged products are high. Coolers are used to lower the temperature for product handling equipment and also to recover heat.

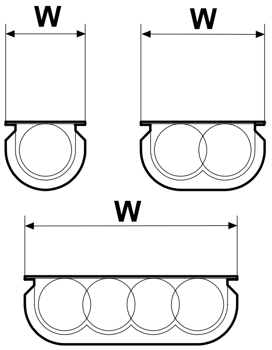
Rotary drum coolers

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** in which heat is transferred from the material to water circulated through tubes inside the cooler.
-

6.68 Holo-Flite® System common sizes





Model	H - overall mm (inch)	L - overall mm (inch)	W - overall mm (inch)	Weight empty tonnes	Power (typical) kW/hp
S0710-4*	335 (13)	4191 (165)	305 (12)	0,8	0.37/0.5
S0714-4	335 (13)	5410 (213)	305 (12)	1,0	0.37/0.5
D0710-4	335 (13)	4191 (165)	457 (18)	1,2	0.56/0.75
D0714-4	335 (13)	5410 (213)	457 (18)	1,5	0.75/1
S1210-5	565 (22)	4496 (177)	457 (18)	1,3	1.2/1.5
S1218-5	565 (22)	6934 (273)	457 (18)	1,9	2.2/3
D1210-5	565 (22)	4826 (190)	711 (28)	2,3	2.2/3
D1218-5	565 (22)	7264 (286)	711 (28)	2,5	3.7/5
S1614-6	635 (25)	6096 (240)	559 (22)	2,2	2.2/3
S1618-6	635 (25)	7315 (288)	559 (22)	2,5	3.7/5
D1614-6	635 (25)	6096 (240)	864 (34)	3,5	5.5/7.5
D1618-6	635 (25)	7315 (288)	864 (34)	4,5	7.5/10
S2414-6	881 (35)	6299 (248)	762 (30)	3,5	3.7/5
S2424-6	881 (35)	9347 (368)	762 (30)	5,5	5.5/7.5
D2414-6	881 (35)	6706 (264)	1219 (48)	6,5	7.5/10
D2424-6	881 (35)	9754 (384)	1219 (48)	9,5	11/15
Q2418-6	881 (35)	7925 (312)	2159 (85)	15,0	15/20
Q2424-6	881 (35)	9754 (384)	2159 (85)	20,0	22/30
S3022-7	1092 (43)	8941 (352)	965 (38)	7,5	5.5/7.5
S3028-7	1092 (43)	10770 (424)	965 (38)	13,0	7.5/10
D3022-7	1092 (43)	9423 (371)	1600 (63)	16,5	11/15
D3028-7	1092 (43)	11252 (443)	1600 (63)	26,0	15/20
Q3022-7	1092 (43)	9423 (371)	2870 (113)	33,5	22/30
Q3028-7	1092 (43)	11252 (443)	2870 (113)	42,0	30/40
S3622-8	1321 (52)	9017 (355)	1092 (43)	17,0	7.5/10
S3628-8	1321 (52)	10846 (427)	1092 (43)	21,0	11/15
D3622-8	1321 (52)	9525 (375)	1803 (71)	25,5	15/20
D3628-8	1321 (52)	11354 (447)	1803 (71)	32,0	18.5/25
Q3622-8	1321 (52)	9525 (375)	3226 (127)	50,5	30/40
Q3628-8	1321 (52)	11354 (447)	3226 (127)	63,0	37/50

*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

Fluid bed coolers

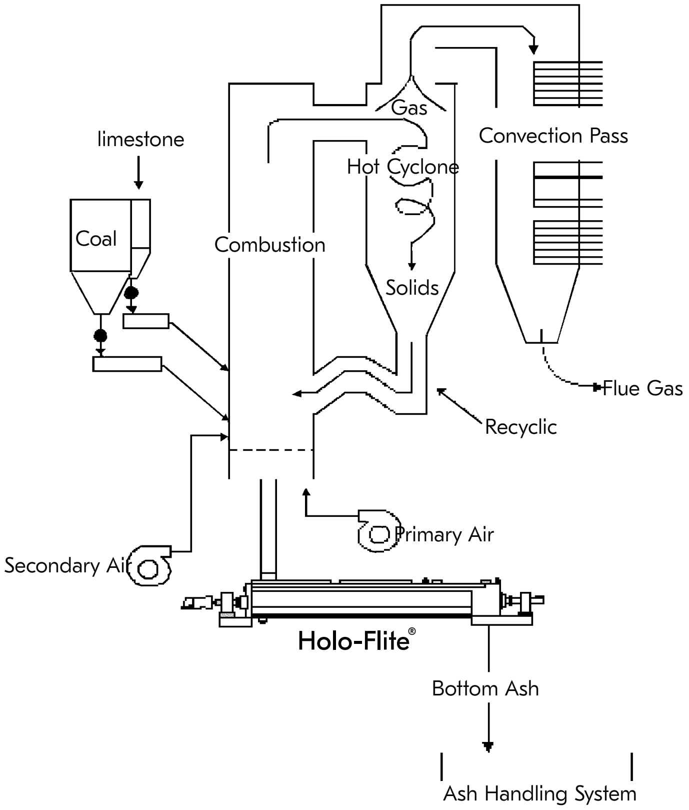
The principles of fluid bed can be used also for cooling purposes. In this case the fluid bed is cooled by the fluidizing air and internal water pipes.

Holo-Flite® coolers

The Holo-Flite® is most often used for cooling applications. In these cases, the cooling medium circulating through the screw is water or a water/glycol mixture. Since the design of the screw permits very high feed temperatures, and due to its vertically compact profile, the Holo-Flite® is a perfect fit for boiler bottom ash cooling applications.

Ash cooling – Typical applications

Circulating fluidized bed boiler



Coolers and heat recovery

Rising fuel prices and heightened awareness of environmental issues drive an ever increasing demand for energy efficiency in thermal processing systems.
The most energy efficient systems usually incorporate heat recovery that makes valuable use of the energy released from product cooling.

6.69 Iron ore pelletizing

What is iron ore pelletizing? Purpose and use of iron ore pelletizing

Pelletizing is the process through which iron ore fines are transformed into an agglomerated form called "iron ore pellets" suitable for use in an iron-making furnace such as a blast furnace or electric arc furnace. Each iron making furnace has specific iron ore pellet chemistry requirements that govern the design criteria of an iron ore pelletizing plant. In its end product form, a typical iron ore pellet is roughly spherical in shape, measuring from six mm to sixteen mm in diameter and having a crushing strength of over 200 Kg, although some variations in these typical parameters can be specified and targeted in the design process.

Under the iron ore pelletizing process, finely ground iron ore is slightly moistened and mixed with a binder. This mixture is continuously fed to a balling disc or drum that forms spheres from the ore fines. The spheres, prior to firing, are called green pellets. Upon discharge from the balling apparatus, the green pellets are separated according to size. Those within the desired size range are transported and fed into an indurating process where they are hardened (indurated) by baking in an oxidizing atmosphere. Off-size pellets are recycled back through the process. The indurating is carried out in a high temperature furnace designed and optimized to achieve the required pellet chemistry. In the final form, the finished pellet product is commonly called "fired pellets" indicating that they have been indurated and hardened. After the pellets are indurated, the fired pellets are transported and screened as necessary to the size required by the customer.

The chemistry, physical properties and metallurgical properties of the fired pellets can be adjusted to suit the end use (iron making furnace) by combining the fine ore mixture with various additives prior to firing. The temperature profile of the indurating furnace can also be adjusted to influence the physical and metallurgical properties of the fired pellets over a wide range.

Modern plants can be designed to produce in excess of 7 million metric tonnes per annum of fired pellets depending on the design requirements and indurating process employed.

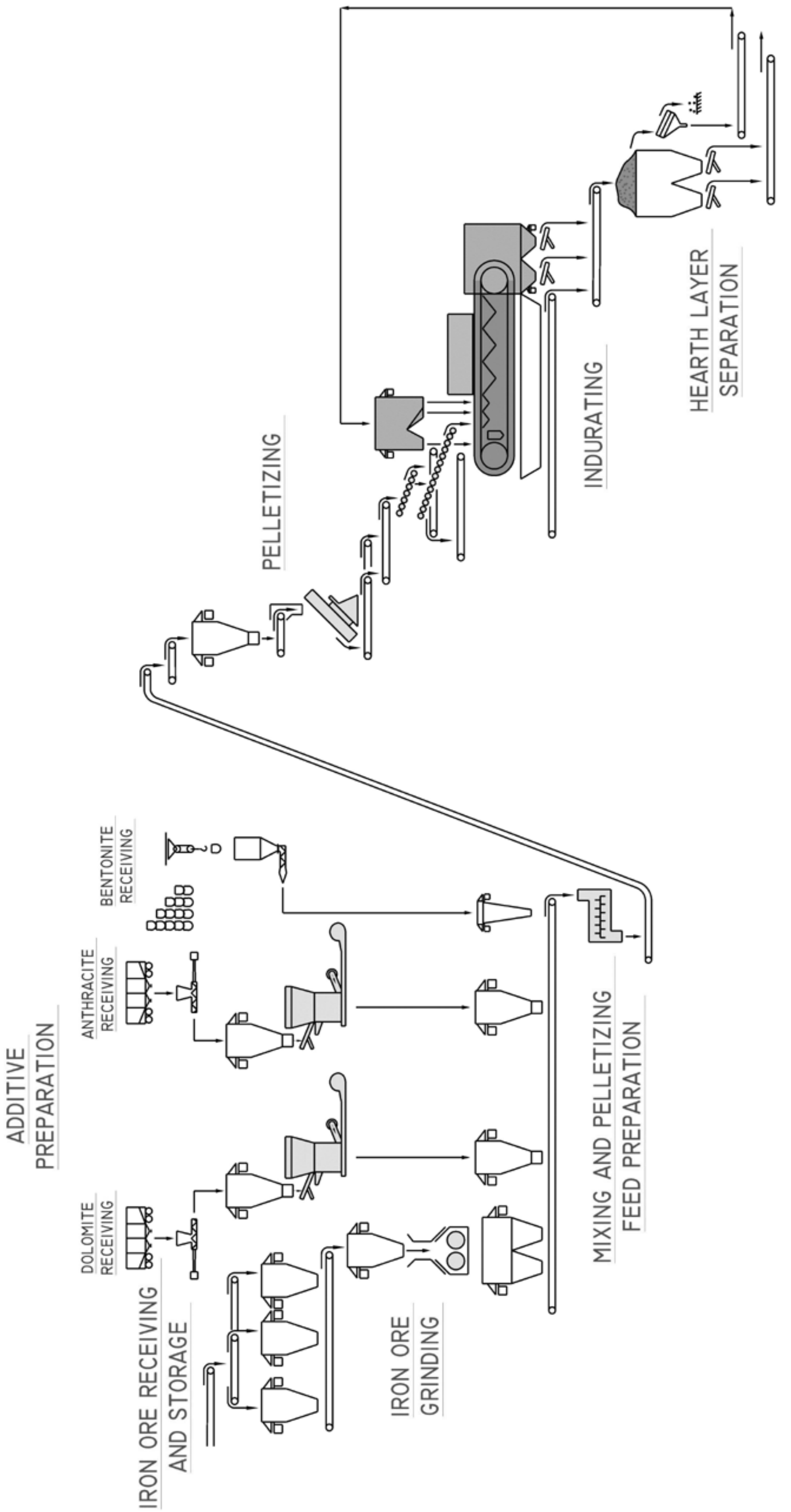
Typical unit operations for iron ore pelletizing

An iron ore pelletizing plant is typically comprised of a series of unit operations in a specific process sequence. Below is a typical schematic for an iron ore pelletizing plant.

The typical pellet plant includes **feed preparation** where green pellets are produced. These green pellets are then fed to **indurating** for firing and hardening and producing the "fired pellets". The fired pellets are then transported to the last unit operation called **product handling.** Product handling is where the fired pellets may be screened for end user size requirements, or simply transported for storage and load out, or separated and recycled back to the **indurating** furnace if needed for further processing. Product handling is variable in nature depending on the end user requirements and indurating process employed.

Note that in an iron ore pelletizing plant, the indurating process can be carried out by one of two technologies; (1) Grate Kiln technology and (2) Straight Grate technology. Both technologies are viable and proven, and are described in further details below as to when they are used and why.

6.70 Typical pellet plant schematic



Feed preparation is the process that produces the green pellet. Feed preparation is the process that combines the iron ore with certain additives to achieve a very specific chemistry for the resulting fired pellet after indurating. Feed preparation for iron ore pellet plants is typically comprised of the following processes.

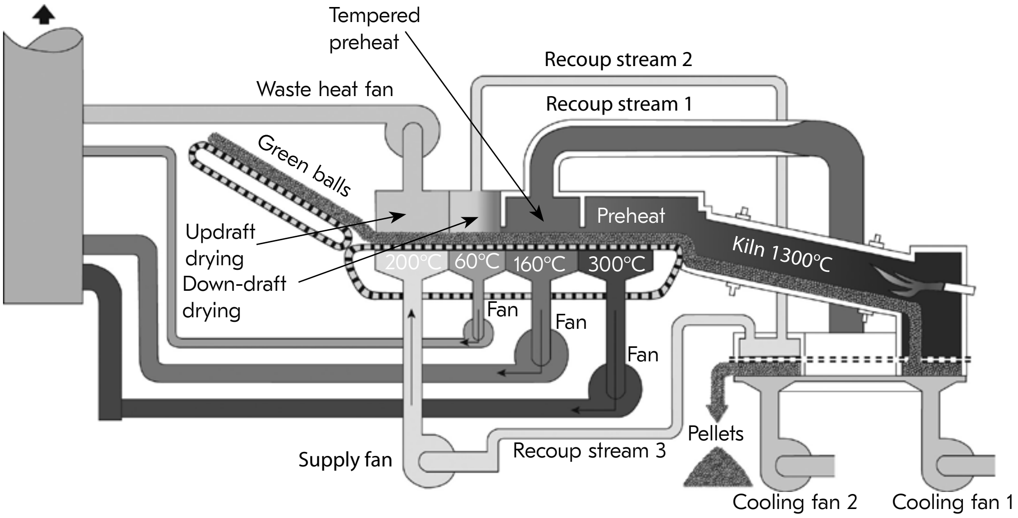
- **Additive preparation** – Depending on the criteria specified by the end user of the iron making furnace, additives will need to be combined with iron ore to produce the desired fired pellet chemistry. The quantity and type of additives are determined from laboratory testing. Typical additives for iron ore pelletizing are limestone, dolomite, coal or coke breeze, and bentonite. Bentonite is a binding agent for creation of the green balls. In some plants, alternate organic binders are used instead of bentonite. In order for the additives to be combined with the iron ore, they must meet a specific particle size requirement. If raw additives are delivered to the plant, they must be ground to proper size. This preparation is accomplished by using either air swept vertical roller mills or horizontal ball mills, depending on the capacity needs. Also, in some applications co-grinding of the limestone, dolomite and coal or coke breeze is appropriate. Bentonite must be ground separately due to significant density and hardness differences from the other additives. Depending on the feed preparation process, some of the additive grinding mills may not be required, since the additives can be co-ground with the iron ore grinding mills. Also, if the end user purchases pre-ground additive, additive grinding mills would not be required. These are all variables to be considered in the design.
- **Iron ore preparation** – Iron ore is supplied to the plant directly from the mine source or supplied from an external source. If the iron ore arrives properly sized and ground for balling (pelletizing), not much iron ore preparation is required. In this instance, the ore will be stored and handled for downstream processing. If not properly sized, the iron ore must be ground to pelletizing size. Iron ore for pelletizing is nominally 80% passing 325 mesh (44 µm), with a Blaine specific surface of between 1600 cm2/g and 1800 cm2/g. If a determination is made, via laboratory testing, that grinding is needed, grinding will be accomplished through the use of either a wet grinding process or a dry grinding process. The selection of the grinding process is determined by the type of ore, availability of water, and downstream process considerations. After grinding, the ore is stored in ground ore storage bins for the downstream processing.
- **Mixing** – Once the additives and iron ore are prepared, they are transported to the mixing area (building) via belt type conveyors where the materials are mixed and blended into a consistent material with a desired moisture content of around 10%, plus or minus some optimum amount. Mixing takes place in high intensity mixers, of either horizontal or vertical design. After mixing, the mixed ore is transported via conveyors to the balling process for making "green pellets".
- **Balling** - The mixed ore is transported to balling feed bins and then to the balling equipment which produces "green pellets" of a spherical shape and variable size distribution. The balling equipment is housed in a building called the "balling building". In the balling process, the moisture content of the mixed ore and resulting green pellets is optimized by the addition of water via spray nozzles or piping fixtures. The balling process is accomplished by metering a specific quantity of mixed ore from the balling feed bins via conveyors to the balling equipment. Typically, two types of balling equipment can be used, either balling drums or balling discs, each with their own unique operations. The nature and type of balling equipment produces the "green pellets" an amazing process to be appreciated. After balling, the green pellets are transported to the Indurating process which produces the fired pellets, the end product.
-

Indurating is the process of taking the green pellets and hardening them through a high temperature furnace application. The fired pellets are hardened such that they can withstand transportation and handling per the end user requirement. Details are as follows:

- **Machine feed** — After the balling process produces the green pellets, the pellets must be transported and fed to the indurating process. In most typical pellet plants, the green pellets are transported via conveyors from the balling process. This means of transportation is accomplished using, in sequence: (1) traditional belt type conveyors, (2) either an oscillating or reciprocating type conveyor for in-line or right angle feed, (3) a wide belt conveyor and (4) a roller screen which directly feeds the green pellets to the indurating equipment. The oscillating or reciprocating type conveyors layer and distribute the green pellets to the wide belt conveyor. The wide belt conveyor transports the pellets to a roller screen for removal of oversize and undersize pellets prior to feeding the indurating process.
- **Drying, firing and cooling** — After the pellets are fed from the roller screen, they are dried, fired and cooled. This is the indurating process. Two indurating technologies can be employed for this process; (1) Grate Kiln technology and (2) Straight Grate technology. The technology selected depends on the type and characterization of iron ore, the fuel, the desired fired pellet chemistry, and end user preferences. In both processes, the chemistry, physical properties and metallurgical properties of the fired iron ore pellets can be adjusted to suit the end user by combining the fine ore mixture with various additives prior to firing. The temperature profile in the indurating furnaces and processes can also be adjusted to influence the physical and metallurgical properties of the fired pellets over a wide range.

6.71 Grate Kiln technology

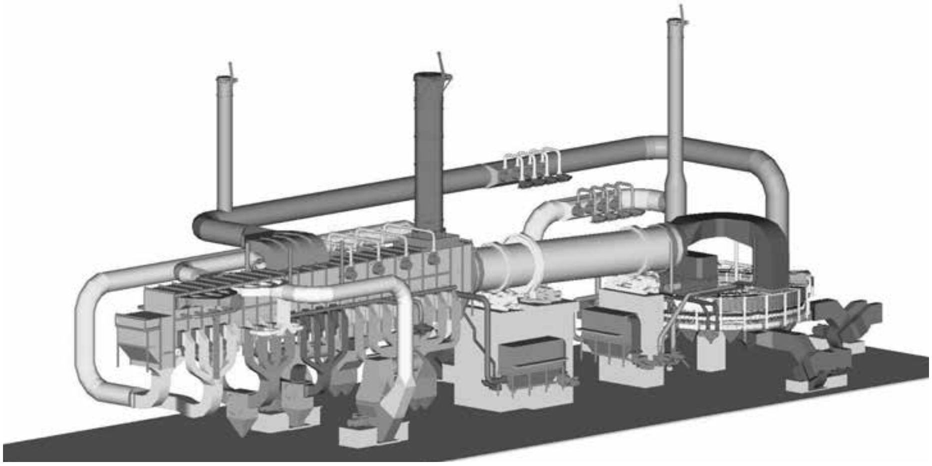
The Grate Kiln technology provides indurating through the use of a traveling mechanical grate for drying the pellets, a rotary kiln for firing the pellets and a rotating annular machine for cooling the pellets.
The following is a typical schematic of the Grate Kiln process.



The traveling grate receives green pellets, removes pellet moisture through drying, and strengthens the pellet by preheating and subsequent partial fusion (induration) of the pellet's mineral bonds. After the drying and initial preheating in the traveling grate, the partially indurated pellets are fed directly into the rotary kiln, where the primary indurating (firing of the pellets) is accomplished.

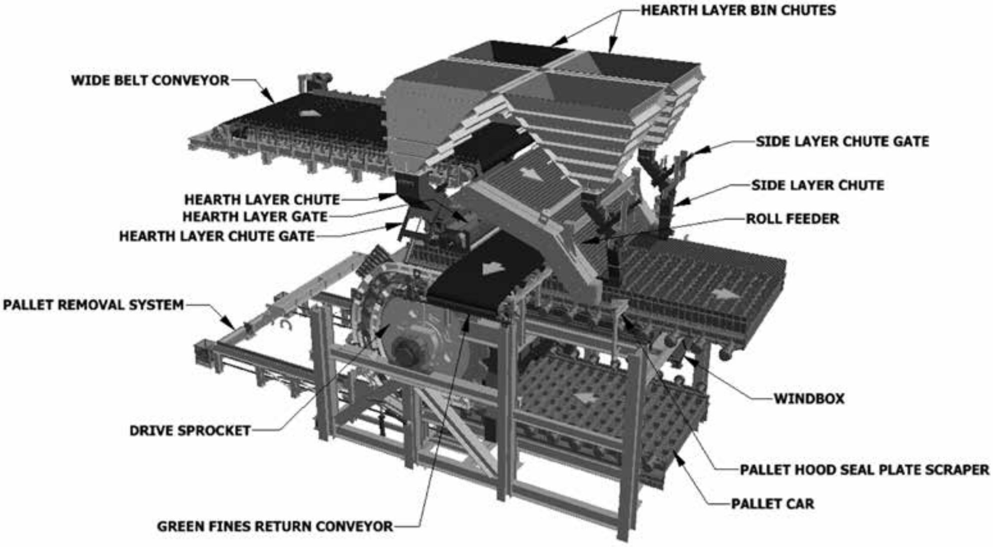
The rotary kiln is a sloped rotating cylindrical furnace comprised of a burner at the discharge end. Through application of heat and uniform mixing of the pellet bed through tumbling as the kiln rotates, the rotary kiln heat-hardens and indurates the pellets, completing a unified formation of the mineral bonds. After the indurating process, the pellets are discharged to the annular cooler.

The annular cooler is a circular structure consisting of a rotating top and stationary bottom which receives the indurated pellets from the rotary kiln. It cools the pellets for subsequent safe handling while simultaneously recuperating sensible heat for use in the traveling grate and kiln.



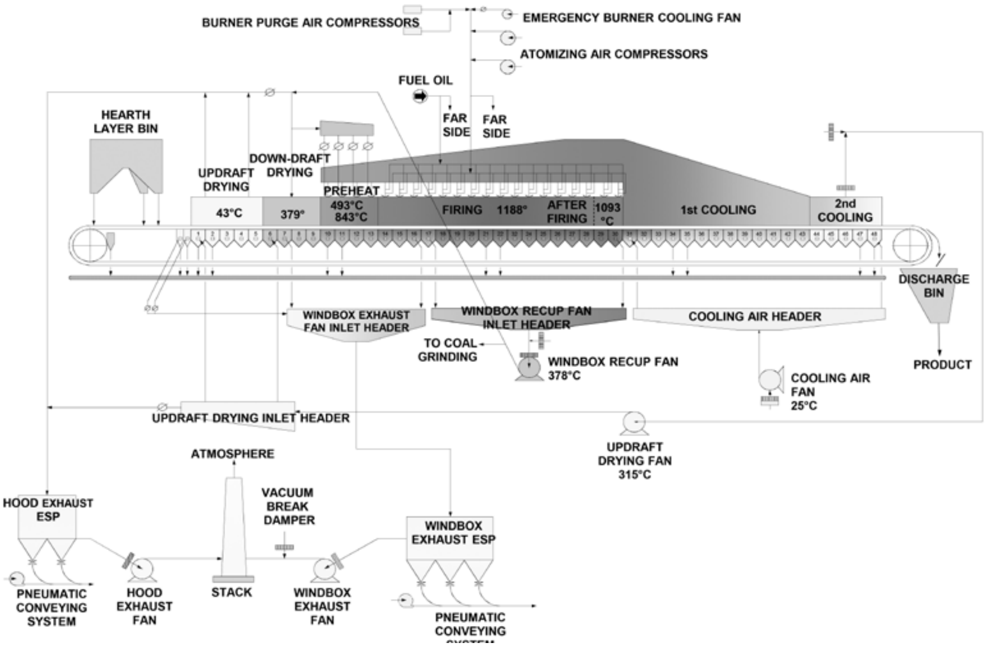
Straight Grate technology

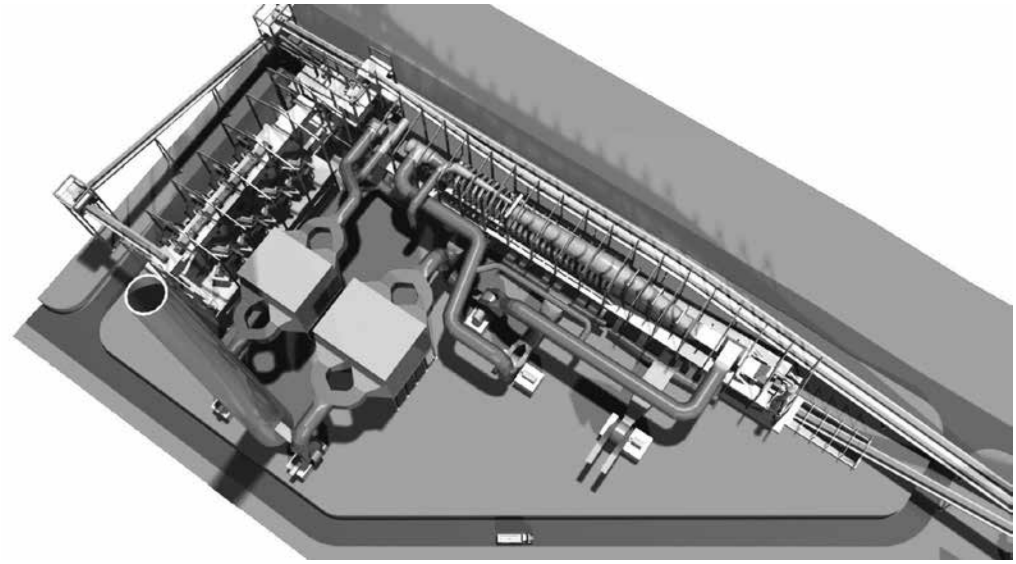
In the Straight Grate indurating process, the green pellets are dried, fired and cooled on a single strand consisting of a series of heavy cast steel pallets. The top surface of each pallet is made of an assembly of cast, high alloy grate bars which permit flow of process air through the bed of pellets. The green pellets are fed continuously to the indurating furnace at a depth of 300 to 400 mm. The following is a typical rendering of the machine drive and feed to the indurating furnace.



The peak firing temperature required to harden the pellet is approximately 1350°C. A typical design separates the furnace hood into six distinct process zones: up-draft drying, down-draft drying, pre-heat, firing, cooling and second cooling. Large fans are employed to move the process air streams from zone to zone. Fresh air is forced into the cooling zone to recover heat from the fired pellets prior to their discharge from the machine. This recovered heat is used to dry and pre-heat the pellets as well as furnish combustion air for the burners.

Heat for firing is provided by a series of burners entering through the side walls of the pre-heat and firing zones of the furnace. The burners can be fired with liquid or gaseous fuels. Burner fuel requirements can be reduced by mixing coal fines with the ore fines before forming the green balls. Air pollution control equipment is provided to control the particulate and gaseous emissions from the process stacks. The following are a typical schematic of the Straight Grate process and a rendering of a typical plant.





After the indurating process, the fired pellets are discharged to the **Product Handling** system. The Product Handling system typically includes a screening process for either mechanical or gravity separation of pellets by size.

If mechanical separation is used, vibrating screens are typically used to separate pellets into three categories: on-size, undersize and oversize. On-size pellets meet the requirements of the end user. Undersize and oversize pellets are collected for other downstream processes such as sinter feed or are recycled back into the indurating process.

Gravity separation is another commonly used process. Due to the nature of pellets in handling, oversize pellets typically migrate to the outer edges of storage bins or piles. By strategically placing chutes, oversize pellets can be diverted and separated in the process from on-size pellets. While this is a crude methodology, it works well in practice and is the least costly approach. If the client has very specific sizing needs, mechanical separation is the best approach.

Product handing for the Straight Grate process is slightly different than the Grate Kiln process. In the Straight Grate process, a portion of the fired pellets must be separated by size and recirculated back to the front end of the indurating machine, where they are layered on top of the pallets underneath the layer of green pellets. This layer of pellets, called the "hearth layer", is used to protect the pallets and grate bars from excessive temperature. These hearth layer pellets can be separated either mechanically or via gravity separation as described above.

6.72 Major process equipment components of iron ore pellet plant

Additive grinding mills — Mills are required for the grinding of limestone, dolomite, coal or coke breeze, and bentonite. Additives are typically ground in either air swept vertical roller mills or horizontal balls mills, depending on the capacity needs. Also, in some applications co-grinding of the limestone, dolomite and coal or coke breeze is appropriate. Bentonite must be ground separately due to significant density and hardness differences with the other additives. Depending on the feed preparation process, some of the additive grinding mills may not be required, since additives may sometimes be co-ground with the iron ore. Also, if the end users purchases pre-ground additives, additive grinding mills would not be required. These are all variables to be considered in the design.

Iron ore rotary dryers - If a dry feed preparation process is designed, rotary dryers prepare the iron ore for feeding to the dry grinding mills by removing nearly 100% of the moisture from the ore.

Iron ore grinding mills — If the iron ore from the supply source is not properly ground to the proper size for pelletizing, ball type grinding mills are used. The ball mills are either dry grinding mills or wet grinding mills depending on the process design. Wet grinding mills produce a slurry for downstream filtration prior to the mixing process. Dry grinding mills produce a final grind directly suitable for feeding to the mixing process.

Filtration equipment — If a wet grinding process is utilized, filtration equipment is supplied to remove water from the iron ore slurry emanating from the wet grinding mills. Depending on the chemical characterization of the iron ore, either Vacuum Filters or Pressure Filters are used. Pressure filters are used commonly when the ore has a high content of alumina (clay) type constituents. Filtration tests are done on the ground ore to determine the applicable filtration equipment.

Slurry handling equipment — The wet grinding process requires equipment to pump, store and thicken the slurry prior to filtration. Rubber lined pumps transport the slurry to and from large slurry storage tanks, a concentrate thickener, and eventually the filtration equipment. A concentrate rake type thickener is used in the process to increase the density of the slurry prior to filtration.

Mixer — Mixers are utilized to blend individual pelletizing feed components, iron ore and additives to a homogeneous balling feed. Typically two types of mixers can be used for this process; (1) horizontal rubber lined paddle type mixer, or (2) vertical type bowl mixers with hardened components. Both are equally suitable.

Balling disk or balling drum — A balling disk is a rotating mechanical platform (dish or disk in form) with retention rims to hold and process material. A balling drum is an inclined cylindrical machine (barrel like vessel) that rotates. Both equipment types receive a finely ground mixture of iron ore and other additives and produce uniform spherical pellets through the addition of moisture and the dynamic forces of rotation or circulation.

Balling disc roller screens — Roller type screens are used to separate on-size and off-size green pellets. The off-size materials are recycled, shredded and re-processed through the balling process. On-size pellets are conveyed to the indurating process.

Conveying equipment — Iron ore pellet plants are heavily dependent on belt conveyors for the transfer of bulk materials and pellets from one unit operation to another.

Reciprocating conveyor mechanism — A layout having the balling building at a right angle to the indurating machine will require the use of a reciprocating type conveyor. The discharge pulley at the end of a belt type conveyor moves back and forth, distributing a layer of pellet across the width of the wide belt conveyor. By means of varying the speed of the reciprocating stroke and pulley speed, and the wide belt speed, a relatively even layer of green balls is spread across the wide belt conveyor.

Oscillating conveyor — A layout having the balling building in line with the indurating machine will require the use of an oscillating type conveyor. The green ball oscillating feed conveyor receives unfired green ball pellets from the balling disc belt conveyors, and then transfers and distributes the pellets onto the wide belt feed conveyor via an oscillating mechanism. The wide belt conveyor is oriented in line with the oscillating conveyor. By varying the speed of the oscillating head and the wide belt speed, a relatively even layer of green balls is spread across the wide belt

Wide belt conveyor — The wide belt conveyor receives green pellets from the oscillating conveyor or reciprocating conveyor and delivers the pellets to the indurating machine feed roller screen. The wide belt conveyor is a non-standard belt conveyor that, due to its extreme width and belt loading, requires special design considerations and components.

Machine feed roller screens (single deck or double deck) — The green balls are fed onto a roller screen where a series of rotating rollers separate and transport the green pellets to the indurating machine (process). Depending on the capacity of the plant and end user needs, either a single deck roller screen (SDRS) or double deck roller screen (DDRS) is used. The number of rolls is dictated by the capacity of the plant and the final fired pellet sizing requirements. The rollers screens are operated by a variable speed drive which alters the speeds of the rolls and optimizes the screening efficiency.

- For the SDRS, the roller screen separates on-size pellets from under size. The undersize pellets fall through the gaps set between the individual rolls. The undersize pellets are shredded and recycled back through the plant for re-balling. The on-size pellets, all pellets having a diameter larger than the gaps, are fed to the indurating machine.
- For the DDRS, two separate roller screen or decks are installed, one called the top deck or oversize roller conveyor, and the other deck called the bottom deck or machine feed roller conveyor. The oversize roller conveyor has gaps set to the largest fired pellet size required by the user, and the machine feed conveyor has gaps between the rolls set to the minimal size of pellet. The oversize pellets are conveyed via rollers to an oversize belt conveyor perpendicular to the roller deck. The oversize belt conveyor feeds into the shredder which reduces the oversize to fines for recirculation back to the balling circuit. On the machine feed roller conveyor, the on-size material is separated from the fines material. The fines material falls through the gaps between the rollers onto the fines belt conveyor(s) located under the machine feed roller screen. The fines are also recirculated to the balling circuit. The "on-size" material discharges directly into the indurating machine.

Indurating machine — Depending on the indurating process employed, either the Grate Kiln indurating process or Straight Grate indurating process will be used. As described above, each process has specific equipment tailored to the process.

Process fans — Both the Grate Kiln and Straight Grate processes use a series of large process fans to move and distribute ambient air and hot process gases through the systems. These fans have specific process requirements which dictate the capacities and sizes of the fan. In general, fans are sized, if possible, to a common size to minimize spare parts needs.

Air quality control equipment — Dust collection and emissions controls are provided for each pellet plant based upon the end user needs to satisfy the applicable emissions regulations. Baghouses, electrostatic precipitators, scrubbers, and even more complicated equipment are used.

6.73 Design criteria and plant sizing

The iron ore pelletizing plant, design and sizing, is affected by many factors which are evaluated during the upfront engineering process for the project. Each project is typically unique to the design criteria, however many plants can be similar in nature. Although plant capacity (i.e. million tons per annum, mtpa), is a commonly used identifier, the details of the design criteria typically vary quite a bit. The following are design criteria that must be considered in the development of a pellet plant design.

Plant Location — Site locations set the ambient conditions for temperature, site elevations, soil bearing capacity, wind conditions, seismic zone and other factors. This affects sizing of equipment and design of structures. The terrain of the site is also important in setting the orientation and configuration of the plant to take advantage in any changes in elevation on the site.

Fired Pellet Chemistry — The end use determines the type of fired pellet needed, such as blast furnace (BF) pellet or direct reduced iron (DRI) pellet. Each pellet type sets the iron content of the fired pellet and chemistry, resulting in the quantity of additives needed to produce the end product.

Raw Material Supply and Characteristics — The type of iron ore and additives and their characterization set the plant design requirements. Is the iron ore as received, properly ground for pelletizing? Will the additives delivered be pre-ground or will on-site grinding be needed. Is the iron ore a magnetite or hematite ore, and what is the iron content (Fe) of the ore? What are the silica and alumina content of the iron ore? What is the type of fuel to be used to create the heat input to the indurating process. There are many questions to be asked. These help determine the overall process and what type of indurating process to be used. This information is used to tailor the chemistry of the pellets to produce desired metallurgical and physical properties in the fired pellets.

Iron Ore Testing Programs – A most critical part in the upfront engineering of a prospective iron ore pelletizing plant project is the iron ore testing program. For iron ore pellet plants, the testing program is called "Pot Grate Testing". These unique testing programs have been developed for fired pellets produced using the Grate Kiln indurating process or the Straight Grate indurating process. These testing programs can take up to three to four months to perform after receipt of the raw materials to be tested. Pot grate testing is the basic tool to determine the optimal firing pattern (temperature profile and process gas flows) within the indurating process to achieve the specified production rate and product quality for the raw materials being supplied. The pot grate testing allows the plant to be designed for the lowest capital, operating and maintenance costs.

6.74 Comparisons of indurating technologies

Iron ore pelletizing plants are similar in the various unit operations making up a typical plant. The one main variable is the type of indurating unit operation utilized. The following are some comparatives between the two processes in respect of capital cost investments, operations and maintenance.

Capital cost comparison

Straight Grate	Grate Kiln
Overall indurating machine length is similar	Overall indurating machine length is similar
Slightly narrower width	Slightly wider width
Similar total plant area when balance of plant is considered	Similar total plant area when balance of plant is considered
Balling area is lower (elevation) because entire machine is at one elevation	Balling area is significantly higher (elevation) so as to feed traveling grate
Less structural steel required because of lower balling area elevation	More structural steel required
Lower capital cost by about 10%	Higher capital cost

Operation comparison

Straight Grate	Grate Kiln
Capable of firing gas, or liquids (no solid fuels)	Capable of firing solid fuel, gas , or liquids
Higher electrical power consumption due to deep bed of pellets	Significantly lower electrical power consumption
Fuel consumption is similar	Fuel consumption is similar
Single machine	3 separate machines – traveling grate, kiln, annular cooler, allows control of residence time in each
Multiple burners provides process flexibility	Single burner in kiln, additional burners in traveling grate when processing hematite

Maintenance comparison

Straight Grate	Grate Kiln
Pallet cars can be taken off-line for maintenance	System must be shut-down for maintenance
Pallet cars made of alloy steel parts	Grate chain and all plates are made of alloy steel parts
Less refractory maintenance	More refractory maintenance, but done at annual shut-down (mostly kiln)
Single machine, one drive to maintain	3 separate machines – traveling grate, kiln, annular cooler, 3 drives to maintain

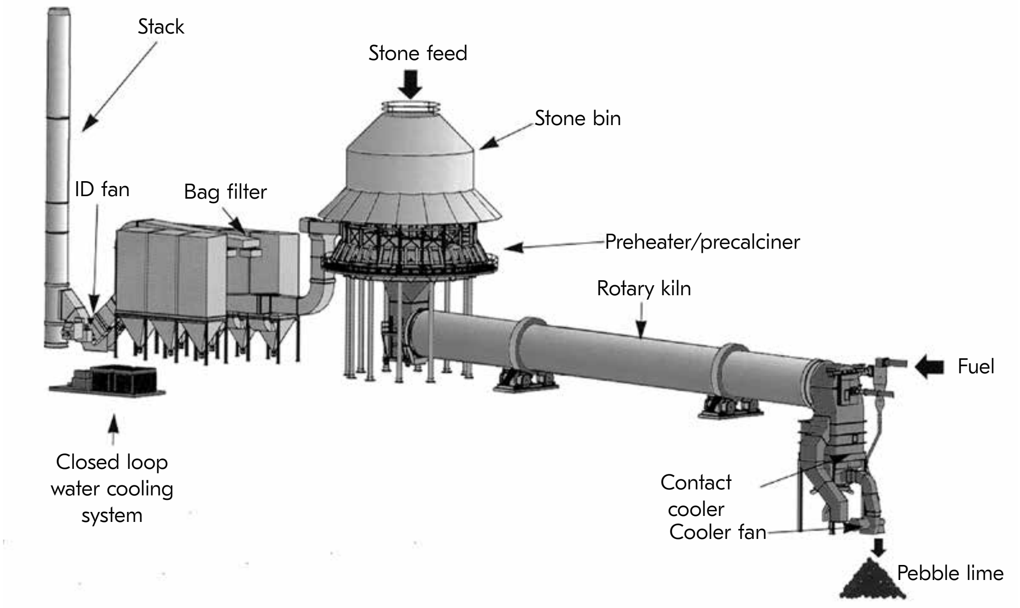
6.75 Lime calcining system

The preheater-rotary kiln system calcines a medium to small size limestone, is capable of high production capacities, and produces a uniform, high quality lime product. The "straight" or "long" rotary kiln (one without a preheater) uses a greater amount of fuel per tonne of product.

General arrangement

A preheater-kiln system includes a stone bin, preheater, rotary kiln and stationary cooler. Calcining begins in the preheater and is completed in the rotary kiln. Heat transfer in a preheater-rotary kiln system is "counter-current". The limestone/lime material travels through the system in one direction and the hot process gases that provide the necessary heat for calcination travel through the system in the opposite direction. The preheater recovers heat from the kiln exhaust gases and the cooler recovers heat from the lime as it discharges from the kiln. The heat recovered from the cooler is used in the kiln as preheated combustion air.

The following figure identifies the major components of a typical polygon preheater-rotary kiln system with coal firing and a "baghouse" type dust collection system. This configuration is typical of lime plant installations in North America, in particular, where regular solid, alternative solid, liquid and gas fuels are plentiful and in turn, relatively inexpensive. In addition, baghouse style dust collection is used nearly exclusively in order to comply with the strict limitations on particulate emissions imposed by the governing agencies.



Process and equipment description

Limestone feed is delivered to the un-insulated, carbon steel stone bin, on an intermittent basis, by an appropriate stone preparation and conveying system. It enters the stone bin through an opening at the center of its roof, and is directed to a series of equally spaced discharge points in an annulus at the bottom of the bin. Limestone leaves the stone bin, by gravity, through a set of stone chutes and enters the integral preheater unit, directly below, replacing partially calcined material as it is discharged from the preheater at a controlled rate.

The refractory-lined preheater is made-up of a series of adjoining compartments, or modules, arranged in something of a circular shape (in plan) with a common discharge hopper at the center. Each preheater module receives stone through a four-sided, vertical chute that connects the module to a corresponding discharge opening in the stone bin directly above. These chutes, which are always full of stone during normal operation, create an adequate seal between the process gas stream within the preheater and ambient (at the stone bin inlet). Hot process gases are pulled through the bed of material in the preheater by an induced draft fan (or I.D. fan). The heat content of the gases entering the preheater is such that calcining begins in the preheater. Once through the material bed, having transferred much of the heat to the material, the gases exit the preheater through two exhaust gas manifolds.

Partially calcined material, which has been raised from the near ambient temperature of inside the stone bin to around 760 °C, is pushed from the sloped floor of each module into the center hopper of the preheater by a discharge plunger within the module. Each of these plungers is moved through its stroke cycle by plunger rods connected to a hydraulic cylinder drive mechanism. The alloy steel plunger castings are the only non-refractory lined components found within the preheater.

The partially calcined material passes through the transfer chute and enters the refractory lined rotary kiln, which is installed on a gradual slope away from the transfer chute. Material travels from the upper to lower end of the rotating kiln, while hot process gases are pulled through the kiln in the opposite direction. It is here where the calcining process is completed.

Calcined lime falls from the discharge of the rotating kiln, through discharge grates at the base of the firing hood into the cooler.

As the name implies, it is the firing hood that provides the insertion point for the single burner of the kiln firing system. After passing through the grates at the base of the firing hood, the calcined lime falls into the cooler. Viewed in plan (from the top), the cooler is square and is divided into four cooling compartment, or quadrants. Air is forced into the cooler by the cooler fan. This air cools the lime in counter-current flow through the cooler and then travels up through the cooler grates into the firing hood and kiln, where it serves as preheated secondary combustion air for the firing system

System capabilities / flexibility

Limestone Feed

Systems has been designed for limestone feed sizes as large as 75 mm, but a more typical maximum top size is 60 mm. Systems have also been designed for feeds as small as 6 mm, but, again, the more typical minimum bottom size is 9 mm. In order to maintain a reasonable pressure drop across the packed bed of material in the preheater, a maximum top-to-bottom size ratio is required. This design feed size ratio if most often a maximum of 4 to 1. However there are preheater-kiln systems in operation today successfully processing stone feed size fractions with top-to-bottom size ratios of 6 or even 7 to 1. Feed size ranges this broad, of course, help to minimize stone cost by maximizing utilization of the quarried stone.

Fuel types

Because a single burner supplies the process heat to the calcining system, a firing system can easily be designed to handle any of the commonly available forms of fuel—solid, liquid or gaseous. The system can be designed to fire a single type of fuel, or a combination of fuels. There are also designed systems for plant sites around the world that use fuels such as fuels oils of various grades, natural gas and coke oven gas, among others.

Fuel rates

The greater the rated capacity of a preheater-kiln system, the less fuel it will consume per tonne of lime product. This is simply because there is less equipment surface area available for system heat loss, per tonne of product, at higher system production capacities. The expected nominal fuel rate for an 1100 metric ton per day preheater-kiln system would be in the range of 1000-1150 kcal/kg of lime (4185-4815 kJ/kg), net basis.

Lime product quality

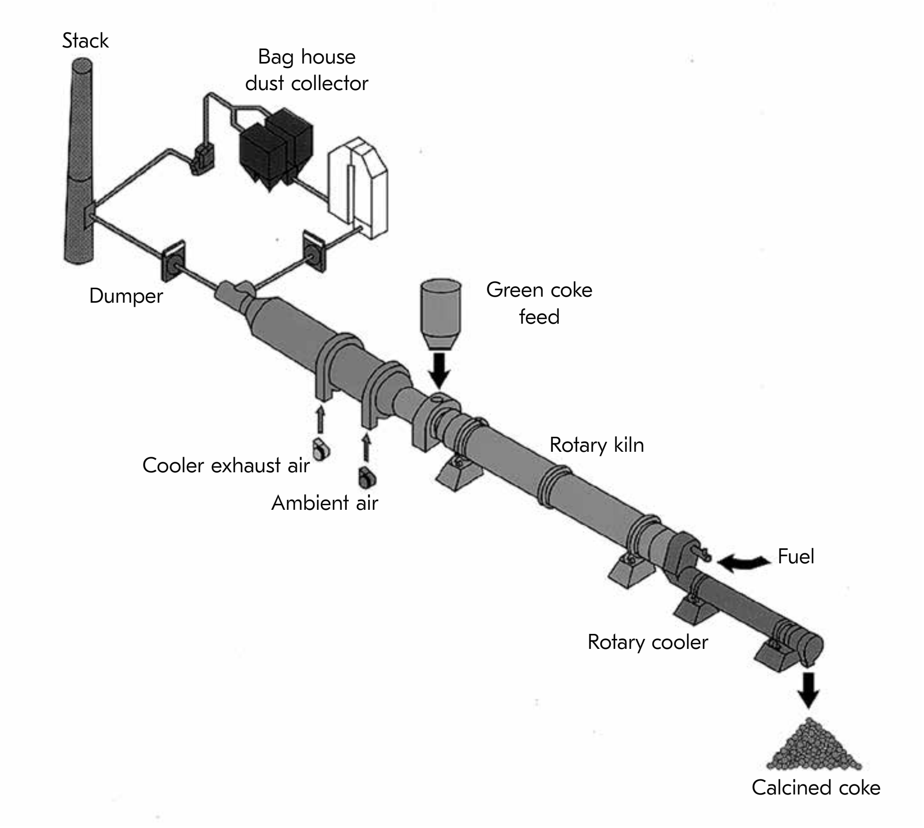
The combination of the preheater and the rotary kiln working together produces an extremely homogenous lime product of very high quality. In the preheater the finer size particles are calcined more completely than are the coarser particles. In the rotary kiln, because the finer material is trapped in the "kidney" of the rotating bed, somewhat isolated from the hot process gases as it travels through the kiln, the opposite is true. The end result is that by the time the material reaches the discharge end of the rotary kiln all of the material is calcined to the same extent. In addition, because limestone feed to the system is typically no larger than 60 mm, each piece of material can be calcined thoroughly, leaving only small amounts of residual CO_2 in the material, when required. The preheater-rotary kiln system is capable of producing limes with a residual CO_2 as high as 3.0% and a high reactivity, and as low as 0.01% – basically dead burned.

The preheater-rotary kiln system is also a proven means of producing steel industry grade—low sulfur—lime. Sulfur capture by the material as it travels through the calcining system is a mass transfer phenomenon, which takes place when sulfur in the process gas stream is in intimate contact with the material. Since the preheater-kiln system maintains a relative short packed bed of material (relative to other types of kiln systems) in the preheater, little opportunity is provided for the transfer. In addition, if a fuel is used that has a sufficiently low sulfur content, some of the sulfur entering the system in the stone can be driven off in the firing zone of the rotary kiln. This sulfur can then attach to the very fine material in the process gas stream and, once through the preheater, be collected .

6.76 Coke calcining system

Petroleum coke (green coke) is a solid residue by-product from refining oils, gasoline and other hydrocarbons. The green coke is removed from a coking drum used in the refining process. The main components of green coke are carbon and volatile compounds. Coke calcining is a process where green coke is converted (by evaporating the volatiles) into nearly pure carbon that is used (mainly) in the production of aluminum. This technology became prevalent in the 1940's and 1950's (when aluminum started to find favor with manufacturers).

The raw, green coke is fed into the rotary kiln where it is calcined using heat from the main burner as well as heat from burning dust and volatiles released from the coke inside the kiln. There is sufficient temperature in the kiln to burn the coke; so, the oxygen content in the kiln must be controlled very carefully to prevent all of the coke from burning. Air is injected through the shell of the kiln to burn a portion of the volatiles released from the coke and provide heat for the calcining process. The calcining process drives off most of the volatiles from the coke. These gases flow up the kiln and enter the afterburner where additional air is injected and the volatiles are burned. The heat energy in the afterburner exhaust gas is recovered in a boiler (to make steam for the refinery or to make electrical energy). The calcined coke travels through the kiln and exits into a cooler where the product temperature is lowered using water quenching or contact cooling. From there, it is taken off to a storage silo.



6.77 Tire pyrolysis

Worldwide, it is estimated that one billion scrap tires are produced every year. Have you ever wondered what happens to all of these scrap tires?

In the US, the majority of tires are used as a supplemental fuel source. The heating value per pound of tires is slightly higher than coal. Cement kilns, waste incinerators and boilers for paper mills are the biggest users (mainly because they can easily handle the leftover metal radials). The second biggest user of scrap tires is the asphalt industry. In the end, however, an estimated 9% of scrap tires (26 million tires per year) end up in a landfill. Worldwide, we know this percentage is much higher, especially in developing countries like China and India. That leaves some 100 million tires ending up in a landfill where they will remain for a long, long time.

To maximize the economy of recycling tires, a process has been developed where all major components of the tire can become revenue streams (money generators) for the recycler. This means making use of the steel, carbon black (major component of the rubber) and the fossil fuel components of the rubber (specifically the oil). These are the big three. Instead of burning the tires, they are roasted at a lower temperature in an atmosphere devoid of oxygen (so that no actual burning occurs). This method of roasting is called pyrolysis, and is used for many different processes. By using pyrolysis, the tire shreds can be broken down into their three basic components (carbon black char, steel radials and oil/gas). Since the three off-coming streams can be captured and sold, the recycling process becomes profitable and not just possible!

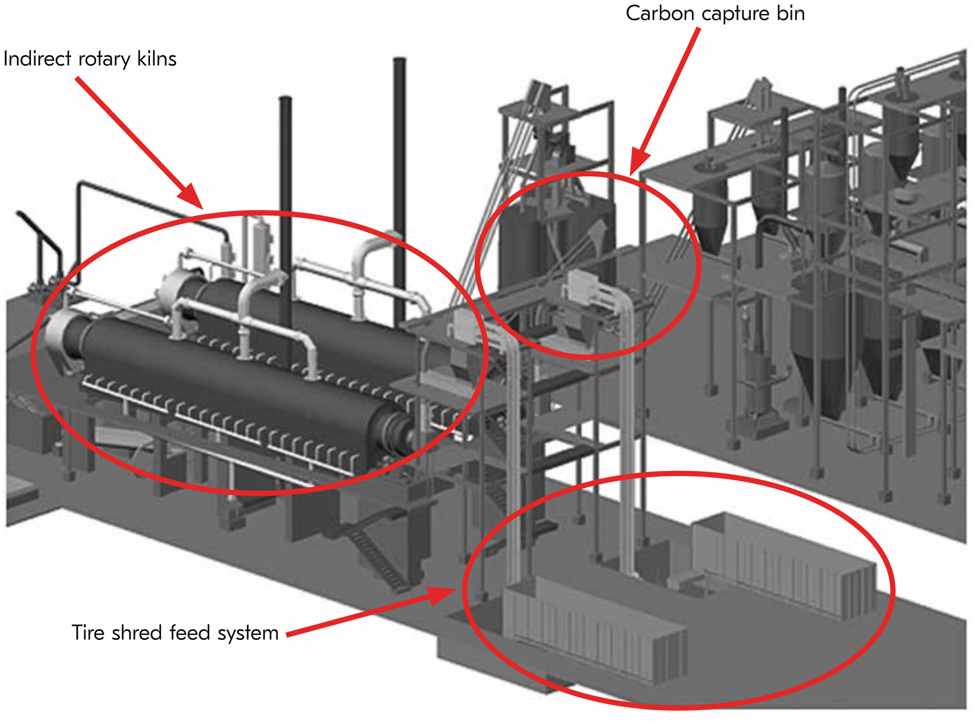
The figure below shows the basic tire pyrolysis system...

Shredded tire chips approximately two inches by four inches are received at the recycling facility. The chips are fed to an indirect rotary kiln using special conveyors. In the indirect kiln, the pyrolysis reaction is carried out. Remember, an indirect kiln adds heat from outside (through the shell) and there is no direct flame inside the kiln. This is done because no oxygen can be present for the pyrolysis reaction to correctly occur. The chips go through three stages inside the kiln. First, the rubber becomes brittle and separates from the steel (we call this the rubber char). In the second stage, the oil and gas are forced from the rubber char and collected.

In the last stage, the char is fully processed into a carbon black-like substance and separated from the steel wires. The char is sent through a holo-flite processor (to cool it) and then sent to a bagging system where it is packaged for transport.

The steel is cooled in an air dryer and the steel wires are compacted and shipped to a steel recycler or steel processing furnace. The off-gas from the kiln is pulled through a patented condenser where oil is extracted. This oil is very similar to a diesel fuel. In addition, there is a gas stream of non-condensable oil that can be sent to a boiler and used for generating steam (for heating or power generation).

From a single tire, approximately 1/3 of the mass recovered is steel, 1/3 becomes carbon black and the other 1/3 is oil. Hundreds of hours of continuous testing and processing of thousands of pounds of tire shreds has been conducted to learn the correct method for heating the tires, the best method for handling the shreds, the best method for handling the wires and also the best configuration for the oil condenser. Many technological hurdles have been crossed through this testing (such as preventing pluggage in the condenser, tangling of the chips as they enter the kiln and effectively cooling the rubber char).



Materials handling

7. Materials handling

7.1 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!

7.2 Loading and unloading

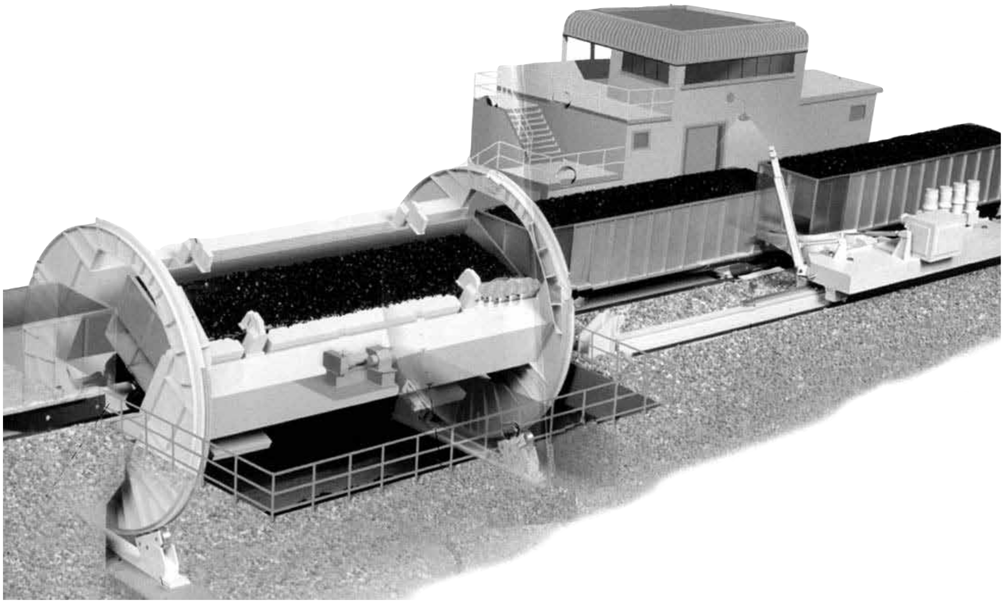
In this section we will only cover loading and unloading conditions related to rail cars and sea vessels (high capacity conditions)

7.3 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.

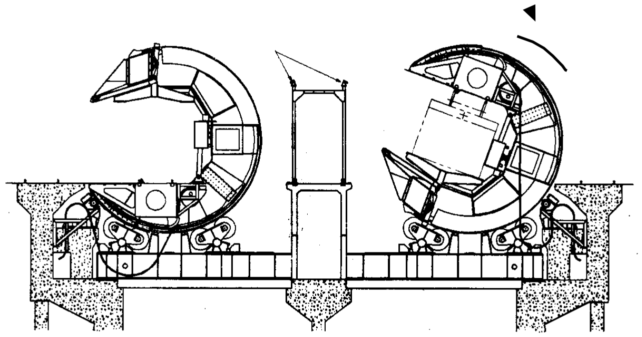
Railcar dumper – rotary type

- Reliable and proven design
- Capacities up to 100 cars/h
- Single, tandem or triple car dumper configurations
- Dust sealed operation
- Integrated dust containment system



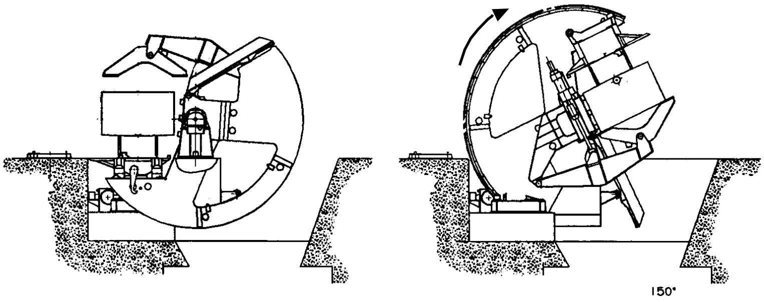
Railcar dumper — "Crescent" design

- 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

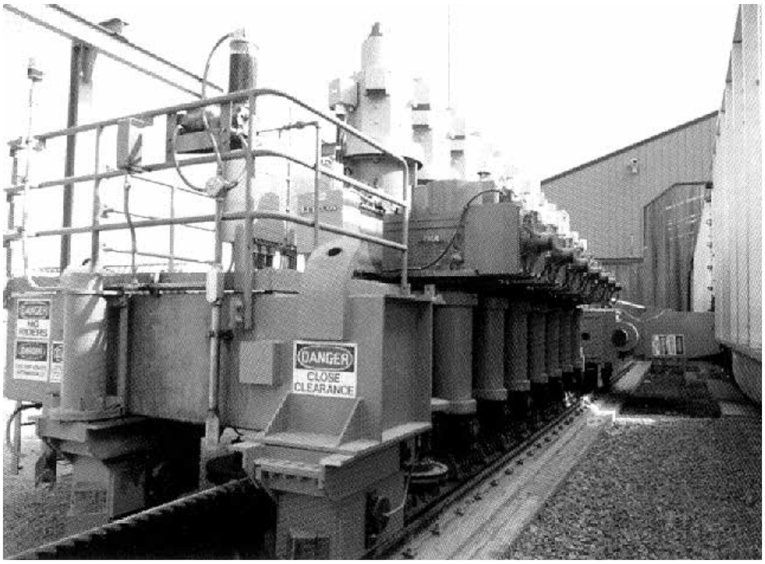
- Hopper position at the side of rail track gives simplified installation
- Proven and simple design
- Low in maintenance
- Rate of unloading 12 cars/h



7.4 Train positioners

A train positioner has to have a high utilization 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

7.5 Unloaders

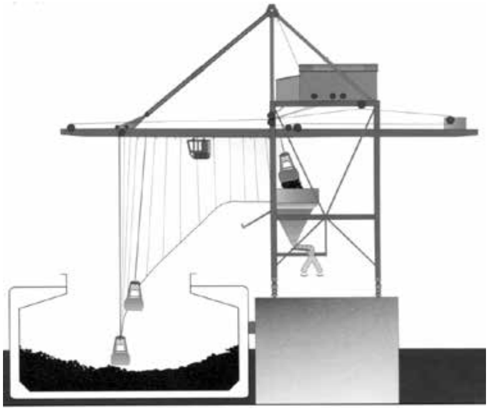
Grab unloader

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)

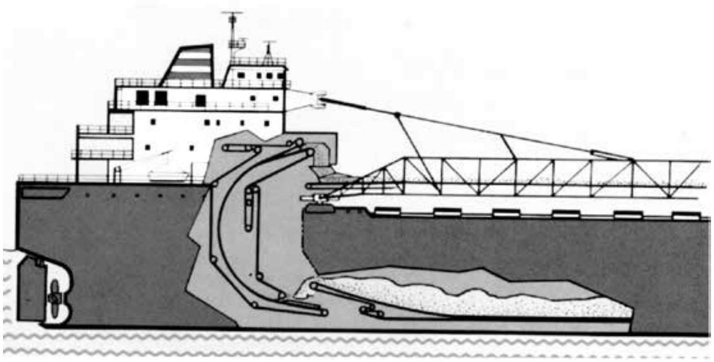
- Grab capacity coal 6 to 25 tonnes
- Grab capacity iron ore 6 to 40 tonnes
- Duty cycle: 36 to 45 sec
- Free digging rate coal 500 to 2000 tonnes/h
- Free digging rate iron ore 500 to 3 400 tonnes/h



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

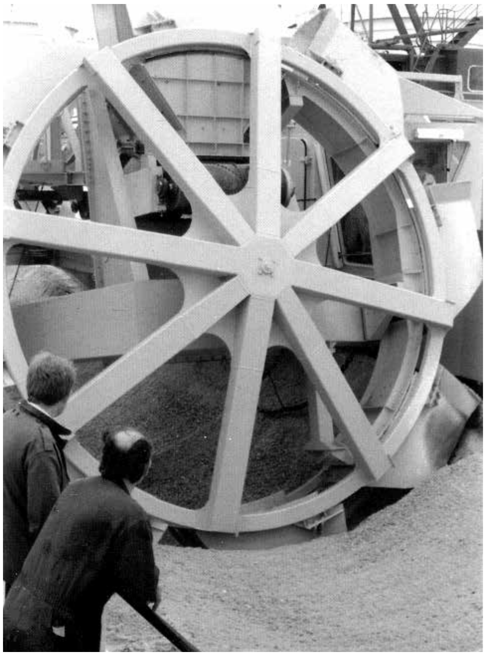
- Inclined bucket elevator
- Loop belt system
- Vertical conveying system see also conveying, page 7:16 and 7:21
- Capacities up to 6 000 tonnes per hour
- Operator friendly, less polluting operation (dust & noise)
- Long service life
- Flexible in sizes and capacities



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 (1 400-4 500m^3)
- Discharge rate to shore 1 200 m^3/h
- Bucket wheel protected in "sea position"



7.6 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:

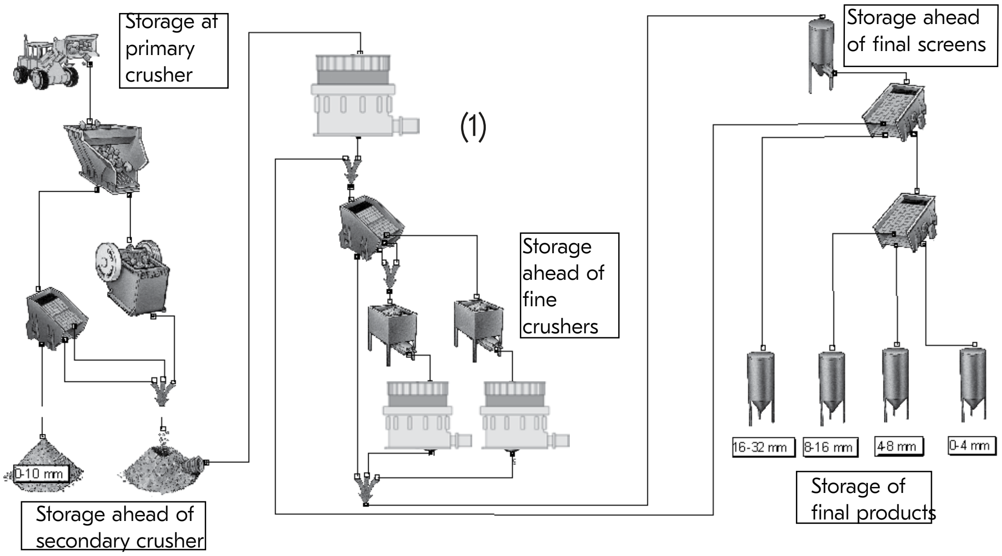
- Different production rates (cont cyclic)
- Shift variations
- Interruptions for repair
- Size variations
- Flow variations
- Variations in mineral value (metal content etc.)

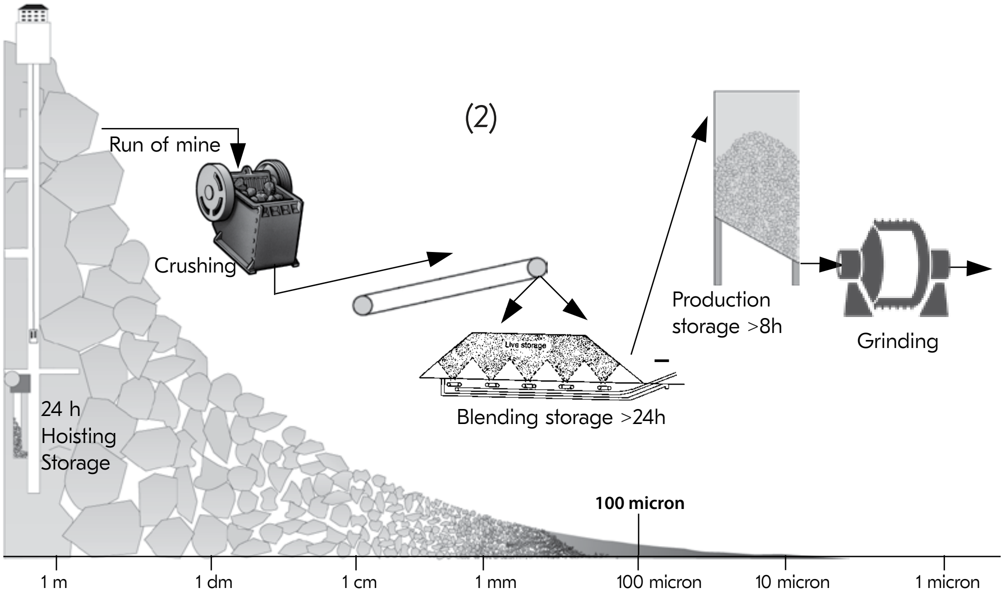
Storage of rock (1)

A matter of material flow (retention time)

Storage of ore and minerals (2)

A matter of material flow (retention time) and blending





7.7 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

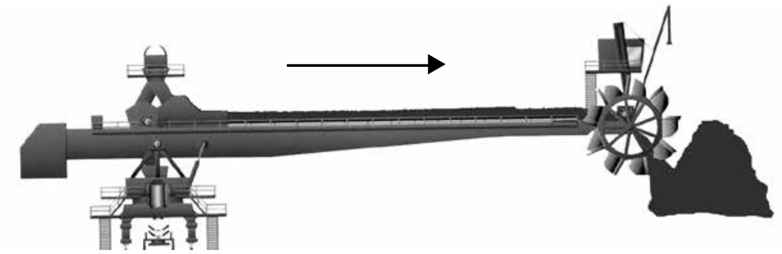
Trenching type stacker reclaimers are used for low-volume, high active storage capacities between 30 000 and 60 000 tons. Reclaiming operations are accomplished by longitudinal pass through the pile.

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.

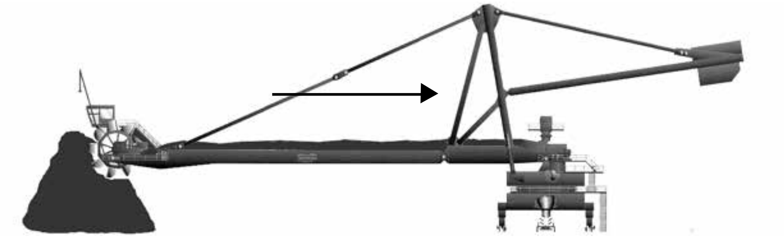
Stacking and reclaim rate up to 6 000 tons/h for coal and 8 000-10 000 tons/h for iron ore.

Stacking



Straight-through boom configuration max length 38 m

Reclaiming



Masted boom configuration length over 38 m

7.8 Scraper reclaimer

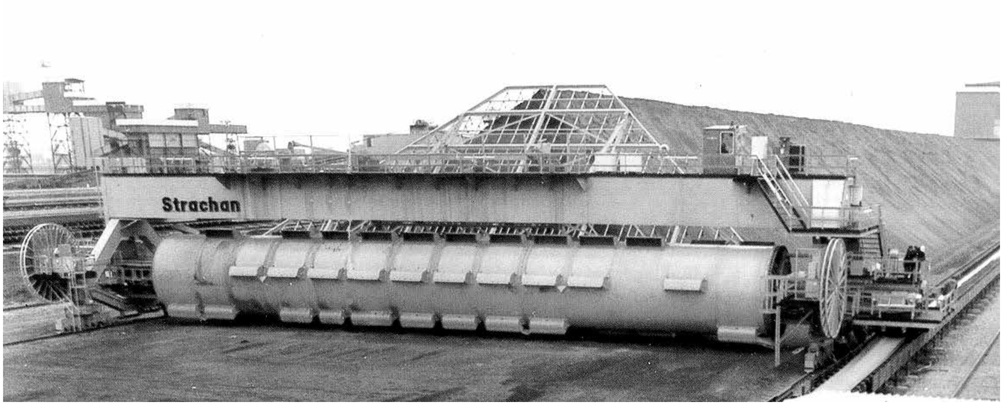
These reclaimers are designed to handle materials as (typical) phosphate, coal, sulphur, fertilizers and woodchips servicing parallel storage piles from booms mounted on either or both sides of the machine.
They incorporate the cost advantage of “back stacking” (the ability to reverse boom flight direction up the storage pile).

- Capacities up to 4 000 tons /h
- Single, twin and double-boom options

7.9 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.

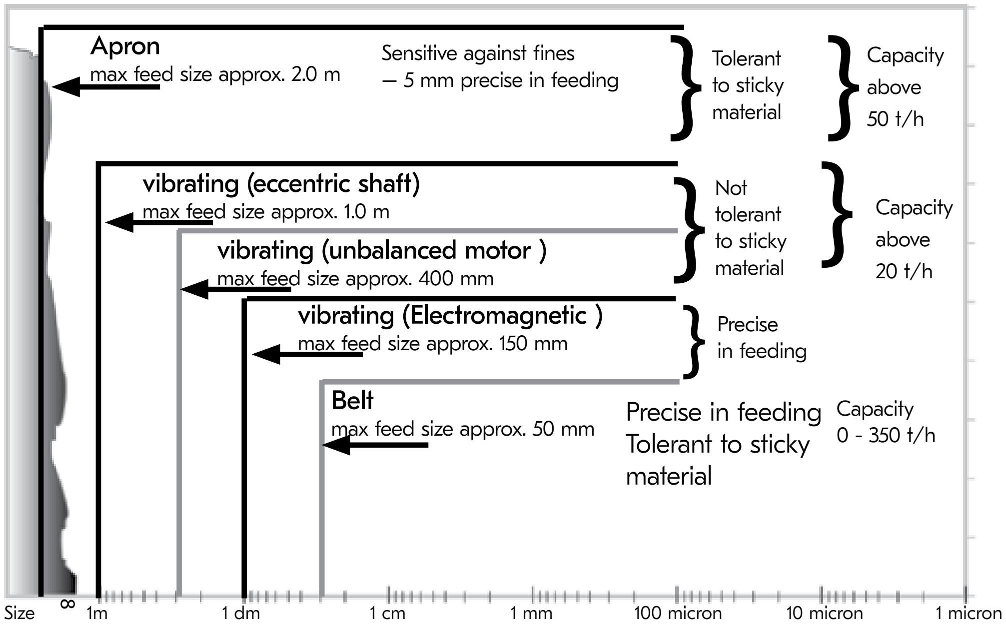
- Very robust a reliable design for high capacities · Variable speed for differing reclaim rates
- Automatic operation (optional)



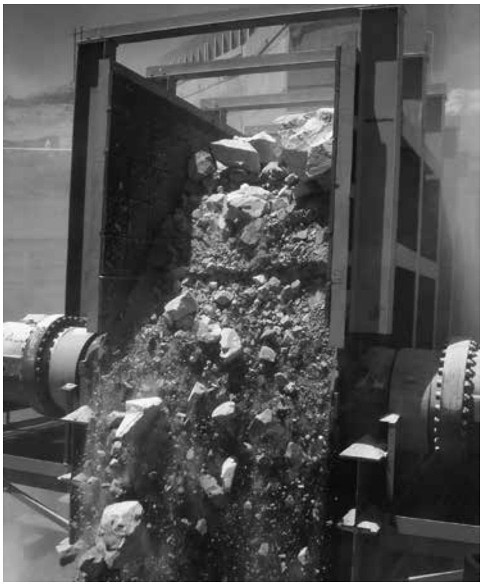
7.10 Feeding

Feeders are necessary whenever we want to deliver a uniform flow of dry or moist fractions of rock or minerals. Generally they are categorized by the size of material to be fed, see below.

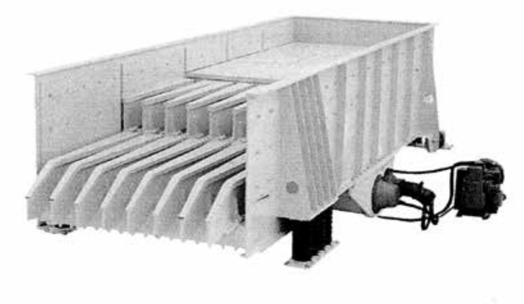
Feeding vs Feed sizes



Primary feeders (For installation under feed bumper hoppers & rail car dumpers)



Apron
Capacity 300 – 12 000 t/h

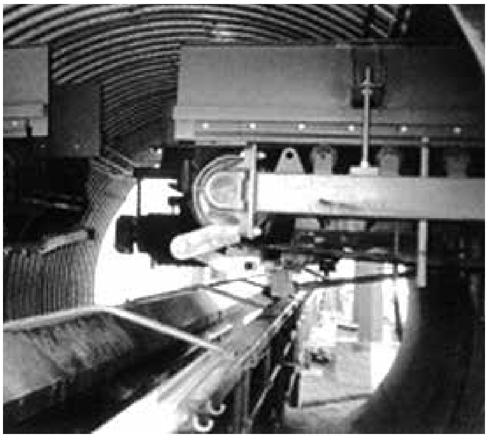


Vibrating
Capacity 300 – 1 200 t/h

"In circuit" feeders (For installations under ore stockpiles, bins & crusher dischargers)

Apron

Capacity 50 — 3 000 t/h



Belt

Capacity 80 — 350 t/h

Vibrating (eccentric shaft)

Capacity 30 — 600 t/h

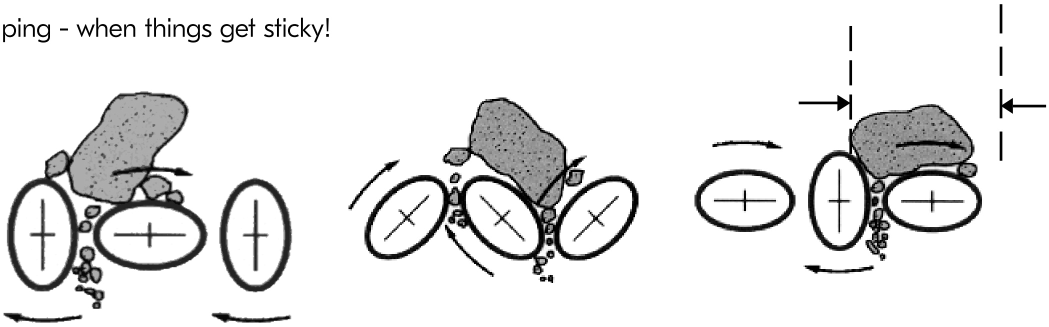
Vibrating (unbalance motor)

Capacity 55 — 460 t/h

See also data sheets 7:10 - 7:14.

Wobbler feeders

Feeding and scalping - when things get sticky!



Openings between elliptic 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)

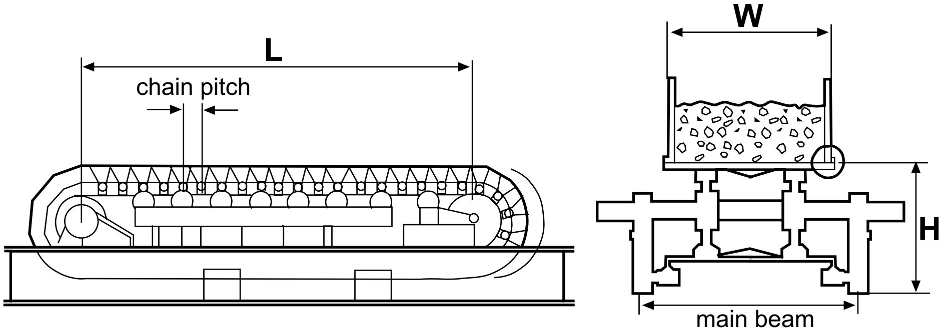
- Fixed and adjustable

Capacity range

- Up to 3 500 t/h (5 sizes)

See data sheet 7:15.

7.11 Feeder — Apron



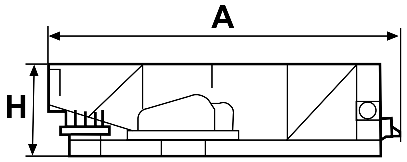
Model Width (pan) mm/inch	AF 4 Weight* ton/lbs	AF 5 Weight* ton/lbs	AF 8 Weight* ton/lbs	AF 10 Weight* ton/lbs	AF 12 Weight* ton/lbs	AF 14 Weight* ton lbs	AF 16 Weight* ton/lbs	AF 18 Weight* ton/lbs
610/24	4.1/9 280							
762/30	4.3/9 734	5.1/11 580						
914/36	4.6/10 300	5.8/1 306						
107/42	4.8/10 840	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

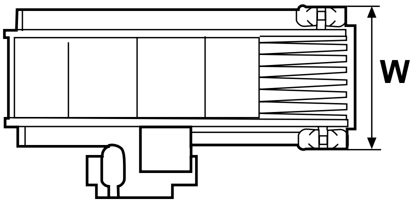
*Approx, weight of an Apron feeder, length 3 m (10ft) excl. load, skirts, chutes etc. For each additional feet (or 0.3 m) add 7 % in weight.

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 pan	Width pan	Width pan	Width pan	Width pan	Width pan	Width pan	Width pan
width mm (inch)	+356 (14)	+457 (18)	+457 (18)	+457 (18)	+508 (20)	+584 (23)	+584 (23)	+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

7.12 Feeder — Vibration (linear motion)

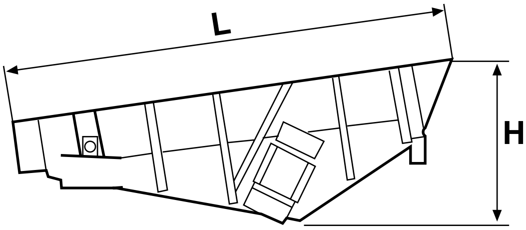


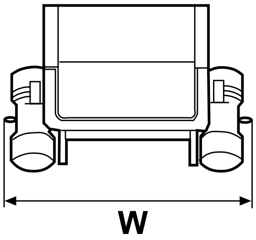


Model (VMHC)*	H mm (inch)	L mm (inch)	W mm (inch)	Weight ton	Capacity ton/h	Max. size mm (inch)
48/12	1 300 (51)	5 200 (205)	2 050 (81)	6.8	280 - 400	650 (26)
48/15	1 300 (51)	5 160 (203)	2 350 (93)	10.0	420 - 600	850 (33)
60/10	1 870 (74)	6 800 (268)	1 860 (73)	13.2	250 - 350	500 (20)
60/12	1 870 (74)	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

7.13 Feeders — Unbalanced motor

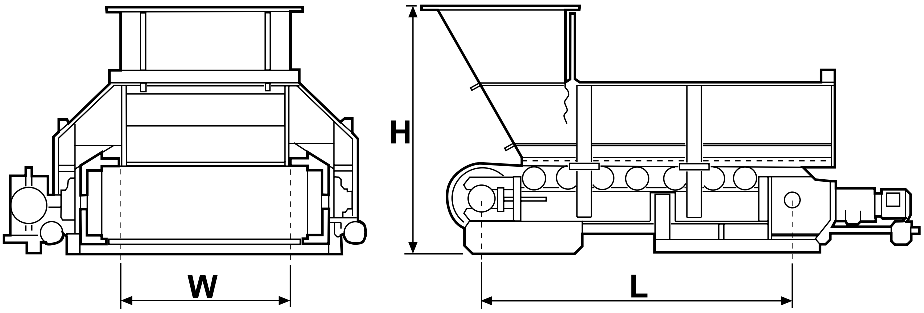




Model (VMO)	H mm (inch)	L mm (inch)	W mm/inch	Weight ton	Capacity* ton/h*
15/6.5 - 3014	780 (31)	1 770 (70)	1 260/50	0.5	30 – 160
17.5/8 - 40	830 (33)	2 050 (81)	1 410/56	0.7	40 – 210
20/10 - 40	950 (37)	2 300 (91)	1 670/66	1.1	60 – 320
30/10 - 40	1 000 (39)	3 300 (130)	1 670/66	1.5	60 – 300
30/10 - 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)

7.14 Feeder – Belt

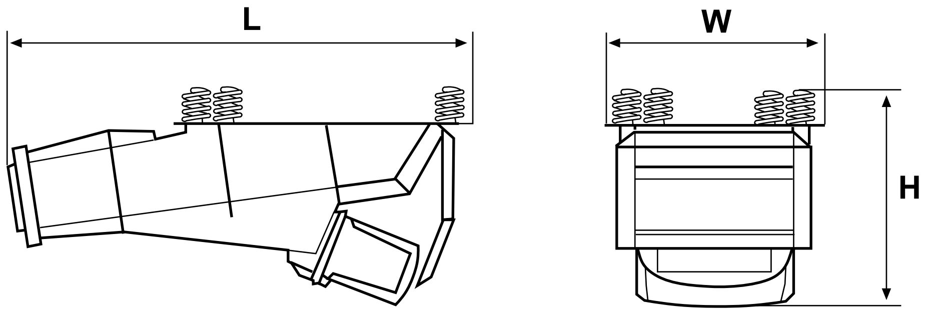


Model (VMO)	H mm (inch)	L mm (inch)	W mm/inch	Weight ton	Capacity* ton/h*
10/4.5	1 050 (41)	1 000 (39)	450 (18)	0.64	180
15/4.5	1 050 (41)	1 500 (59)	450 (18)	0.71	180
20/4.5	1 050 (41)	2 000 (78)	450 (18)	0.80	180
10/6	1 200 (47)	1 000 (39)	600 (24)	0.77	250
15/6	1 200 (47)	1 500 (59)	600 (24)	0.89	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")

Technical data sheet

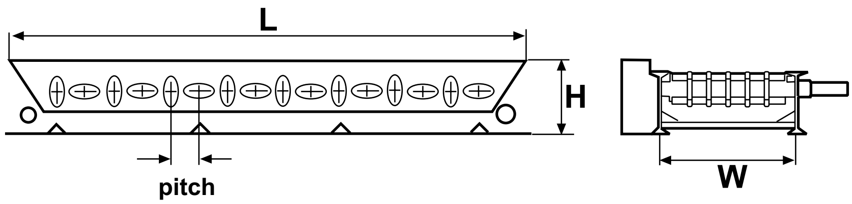
7.15 Feeder — Electromagnetic



Model (VMm)	H mm (inch)	L mm (inch)	W mm/inch	Weight ton	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%)

7.16 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

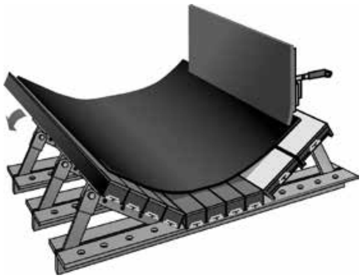
Max feed size 762 mm (30")

Wobbler feeder also available with 318 mm (12.5") pitch and 368 mm (14.5") pitch for feed size up to 1900 mm (75").

7.17 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.

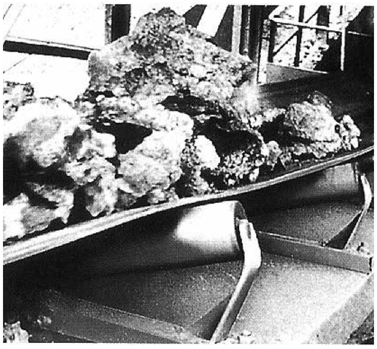
Conveyor – general



Wear Part

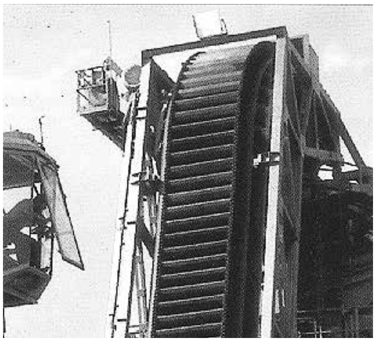
Conveyors are selected from 4 key parameters:
- Tonnage
- Material and size
- Inclination
- Distance

We also must consider wear in operation
and the environment (dust, heat, oil or chemicals etc)



Tonnage and size

Distance

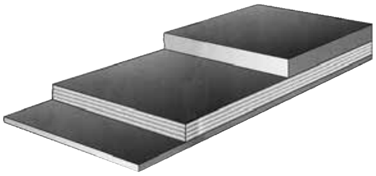


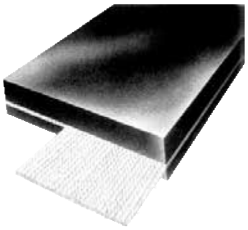
Inclination

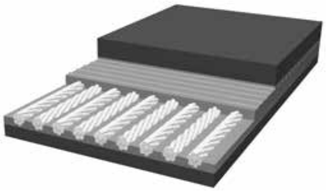
Conveyor belts

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.

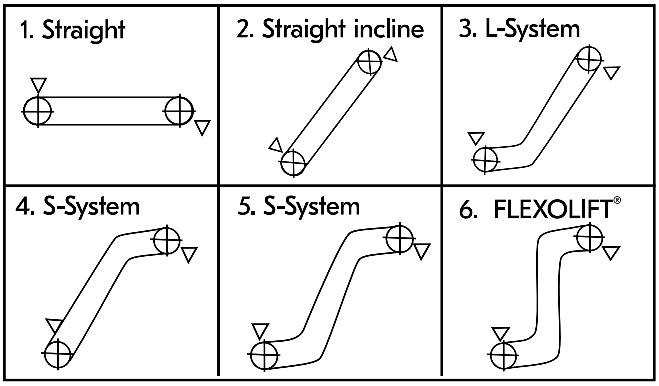
See data sheet 7:20

7.18 Conveying systems

Vertical conveyor system “When space is critical”

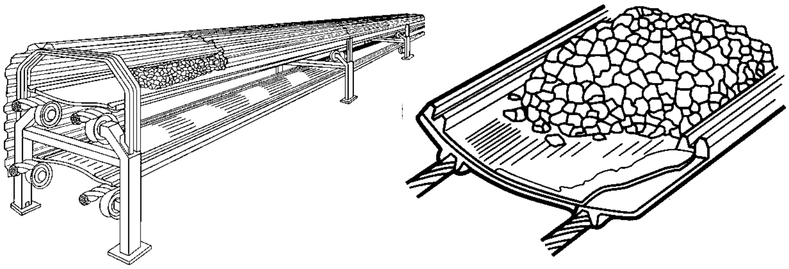
Vertical conveying systems normally is the only option when lifting angle is exceeding 30°. The system is very flexible and gives a number of transportation solutions when space and lifting angles are critical.

See data sheet 7:21



Cable Belt® conveyor system “When distance is critical”

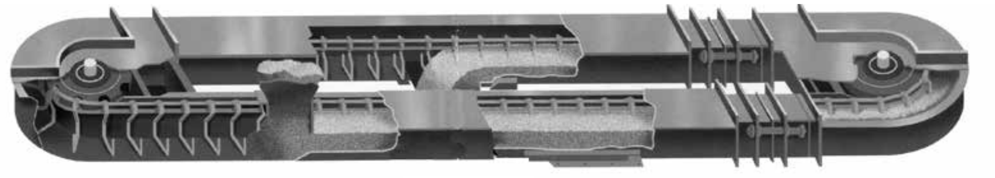
Conveying with high capacities over long distances means that conventional conveying systems are out. An alternative to truck hauling is Cable Belt® conveyors which become competitive from, say, 500 m and upwards taking on capacities from 500 up to 5000t/h.

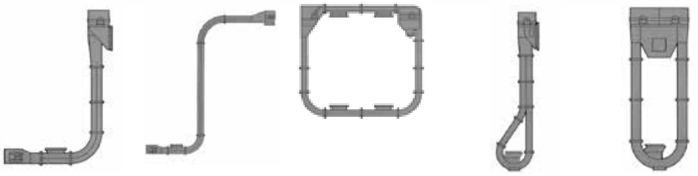


See also 7:21

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.



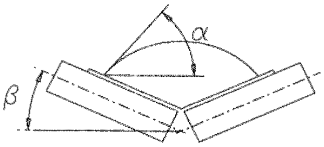
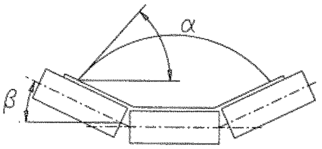
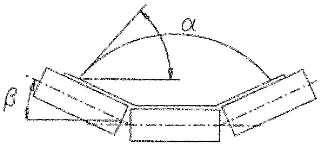
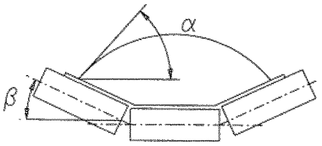


Configurations

7.19 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 m^3 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

7.20 Volume weight and angle of inclination

The capacity and the inclination of the conveyors depend on the character of the material to be conveyed.

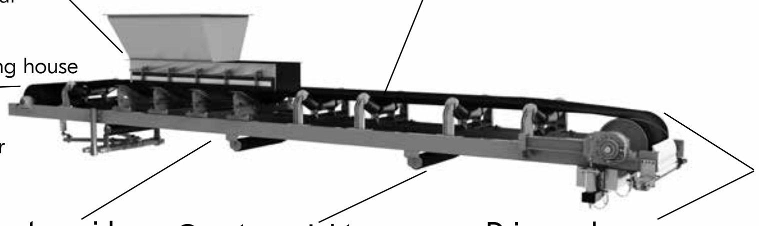
Material	**Volume weight in tons/cbm.**	**Max. inclination in degrees**
Bauxit, crushed	1.3	18
Briquettes, normal	0.7-0.82	15-18
Briquettes, oviform	0.7-0.82	12-13
Cement	1.2-1.6	20-22
Cement clinkers	1.2-1.3	18
Chalk, crushed	1.2-1.4	18
Charcoal	0.2-0.25	18
Clay, lumps, moist	1.5-1.7	18
Clinkers	1.2-1.5	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

7.21 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



Loading of belt conveyor
Material wear liner
Sealing blocks
Impact bars
Impact mat

Idler station of carrying side
Idler station
Self-aligning idler bracket for the carrying side idlers

Tail end
Tail pulley + bearing house + bearing
Tail pulley cleaner
Return belt cleaner

Idler station of return side
Idler station
Self-aligning idler bracket for the return side idlers
Cap cover of the idler

Counter weight
Counter weight pulleys with beariings
Pulley cleaners
Idlers

Drive end
Drive pulley
Gear and back stop
Motor
Electrical safety devices for belt conveyors such as emergency switch, rotation detector, belt misalignment switch, safety switch and blockage detector belt cleaners and inspection hatches

Belt splice damages?
- check vulcanizing products

Spillage?
- check loading point

Belt slippage?
- check pulley lagging

Misaligned belt?
- check belt conductor

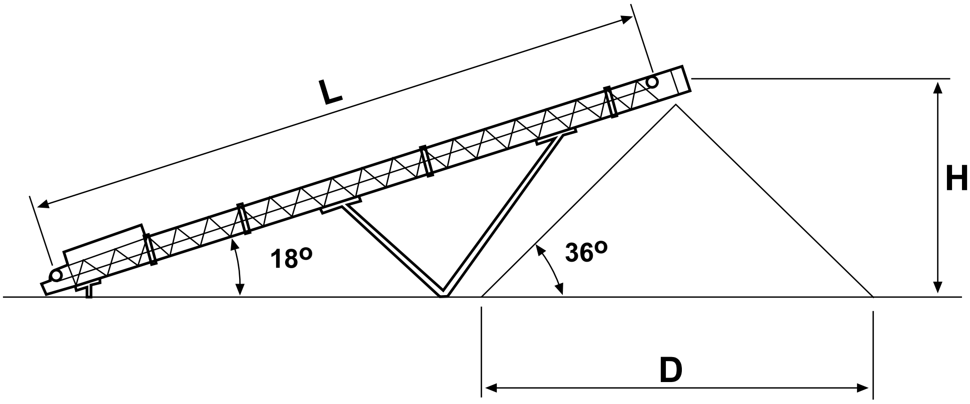
Pinching accidents?
- check return roll guard

Impact damages?
- check loading point

Carry Back?
- check belt cleaners

Dust?
- check dust sealing

7.22 Conveyor — Standard belt

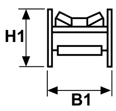


L m (ft)		H m (ft)		D mm (ft)		Volume m³ (ft³)	
6	(20)	2.4	(7.8)	6.5	(21.3)	26	(918)
7	(23)	2.7	(8.9)	7.3	(24.0)	38	(1 342)
8	(26)	3.0	(9.8)	8.2	(26.9)	53	(1 872)
9	(30)	3.3	(10.8)	9.0	(30.0)	71	(2 507)
10	(33)	3.6	(11.8)	9.9	(32.5)	93	(3 284)
12	(40)	4.2	(13.8)	11.6	(38.1)	149	(5 263)
14	(46)	4.8	(15.7)	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)

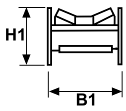
Frame height (H1) — width (B1)

Lenght (belt) m/ft	Belt width 500 mm/20 in H1 - B1 mm/in	Belt width 650 mm/26 in H1 — B1 mm/in	Belt width 800 mm/32 in H1 — B1 mm/in	Belt width 1000 mm/40in H1 — B1 mm/in	Belt width 1200 mm/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

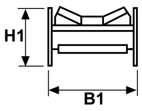
500 mm



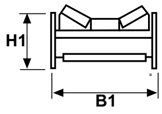
650 mm



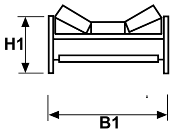
800 mm



1000 mm

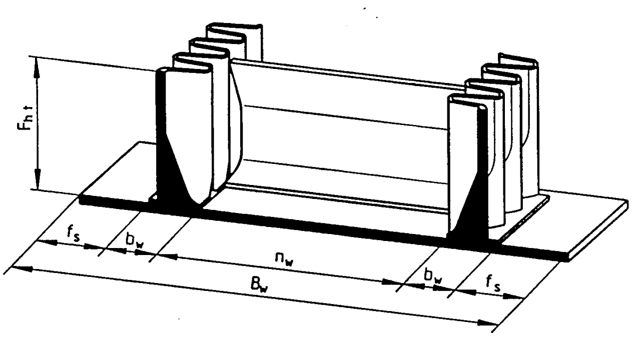


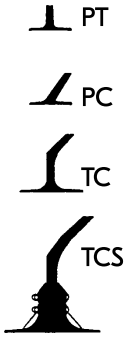
1200 mm



7.23 Vertical conveyor system

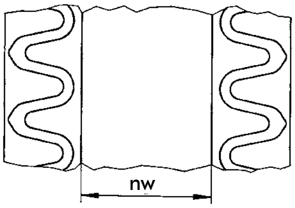
The vertical conveyer systems for material transportation is an engineered system with many variations. Below you will find some basic data covering the belt, the sidewalls and the cleats to be considered.



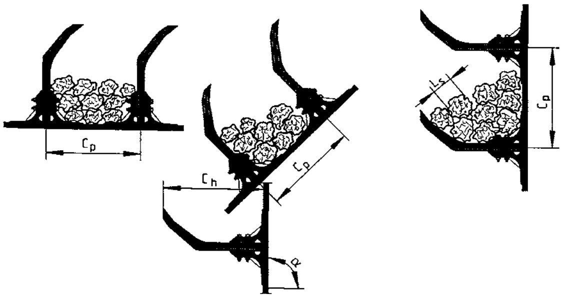


Belt width: (Bw)	depending on net width (see below)
Free lateral space: (fs)	depending on belt deflection discs
Net belt width: (nw)	depending on material size, see below
Sidewall height: (Fht)	depending on material size, see below
Sidewall width: (bw)	depending on sidewall height above
Cleat type:	depending 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

8. Slurry Handling

8.1 Slurry Handling — Introduction

Hydraulic transportation of solids

In all wet industrial processes "hydraulic transportation of solids" involves different stages of solid/liquid mixing, solid/solid separation and solid/liquid separation. These wet industrial processes are further described on page 8:20 - Application Guide.

What type of solids?

A solid can be almost anything that is:
Hard
Heavy
Crystalline
Sticky
Long fibrous
Coarse
Abrasive
Sharp
Flaky
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

- A mixture of solids and liquids is normally referred to as "slurry".
- A slurry can be described as a two phase medium (liquid/solid).
- Slurry mixed with air (common in many chemical processes) is described as a three phase fluid medium (liquid/solid/gas).
- Slurries can be settling or non-settling and some terms describing them are:

Mud
Suspensions
Slip
Dispersions
Silts
Tailings
Concentrate
Paste
Slime
Pulp
Broth
Slurry
Sludge
Froth

What are the limitations in flow?

In theory there are no limits to what can be hydraulically transported. However, particle size, shape, slurry concentration and pipe line designs can restrict flow capabilities.

In practice, the limitations in flow for a slurry pump range from 1 m^3/hour (4.4 US gpm) up to 30 000 m^3/hour (132,000 US gpm).

The lower flow limit is determined by the efficiency drop for smaller pumps. The higher flow limit is determined by the dramatic increase of costs for large slurry pumps as compared to the use of multiple pump installations.

Concentrations up to 40 % by volume of solids are typically considered to be the limit for pumping slurries using centrifugal pumps, though higher concentrations have been pumped.

Applications with high concentrations of solids, particularly those with fine particles, must be evaluated carefully, the slurry must be capable of flowing into the impeller eye for it to be pumped.

What are the limitations for solids?

The limitation for the solids is the geometrical shape and size and the risk of blocking the passage through a slurry pump. The maximum practical size of material to be mass transported in a slurry pump is approximately 200 mm (8").
However, individual lumps of material passing through a large dredge pump can be up to 350 mm (14") (depending on the dimensions of the wet end passages).

Physical properties of solids to be considered in pump selection:

Maximum size	*Particle size distribution (d50 and d80)*
Shape	*Hardness*
Solid density	*Concentration (by weight or volume)*

Slurry pumps in industry

Slurry pumps represent only 5 % of all centrifugal pumps installed in the industry. Yet, understandably, they can represent 80 % of the operating costs.

Consequently, it is very important to select and size slurry pumps to match the application. Metso Outotec is constantly developing and implementing product improvements as well as working with end users to provide equipment that increases operating efficiencies.

8.2 Basic definitions

Why slurry pumps?

By definition slurry pumps are a heavy and robust version of a centrifugal pump, capable of handling tough and abrasive duties. "A slurry pump should be considered to be a generic term, to distinguish it from other centrifugal pumps mainly intended for clear liquids".

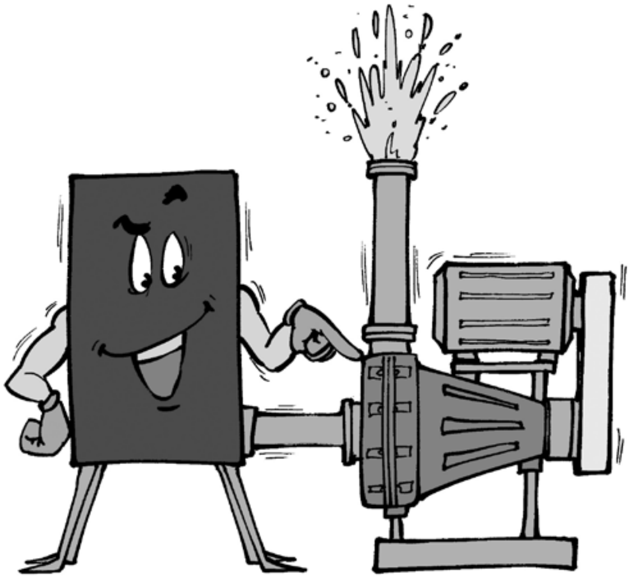
Slurry pump – name by duty

The term slurry pump, as stated, covers various types of heavy duty centrifugal pumps used for hydraulic transportation of solids. A more precise terminology is to use the classification of solids handled in the various pump applications.
Slurry and sand 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 (<< 400 Mesh)
- Silt 2-50 microns (up to 270 Mesh)
- Sand, fine 50-100 microns (270 – 150 Mesh)
- Sand, medium 100-500 microns (150 – 32 Mesh)
- Sand, coarse 500-2000 microns (32 – 9 Mesh)

Gravel pumps cover pumping of shingle, gravel and pebbles in the 2 - 64 mm (9 Mesh – 2.5") size range.
Dredge pumps cover pumping of solid sizes up to and above 64 mm (2,5").



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 CIP (carbon in pulp) and CIL (carbon in leach) circuits.

Sump pumps have an established name typically used for vertical pumps operating in wet pits. They have long cantilevered shafts so that bearing housings and drives can be mounted clear of the liquid surface while the pump housing is submerged.

Slurry pump – dry or semi dry?

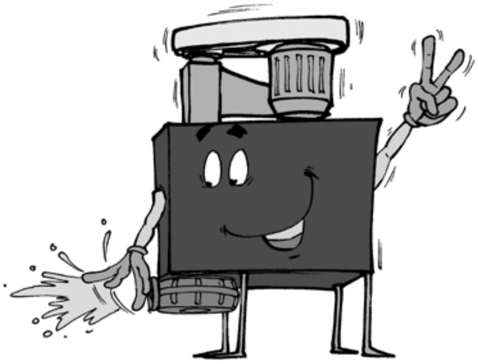
Dry installations

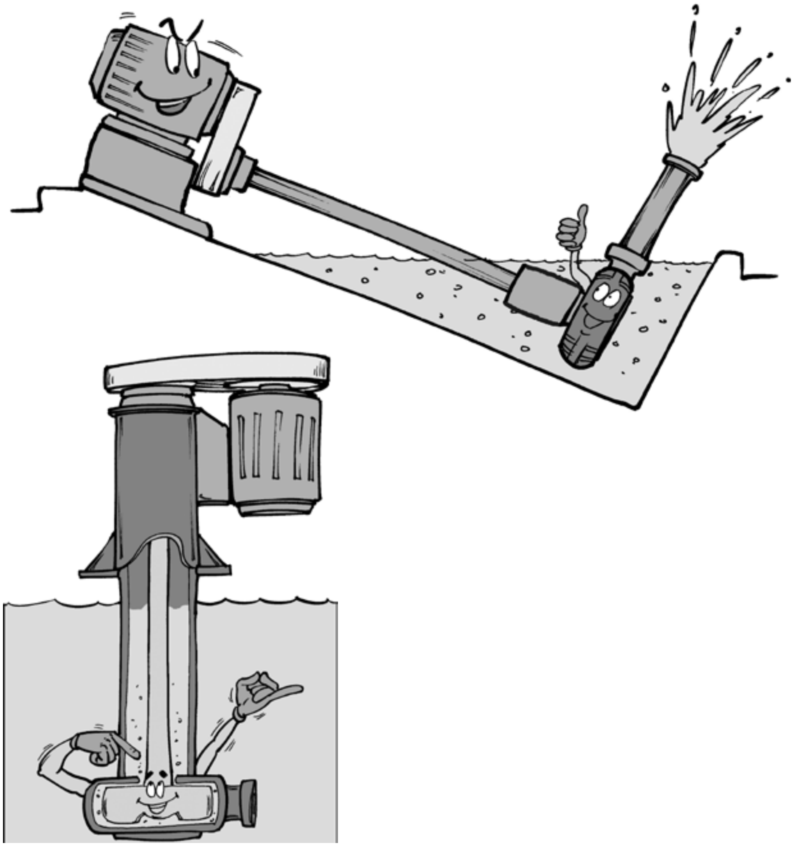
Most horizontal slurry pumps are installed dry, where the drive and bearings are kept out of the slurry and the "wet end" is closed. The pumps are free standing, clear from surrounding liquid.

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

Semi dry installations

A special arrangement can be used for dredging applications, where horizontal pumps are used with the "wet end" (and submerged bearings) flooded. This calls for special sealing arrangements for the bearings.
The sump pump has a flooded "wet end" installed at the end of a cantilever shaft (no submerged bearings) and a dry drive.





Slurry pumps and wear conditions

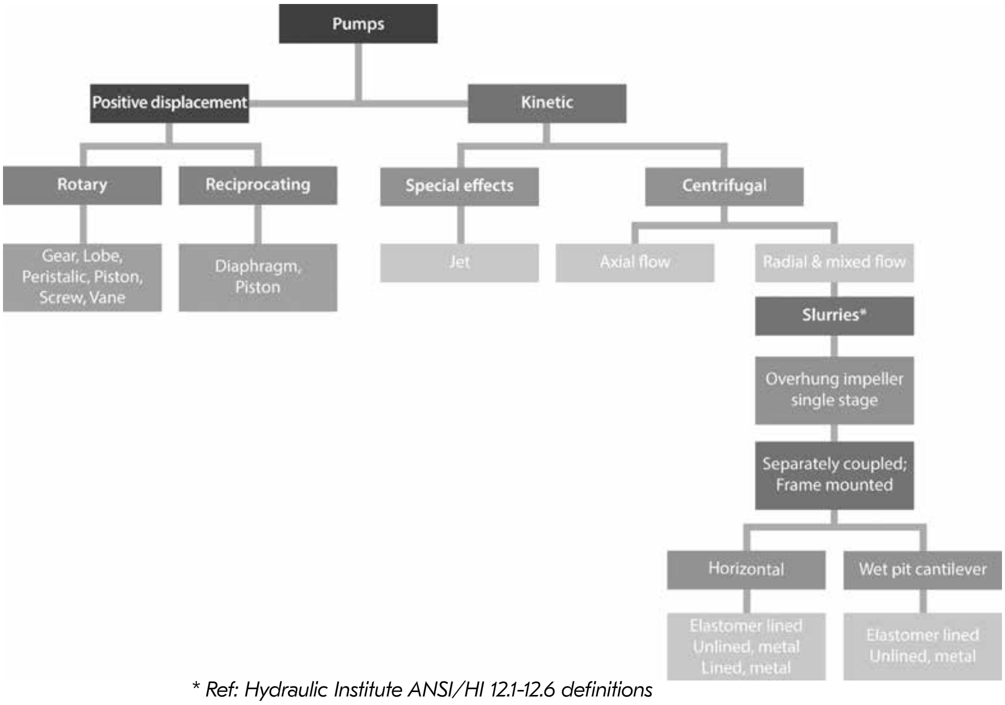
To ensure good service performance under a variety of working conditions and applications several factors must be considered when selecting pumps.
A primary factor is to identify the duty according to its wear service class, using the guidelines given in Hydraulic Institute Standard ANSI/HI 12.1-12.6 "Rotodynamic (centrifugal) slurry pumps"

Wear service class	Slurry class	Metso Outotec equivalent duty class
1	Light	Mildly abrasive
2	Medium	Abrasive
3	Heavy	Highly abrasive
4	Very heavy	Extremely abrasive

The HI Standard recommends operating limits for these service classes. These combined with Metso Outotec's pump designs and appropriate material selections will result in optimum wear life.
Metso Outotec's PumpDim sizing program, in conjunction with the HI Standard, is a valuable user friendly resource for selecting pumps for specific applications.

Type of pumps

Pumps can be classified by type.
This chart gives an overview of major types and the category in which Metso Outotec slurry pumps belong.



** Ref: Hydraulic Institute ANSI/HI 12.1-12.6 definitions*

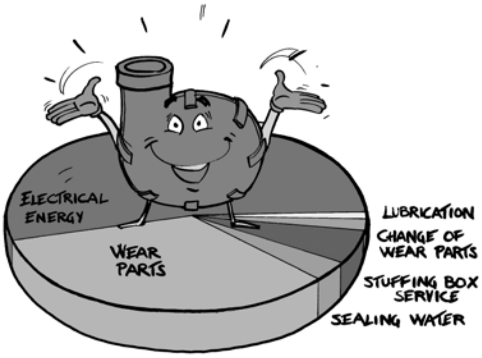
8.3 Technical description

General

If you look at a breakdown of the relative operating costs for a "normal" slurry pump installation you will find the factors that guide our design of slurry pumps.

These are our contributions to good operation and economy using Metso Outotec Slurry Pumps as described in this section. Visit www.metso.com/pumps

- High efficiency and minimised solids effect on efficiency drop giving lower power consumption
- New wear materials, both elastomers and metal, of good design giving long life for wear parts
- Service features in the design giving short shut down cycles and low maintenance costs
- Modern sealing designs giving low down time and costs for shaft sealing



Nomenclature

Series	Description - Horizontal pumps
MDM	Mill Discharge Pump with Metal Parts
MDR	Mill Discharge Pump with Rubber Parts
XM	EXtra Heavy Duty Slurry Pump with Metal Wear Parts
XR	EXtra Heavy Duty Slurry Pump with Rubber Wear Parts
XG	EXtra Heavy Duty Gravel Pump
HM	Heavy Duty Slurry Pump with Metal Wear Parts
HR	Heavy Duty Slurry Pump with Rubber Wear Parts
HG	Heavy Duty Gravel Pump
HH/HMP	High Head/ Pressure Pump with Metal Wear parts
HP	Heavy Duty High Pressure Pump
HT	Heavy Duty Tunneling Pump
MM	Mining Duty Slurry Pump with Metal Parts
MR	Mining Duty Slurry Pump with Rubber Parts
MA	MAtrix Pump
Thomas	Dredge Pump
Marathon	Dredge Pump
VASA HD	Heavy Duty – Sala design with Metal or Rubber wear parts

Series	Description - Vertical pumps
VF	Vertical Slurry Pump – Froth type with metal or rubber parts
VS	Vertical Slurry Pump – Sump type with metal or rubber parts
VT	Vertical Slurry Pump – Tank type with metal or rubber parts
VSHG	Vertical Slurry Pump – Sump type, Heavy Duty Gravel wet-end
VSHM	Vertical Slurry Pump – Sump type, Heavy Duty with Metal parts
VSHR	Vertical Slurry Pump – Sump type, Heavy Duty with Rubber parts
VSMM	Vertical Slurry Pump – Sump type, Mining Duty with Metal parts

8.4 Metso Outotec slurry pump series and sizes

Pump size – inlet flange

Inlet size (mm) (inch)	50 2	75 3	100 4	150 6	200 8	250 10	300 12	350 14	400 16	450 18	500 20	550 22	600 24	650 26	700 28	800 32
Metso Outotec MD series																
MDM						■	■	■	■	■	■	■		■	■	
MDR						■	■	■	■	■	■	■				
Orion series																
MM			■	■	■	■	■	■	■							
MM - WFR			■	■	■		■	■								
MR							■	■								
HM	■	■	■	■	■	■	■									
HM - WFR	■	■	■	■		■										
HR	■	■	■	■	■	■										
HH					■											
HG			■	■		■										
HG - WFR			■	■												
HP			■	■	■	■										
HT				■	■											
Thomas series																
MM											■					
MR											■					
XM								■	■		■		■		■	
XR							■	■	■							
Thomas Dredge				■	■	■	■	■	■	■	■		■			■
Marathon Dredge							■	■	■	■						
MA - Matrix											■					
Sala series																
VSMM			■	■	■	■	■	■	■							
VSMM - WFR			■	■	■		■	■								
VSHM	■	■	■	■	■	■										
VSHM - WFR	■	■	■	■		■										
VSHR	■	■	■	■	■	■										
VSHG			■	■		■										
VSHG - WFR			■	■												

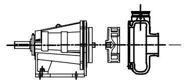
Pump size – outlet flange

Outlet size (mm) (inch)	25 1	40 1,5	50 2	80 8	100 4	150 6	200 8	250 10	300 12	350 14
Sala series										
VS	■		■	■	■	■	■	■		
VT		■	■	■	■	■	■	■		
VF			■	■	■	■	■	■	■	■
VASA HD					■	■	■			

8.5 Metso Outotec horizontal slurry pump wet-end modular configurations

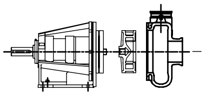
Frame and wet end modular configurations Orion and X-series

Frame 250



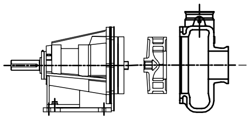
HM50
HR50
HM75
HR75
MM100
MR100 *)
HP75
HT100

Frame 300



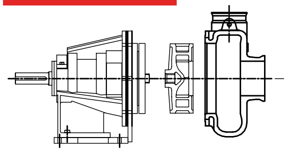
HM100
HR100
MM150
MR150 *)
HG100
HP100
HT150

Frame 400



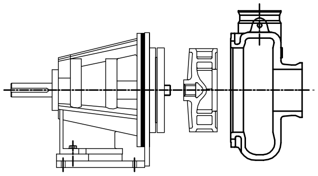
HM150
HR150
MM200
MR200 *)
HG150
HP150
HMPT100 *)

Frame 500



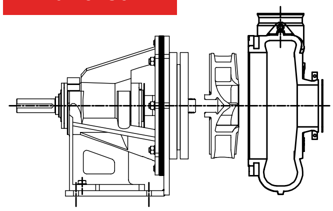
HM200
HR200
MM250
MR250 *)
HP200

Frame 600



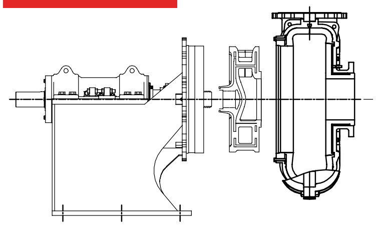
HM250
HR250
MM300
MM350
MR300
HG200
HG250
HP250
HH200
HMP150 *)
HMPT150 *)

Frame 750



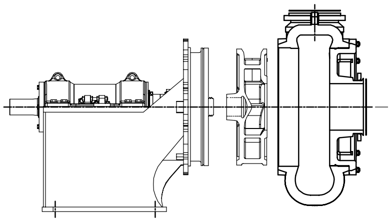
HM300
HR300
MM400
MR350
XG250
XR300
MDM250
MDR250
MDR300

Frame 900



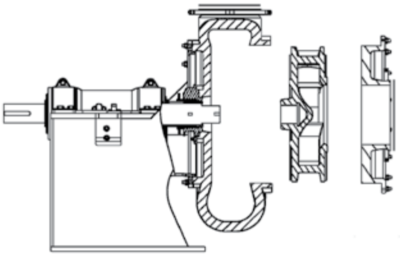
MDM300
MDR350
XM350
XR350
MM500

Frame 1000



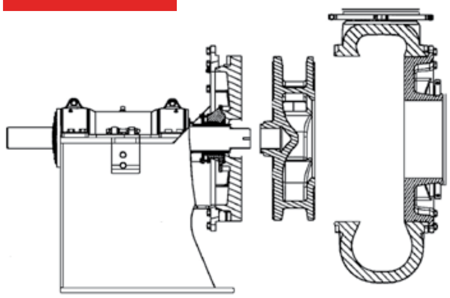
MDM350
MR500
XM400
XR400
XG350

Frame 1200



MDM400
MDR400
MDM450
MDR450
XM500

Frame 1400

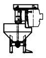
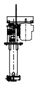
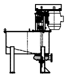
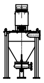
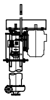
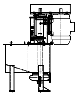
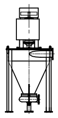
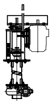
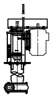
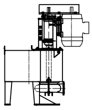
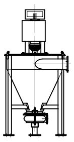
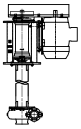
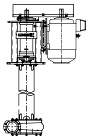
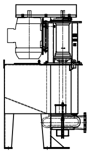
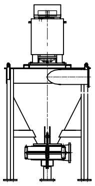
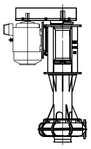
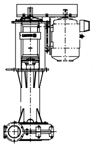
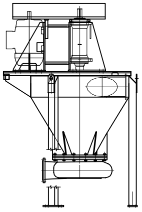


MDM500
MDR500
MDM550
MDR550
XM600
XM700

**) Refer to Metso Outotec application engineering*

8.6 Metso Outotec vertical slurry pump wet-end modular configurations

Frame and wet end modular configurations Sala-series

VSHM, VSHR, VSMM	VS RANGE	VT RANGE	VF RANGE	Frame size
		 VT40		VA
	 VS25 L80 VS50 L80	 VT50	 VF50	VB
	 VS25 L120-180 VS80 L80 VS100 L80	 VT80 VT100	 VF80	VC
 L120 - 180 VSHM50 VSHR50 VSHM75 VSHR75 VSHM100 VSHR100 VSMM100 VSMM150	 VS50 L120-180 VS80 L120-180 VS100 L120-180 VS150 L120	 VT150	 VF100 VF150	VD
 L120 - 180 VSHM150 VSHR150 VSHM200 VSHR200 VSMM200 VSMM250	 VS150 L150-180 VS200 L120-180	 VT200 VT250	 VF200 VF250	VE
 VSHM250 L120-180 VSHR250 L120-180 VSMM300 L120-180 VSMM350 L150-180	 VS250 L150-180			VF
			 VF350	VG

8.7 Slurry pump range MD

Mill Discharge slurry pumps MDM and MDR

Specifically designed from its inception for mill circuit applications, the Metso Outotec MD series of mill discharge MDM hard metal and MDR rubber lined slurry pumps offer sustained performance with maximum time between mill shutdowns.

Hydraulic design is consistent across the entire range and by limiting the inlet velocity at design BEP impact damage from coarse heavy solids is kept to an absolute minimum.

Large diameter high aspect ratio impellers provide for excellent hydraulic efficiency with minimum turbulence at minimum rotational speed, thereby reducing the rate of wear.

Reduced impeller overhang restricts shaft deflection across a wide range of flows, and in so doing maximizes shaft seal and radial bearing life.

Suction side recirculation is restricted by an adjustable inlet liner/wear plate.

When used in conjunction with the axially adjustable bearing cartridge, the design provides for 'double adjustment' ensuring that both suction side and gland side impeller clearances can be set and reset at a minimum.

Summary of design features

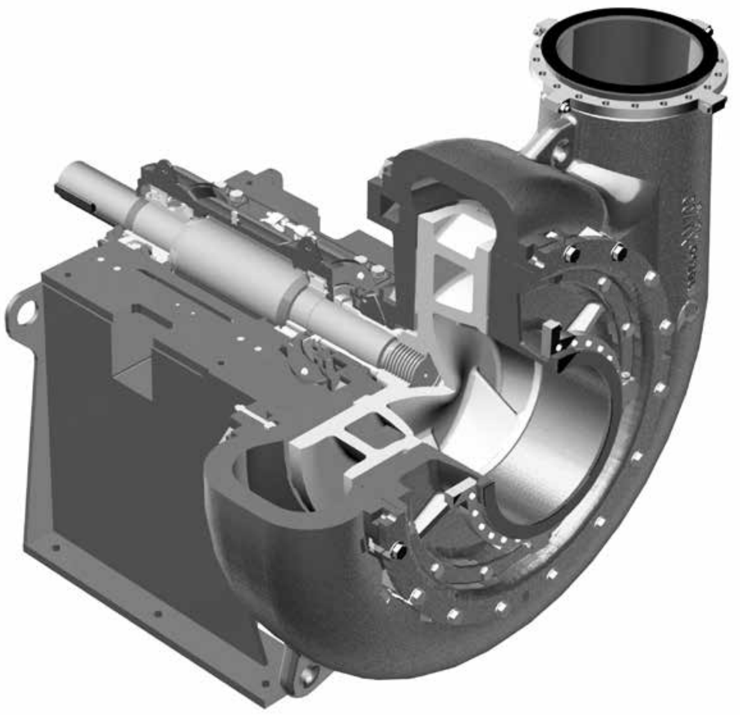
- High sustained efficiency
- Even hydraulic wear
- Longer operating life
- Oversized robust steel shaft
- Extra thick casings and liners at known points of wear
- Back pull-out option for ease of maintenance
- Self-contained oil or grease lubricated bearing cartridge assembly with noncontact labyrinth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

PUMP DESIGNATION
MDM350
MDR350
Pump range ⌟ ⌞ Inlet size (mm)

8.8 Slurry pump range XM

The Thomas series of extra heavy duty hard metal slurry pumps

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



Summary of design features

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

PUMP DESIGNATION
XM350

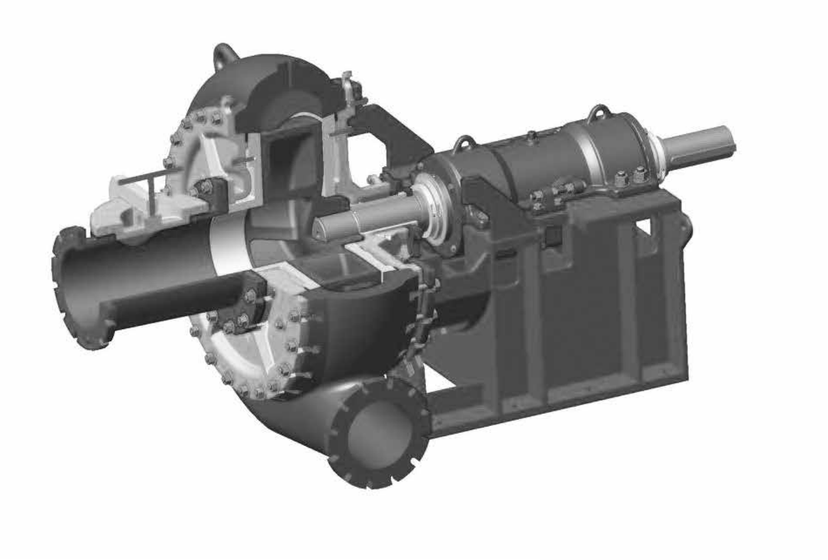
Pump Range

Inlet size (mm)

8.9 Dredge pumps

Thomas series of "Simplicity" dredge pumps

The Thomas "Simplicity" dredge pump is engineered for your specific operation. Years of operation and many design improvements have resulted in a pump which will give you lowest operating cost of any pump in the industry when handling abrasive materials.
The rugged wet-end parts are designed to feature extra heavy metal sections at points of extreme wear – the extra weight pays off in performance and low maintenance cost.
No other dredge pump manufacturer offers the wide range of wearresistant alloys as provided by Metso Outotec. Matching the correct alloy to your specific application will give you the best performance and lowest cost.



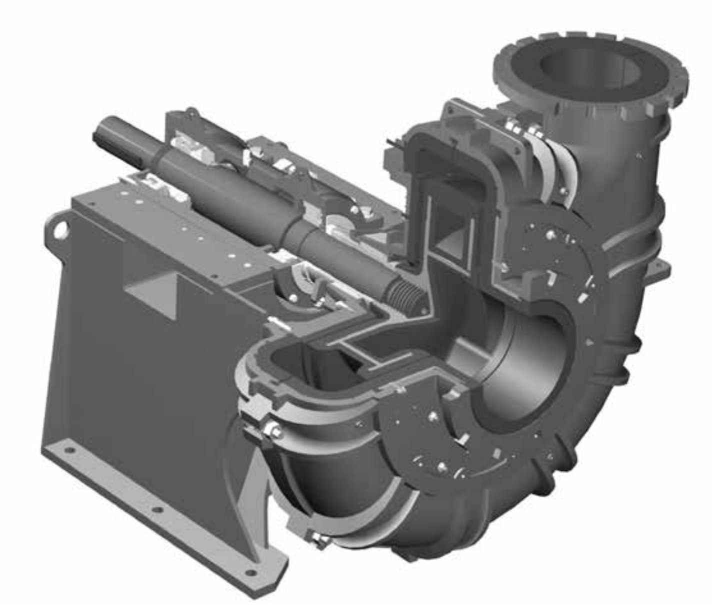
Summary of design features

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

8.10 Slurry pump range VASA HD and XR

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

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



Summary of design features

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

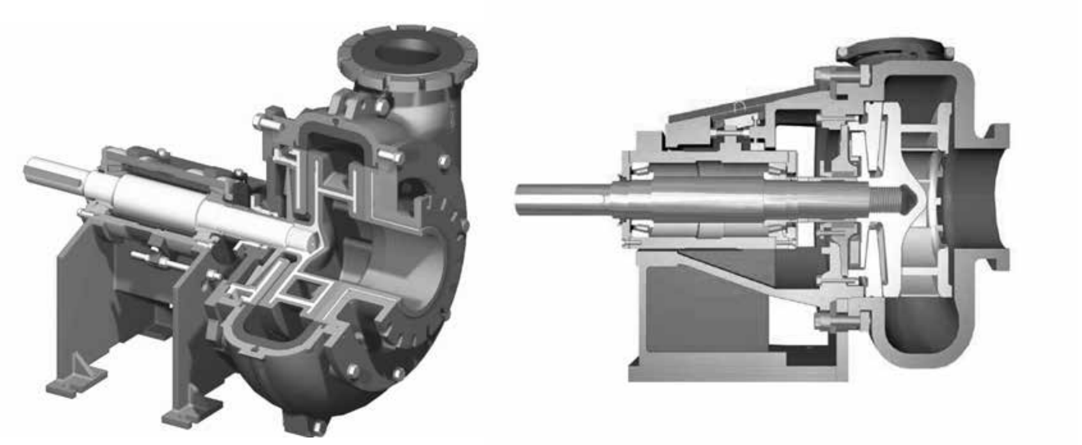
PUMP DESIGNATION
XR350

Pump Range Inlet Size (mm)

8.11 Slurry pump range HR and HM

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

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

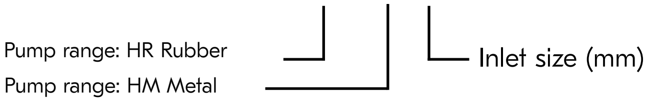


HR wet end single adjust, HM wet end double adjust

Summary of design features

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

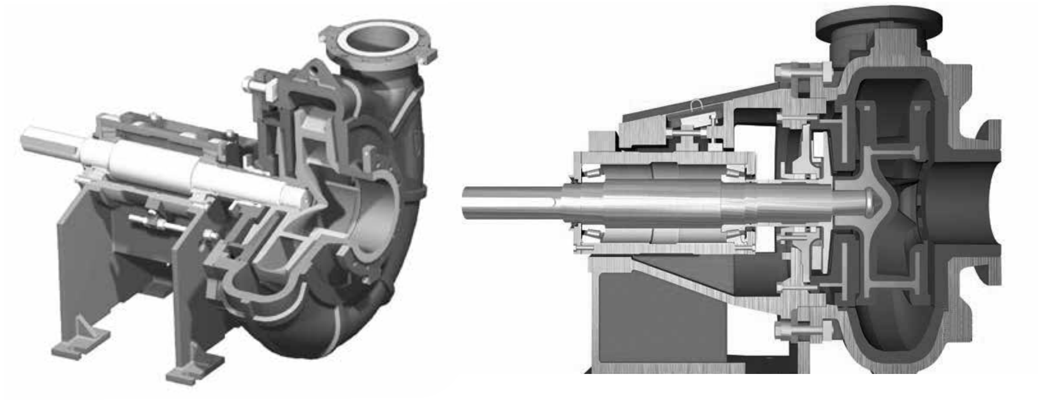
PUMP DESIGNATION
HR or HM100



8.12 Slurry pump range MR and MM

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

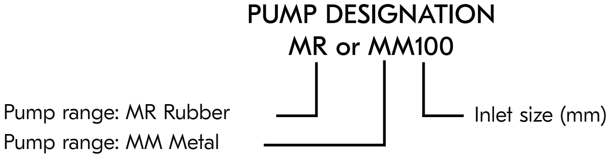
The MR (rubber lined) and MM (hard metal) mining duty, slurry pump ranges are designed to provide an economical solution to all slurry pump applications. Excellent hydraulic designs maximise efficiency throughout the life of the pump and selection of wear part materials from the extensive Metso Outotec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



MM wet end single adjust, MR wet end double adjust

Summary of design features

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



8.13 Slurry pump range VT

The Sala series of vertical tank pumps

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

Summary of design features

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

PUMP DESIGNATION
VT100

Pump range
Discharge size (mm)

8.14 Slurry pump range VF

The Sala series of vertical froth pumps

Metso Outotec's froth pumps are designed to increase the pumpability of frothy suspensions. The principal of operation is similar to that of hydrocyclone separation.
Air is separated from the slurry in a vortex created by the impeller rotation and the tangential inlet to the pump's conical sump. This results in a more efficient pumping at higher capacities and a smooth operation free from fluctuations.

Summary of design features

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

PUMP DESIGNATION
VF100

Pump range
Outlet size (mm)

8.15 Slurry pump range VS

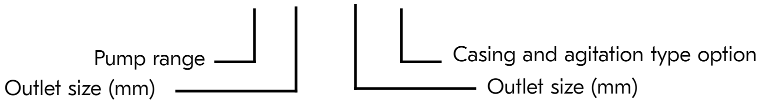
The Sala series of vertical sump pumps

Metso Outotec sump pumps are designed specifically for abrasive slurries and feature robust design with ease of maintenance. The VS sump pump range is one of the strongest, toughest and reliable high volume ranges available on the market. It is for this reason that the range is preferred throughout the world by most heavy industries.

Summary of design features

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

PUMP DESIGNATION
VS100 L120 O4S



8.16 Slurry pump range VSHM, VSHR 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 to the customer: the same wet end parts are used for both horizontal slurry pumps and sump pumps, thus reducing parts inventory and simplifying maintenance. It does also make it possible to generate a higher TDH, pump head.

Summary of design features

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

PUMP DESIGNATION
VSHM150 L120 C5

Pump range
HM150 is the horizontal pump wear parts (150 is the inlet size, mm)
5 vane closed impeller
Frame length (cm)

8.17 Application guide

General

This section is a guide to the selection of the correct slurry pump range for various applications. As previously stated the sizing of the slurry pump and its system is very important. Equally important is to choose the right type of slurry pump for the process application in question. The slurry pump range presented in this handbook represents a broad coverage of applications for hydraulic transport of solids.

Selecting against duty means selecting pumps considering parameters like:

- Volumetric flow rate (nom., min., max)
- Head (nom., min., max.)
- Solids (size, shape, density etc.)
- Liquid (corrosive, thixotropic, frothy)

Selection by duty or industrial application?

How to pump

- Industrial waste
- Leaching residue
- Mill scales
- Mineral tailings
- Wood chips
- etc.**How to feed**
- Hydrocyclones
- Pressure filters
- Tube presses
- Flotation machines
- etc.

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

Selection by duty

In this section we are selecting the optimal slurry pump simply against the specified pump duty. This guide is strictly based on technical performance reflecting various Solid/Liquid parameters.

Selection by industrial applications

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

8.18 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: MDM , 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: MD, 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).
Recoomendation: H and V ranges

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.

8.19 Duties realted to head and volume

Duty: High head

Comments: Normally metal pump applications due to the high peripheral speed on the impeller. If you need rubber lined pumps, series pumping may be needed.
Max. head on hard metal pump 125 m (410 ft).
Max. head on rubber impeller 45 m (148 ft).
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 variable (frequency control) drives.
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 (16 - 26 ft). 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.
Risk for cavitation.
Recommendation: All ranges.

Duty: Low flow

Comments: 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.

8.20 Duties realted to slurry type

Duty: Fragile slurries

Comments: Use induced flow impellers (fully recessed).
Both metal and rubber pumps can be used. Both horizontal and vertical pumps can be used.
Recommendation: All ranges.

Duty: Hydrocarbon slurries (oil and reagents contaminated)

Comments: Natural rubber is out.
Be careful with seal material of natural rubber. Use synthetic seals.
Use metallic pumps or wear parts in polyurethane.
Recommendation: All ranges.

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

Comments: Temperature limit for natural rubber is 60° C (149 °)F).See section 9 for synthetic rubbers.
Practical limit for operating temperature is 135° C (275°F).

Above this temperature the bearings can be over-heated!
Recommendation: All horizontal ranges.

Duty: Frothy slurries

Comments: Use a froth pump of vertical design.
Recommendation: VF range.

Duty: Hazardous slurries

Comments: Warning! This case has to be referred back to the pump sales support departments.
Shaft sealing is critical from explosion point of view. Normally closed pump systems are used.
Recommendation: Horizontal ranges.

Duty: Corrosive slurries (low pH)

Comments: For acidic duties use rubber or elastomer.
For metal pumps with chrome iron parts the acid limit is pH 2,5.
Sea water slurries (containing chlorides) must have a rubber pump.
Note! $CuSO_4$ (used in flotation circuits) is extremely corrosive, use rubber pumps.
Recommendation: All ranges.

Duty: High viscosity fluids (Newtonian)

Comments: Pumping becomes critical when viscosity gets up to 5 times the viscosity of water. With this restriction basically any pump in our range can be used, if properly sized.
Recommendation: All sizes.

Duty: High viscosity fluids (non-Newtonian)

Comments /Recommendations
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.

8.21 Selection of slurry pumps – by industrial application

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

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

Pumps for grinding circuits

Comments: Our MD, 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: MDR/MDM, XR/XM, HR/HM.

Application: Pumps for froth

Comments: The VF range is specially designed for froth pumping.
Be cautious for heads greater than 15 m.
Recommendation: VF.

Application: Pumps for floor sumps

Comments: Use sump pumps type VS with metallic wear parts, since there often is a risk for oversize tramp material coming into floor sumps.
If rubber must be used, put a strainer in front of the pump or around the pump.
Recommendation: VS range.

Application: Pumps for tailing

Comments: Depending on particle size both rubber and metal pumps can be used. For long distances installations (in series) use multiple pumps in series.
Recommendation: MD, X and H ranges, both rubber and metal.

Application: Pumps for hydro-cyclone feed

Comments: For sharp classification use horizontal pumps type MD, X or H. For dewatering cyclones use tank pumps.
Recommendation: MD, 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 8:22.

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.

8.22 Industrial segment: Construction

Application: Pumps for wash water (sand and gravel)

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

Application: Pumps for sand transportation

Comments: Horizontal pumps with rubber lining are preferred.
Recommendation: MR.

Application: Pumps for tunnel dewatering

Comments: As front pumps use drainage pumps. For the first transportation stage vertical pump type VS is normally used.
For horizontal distant pumping use HM range.
For cuttings from full face boring (TBM:s) use HM and MM pumps.
For small tunnels (micro bore) use small HM.
Recommendation: H, M and VS range. (No rubber due to oil.)

8.23 Industrial segment: Coal

Application: Pumps for coal washing

Comments: Generally metal pumps are used because of risk for oversized tramp material.
Recommendation: HM and MM ranges.

Application: Pumps for froth (coal)

Comments: Use vertical pump type VF.
Recommendation: VF.

Application: Pumps for coal/water mixtures

Comments: Use conventional pumps M ranges.
Recommendation: M ranges.

Application: Pumps for general purpose (coal)

Comments: Coal industry normally does not use rubber pumps.
Recommendation: Use HM and MM.

8.24 Industrial segment: 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.

8.25 Industrial segment: power & FGD

Application: Pumps for FGD reactor feed (lime)

Comments: Normally the mineral applications use X, H and M ranges, all with rubber and/or metal parts.
Rubber for high chloride concentrations.
Recommendation: X, H and M ranges.

Application: Pumps for FGD reactor discharge (gypsum)

Comments: See lime pumps 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.

8.26 Industrial segments: Pulp & paper

Application: Pumps for liquors

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

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

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.

8.27 Industrial segment: Metallurgy

Application: Pumps for mill scale transportation

Comments: First choice is vertical pump type VS with induced flow impeller and metallic parts.
Horizontal pumps use type HM with metal parts only
Recommendation: HM and VS ranges.

Application: Pumps for slag transportation

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

Application: Pumps for wet scrubber effluents

Comments: Normally we recommend pump of horizontal type M range or vertical pumps of VS range.
If pH is very low use rubber.
If pH is very low and temperature is very high use stainless steel parts or synthetic rubber.
Recommendation: MR and VS ranges.

Application: Pumps for iron powder transportation

Comments: See dense media pumps above.

Application: Pumps for machine tool cuttings

Comments: No rubber parts can be used due to oil.
Vertical pump of type VS and horizontal pumps type M.
Recommendation: VS and MM.

8.28 Industrial segment: Chemical

Application: Pumps for acid slurries

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

Application: Pumps for brines

Comments: Very corrosive applications. Can also be abrasive (crystals).
Polyurethane can be used to avoid crystallization on pump parts.
Recommendation: HM, HR, MM, MR and VS (polyurethane parts).

Application: Pumps for caustics

Comments: Both rubber and metal pumps can be used.
Recommendation: MM, MR, HM and VS ranges.

8.29 Industrial segment: Mining

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

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

Application: Pumps for mine water (with solids)

Comments: Normal recommendation is horizontal pumps type HM (multistage if required).
Watch out for corrosion!
Recommendation: HM.

8.30 Slurry transport

The **Metso Outotec Slurry Hose System Design Manual** is a useful reference offering advice and instructions on the installation of Metso Outotec piping used in slurry transportation. A significant amount of the information below is from that document.

Piping used in slurry handling applications should be sized and selected to provide long wear life, ease of maintenance and economical power consumption. Piping is available in steel, elastomer-lined steel or non-metallic materials such as rubber, plastic and concrete.

Steel pipelines are used for high pressures and when the slurry is relatively fine and not corrosive. Thick walled pipe can be used to prolong operating life from wear and corrosion. In some instances, more expensive special hardened steels are used but significant improvement in wear life has not been observed.

To increase wear resistance, pipes are often lined with different kinds of materials. Rubber lined steel pipes are used for transportation of wearing material under high pressures and the service life of the pipeline is prolonged considerably.

Rubber pipes offer superior wear resistance when handling abrasive slurry material. When used with rubber lined steel pipes the combination allows for excellent flexibility in piping layout and the ability to make future changes with minimal structural modifications.

Plastic pipes can be used for transporting fine materials under low pressures and velocities. Some benefits are their light weight, better corrosion resistance compared to steel and low friction losses but some of the drawbacks are limited wear resistance and high coefficient of expansion. Concrete pipes have high friction losses and may be suitable for limited applications only.

Applications

Slurry hose, in conjunction with lined pipe, can be used in many industries and some examples of these applications are given below.

Mining industry

Transportation of crushed ore, ground ore and waste products.

Stone and gravel industry

Transportation of sand, gravel, crushed rock and ground rock.

Cement industry

Transportation of lime slurry and chalk.

Chemical industry

Transportation of leached uranium ore, granular gypsum, phosphate slurry, china clay, fluorspar and salt.

Steel works

Transportation of oxide scale in suspension.

Coal industry

Transportation of coal slurry in washing plants.

8.31 Slurry pipeline sizing

The following factors have a significant effect on the selection and sizing of a slurry transport pipeline because they are related to the wear life, power consumption, maintenance and operating costs in an application.

Particle characteristics

- Size
- Size distribution
- Shape
- Hardness
- Density (concentration)
- Temperature

Liquid characteristics

- Density
- Viscosity
- Temperature
- pH

Pipe conditions

- Pipe material or pipe lining material
- Diameter
- Circuit layout – bends, inclination, uneven path of piping

Type of flow

- Laminar or turbulent
- Heterogeneous or homogeneous
- Flow velocity

Flow regimes

Large particles are more difficult to keep in suspension than small ones in a slurry mixture. At low flow velocities particles will have a tendency to settle out in a pipeline. Therefore, low velocity conditions can result in blockages whereas high velocities increase friction losses.

Flow regimes can be described as stationary bed, sliding bed, heterogeneous and homogeneous.

Stationary bed conditions should be avoided because these will cause production problems. Sliding bed conditions may be acceptable in some applications that have short pipelines but are not recommended.

Homogeneous and heterogeneous flow conditions are preferred for slurry transport.Slurry with uniform particle distribution in the pipe cross-section and particle size smaller than 50μ (0.002″) is classified as a homogeneous suspension. Rheological properties of such mixtures should be determined so as to account for viscosity effects that will occur under operating conditions.

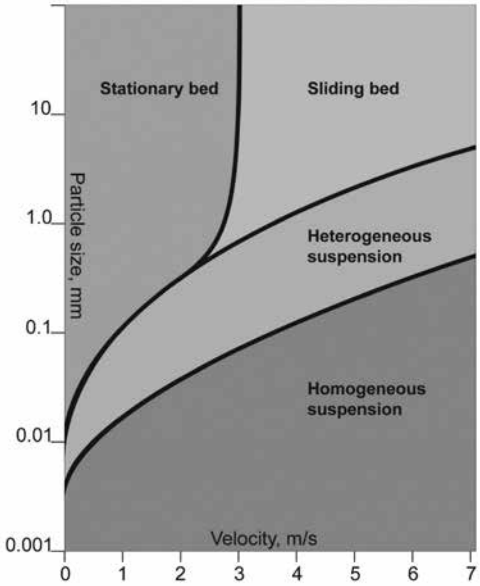


Figure 1: Example of flow configurations (sand density = 2700 kg/m3, pipe diameter = 160 mm)

Compared to homogeneous suspensions, heterogeneous suspensions have larger particles which are suspended mainly through liquid turbulence. Flow velocities should be above a 'critical velocity' so as to prevent sedimentation or clogging in the pipeline. Critical velocity calculations are a function of particle size, particle density, pipe diameter and volumetric concentration.

Figures 1 to 3 provide a visual overview and explanation of the above commentary.

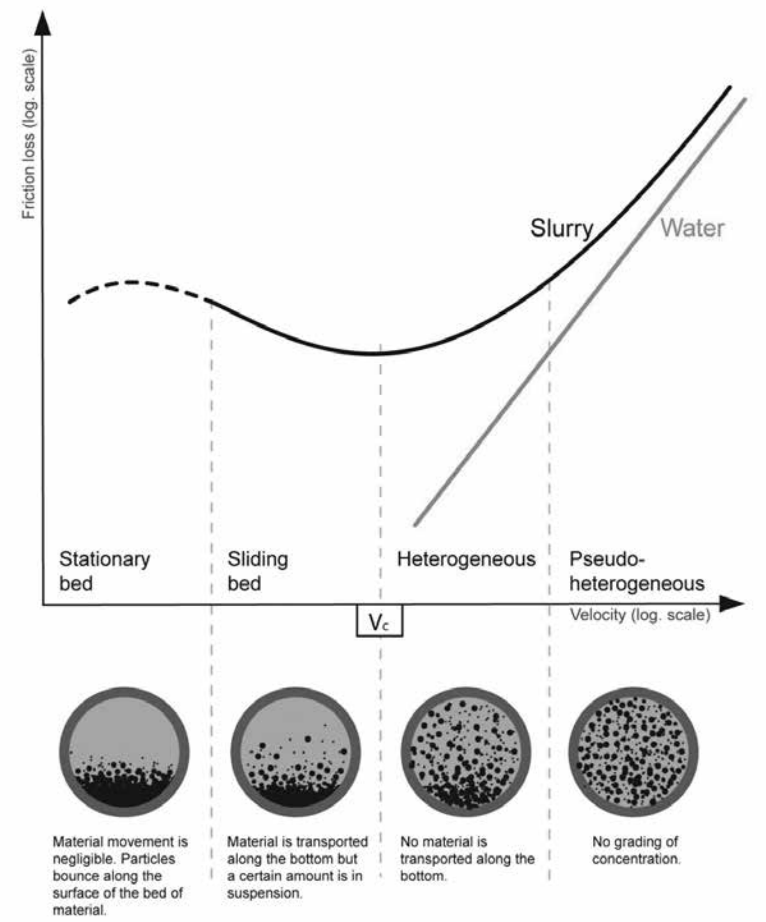


Figure 2: Relationship between different flow conditions and friction losses

Figure 3: Different flow conditions. The lowest variant represents the preferred flow conditions.

8.32 Wear

Particle shape, hardness, concentration of solid material and flow velocity affect wear in pipelines. Improperly sized piping, misaligned connections, sharp bends, uneven path, inclination of piping are factors that also have to be considered in the design of a circuit. The life cycle can be extended if, where possible, piping can be rotated at specified maintenance intervals resulting in uniform wear of the part.

Wear in slurry handling equipment can be caused by sliding, cutting and crushing actions of the solids. Pipelines mostly see sliding wear although cutting wear can also occur. Crushing wear is mostly non-existent in pipelines.

The angle of incidence at which particles impact the pipe surface is important in the wear process. Low angles of incidence, common in sliding wear, are ideal for rubber surfaces and result in superior wear resistance. See example below in Figure 4 of the economic benefits of an application using a rubber surface in slurry transport.

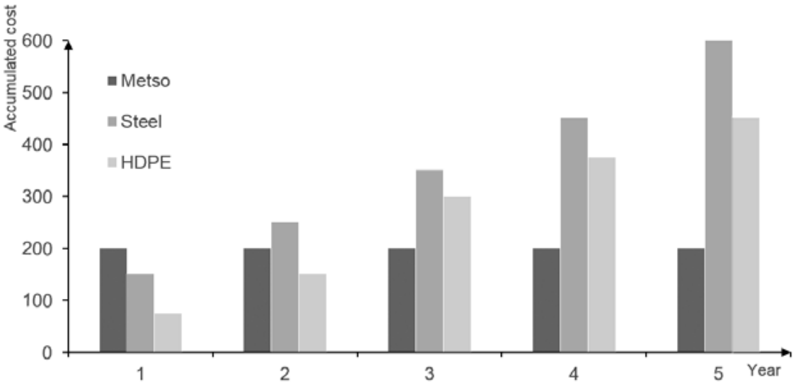


Figure 4 A cost comparison between Metso Outotec, conventional steel pipes and HDPE, based on the following operational date: 2 lines with total lenght of approx. 100ft (300m) having an inside diameter of 6 in. (152 mm) for carrying slurry (35% solid material of diabase and gneiss with a particle size up to 3/16 in. (5mm) Working pressure 75 psi (5kp/cm2). Flow rate 11 ft/sec (3.3 m/s). Capacity 140 000 tons of solid material per year.

Hose and lined pipe

Rubber hose and rubber lined steel pipe is available over a wide range of diameters and, depending on size, working pressures up to 25 Bar (360 psi). The hose can withstand certain vacuum conditions. Chemical resistance depends on factors such as temperature, concentration, pressure, flow rate, exposure time and liquid stability.

Hose is made by winding several layers of different materials on a rubber Wear Tube as depicted in the Figure 5 below. The windings are laid in a specially predetermined pattern to provide the reinforcement necessary to withstand the rated pressures. A vulcanizing process bonds the components to make a solid assembly. The outer cover protects the reinforcements from external damage such as abrasion, corrosion, sunlight and ozone.

1. Wear tube T-40, T-60
2. Polyester cord, 2 plies
3. "Sandwich" rubber
4. Steel Spiral
5. Polyester cord, 2 plies
6. SBR Cover rubber

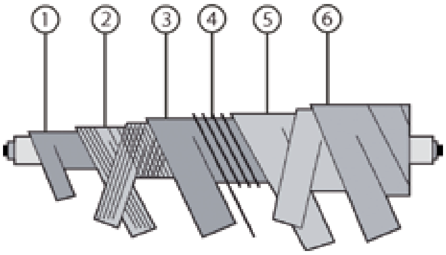


Figure 5

Rubber lined steel pipe can be used in straight runs and can be self-supporting whereas a support structure is recommended for hose. The pipe and hose can be connected with the aid of split-flange couplings and gaskets for an obstruction free joint. Other accessories such as bends, branch pipes, reducers, compensators and dart valves are available and provide the flexibility required to build a complete circuit. Figures 6 - 9 and pictures 1-5 illustrate several piping components and piping layouts.

Figure 6: Branch Pipe 90°

Figure 7: Compensator

Figure 8: Branch Pipe 45°

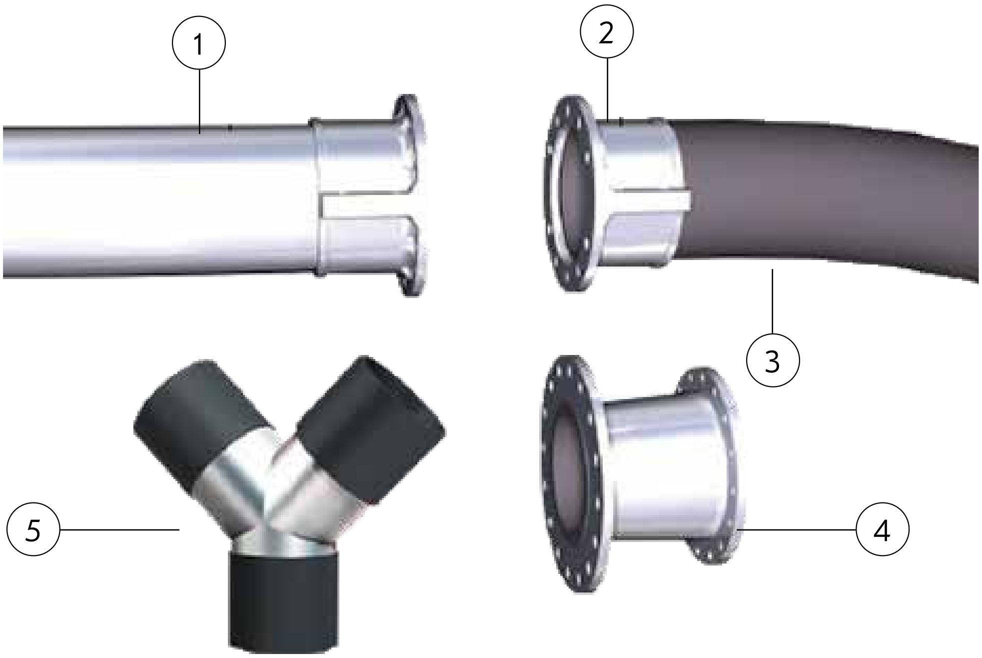


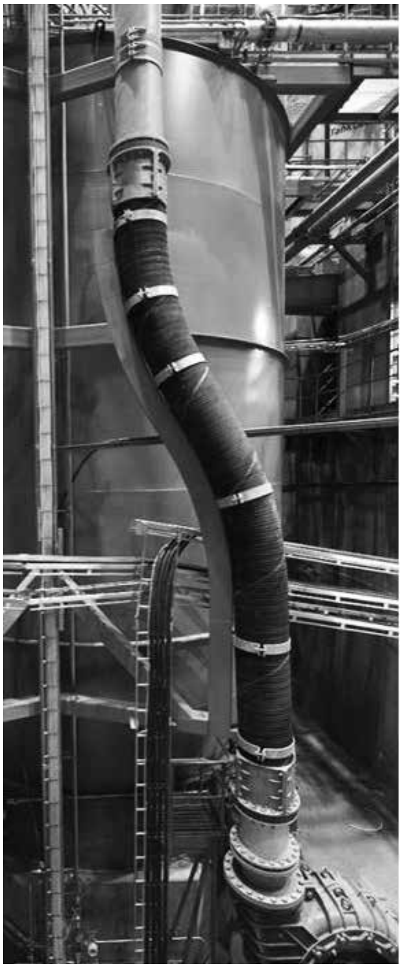
Figure 9: Example of Slurry hose piping and connectors

8.33 Accessories:

1. Rubber Lined Steel Pipe
2. Coupling
3. 3xD Rubber Bend
4. Rubber Lined Steel Reducer
5. Branch Pipe

Examples of installations using Metso Outotec slurry hose and piping

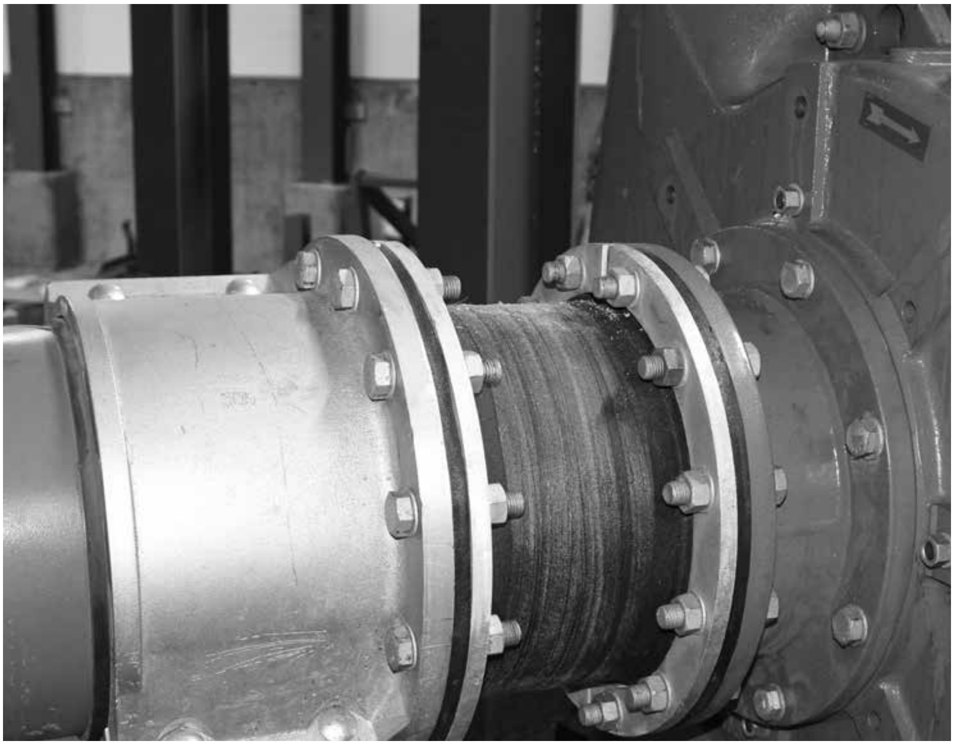
Picture 1: Material handling hose and rubber lined steel pipe



Picture 2: Material handling hose with support beam and clamps

Picture 3: Material handling hose, rubber lined steel pipe, 3xd 90 degree bend and support clamps

Picture 4: Material handling hose with 3xD 90 degree bend



Picture 5: Rubber lined steel pipe and compensator

8.34 Slurry valves – Introduction

Valves are a necessity in any piping circuit. They aid in controlling flow in all types of operating conditions, from start-up, during production cycles and at shut-down.

Valves come in many designs, such as gate, pinch, ball, butterfly and plug to name a few. Operation can be manual, pneumatic, hydraulic or electric. Additional features can be added to automate the control process and optimize performance.

Valves handling solids laden fluids, as compared to those for clear fluids, face severe performance demands and they have to be of a robust design to function reliably in order to withstand the wear and tear that can occur in such applications. Valve designs are therefore limited to specific types as is described here.

Applications

Slurry valves are used in many mineral processing applications and some of the industries served are listed below.

- Mining
- Oil Sands
- Pulp and Paper
- Stone and Gravel
- Cement
- Chemical
- Steel Works
- Coal

Slurry valve sizing

Valve and piping selection in slurry applications requires skilled system analysis and support from personnel with expertise in this field. The following factors have a significant effect on the selection and sizing of a slurry valve because they are related to the wear life, power consumption, maintenance and operating costs in an application.

Particle characteristics

- Size
- Size distribution
- Shape
- Hardness
- Density (concentration)
- Temperature

Liquid characteristics

- Density
- Viscosity
- Temperature
- pH

Type of flow

- Laminar or turbulent
- Heterogeneous or homogeneous
- Flow velocity

Pipe conditions

- Pipe material or pipe lining material
- Diameter
- Circuit layout – used to define valve location

Flow regimes

See page 8:29 Slurry transport for more information on this subject. Flow regimes in a circuit can be described as stationary bed, sliding bed, heterogeneous and homogeneous. Stationary and sliding bed conditions are not recommended. Homogeneous and heterogeneous flow conditions are preferred for slurry transport.

Wear

In slurry handling applications, equipment will commonly see abrasive, erosive and corrosive wear. These three can occur individually or in combination depending on the factors given above. Valves, for example, can see:

- Abrasion when particles get trapped between surfaces moving relative to each other
- Erosion when particles impact surfaces at different angles and depends on conditions such as high flow velocities, cavitation, particle characteristics and valve setting
- Corrosion is due to chemical attack on materials that are incompatible with the fluid being pumped

8.35 Slurry valves

Metso Outotec slurry valves used in mineral processing applications are of the following designs. Contact Metso Outotec application engineering for technical assistance in the selection process.

Knife gate valves

These valves are suitable for most abrasive slurries and the 'full-bore' design with 'shut-off' isolation features offer bi-directional operational reliability. Actuation by manual, pneumatic or other means is possible.
In the open setting, the elastomeric seats seal tightly against each other when the gate is fully withdrawn out of the flow stream. Only the seats are exposed to the slurry while providing a full-bore opening and no area for media build up.
During the closing action the seats are axially separated and seal against the gate. Residue can be discharged from the bottom of the valve at the end of the cycle.

Open *Open* *Closed*

The table below lists sizes available and the pressure ratings.

Size range	DN 50 – DN 600 ASME 2" – 24"	
Pressure rating	Flange	Max. differential pressure at ambient temperature
	DN 50 – DN 400	10 bar
	DN 450 – DN 600	5 bar
	ANSI 2" – 16"	150 psi
	ANSI 18" – 24"	75 psi

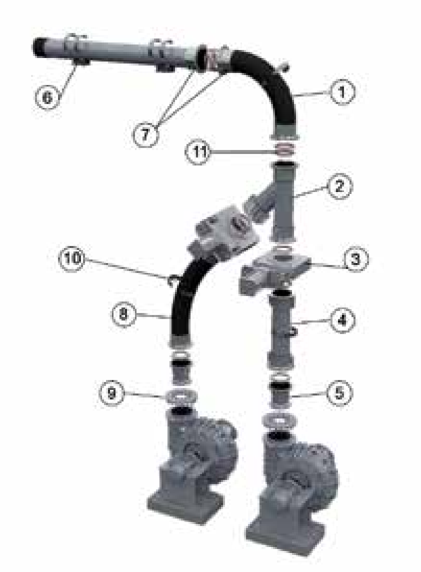
Temperature rating and chemical resistance depend on the type of elastomer used. Contact Metso Outotec application engineering for details.

Dart valves

Dart valves are used for flow shut off inside sump tanks with vertical outlets. They are suitable for applications handling abrasive slurries, powders or granular substances. The valve and seat are elastomer lined over all the surfaces that come in contact with slurry. There is no flow restriction in the open position.

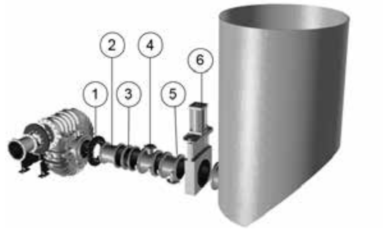
The inside diameter of the seat is the same as the Slurry Hose System offered by Metso Outotec. Valves from DN100 – DN600 mm (4"-24") sizes in DIN flanges are available. Pneumatic, hydraulic or electrically operated actuators can be used for regulating the dart valve.

Examples of Metso Outotec slurry hose and valve installations.

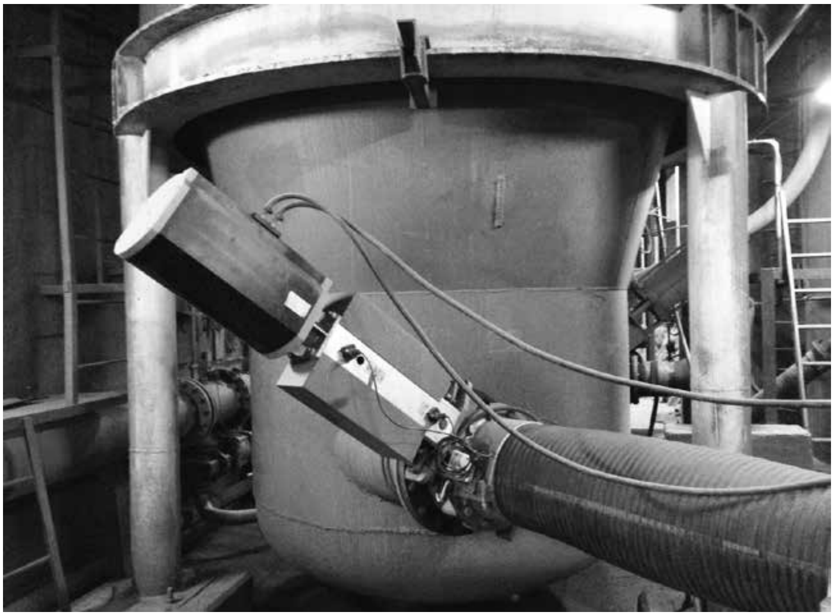


1. Metso Outotec 3xD Bend 90°
2. Branch Pipe K45
3. Knife Gate Valve
4. Rubber Lined Steel Pipe
5. Rubber Lined Steel Reducer
6. Sliding Support Clamp
7. Alu Coupling
8. Material Handling Hose
9. Flange Adaptor
10. Support Clamp
11. Trellex Gasket

1. Flange Adapter
2. Rubber Lined Steel Reducer
3. Branch Pipe T90 inlet water
4. Branch Pipe T90 drainage
5. Metso Outotec 3xD Bend
6. Metso Outotec Dart Valve Seat
7. Metso Outotec Dart Valve



1. Flange Adapter
2. Rubber Lined Steel Reducer
3. Rubber Compensator
4. Branch Pipe T90 inlet water
5. Branch Pipe T90 drainage
6. Knife Gate Valve



Sump tank with shut off valve

Shut off valve for slurry pump line with K45 branch pipe

Contact Metso Outotec application engineering for technical assistance in the selection process.

Wear in operation

9. Wear in operation

9.1 Wear in operation - 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.

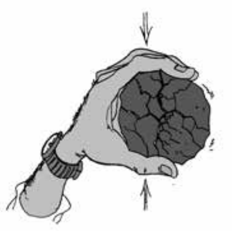
Why wear at all?

Wear is caused by the normal rock stress forces

- Compression (1)
- Impaction (2)
- Shearing (3)
- Attrition (4)

How much wear you get depends on mineral abrasion and hardness.

1



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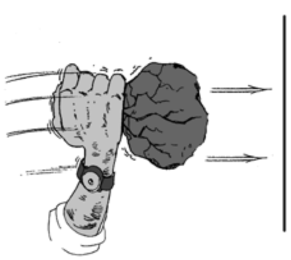

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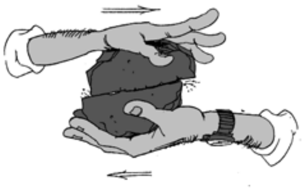


4

9.2 Wear in operation

The choice of wear part material depends on which type of wear the application is exposed to.

caused by

COMPRESSION

IMPACTION HIGH VELOCITY >7m/s

IMPACTION LOW VELOCITY <7m/s

sliding

protected by

Metals

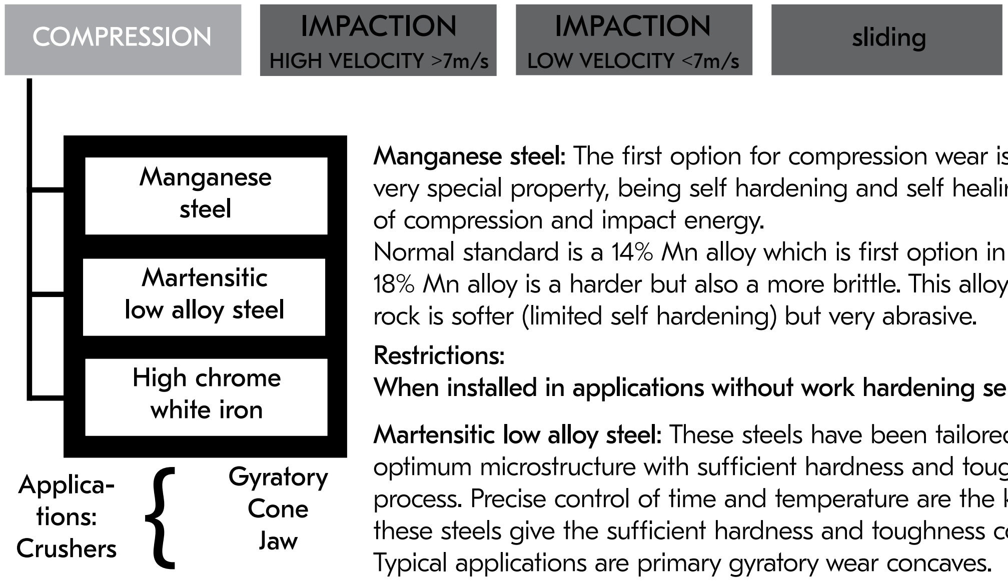
- Manganese steel
- Abrasion resistant rolled steel
- Cr-Mo steel
- Martensitic low alloy steel

High chrome white iron

Polymers

- Rubber
- Polyurethane
- Ceramics

9.3 Wear by compression



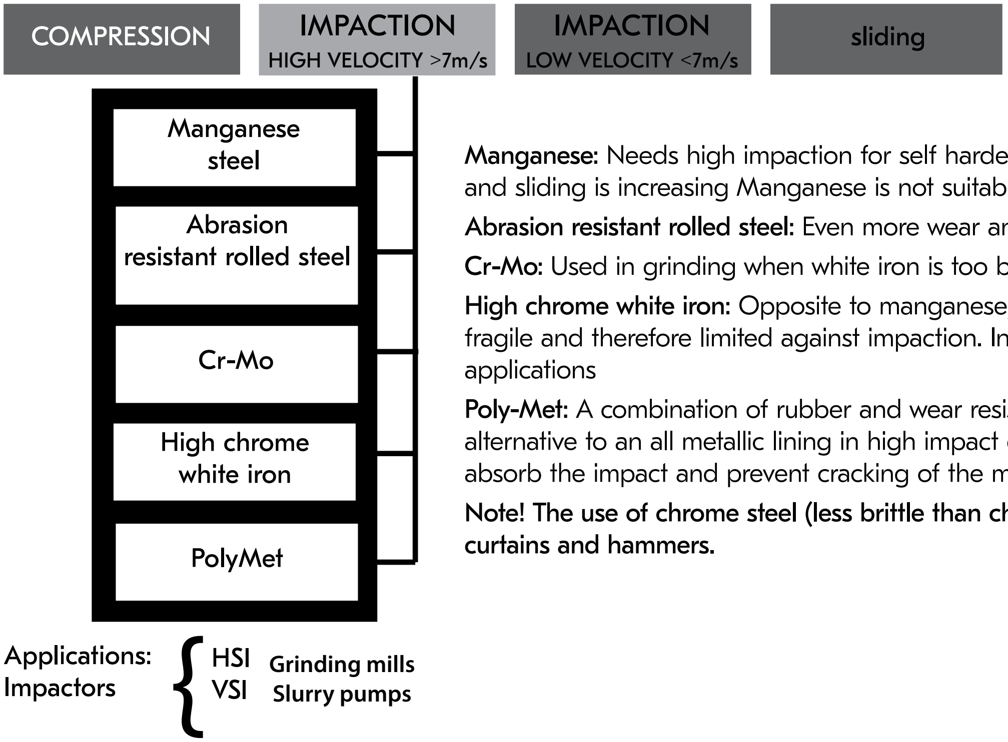
Manganese steel: The first option for compression wear is manganese steel. This alloy has a very special property, being self hardening and self healing when exposed to large amounts of compression and impact energy.
Normal standard is a 14% Mn alloy which is first option in most crushing applications.
18% Mn alloy is a harder but also a more brittle. This alloy is 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!

Martensitic low alloy steel: These steels have been tailored for various solutions having optimum microstructure with sufficient hardness and toughness achieved by heat treatment process. Precise control of time and temperature are the key parameters. Concerning wear these steels give the sufficient hardness and toughness combination with economical way. Typical applications are primary gyratory wear concaves.

High chrome white iron: The wear resistance is based on the hard carbides on the relative hard matrix, still the composition and structure can be tailored considerably. Generally high chromium irons are commonly used in abrasive wear applications. Typical applications are primary gyratory concaves. The alloys of cast "white iron" type (High-chrome and Ni-hard) shall be avoided in crushers submitted to heavy compression.

9.4 Wear by impaction (high)



Manganese: Needs high impaction for self hardening. If impaction is getting lower and sliding is increasing Manganese is not suitable.

Abrasion resistant rolled steel: Even more wear and impact resitant than Cr-Mo

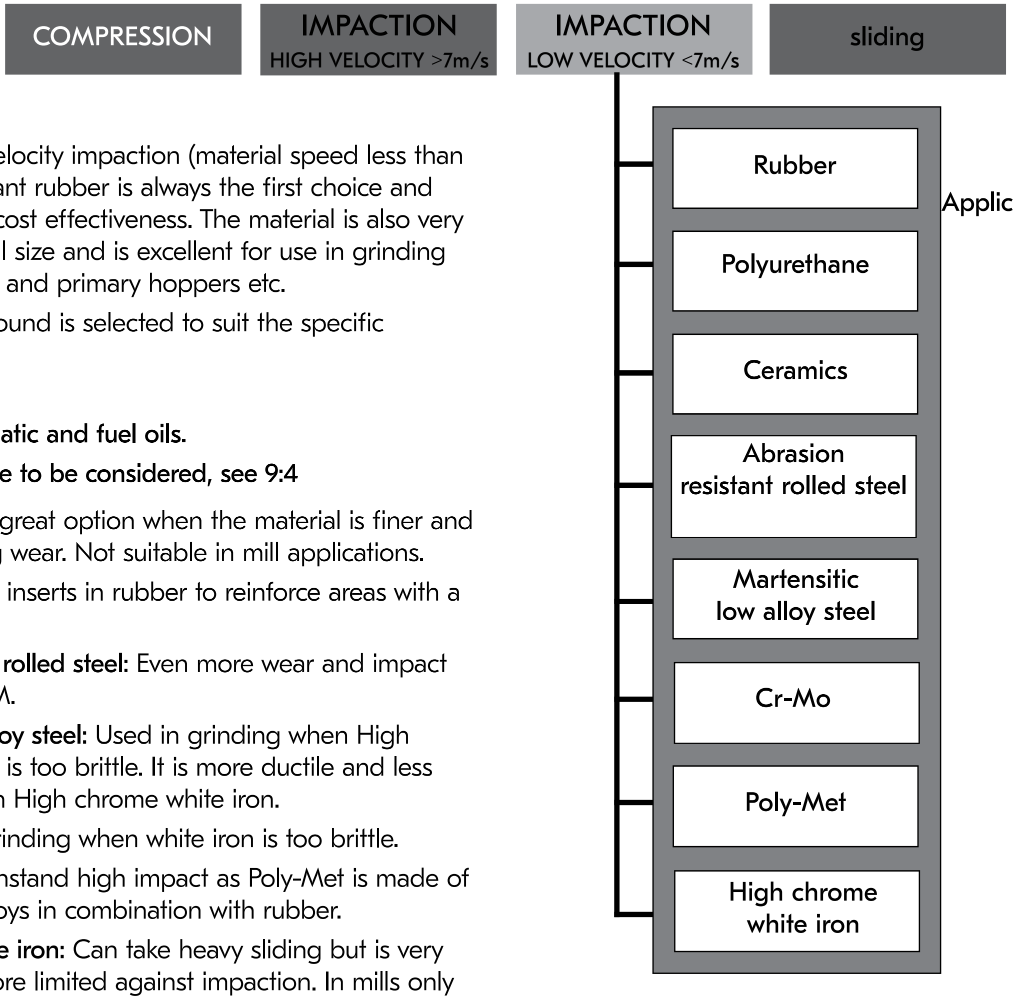
Cr-Mo: Used in grinding when white iron is too brittle.

High chrome white iron: Opposite to manganese, can take heavy sliding but is very fragile and therefore limited against impaction. In mills only used in low impact applications

Poly-Met: A combination of rubber and wear resistant metallic alloys is often an alternative to an all metallic lining in high impact grinding mills as the rubber will absorb the impact and prevent cracking of the metal.

Note! The use of chrome steel (less brittle than chrome iron) is increasing for liners, curtains and hammers.

9.5 Wear by impaction (low)



Rubber: For low velocity impaction (material speed less than 7 m/s) wear resistant rubber 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 etc.

The rubber compound is selected to suit the specific application.

Restrictions:

Look out for aromatic and fuel oils.

Impact angles have to be considered, see 9:4

Polyurethane: is a great option when the material is finer and exposed to sliding wear. Not suitable in mill applications.

Ceramic: Used as inserts in rubber to reinforce areas with a lot of sliding wear.

Abrasion resistant rolled steel: Even more wear and impact resistant than Cr-M.

Martensitic low alloy steel: Used in grinding when High chrome white iron is too brittle. It is more ductile and less wear resistant than High chrome white iron.

Cr-Mo: Used in grinding when white iron is too brittle.

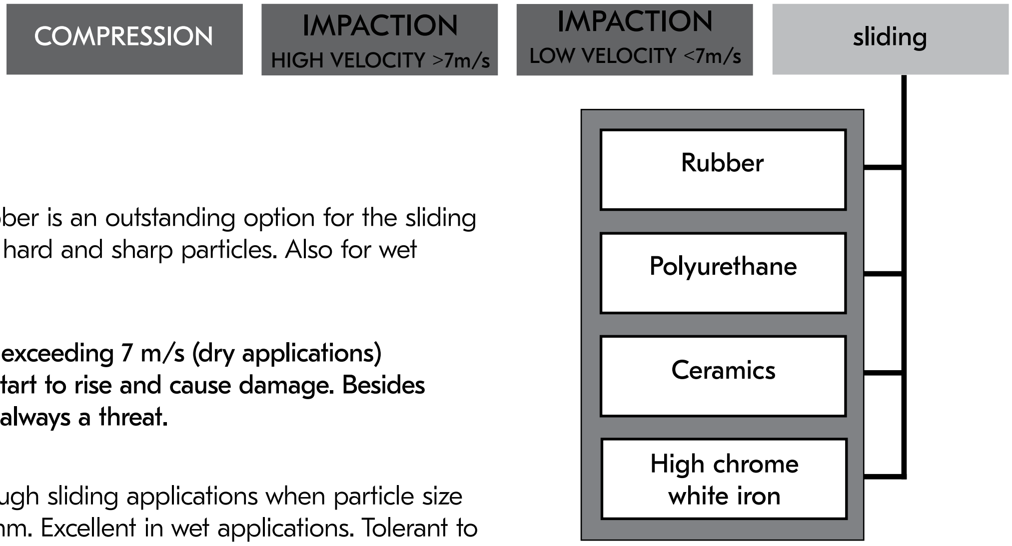
Poly-Met: Can withstand high impact as Poly-Met is made of highly resistant alloys in combination with rubber.

High chrome white iron: Can take heavy sliding but is very fragile and therefore limited against impaction. In mills only used in low impact applications.

Applications:

Dump Trucks, Haul trucks, Feeder hoppers, Transfer points, Grinding Mills, Screens, Chutes, Conveyors, Slurry pumps.

9.6 Wear by sliding



Applications: Chutes, Spouts

Rubber:

Wear resistant 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:

Best option for tough sliding applications when particle size is lower than 50 mm. Excellent in wet applications. Tolerant to chemicals and oil.

Restrictions:
Large sizes and high velocity might cause problems.
Ceramics:
The natural choice when mission is too hard for the options above. Hardness, resistance to temperature and corrosion plus low weight makes it ideal to protect from sliding abrasion.

Al_20_3 (Aluminum oxide) is the most cost-effective material. High chrome white iron: good choice in chutes were it is low impact and lots of sliding.

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.

High chrome white iron: Due to the high abrasion resistance white irons are suitable for sliding wear applications. Due to brittle structure the impact resistance is limited.

9.7 Wear protection – Wear lining and sheeting

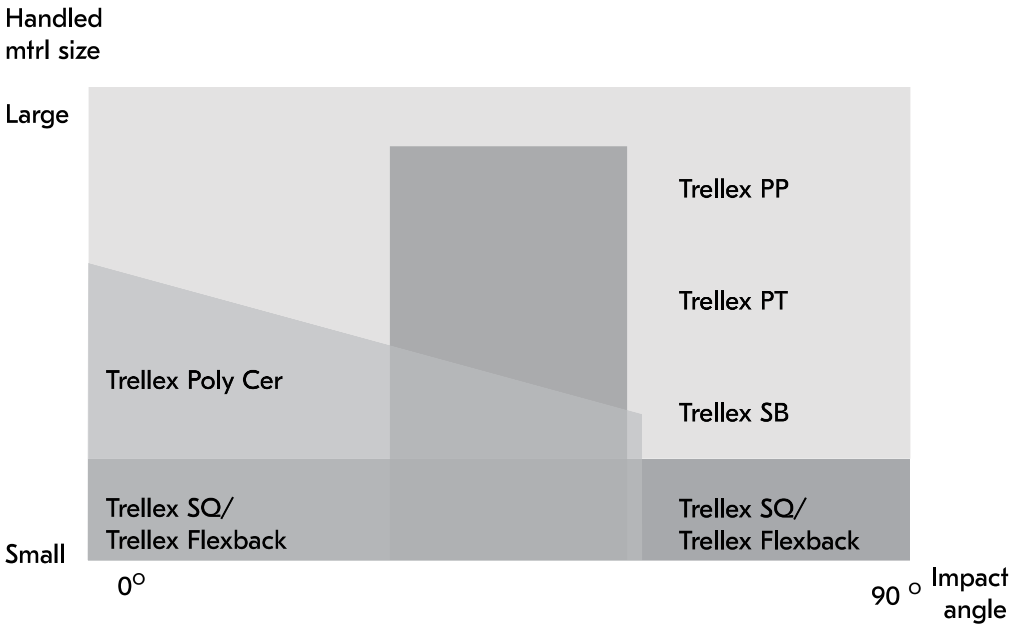
Lining system overview

Selection guide

The selection guide for lining solutions is divided into three sections: wear improvements, flow improvements and noise reduction. Pick your critical areas for improvement and let the selection guide help you find the product that brings the most value to your application.
Your choice will be based on processing conditions, material size, shape, drop height, volume, angle of impact, etc.

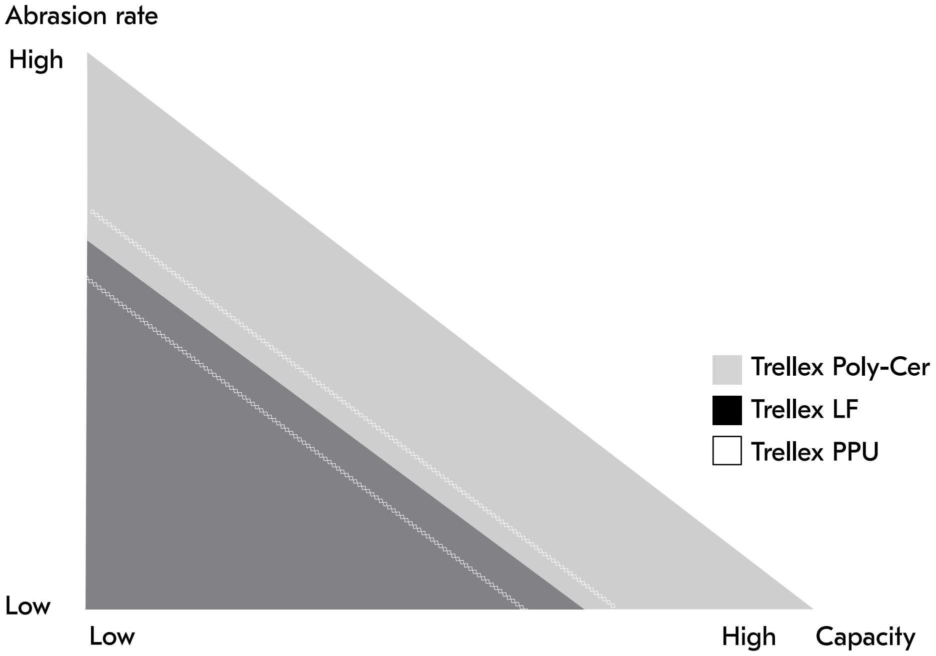
General wear improvement lining guide

Improve wear life of lining applications with Metso Outotec lining products. We offer a wide range of various lining products suitable for any application – wet or dry application, small or large material size and different impact angles.
Below you find an overview of products for various applications. Some products overlap and can be used in the same application.



General flow improvement lining guide

Lining products for flow improvement are available in a range of options, based onhigh wear and capacity.
Below you will find an overview of products for various areas of use.
Some productsoverlap and can be used in various applications.



General noise-reduction lining guide

Excessive noise is a problem in mining and construction operations. Managing
noise pollution is more important than ever. All wear rubber products such as Trellex PP, Trellex SP, Trellex PT, Trellex SB, Trellex WB, Trellex SQ, Trellex Flexback and Trellex Poly-Cer will contribute to reducing noise levels by up to 20 decibel. Reducing the noise by 10 decibel corresponds to the effect of cutting the noise by half. Less noise means better work conditions.
See also page 10:5

Diagram sound level - Loading truck

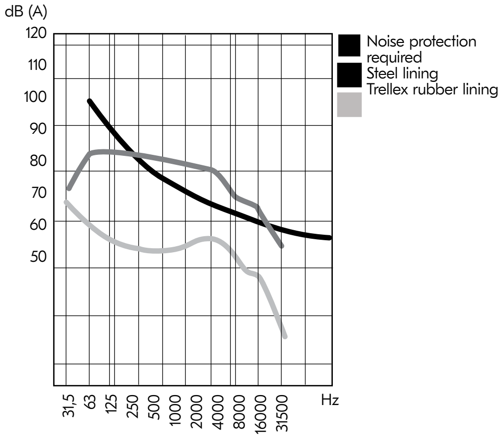
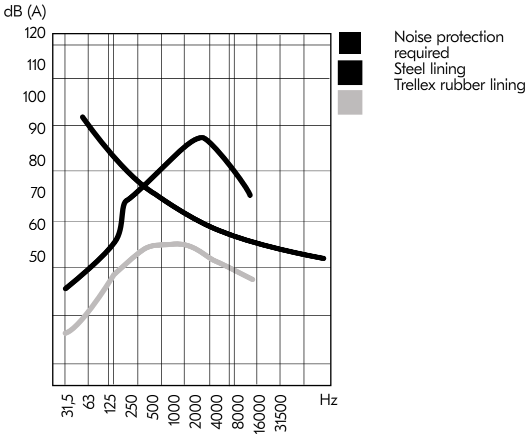


Diagram sound level - Loading truck

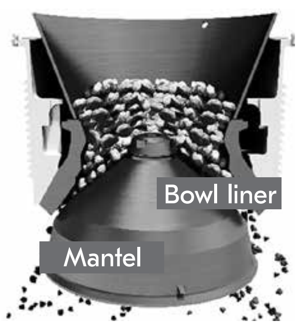


9.8 Wear protection – Wear parts

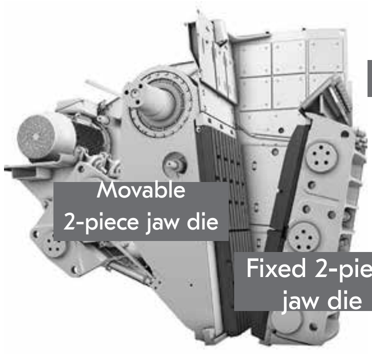
Wear parts – Crushing

The importance of the right wear part design

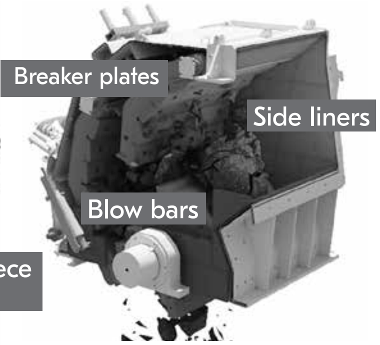
The crushing chamber of a crusher consists of a mantle and a concave or a bowl liner in cone and gyratory crushers, a fixed jaw and a movable jaw in jaw crushers, and breaker plates and blow bars in impact crushers. These components are also known as the wear parts of the crusher. They perform the actual crushing and are in constant contact with the rock or ore. This causes the parts to wear out, and therefore, they need to be changed regularly.



Cone crusher wear parts



Jaw crusher wear parts



Horizontal impact crusher wear parts

The wear parts of a crusher play a significant role in the entire size reduction process, and must be selected to accommodate the feed material. Their shape, material and other properties have a direct impact on the crusher's performance. The chamber design (i.e. the design of the wear parts) can affect e.g. capacity, discharge gradation and power draw.
One key factor in selecting the right wear parts is the crushability of the feed material. Crushability indicates how easily the rock material breaks down. Difficult rock with a low crushability value requires more crushing energy than easier rocks with a higher crushability value.

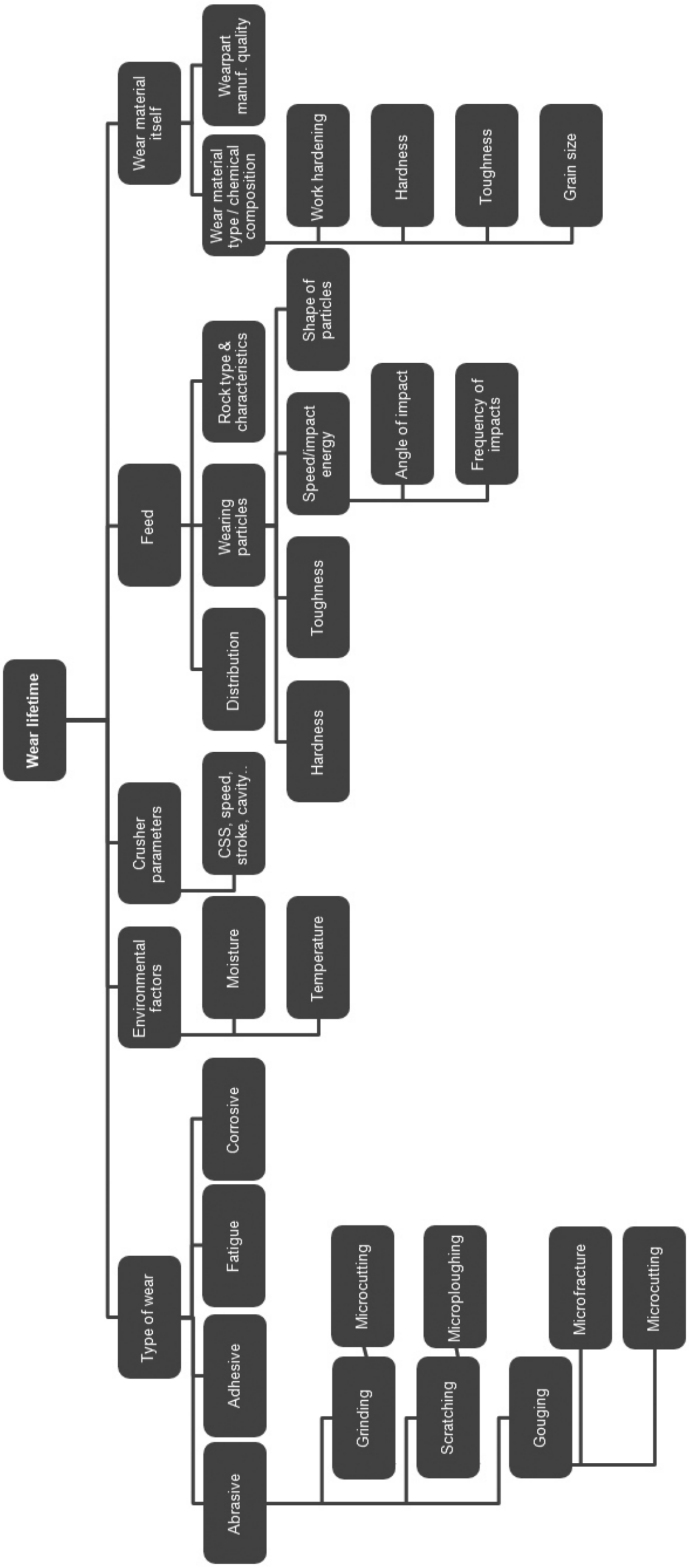
Crushability classification

	Bond work index (kWh/t)	Crushability (%)	Loas Angeles value	Ai-8 mm product	Shatter index
Very easy	0 - 7	50 -	27 -	60 -	40 -
Easy	7 - 10	40 - 50	22 - 27	45 - 60	35 - 40
Medium	10 - 14	30 - 40	17 - 22	30 - 45	30 - 35
Difficult	14 - 18	20 - 30	12 - 17	15 - 30	25 - 30
Very difficult	18 -	- 20	- 12	- 15	- 25

However, the characteristics of the feed material are not always fully known when selecting the original wear parts, or the characteristics change over time as mining proceeds. Sometimes, the requirements for the crusher itself change as the process evolves; it may, for example, need to crush more or produce finer end-product. In all these cases, the chamber design should be revisited for optimal results. By analyzing accurate and current feed characteristics and process parameters, Metso Outotec can provide optimized, tailor-made wear parts that are designed with a simulation tool. Typically, optimized crusher wear parts have a longer wear life, and a significant positive impact on the performance of the crusher.

Factors affecting wear life

When it comes to the lifetime of crusher wear parts, longer is usually always better. Extending the wear life of the parts increases the uptime of the crusher, as fewer maintenance stops are needed. Higher uptime generally lowers the operating expenses of a plant, making it more profitable.



Several different factors affect the wear life of wear parts. Type of wear, environmental factors, crusher operating parameters, feed material and wear part properties are just a few of these. However, one of the most notable factors in the wear of crusher wear parts is the abrasiveness of feed material, which must be considered already in the selection of parts.
The abrasiveness of the feed material can be determined at Metso Outotec's rock laboratory using a test for abrasiveness. The following table indicates the abrasiveness of rock based on this test.

Abrasiveness classification

	French abrasiveness (g/ton)	Abrasion index
Non abrasive	0 - 7	50 -
Slightly abrasive	7 - 10	40 - 50
Medium abrasive	10 - 14	30 - 40
Abrasive	14 - 18	20 - 30
Very abrasive	18 -	- 20

Operating with a set of wear parts until they are completely worn out in the hopes of longer wear life is not a good practice, as it can severely damage the crusher itself. Instead, longer wear life can be achieved by the right alloy selection and optimized chamber design. More information about different alloys and chamber options can be found in Metso Outotec's Crusher Wear Part Handbooks.

Measuring and comparing the true wear life of crusher wear parts

Assessing the performance of a set of crusher wear parts requires comparing the wear to consumed kilowatt hours; grams per KWh. To calculate this, the removal weight of the parts is first subtracted from the installation weight to determine how many grams of material has worn out. Then, the amount of worn grams is divided by the kilowatt hours consumed during the lifetime of the parts. This method is the most accurate indicator, because it is based on true amount of operation, and takes into account idle periods. However, if the kilowatt hours are not known, hours operated or tons produced can also act as a measure for wear life, provided that the operating conditions are stable.

Screening media – Screening

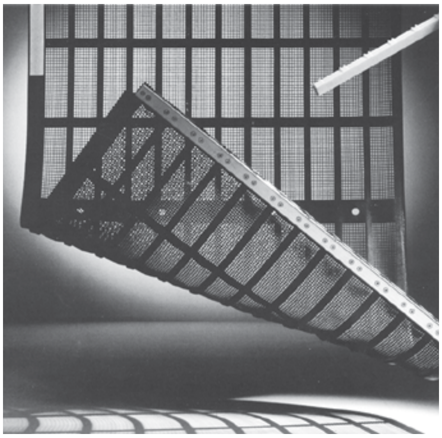
Selection of the correct size and type of screen is important. Equally important is the selection of the screening media. This refers not only to a correct aperture related to the "cut size ", but also to the wear in operation of these screens.
See more information; page 4:4

Self supporting rubber panels

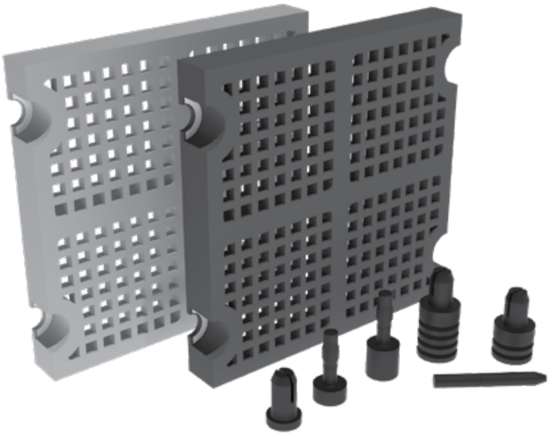
Rubber & polyurethane tension mats

Rubber & polyurethane bolt down panels

Antiblinding rubber mats



Rubber / polyurethane modular systems



Mill lining

The choice of mill lining depends on application objectives and current operating conditions.

Rubber lining has benefits such as low weight, no leakage or peening and it significantly reduces the noise level.

Poly-Met linings combines steel and rubber. It allows the use of more resistant alloys of iron and steel than can be used in a conventional metallic lining, as the rubber substantially dampens the impact forces.

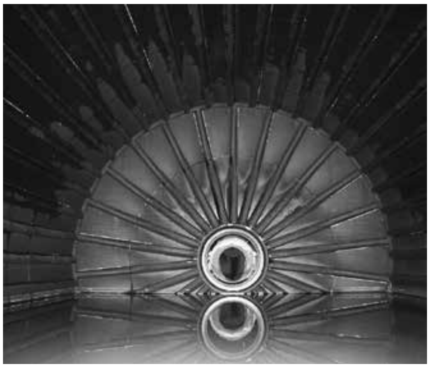
Metallic linings offer total freedom of design and can be made in different alloys in order to maximize performance based on operating data.

The **Orebed** lining consists of a series of powerful magnets embedded in rubber. The ferromagnetic material in the mill load forms a layer that protects the lining.

A combination between the different mill lining materials can often be the best solution.

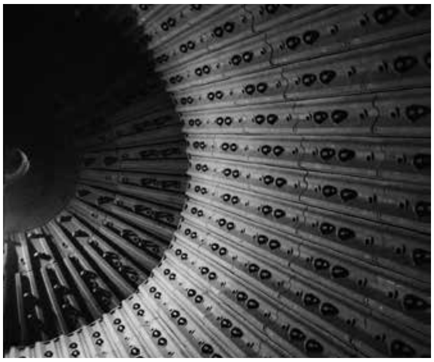
Using each material where it performs the best in order to optimize the grinding process.

Rubber linings

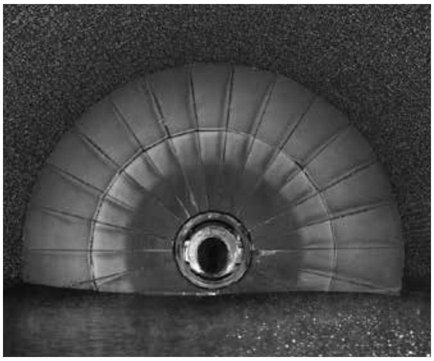


Poly-Met® linings

Metallic linings

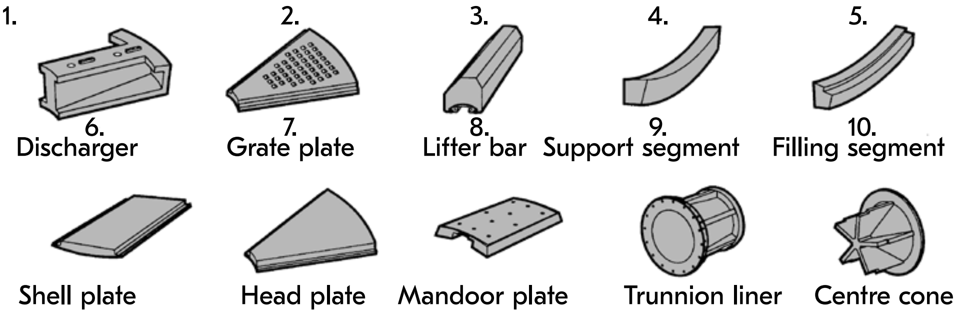


Orebed® linings



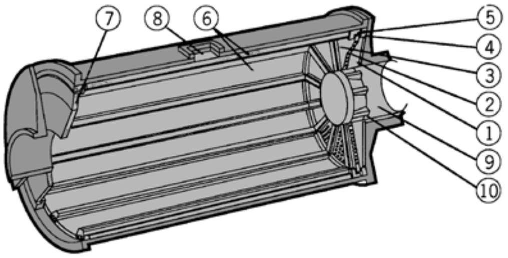
Tumbling mill – typical mill lining components

Linings for mills



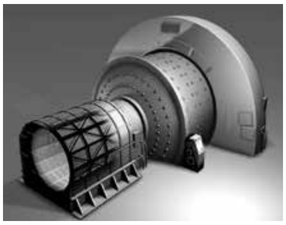
Lining life time – typical linings "ball park figures"

Type of mill	Months
AG	8 – 15
SAG	3 – 12
Rod	6 – 24
Ball	6 – 36
Pebble	12 – 48



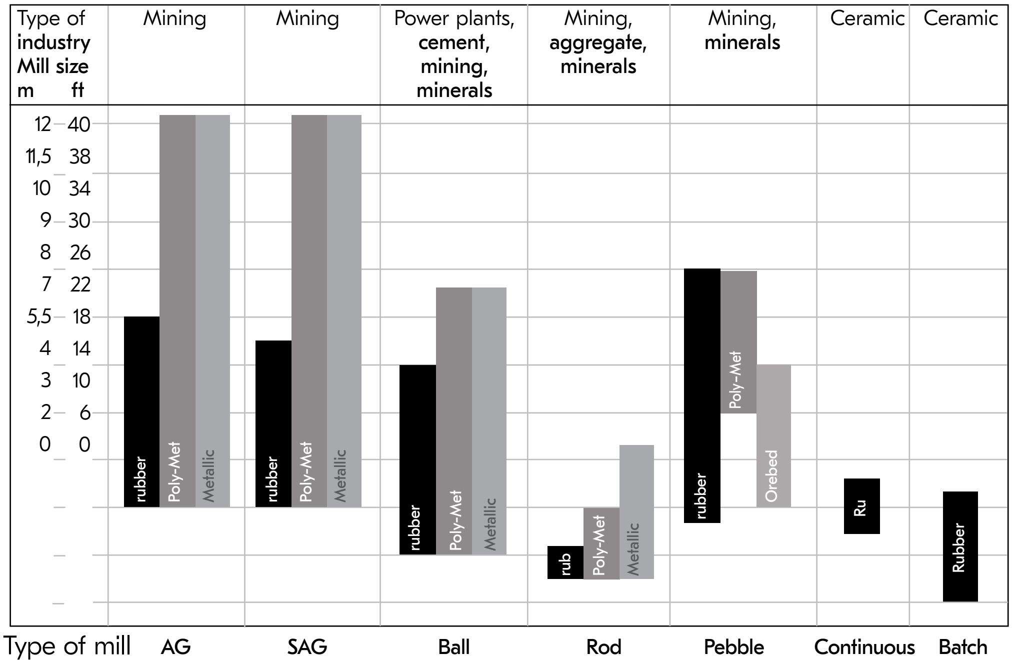
Trommel screens

The frame and the replaceable trommel panels is protected by a wear resistant rubber or polyurethane layer.



Lining from mills

This is a general view of suitable linings. Please contact Metso Outotec for more detailed information.



Discharge systems, trunnion linings and trommel screens are suitable for all sizes.

Tumbling mill liners – material

AG mills

- Dry: White iron or Cr-Mo
- Wet: White iron, Cr-Mo or Poly-Met

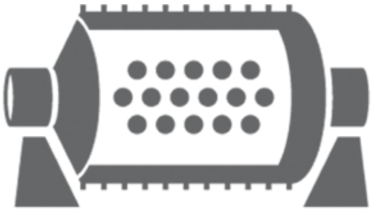
Rod mills

- Dry: White iron or Cr-Mo
- Wet: White iron
- Rubber and Poly-Met, or Cr-Mo
- Head liners in rod mills are always Cr-Mo

SAG mills

- Dry: Cr-Mo
- Wet:Cr-Mo or Poly-Met

Ball and Pebble mills



- Primary or secondary mills:
  Rubber, Poly-Met, white iron or Cr-Mo. Select type of insert based on level of impact in the mill.
- Regrind: Rubber

VERTIMILL® mill liners – material

Screw:

White iron

Chamber:

Orebed magnetic liners.

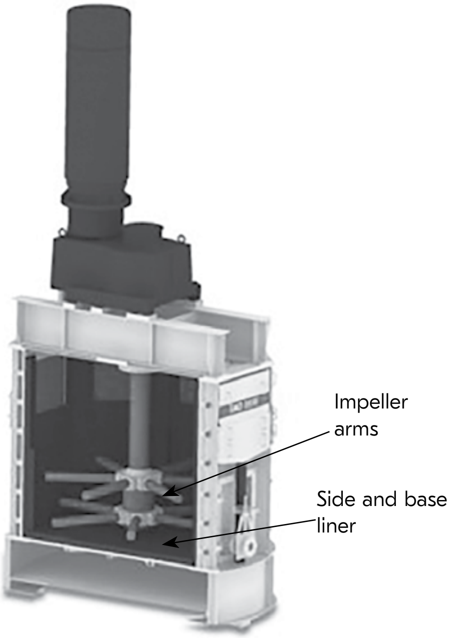
SMD mill liners – material

Side and base liner:

Rubber

Rubber impeller arms:

Rubber



Grinding media

Grinding is often carried out in large, horizontally tumbling mills, partly filled with steels balls (grinding media). The so called 'slurry' (ore particles plus water) is made to flow continuously from one side of the mill to the other while the mill rotates around its horizontal axis at speed to allow the balls and the slurry to be repeatedly lifted and thrown back to the mill. While the repetitive impact liberates the ingrained mineral, it also causes the balls and mill liners to wear, requiring continuous refilling of new grinding media and continuous liner wear monitoring and liner replacements.

Grinding media is often thought of as a commodity within mineral processing plants. However, a customized product selection and grinding media designed to last has a profound impact on grinding costs and performance. The choice of grinding media affects media and mill lining life, production efficiency and energy consumption.

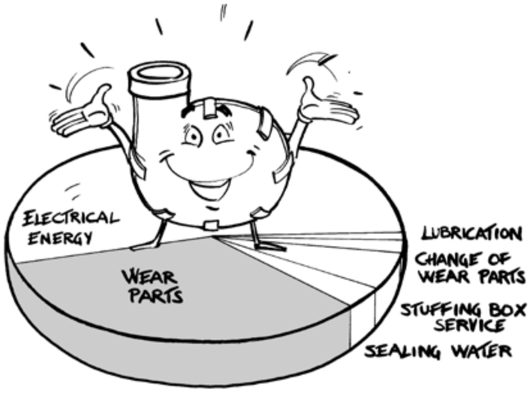
Consumption of grinding media is related primarily to the volume of ore processed, the energy consumed in grinding and ore characteristics (abrasiveness, particle size and specific energy input). Material characteristics of the media being worn is defined essentially by hardness and impact toughness. These two performance parameters are a function of chemical composition, microstructure, manufacture method and shape.

Grinding media materials		Advantages	Disadvantages
Alloy cast iron	High / Medium chromium	The best cost/benefit ratio occurs when there is a relatively low impact and high abrasion. In this case the durability is superior to forged steel balls. Ex.: mills for cement. Dry grinding applications. Low wear rate	For larger balls it can be necessary to add expensive alloy elements such as molybdenum. Difficult to manufacture specially in large diameters. Low impact resistance.
Forged, cast or rolled martensitic steel (usually heat treated)	High carbon steel	Used when there is high impact, such as SAG mills. Widely available for wet grinding applications (Ball Mills) Although wear life is usually less, total cost of operation is reduced compared High Chrome media	Higher wear rate compared to cast high chromium iron. Low corrosion resistance compared to high chromium alloy steel. Not available in very small diameters >20mm for regrind applications
	High chromium alloy steel	Used when the ore is very abrasive. These steel balls have better corrosion resistance and hardenability. Available is small diameters	More expensive when compared to high carbon steel, so total cost of operation for wet grinding applications is higher.
Ceramic (< 25 mm)	Alumina Zirconia	Mainly used for ultrafine grinding applications Ditritors (SMDs, Isamills...) Clear definition of appliaction is key for good performance.	Not widely available on a global basis. Requires more analysis and lab tests to find the right application. Has a direct effect to mill components and wear parts. Operation cost has to be closely monitored.

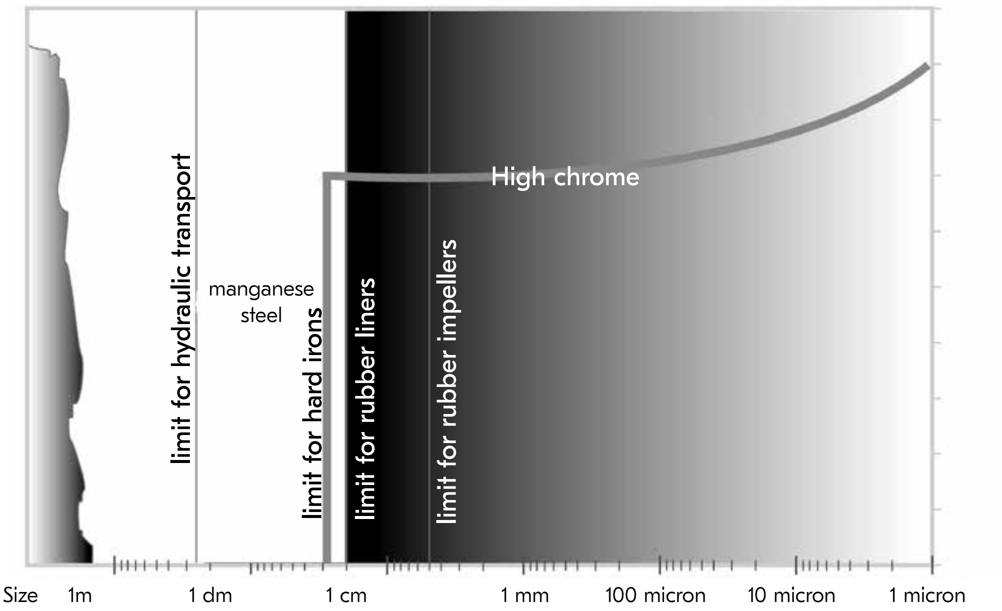
More information about grinding and product range can be found in Metso Outotec's grinding media handbook.

9.9 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 carbon	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

9.10 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.

9.11 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

10. Operation and environment

10.1 Operation and environment – Introduction

From environmental, health and safety point of view most mineral processing operations have some negative effects 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).

10.2 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.

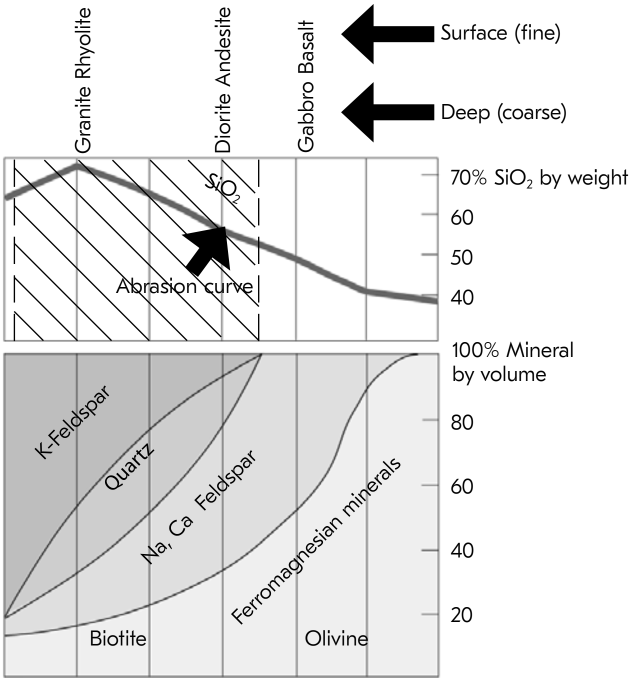
Dust – Chemical composition

A parameter of interest is the chemical composition. Hard rock in many cases is hazardous due to the silica content.

Free quarts (SiO2) 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.

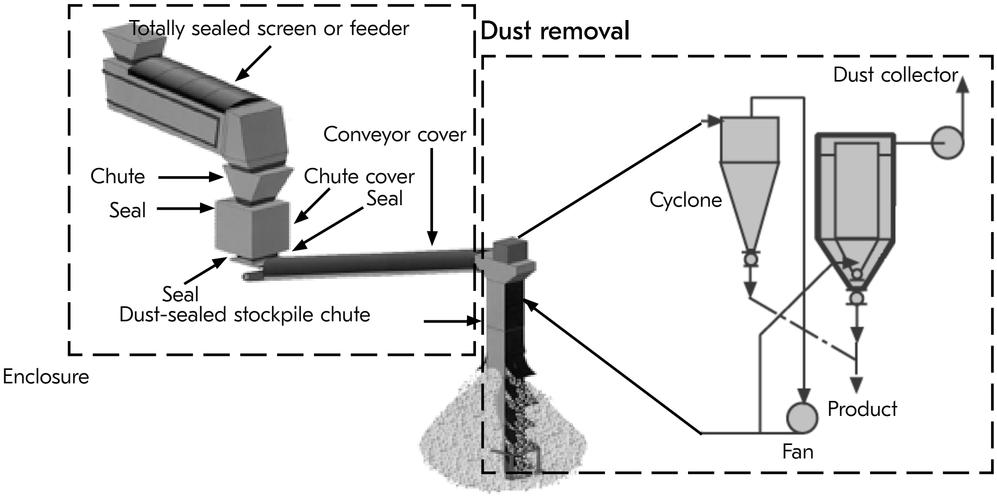
As many of the silicates are hard and abrasive these dust fractions also are causing heavy wear when exposed to bearings, motors etc.
Dust fractions of non - silica type are normally not too dangerous for the operators and give more like a "housekeeping" problem.

Dust – SiO_2 levels



SiO_2 levels in magmatic rock

10.3 Dust control – Basic

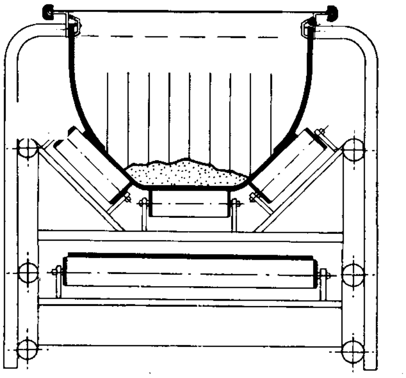


Some guidelines:

10.4 Dust control – Basic

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 removal* 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

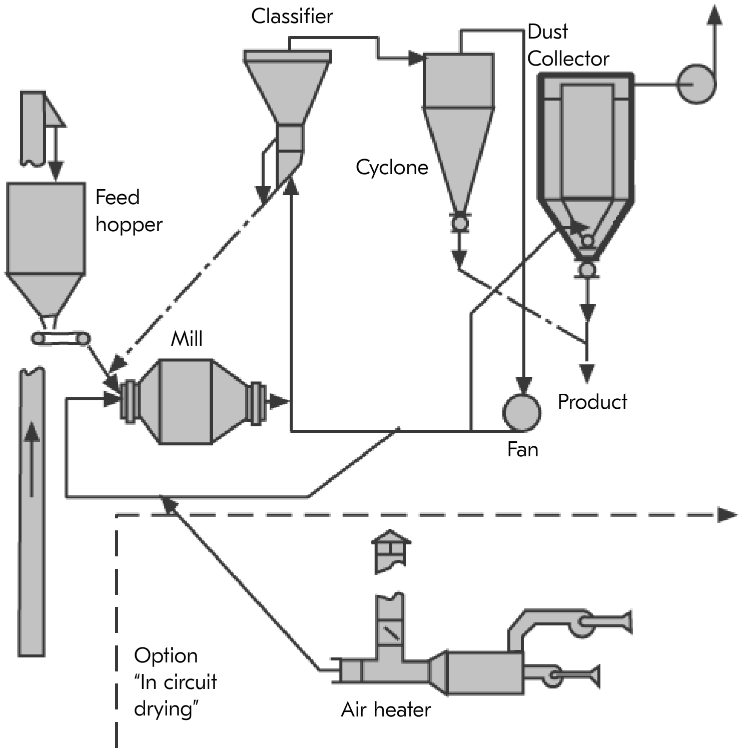
The dust removal and dust collecting systems are very similar to a normal dry classification circuit. Dry classification is in fact a dust removal system where the max size of the dust is controlled by a classifier (or ventilation criteria), See below.

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).



10.5 Noise

General

In mineral processing there are a number of machines considered to be very noisy (crushers, screens and grinding mills are typical).

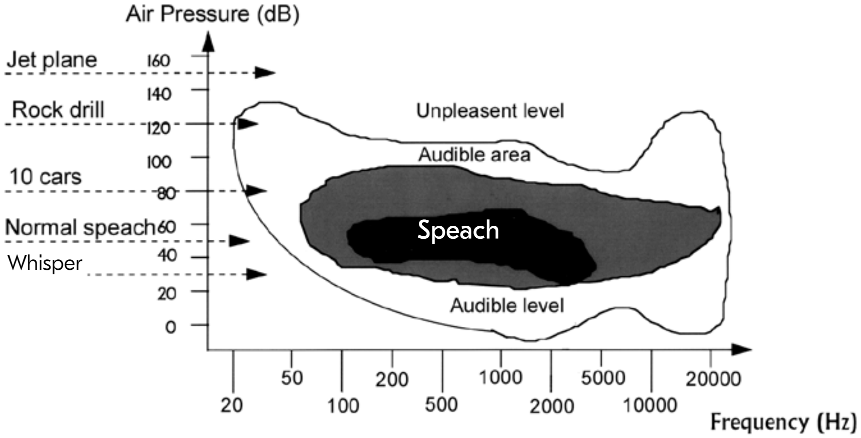
By definition noise is an "undesirable" sound. As sound is **air borne sound pressure variations,** we have to find a sound pressure level, which can be tolerated by the operators. Noise is not only harmful to the hearing but also affects the heart action and the ability of concentration. It also restricts 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)

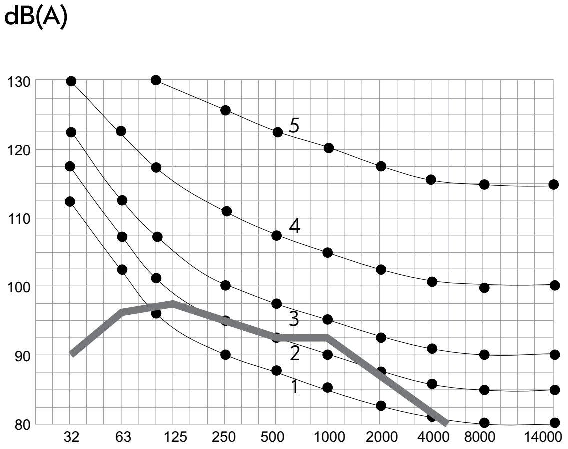
Mechanical noise is measured in dB (A) indicating that an A-filter is used, damping lower frequencies (of less harm to the operators).

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).

10.6 Noise reduction

There are 4 main ways to reduce the noise levels for processing systems including crushers, mills and screens.

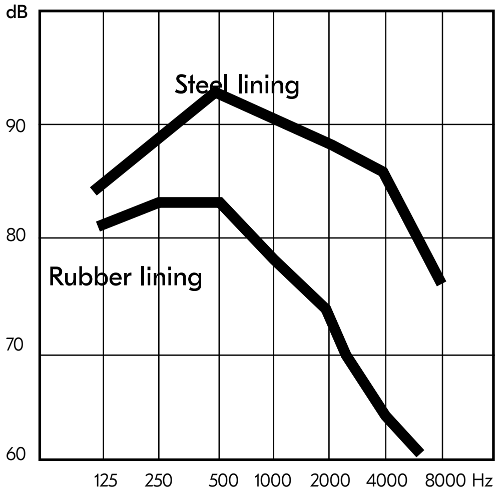
- Optimum operation
- Use of "internal" polymers (wear material and wear products)
- Use of "external" polymers (dust enclosures)
- Enclosure with noise reduction walls

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

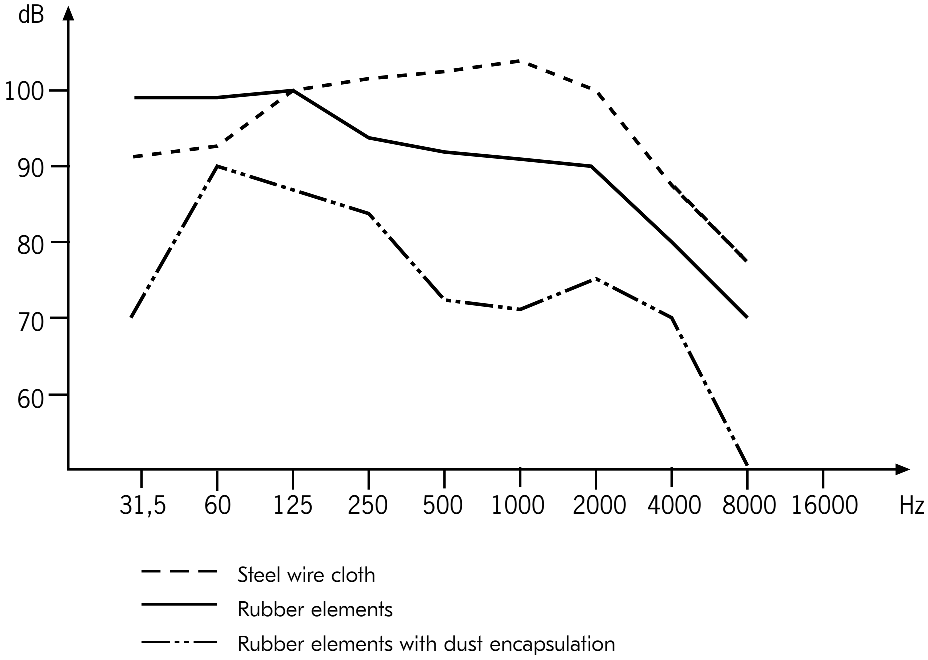
The use of polymers as mill liners, screening media and wear protection in material handling systems (chutes and transfer points) have a dramatic effect on noise reduction.
For grinding mills a rubber lining can reduce the noise level up to 10 dB(A) compared to a steel lining.



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.



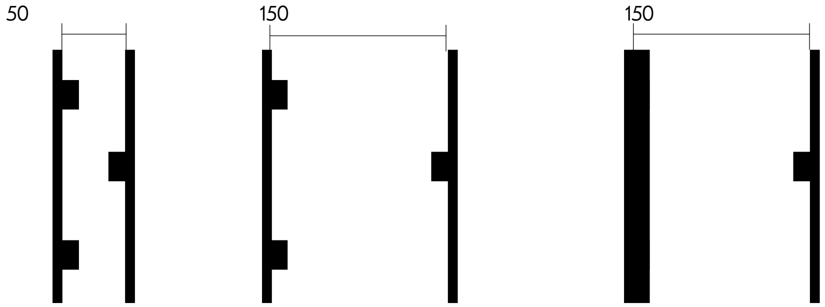
A simple rule: The more polymers used for various purposes in the mineral process systems the lower the noise levels!

Noise reduction walls

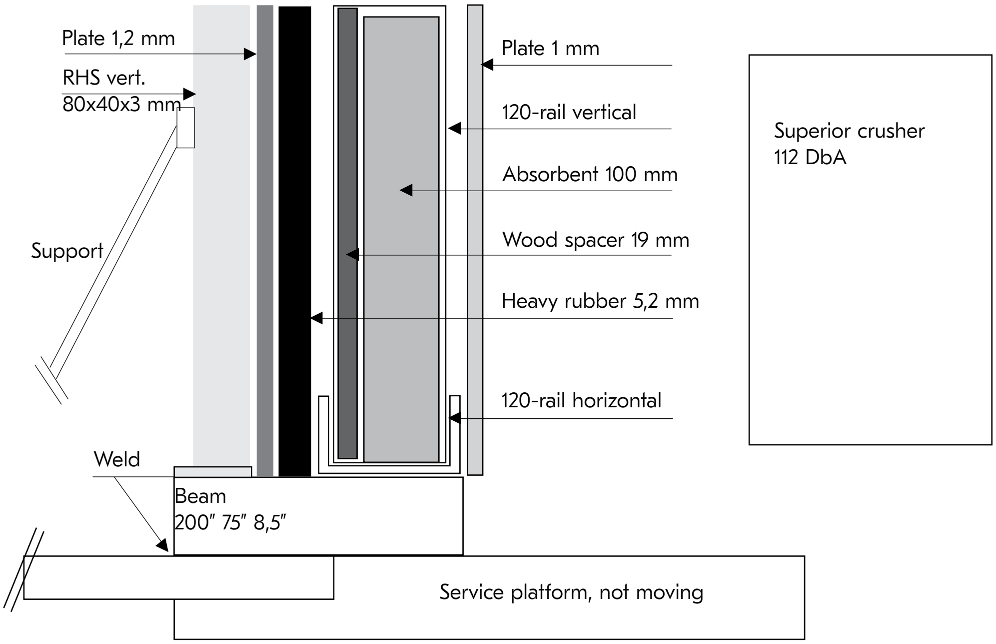
Enclosure is an effective way of reducing noise. Enclosure can be more or less extensive (enclosure of drive or machine or both). With a total enclosure noise levels can drop by 10-15 dB (A).

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



10.7 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

11. Process system

11.1 Process system – Introduction

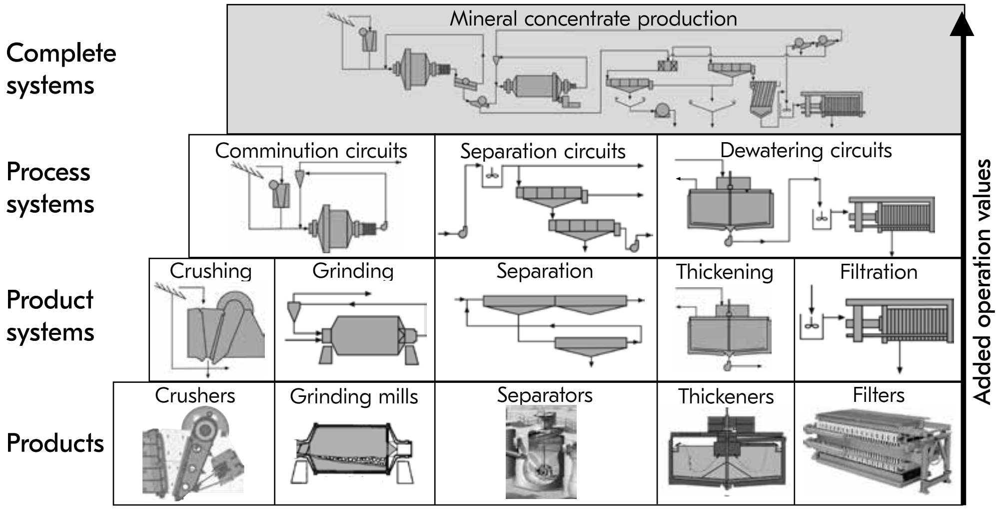
A machine working in a mineral process flow cannot perform better than the process environment will allow it to.

Parameters like type, size and amount of feed, % solids in slurries, additives, discharge conditions etc. will always guide equipment performance and operation economy.

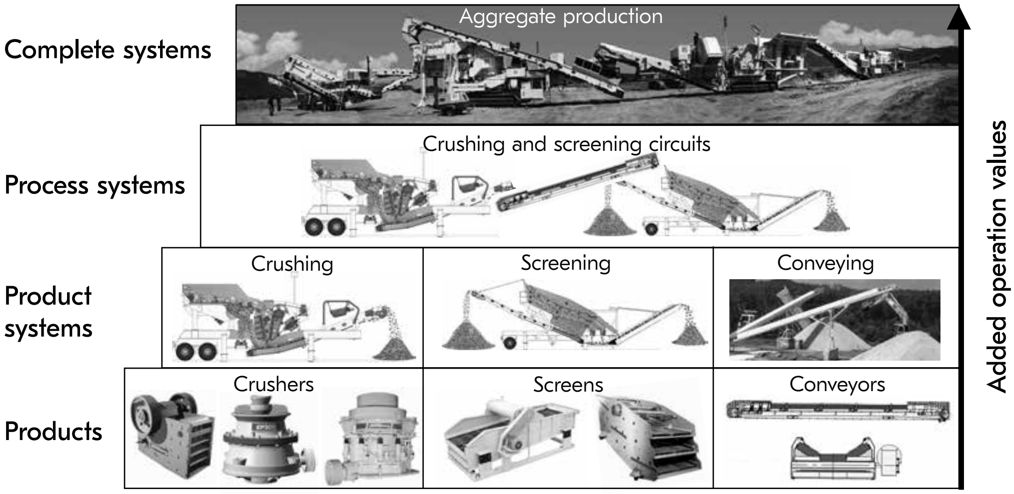
There is a strong trend amongst both suppliers and users to work in terms of systems, meaning solutions to various operation problems more than installing equipment. This will effectively increase the operation values as presented in section 2:9

Examples covering systems levels and system modules are shown in this section.

System levels in ore / Minerals processing



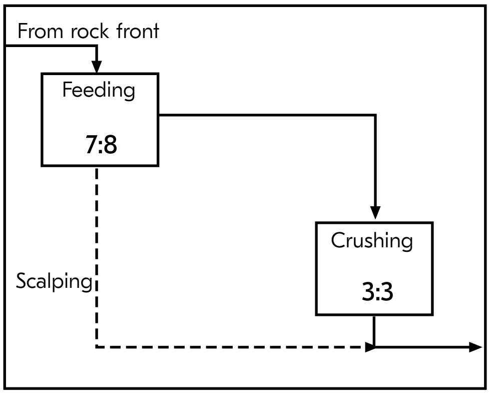
System levels in rock processing (Quarrying)



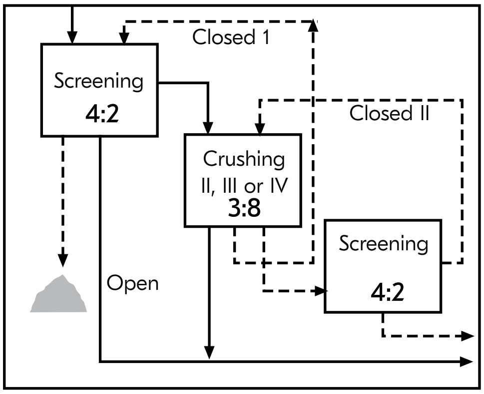
11.2 System modules – Aggregates

A good way to understand and work with process systems is to use **system modules** in various combinations.

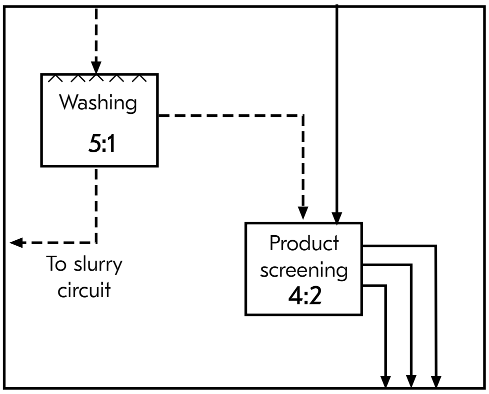
Primary crushing module



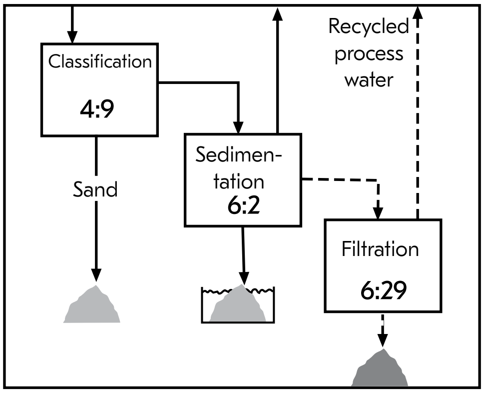
Intermediate crushing module



Final products module

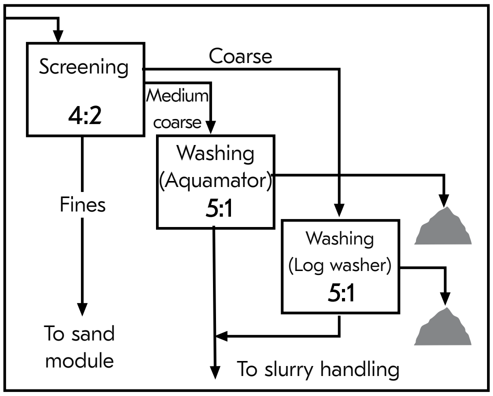


Slurry handling module

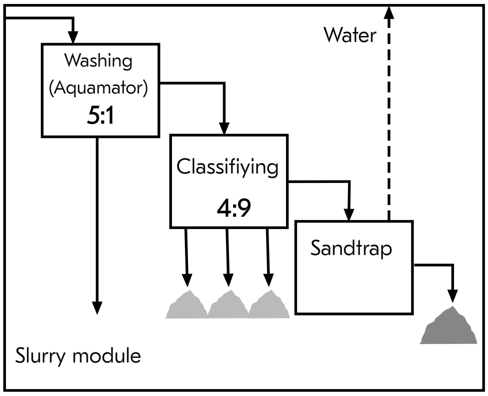


11.3 System modules – Sand and gravel

Sand and gravel module



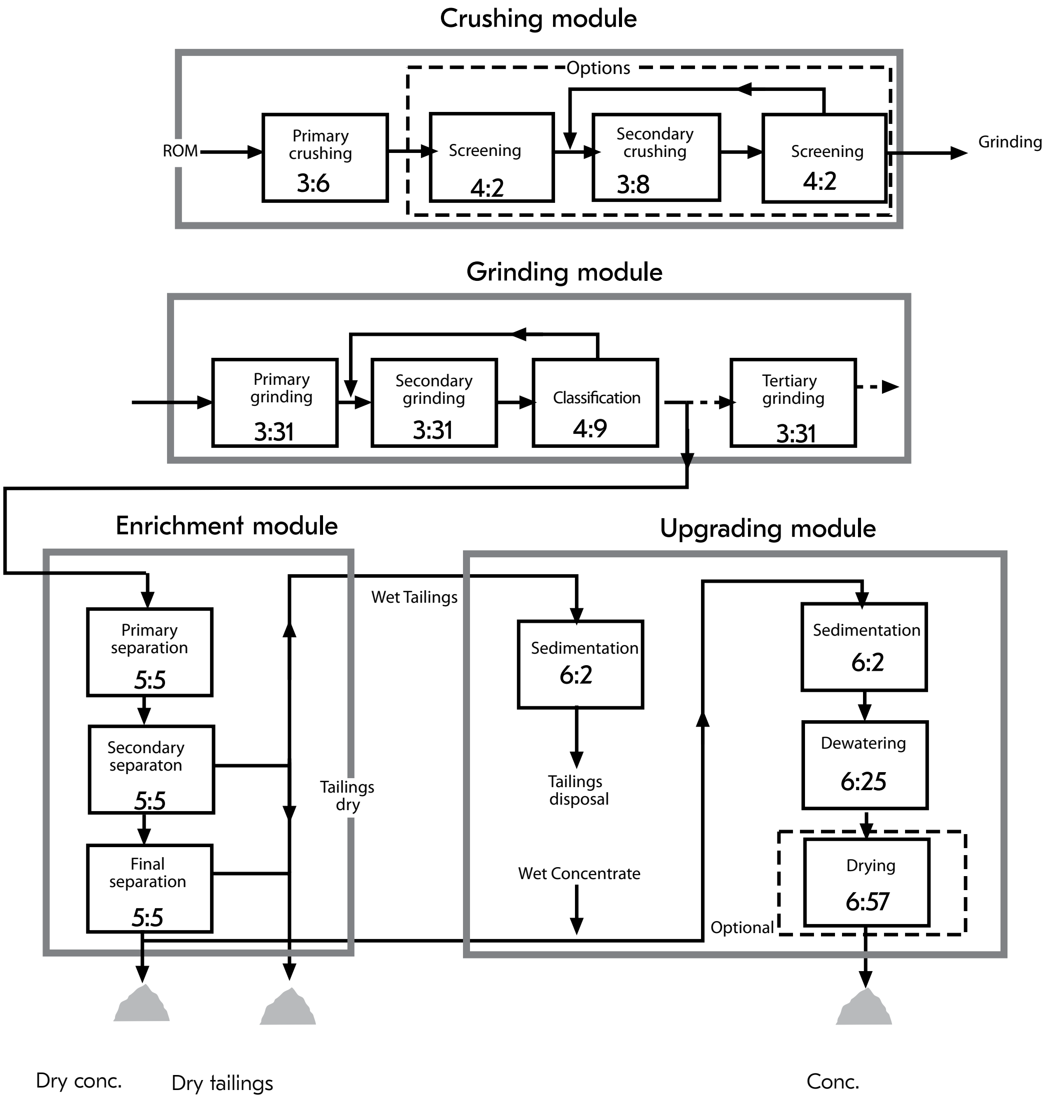
Sand and gravel module



- - - - - = option or alternative

7:5 = referring to actual chapters and pages

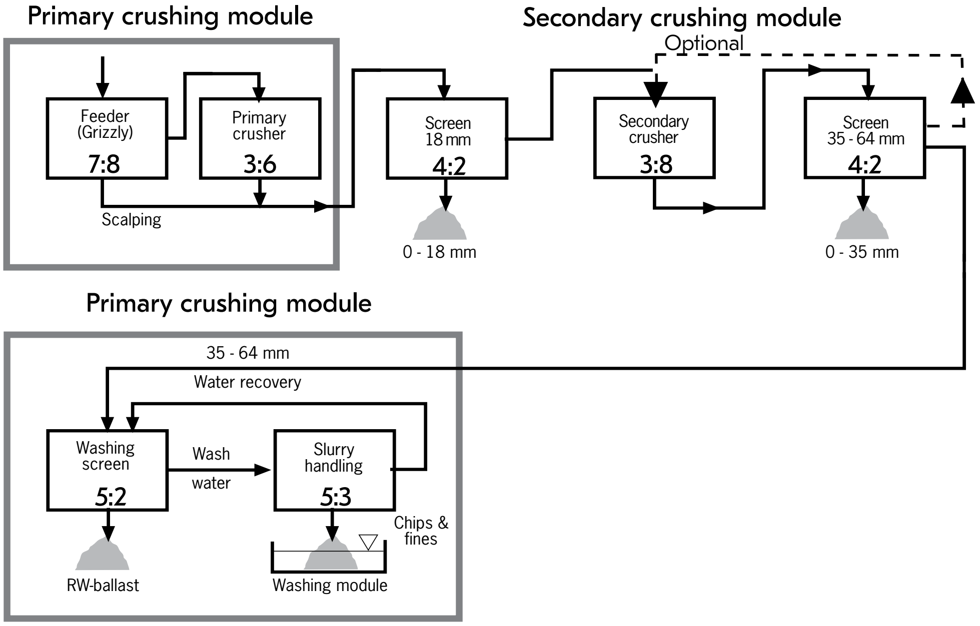
11.4 System modules – Ore and minerals



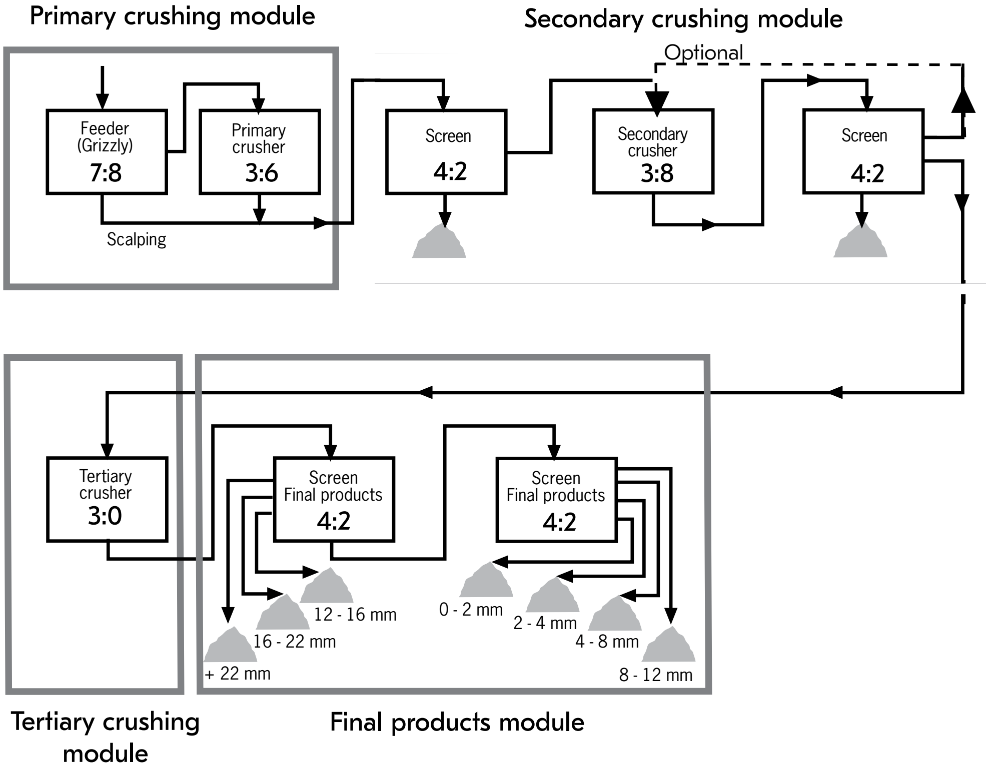
- - - - - - = option or alternative

7:5 = referring to actual chapters and pages

11.5 Process system — Railway ballast



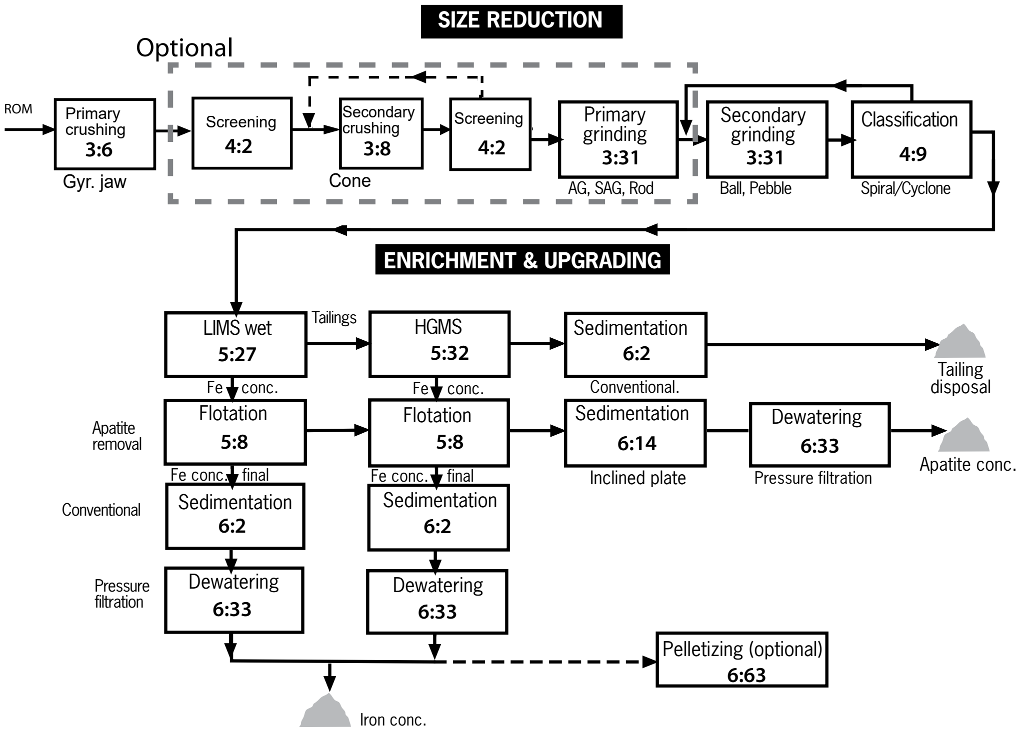
11.6 Process systems — Asphalt / Concrete ballast



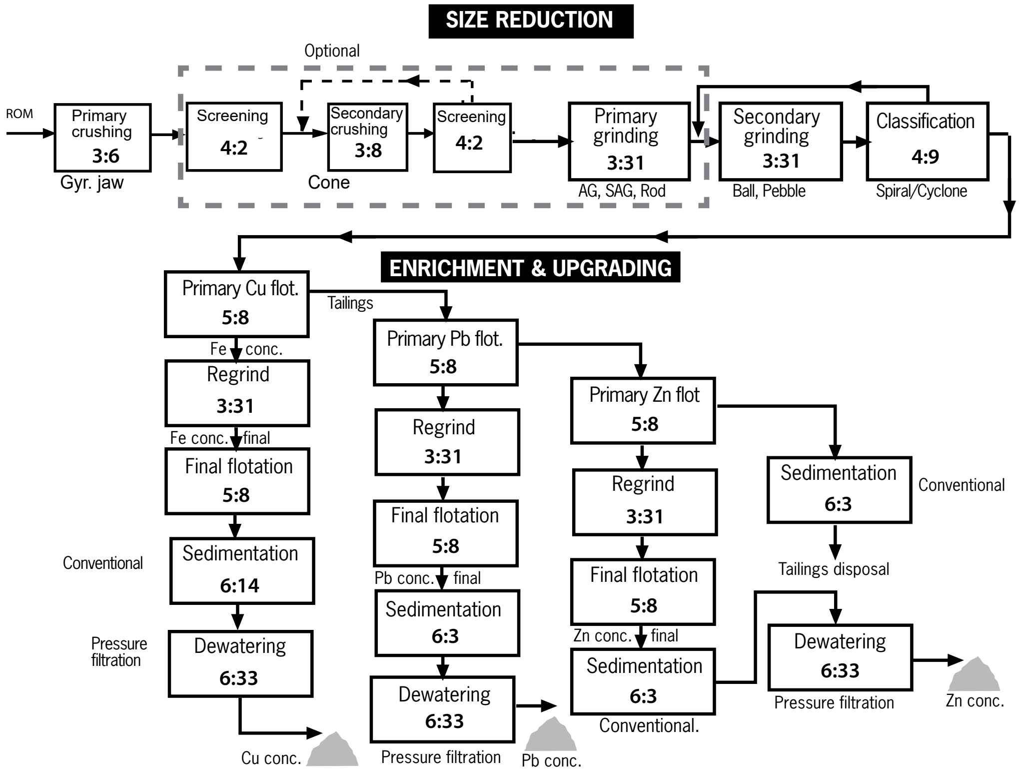
- - - - - = option or alternative

7:5 = referring to actual chapters and pages

11.7 Process system — Ferrous ore (hosting apatite)



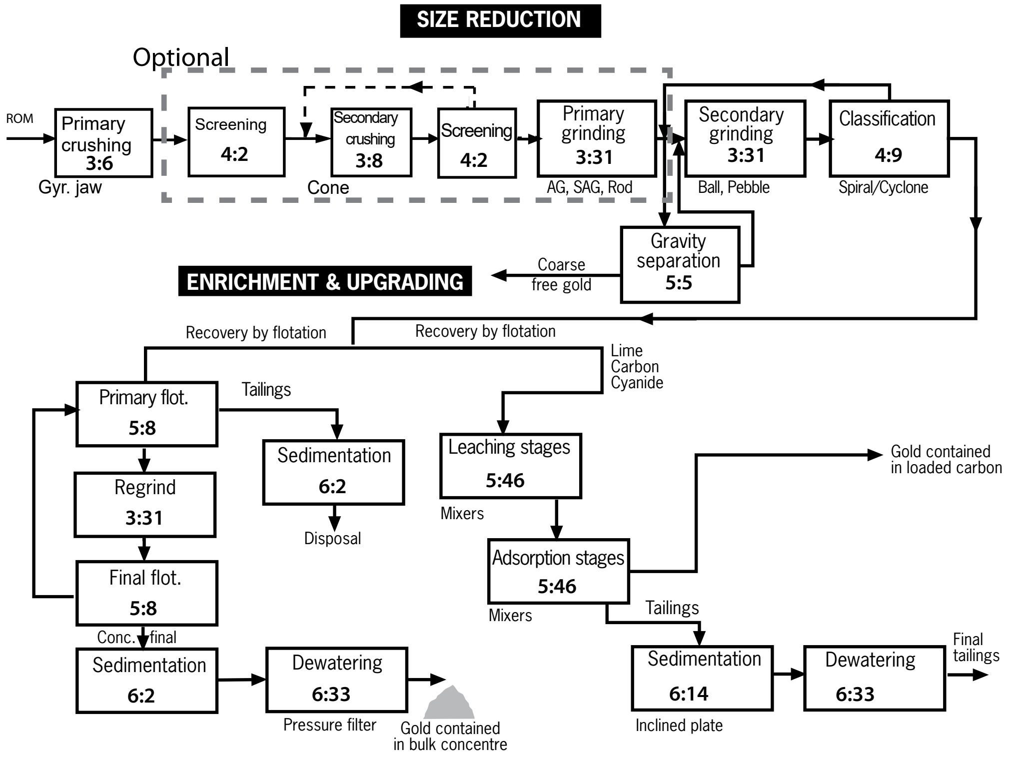
11.8 Process system — Base metal ore



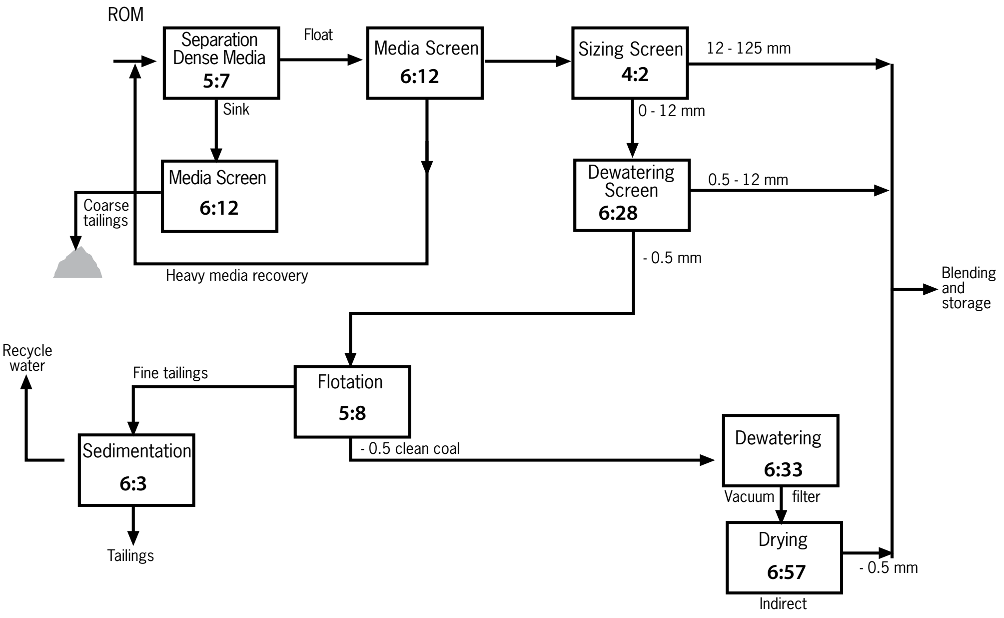
- - - - - = option or alternative

7:5 = referring to actual chapters and pages

11.9 Process system – Gold bearing ore



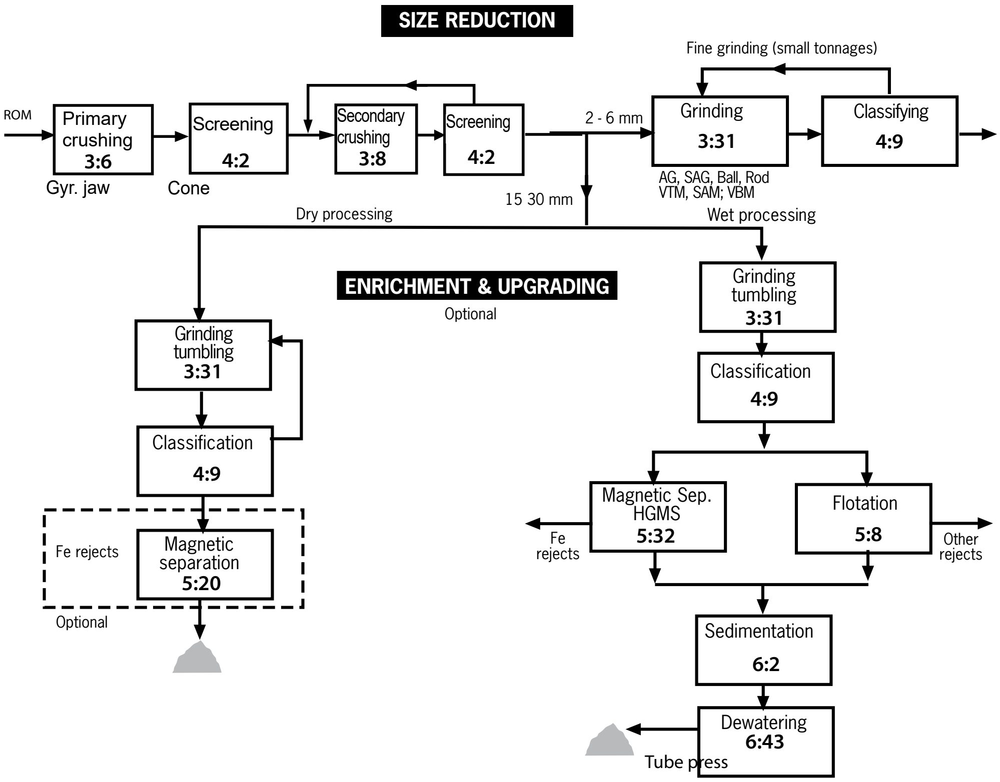
11.10 Process system – Coal



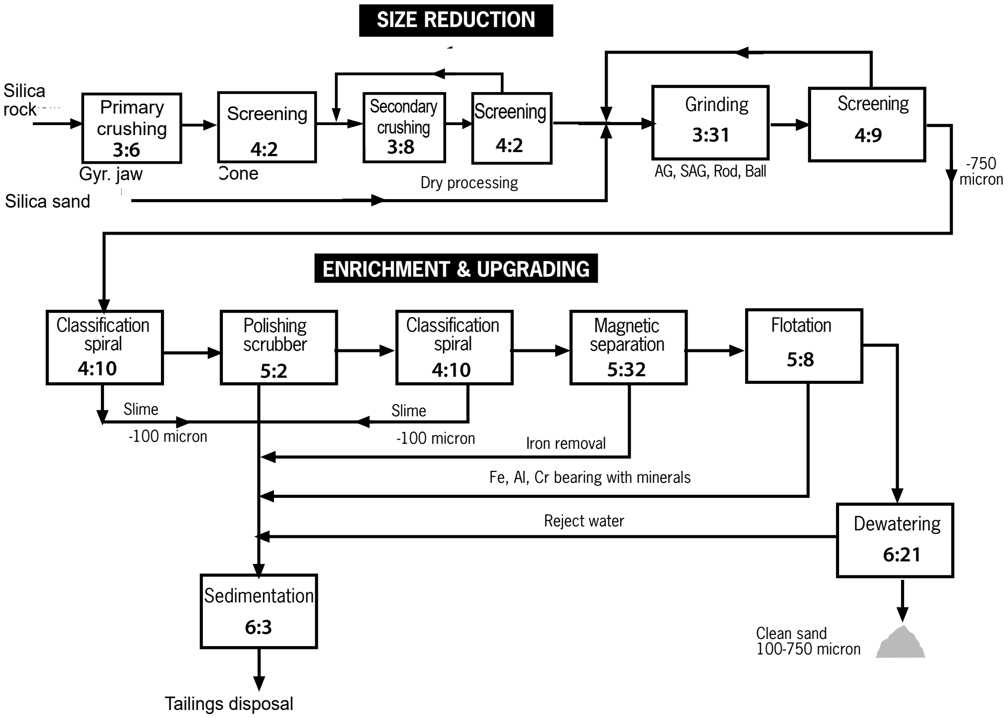
- - - - - = option or alternative

7:5 = referring to actual chapters and pages

11.11 Process system – Industrial mineral fillers



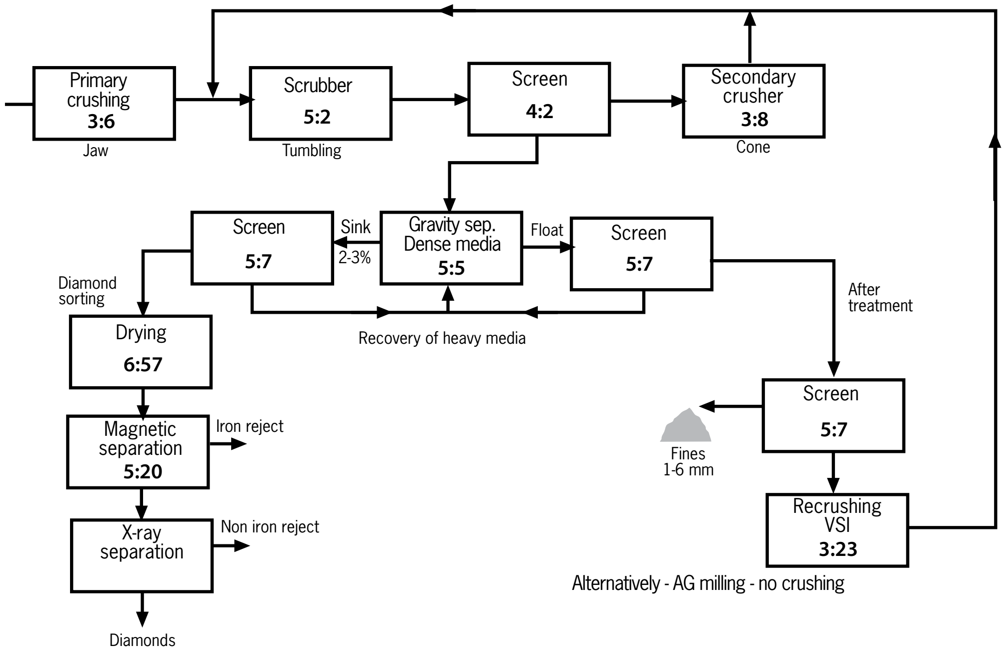
11.12 Process system – Glass sand



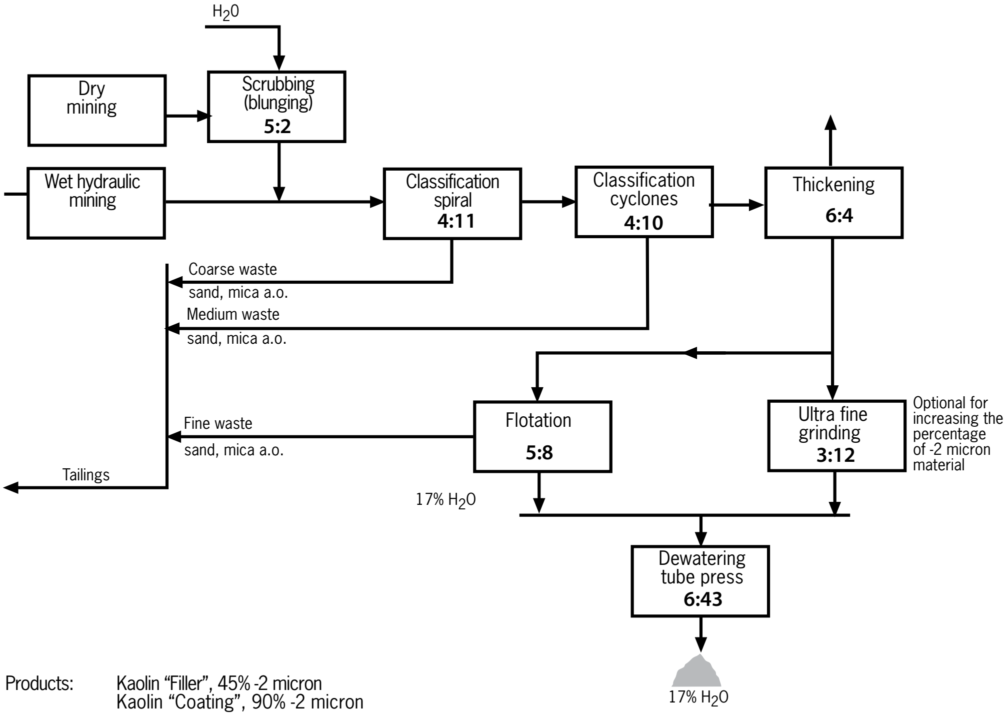
- - - - - = option or alternative

7:5 = referring to actual chapters and pages

11.13 Process system – Diamonds (Kimberlite)



11.14 Process system – Kaolin



Products: Kaolin “Filler”, 45% -2 micron
Kaolin “Coating”, 90% -2 micron

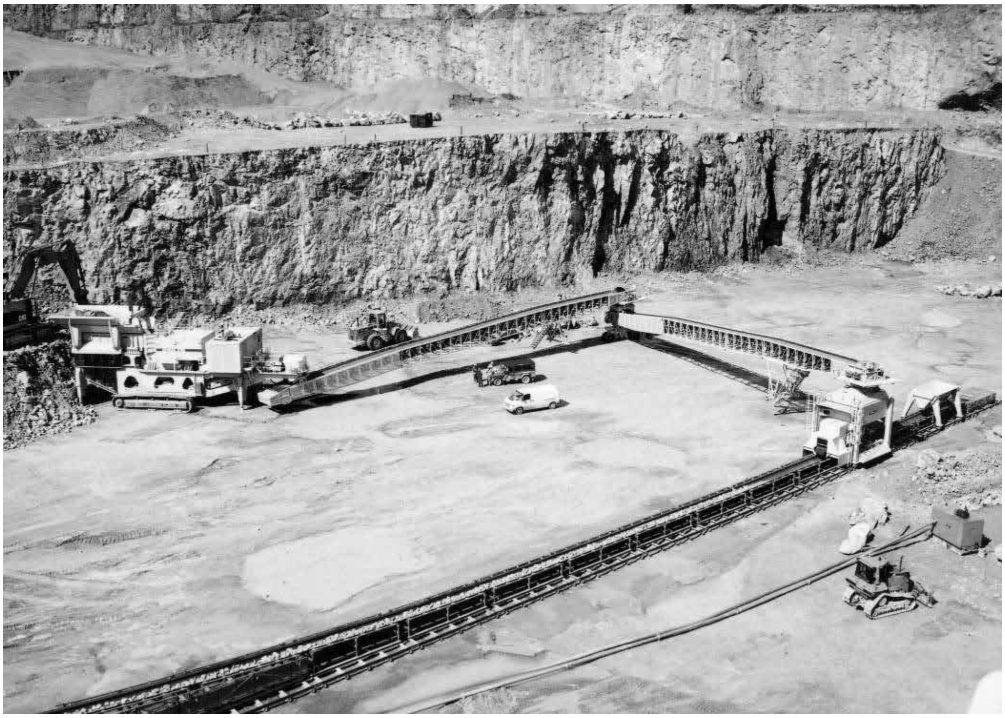
- - - - - = option or alternative

7:5 = referring to actual chapters and pages

11.15 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.

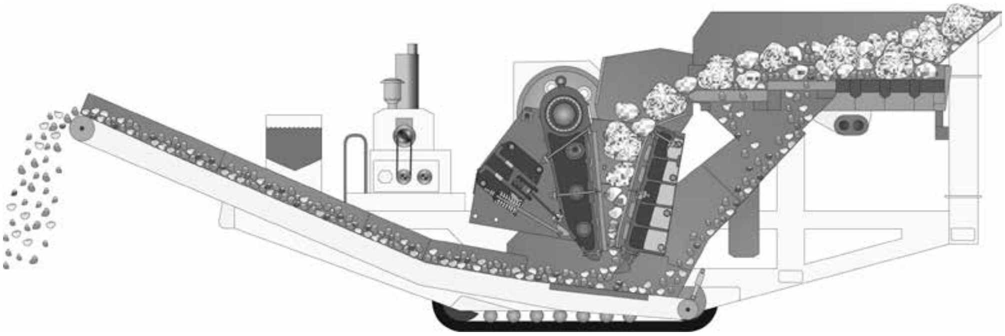
Mobile crushing and conveying system



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

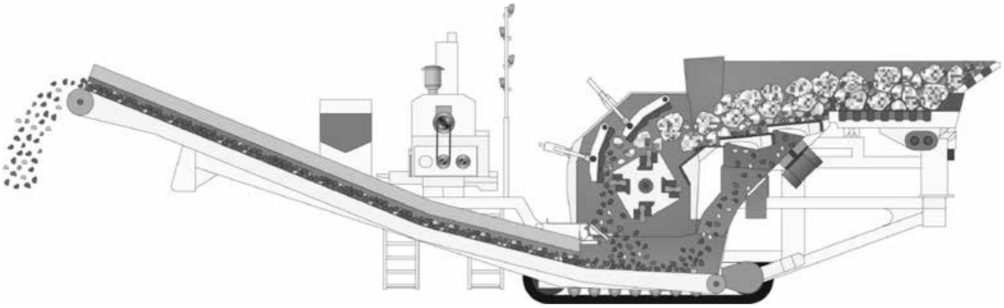
11.16 Primary jaw crusher + Grizzly (typical)



Type*	Max feed/product size mm (inch)	Capacity 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.

11.17 Primary impact crusher + Grizzly (typical)



Type*	Max feed/product size mm (inch)	Capacity 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.

11.18 Metso simulation tools

Bruno™ is a steady state simulation tool for the design and evaluation of crushing and screening plants. It is easy-to-use and the designer can quickly evaluate flowsheet options, select appropriate Metso equipment and forecast product quality and overall instantaneous system productivity.
For more information and/or to acquire a copy of the Bruno software, please contact your local Metso sales office.

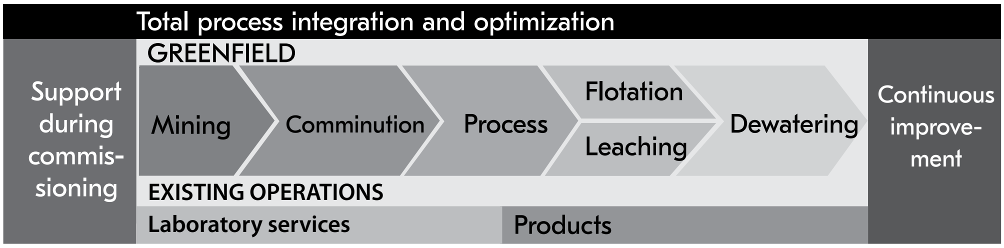
11.19 Consulting business

Technology development

Metso offers a global consulting service focused on simulation and automation.
In the area of Simulation Metso has a unique dynamic population balance modeling and simulation tool – Metso ProSim™ - which can be used to analyze, optimize and design mineral processing circuits. In addition to the usual suite of unit operation models, Metso ProSim™ utilizes multi-component structure and also allows for the inclusion of maintenance outages – planned and unplanned – moving toward the virtual plant. Metso also has a world-class multi physics simulation capability that allows for mircoscale analysis, design and optimization of components of process equipment, looking at productivity, product quality, wear and potential failure modes. This work involves the use of DEM, CFD, SPH, DGB, and other complex solution methodologies, requiring super computing platforms to deliver timely results. Finally, as part of the automation work (OCS© – 4D), Metso provides dynamic simulation capabilities that can be used to help design resilient process control solutions, develop custom advanced control strategies, and for training plant operators on new circuits.
In the area of Automation, Metso offers comprehensive control systems integration services which can include full electrical and instrumentation capabilities. In addition, process audits and training programs centered around regulatory automation needs are also part of the scope of services. Metso Computer Based Training (CBT) is also available to train plant operators on all aspects of the operation of comminution and/or flotation circuits Metso is also a leader in the field of Advanced Process Control (OCS©: model-based expert control) and Advanced Sensing (Visio™: machine vision, Audio™: machine acoustics), and is moving quickly into the related fields of Abnormal Situation Management and real-time data and image mining.
The objective of the Technology Development consulting activities is to identify and implement cost effective ways to improve plant productivity and lower unit costs, while respecting and enhancing the operational integrity and safety requirements of a plant.

11.20 Process technology and innovation

Process integration and optimization, is the development of integrated operating and control strategies from the mine to the plant that maximise throughput, minimise the overall cost per tonne and maximise profitability.
We offer consulting, laboratory and pilot plant services, and have developed supply and support for a range of products that have been designed to enhance the operation of mineral processes. Significant increases in throughput (5 to 30%) and metal recovery, cost and energy reduction, as well as overall process efficiency increases (from the mine to the plant) have been achieved at a number of operations worldwide.
Our particular focus is providing the industry with total process integration and optimization including optimization of the mining (drill and blast), comminution, flotation and dewatering processes for both Greenfield and existing operations. The main objectives are to reduce operating costs, increase production rates and improve overall process, energy and water efficiency.



For more information on Metso's technology consulting businesses, please contact your local Metso sales office.

Miscellaneous

12. Miscellaneous

12.1 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^{2}h)
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)

12.2 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

12.3 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
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

Mineral	Density
Spinel	3.6
Spodumene	3.1 - 3.2
Stannite	4.3 - 4.5
Stibnite (Antimonite)	4.6
Sulphur	2.1
Sylvite	2.0
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 **Density of solids: 1.8**

A	B	C	A	B	C	A	B	C	A	B	C
1	1.003	99.714	41	1.133	2.153	1	1.004	99.556	41	1.223	1.995
2	1.006	49.714	42	1.136	2.095	2	1.009	49.556	42	1.230	1.937
3	1.009	33.048	43	1.140	2.040	3	1.014	32.889	43	1.236	1.881
4	1.012	24.714	44	1.144	1.987	4	1.018	24.556	44	1.243	1.828
5	1.014	19.714	45	1.148	1.937	5	1.023	19.556	45	1.250	1.778
6	1.017	16.381	46	1.151	1.888	6	1.027	16.222	46	1.257	1.729
7	1.020	14.000	47	1.155	1.842	7	1.032	13.841	47	1.264	1.683
8	1.023	12.214	48	1.159	1.798	8	1.037	12.056	48	1.271	1.639
9	1.026	10.825	49	1.163	1.755	9	1.042	10.667	49	1.278	1.596
10	1.029	9.714	50	1.167	1.714	10	1.047	9.556	50	1.286	1.556
11	1.032	8.805	51	1.171	1.675	11	1.051	8.646	51	1.293	1.516
12	1.036	8.048	52	1.174	1.637	12	1.056	7.889	52	1.301	1.479
13	1.039	7.407	53	1.178	1.601	13	1.061	7.248	53	1.308	1.442
14	1.042	6.857	54	1.182	1.566	14	1.066	6.698	54	1.316	1.407
15	1.045	6.381	55	1.186	1.532	15	1.071	6.222	55	1.324	1.374
16	1.048	5.964	56	1.190	1.500	16	1.077	5.806	56	1.331	1.341
17	1.051	5.597	57	1.195	1.469	17	1.082	5.438	57	1.339	1.310
18	1.054	5.270	58	1.199	1.438	18	1.087	5.111	58	1.347	1.280
19	1.057	4.977	59	1.203	1.409	19	1.092	4.819	59	1.355	1.250
20	1.061	4.714	60	1.207	1.381	20	1.098	4.556	60	1.364	1.222
21	1.064	4.476	61	1.211	1.354	21	1.103	4.317	61	1.372	1.195
22	1.067	4.260	62	1.215	1.327	22	1.108	4.101	62	1.380	1.168
23	1.070	4.062	63	1.220	1.302	23	1.114	3.903	63	1.389	1.143
24	1.074	3.881	64	1.224	1.277	24	1.119	3.722	64	1.398	1.118
25	1.077	3.714	65	1.228	1.253	25	1.125	3.556	65	1.406	1.094
26	1.080	3.560	66	1.232	1.229	26	1.131	3.402	66	1.415	1.071
27	1.084	3.418	67	1.237	1.207	27	1.136	3.259	67	1.424	1.048
28	1.087	3.286	68	1.241	1.185	28	1.142	3.127	68	1.433	1.026
29	1.090	3.163	69	1.246	1.164	29	1.148	3.004	69	1.442	1.005
30	1.094	3.048	70	1.250	1.143	30	1.154	2.889	70	1.452	0.984
31	1.097	2.940	71	1.254	1.123	31	1.160	2.781	71	1.461	0.964
32	1.101	2.839	72	1.259	1.103	32	1.166	2.681	72	1.471	0.944
33	1.104	2.745	73	1.264	1.084	33	1.172	2.586	73	1.480	0.925
34	1.108	2.655	74	1.268	1.066	34	1.178	2.497	74	1.490	0.907
35	1.111	2.571	75	1.273	1.048	35	1.184	2.413	75	1.500	0.889
36	1.115	2.492	76	1.277	1.030	36	1.190	2.333	76	1.510	0.871
37	1.118	2.417	77	1.282	1.013	37	1.197	2.258	77	1.520	0.854
38	1.122	2.346	78	1.287	0.996	38	1.203	2.187	78	1.531	0.838
39	1.125	2.278	79	1.292	0.980	39	1.210	2.120	79	1.541	0.821
40	1.129	2.214	80	1.296	0.964	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

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: 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/m^3]
C = Pulp volume [m^3/ton solids]

Density of solids: 2.8 **Density of solids: 3.0**

A	B	C	A	B	C	A	B	C	A	B	C
1	1.006	99.357	41	1.358	1.796	1	1.007	99.333	41	1.376	1.772
2	1.013	49.357	42	1.370	1.738	2	1.014	49.333	42	1.389	1.714
3	1.020	32.690	43	1.382	1.683	3	1.020	32.667	43	1.402	1.659
4	1.026	24.357	44	1.394	1.630	4	1.027	24.333	44	1.415	1.606
5	1.033	19.357	45	1.407	1.579	5	1.034	19.333	45	1.429	1.556
6	1.040	16.024	46	1.420	1.531	6	1.042	16.000	46	1.442	1.507
7	1.047	13.643	47	1.433	1.485	7	1.049	13.619	47	1.456	1.461
8	1.054	11.857	48	1.446	1.440	8	1.056	11.833	48	1.471	1.417
9	1.061	10.468	49	1.460	1.398	9	1.064	10.444	49	1.485	1.374
10	1.069	9.357	50	1.474	1.357	10	1.071	9.333	50	1.500	1.333
11	1.076	8.448	51	1.488	1.318	11	1.079	8.424	51	1.515	1.294
12	1.084	7.690	52	1.502	1.280	12	1.087	7.667	52	1.531	1.256
13	1.091	7.049	53	1.517	1.244	13	1.095	7.026	53	1.546	1.220
14	1.099	6.500	54	1.532	1.209	14	1.103	6.476	54	1.563	1.185
15	1.107	6.024	55	1.547	1.175	15	1.111	6.000	55	1.579	1.152
16	1.115	5.607	56	1.563	1.143	16	1.119	5.583	56	1.596	1.119
17	1.123	5.239	57	1.578	1.112	17	1.128	5.216	57	1.613	1.088
18	1.131	4.913	58	1.595	1.081	18	1.136	4.889	58	1.630	1.057
19	1.139	4.620	59	1.611	1.052	19	1.145	4.596	59	1.648	1.028
20	1.148	4.357	60	1.628	1.024	20	1.154	4.333	60	1.667	1.000
21	1.156	4.119	61	1.645	0.996	21	1.163	4.095	61	1.685	0.973
22	1.165	3.903	62	1.663	0.970	22	1.172	3.879	62	1.705	0.946
23	1.174	3.705	63	1.681	0.944	23	1.181	3.681	63	1.724	0.921
24	1.182	3.524	64	1.699	0.920	24	1.190	3.500	64	1.744	0.896
25	1.191	3.357	65	1.718	0.896	25	1.200	3.333	65	1.765	0.872
26	1.201	3.203	66	1.737	0.872	26	1.210	3.179	66	1.786	0.848
27	1.210	3.061	67	1.757	0.850	27	1.220	3.037	67	1.807	0.826
28	1.220	2.929	68	1.777	0.828	28	1.230	2.905	68	1.829	0.804
29	1.229	2.805	69	1.797	0.806	29	1.240	2.782	69	1.852	0.783
30	1.239	2.690	70	1.818	0.786	30	1.250	2.667	70	1.875	0.762
31	1.249	2.583	71	1.840	0.766	31	1.261	2.559	71	1.899	0.742
32	1.259	2.482	72	1.862	0.746	32	1.271	2.458	72	1.923	0.722
33	1.269	2.387	73	1.884	0.727	33	1.282	2.364	73	1.948	0.703
34	1.280	2.298	74	1.907	0.708	34	1.293	2.275	74	1.974	0.685
35	1.290	2.214	75	1.931	0.690	35	1.304	2.190	75	2.000	0.667
36	1.301	2.135	76	1.955	0.673	36	1.316	2.111	76	2.027	0.649
37	1.312	2.060	77	1.980	0.656	37	1.327	2.036	77	2.055	0.632
38	1.323	1.989	78	2.006	0.639	38	1.339	1.965	78	2.083	0.615
39	1.335	1.921	79	2.032	0.623	39	1.351	1.897	79	2.113	0.599
40	1.346	1.857	80	2.059	0.607	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 **Density of solids: 3.0**

A	B	C	A	B	C	A	B	C	A	B	C
1	1.006	23811	41	1.358	430	1	1.007	23805	41	1.376	425
2	1.013	11829	42	1.370	417	2	1.014	11823	42	1.389	411
3	1.020	7834	43	1.382	403	3	1.020	7829	43	1.402	398
4	1.026	5837	44	1.394	391	4	1.027	5831	44	1.415	385
5	1.033	4639	45	1.407	378	5	1.034	4633	45	1.429	373
6	1.040	3840	46	1.420	367	6	1.042	3834	46	1.442	361
7	1.047	3270	47	1.433	356	7	1.049	3264	47	1.456	350
8	1.054	2842	48	1.446	345	8	1.056	2836	48	1.471	340
9	1.061	2509	49	1.460	335	9	1.064	2503	49	1.485	329
10	1.069	2242	50	1.474	325	10	1.071	2237	50	1.500	319
11	1.076	2025	51	1.488	316	11	1.079	2019	51	1.515	310
12	1.084	1843	52	1.502	307	12	1.087	1837	52	1.531	301
13	1.091	1689	53	1.517	298	13	1.095	1684	53	1.546	292
14	1.099	1558	54	1.532	290	14	1.103	1552	54	1.563	284
15	1.107	1444	55	1.547	282	15	1.111	1438	55	1.579	276
16	1.115	1344	56	1.563	274	16	1.119	1338	56	1.596	268
17	1.123	1256	57	1.578	266	17	1.128	1250	57	1.613	261
18	1.131	1177	58	1.595	259	18	1.136	1172	58	1.630	253
19	1.139	1107	59	1.611	252	19	1.145	1101	59	1.648	246
20	1.148	1044	60	1.628	245	20	1.154	1038	60	1.667	240
21	1.156	987	61	1.645	239	21	1.163	981	61	1.685	233
22	1.165	935	62	1.663	232	22	1.172	930	62	1.705	227
23	1.174	888	63	1.681	226	23	1.181	882	63	1.724	221
24	1.182	845	64	1.699	220	24	1.190	839	64	1.744	215
25	1.191	805	65	1.718	215	25	1.200	799	65	1.765	209
26	1.201	768	66	1.737	209	26	1.210	762	66	1.786	203
27	1.210	734	67	1.757	204	27	1.220	728	67	1.807	198
28	1.220	702	68	1.777	198	28	1.230	696	68	1.829	193
29	1.229	672	69	1.797	193	29	1.240	667	69	1.852	188
30	1.239	645	70	1.818	188	30	1.250	639	70	1.875	183
31	1.249	619	71	1.840	184	31	1.261	613	71	1.899	178
32	1.259	595	72	1.862	179	32	1.271	589	72	1.923	173
33	1.269	572	73	1.884	174	33	1.282	567	73	1.948	168
34	1.280	551	74	1.907	170	34	1.293	545	74	1.974	164
35	1.290	531	75	1.931	165	35	1.304	525	75	2.000	160
36	1.301	512	76	1.955	161	36	1.316	506	76	2.027	156
37	1.312	494	77	1.980	157	37	1.327	488	77	2.055	151
38	1.323	477	78	2.006	153	38	1.339	471	78	2.083	147
39	1.335	460	79	2.032	149	39	1.351	455	79	2.113	144
40	1.346	445	80	2.059	145	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 **Density of solids: 3.4**

A	B	C	A	B	C	A	B	C	A	B	C
1	1.007	99.313	41	1.393	1.752	1	1.007	99.294	41	1.407	1.733
2	1.014	49.313	42	1.406	1.693	2	1.014	49.294	42	1.421	1.675
3	1.021	32.646	43	1.420	1.638	3	1.022	32.627	43	1.436	1.620
4	1.028	24.313	44	1.434	1.585	4	1.029	24.294	44	1.451	1.567
5	1.036	19.313	45	1.448	1.535	5	1.037	19.294	45	1.466	1.516
6	1.043	15.979	46	1.463	1.486	6	1.044	15.961	46	1.481	1.468
7	1.051	13.598	47	1.477	1.440	7	1.052	13.580	47	1.496	1.422
8	1.058	11.813	48	1.493	1.396	8	1.060	11.794	48	1.512	1.377
9	1.066	10.424	49	1.508	1.353	9	1.068	10.405	49	1.529	1.335
10	1.074	9.313	50	1.524	1.313	10	1.076	9.294	50	1.545	1.294
11	1.082	8.403	51	1.540	1.273	11	1.084	8.385	51	1.563	1.255
12	1.090	7.646	52	1.556	1.236	12	1.093	7.627	52	1.580	1.217
13	1.098	7.005	53	1.573	1.199	13	1.101	6.986	53	1.598	1.181
14	1.107	6.455	54	1.590	1.164	14	1.110	6.437	54	1.616	1.146
15	1.115	5.979	55	1.608	1.131	15	1.118	5.961	55	1.635	1.112
16	1.124	5.563	56	1.626	1.098	16	1.127	5.544	56	1.654	1.080
17	1.132	5.195	57	1.644	1.067	17	1.136	5.176	57	1.673	1.049
18	1.141	4.868	58	1.663	1.037	18	1.146	4.850	58	1.693	1.018
19	1.150	4.576	59	1.682	1.007	19	1.155	4.557	59	1.714	0.989
20	1.159	4.313	60	1.702	0.979	20	1.164	4.294	60	1.735	0.961
21	1.169	4.074	61	1.722	0.952	21	1.174	4.056	61	1.756	0.933
22	1.178	3.858	62	1.743	0.925	22	1.184	3.840	62	1.778	0.907
23	1.188	3.660	63	1.764	0.900	23	1.194	3.642	63	1.801	0.881
24	1.198	3.479	64	1.786	0.875	24	1.204	3.461	64	1.824	0.857
25	1.208	3.313	65	1.808	0.851	25	1.214	3.294	65	1.848	0.833
26	1.218	3.159	66	1.831	0.828	26	1.225	3.140	66	1.872	0.809
27	1.228	3.016	67	1.854	0.805	27	1.235	2.998	67	1.897	0.787
28	1.238	2.884	68	1.878	0.783	28	1.246	2.866	68	1.923	0.765
29	1.249	2.761	69	1.902	0.762	29	1.257	2.742	69	1.950	0.743
30	1.260	2.646	70	1.928	0.741	30	1.269	2.627	70	1.977	0.723
31	1.271	2.538	71	1.954	0.721	31	1.280	2.520	71	2.005	0.703
32	1.282	2.438	72	1.980	0.701	32	1.292	2.419	72	2.033	0.683
33	1.293	2.343	73	2.008	0.682	33	1.304	2.324	73	2.063	0.664
34	1.305	2.254	74	2.036	0.664	34	1.316	2.235	74	2.094	0.645
35	1.317	2.170	75	2.065	0.646	35	1.328	2.151	75	2.125	0.627
36	1.329	2.090	76	2.094	0.628	36	1.341	2.072	76	2.157	0.610
37	1.341	2.015	77	2.125	0.611	37	1.354	1.997	77	2.191	0.593
38	1.354	1.944	78	2.156	0.595	38	1.367	1.926	78	2.225	0.576
39	1.366	1.877	79	2.189	0.578	39	1.380	1.858	79	2.261	0.560
40	1.379	1.813	80	2.222	0.563	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						Density of solids: 3.8					
A	B	C	A	B	C	A	B	C	A	B	C
1	1.007	99.278	41	1.421	1.717	1	1.007	99.263	41	1.433	1.702
2	1.015	49.278	42	1.435	1.659	2	1.015	49.263	42	1.448	1.644
3	1.022	32.611	43	1.450	1.603	3	1.023	32.596	43	1.464	1.589
4	1.030	24.278	44	1.466	1.551	4	1.030	24.263	44	1.480	1.536
5	1.037	19.278	45	1.481	1.500	5	1.038	19.263	45	1.496	1.485
6	1.045	15.944	46	1.498	1.452	6	1.046	15.930	46	1.513	1.437
7	1.053	13.563	47	1.514	1.405	7	1.054	13.549	47	1.530	1.391
8	1.061	11.778	48	1.531	1.361	8	1.063	11.763	48	1.547	1.346
9	1.070	10.389	49	1.548	1.319	9	1.071	10.374	49	1.565	1.304
10	1.078	9.278	50	1.565	1.278	10	1.080	9.263	50	1.583	1.263
11	1.086	8.369	51	1.583	1.239	11	1.088	8.354	51	1.602	1.224
12	1.095	7.611	52	1.601	1.201	12	1.097	7.596	52	1.621	1.186
13	1.104	6.970	53	1.620	1.165	13	1.106	6.955	53	1.641	1.150
14	1.112	6.421	54	1.639	1.130	14	1.115	6.406	54	1.661	1.115
15	1.121	5.944	55	1.659	1.096	15	1.124	5.930	55	1.681	1.081
16	1.131	5.528	56	1.679	1.063	16	1.134	5.513	56	1.703	1.049
17	1.140	5.160	57	1.700	1.032	17	1.143	5.146	57	1.724	1.018
18	1.149	4.833	58	1.721	1.002	18	1.153	4.819	58	1.746	0.987
19	1.159	4.541	59	1.742	0.973	19	1.163	4.526	59	1.769	0.958
20	1.169	4.278	60	1.765	0.944	20	1.173	4.263	60	1.792	0.930
21	1.179	4.040	61	1.787	0.917	21	1.183	4.025	61	1.816	0.903
22	1.189	3.823	62	1.811	0.891	22	1.193	3.809	62	1.841	0.876
23	1.199	3.626	63	1.835	0.865	23	1.204	3.611	63	1.866	0.850
24	1.210	3.444	64	1.860	0.840	24	1.215	3.430	64	1.892	0.826
25	1.220	3.278	65	1.885	0.816	25	1.226	3.263	65	1.919	0.802
26	1.231	3.124	66	1.911	0.793	26	1.237	3.109	66	1.947	0.778
27	1.242	2.981	67	1.938	0.770	27	1.248	2.967	67	1.975	0.756
28	1.253	2.849	68	1.965	0.748	28	1.260	2.835	68	2.004	0.734
29	1.265	2.726	69	1.993	0.727	29	1.272	2.711	69	2.034	0.712
30	1.277	2.611	70	2.022	0.706	30	1.284	2.596	70	2.065	0.692
31	1.288	2.504	71	2.052	0.686	31	1.296	2.489	71	2.097	0.672
32	1.301	2.403	72	2.083	0.667	32	1.309	2.388	72	2.130	0.652
33	1.313	2.308	73	2.115	0.648	33	1.321	2.293	73	2.164	0.633
34	1.325	2.219	74	2.148	0.629	34	1.334	2.204	74	2.199	0.615
35	1.338	2.135	75	2.182	0.611	35	1.348	2.120	75	2.235	0.596
36	1.351	2.056	76	2.217	0.594	36	1.361	2.041	76	2.273	0.579
37	1.365	1.980	77	2.253	0.576	37	1.375	1.966	77	2.311	0.562
38	1.378	1.909	78	2.290	0.560	38	1.389	1.895	78	2.351	0.545
39	1.392	1.842	79	2.329	0.544	39	1.403	1.827	79	2.393	0.529
40	1.406	1.778	80	2.368	0.528	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

Metso Outotec is a frontrunner in sustainable technologies, end-to-end solutions and services for the aggregates, minerals processing and metals refining industries globally. By improving our customers' energy and water efficiency, increasing their productivity, and reducing environmental risks with our product and process expertise, we are the partner for positive change.

Partner for positive change

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