# MINERAL PROCESSING

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# Mineral Processing

by Abhijeet

Date: 2/1/2014

AJ Sir

Mineral Processing
Mineral Dressing
Mineral Engineering
Mineral processing Technology
Ore dressing
Mineral Beneficiation

Books
Gaudin.
Chow
✓ B.A. Wills.
✓ Jain.
Taggard (Handbook)
Bryor

Mineral → solid, Homogenous, naturally occurring, definite chemical composition, formed by inorganic process, ordered domic characteristics.

Rock → An aggregate of minerals, one or more

ex.) Quartzite → only quartz } Mono
limestone } mineralic

Granite → Quartz and felspar } ~~Dimineralty~~ Dimineralic rock.

Ore → an ~~aggregat~~ aggregate rock but all rock are not ores. Ore is aggregate of gangue mineral and valuable mineral which can be extracted economically.

~~Ore~~ Mineral ← Chalcopyrite ($CuFeS_2$) $\xrightarrow{\text{Mineral}}$ Processing Cu
It is ~~an~~ not ore.

Galena
Sphalerite
BHJ – Banded Haematite Jasper
BHQ – Banded Haematite Quartz
Ore of lead, Zn, Mn, Gold.

ore of Cu is composed of Quartz, felspar, phyllite + chalcopyrite.
ore is always associated with gangue material.

Suppose :-
Copper ore
0.6%.

(1cm – 1m)
ROM → (first product after blasting)

→ Cut off point of copper is 0.35% in India

Tenor – Content of valuable metal in ore. It may be represented in (%age), or (ppm) or in (gm/t) or sometimes.

Carat → Gemstone $\boxed{200 \text{ mg} = 1 \text{ carat}}$
Carat → purity of gold
24 carat is 100% pure, 2 carat is copper.
due to high hardness and colour similar to gold.

Crushing of ROM is required upto $\mu m$ size because sizes of chalcopyrite grain is about 45 $\mu m$. This is already studied during exploration stage. So this is done step by step.

ROM → Primary crushing
↓
secondary crushing
↓
Tertiary crushing
↓ (Coarse grinding is not required if tertiary crushing is done.)
Fine grinding
↓
Superfine grinding
→ Concentration process (Froth floatation, etc.)

Tenor remains same

The whole exercise of crushing is just to liberate valuable ore mineral from the gangue mineral.

Separation of Quatz from somewhere

Quatz

chalcopyrite

Quartz

chalcopyrite

liberation

6/1/2014

AKS Sir

→ Mineral is naturally occuring inorganic homogeneous solid substance having fixed chemical composition and very often fixed crystal structure (changes in case of isomers)

→ ore is natural aggregation of mineral from which metal or metallic compound can be extracted profitably or economically

→ Rock is natural aggregation of mineral, in ~~...~~ the form they occurs in nature.

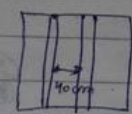
Jamal Sir

09/01/2014

## Concept of Liberation and its measurement:-

ROM → Grizly $\xrightarrow[(-)\ (<40cm)]{(+)\ (>40cm)}$ P Crushing

Tenor 0.5%




↓

Secondary Crusher

↓

Coarse Grinding

↓

0.5% Fine Grinding

↓ ≈75 μm

Froth flotation

Tailing (gangue minerals)

Concentrate 7(6% - 21%) (ore concentrate)

↓

smelter (99%)

↓

Electrorefining (99.99%)

## Concentration processes:—

Heavy Media Separator
Wilfrey Table
Magnetic separator
Gravity concentration (Jigging)

ch + gangue $\xrightarrow{\text{liberation}}$ ch, gangue

Liberation → freeing
In case of Cu ore → ~~stdof~~ chalcopyrite
In case of Fe ore → Hematite
BHQ

Crushing and grinding is done to liberate ore mineral from gangue particles.

In case of Iron ore BHQ, Jigging is done:—

Jigging → Concentrate (Hematite)
Jigging → Middlings (Hematite and Quartz)
Jigging → Tailing (Quartz)

To know the size of minerals, ore Microscopy is done.

→ liberation is necessary for separation and separation cannot be perfect with poor liberation.

ROM (~1m)
↓
Primary Crusher
(Jaw Crusher and Gyratory Crusher)
—— Secondary Crusher
feed size ≃ 10 cm
discharge size ≃ 3 cm
↓
Coarse grinding (rod mill)
(3 cm → 6 mm)
↓
Fine grinding (Ball mill)
Here a 75 µm screen with 200# (In 1 linear square inch there are 200 wires and 200 apertures and thickness of wire is 75 µm and aperture is 75 µm)

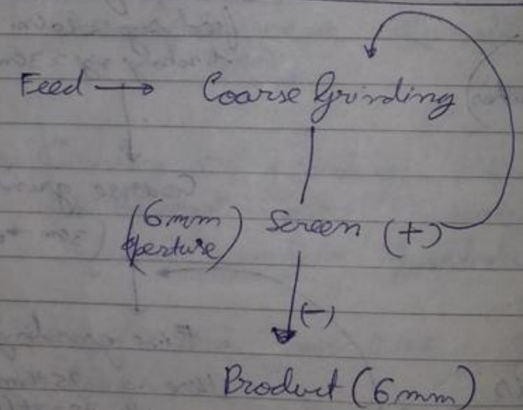
+ (> 75 µm)
screen
(−) (< 75 µm)

This is closed circuit

When the material is recirculating in the crushing and grinding circuit it is called closed circuit. To increase efficiency screening can be done at each stage but screening is the slowest process.

→ If the ROM has ~~size~~ ~~(+)~~ particles with size of 3Cm then at the top of primary crusher there is a screen which screens out particles greater than 3Cm and these are sent to the primary crusher ~~where~~ whereas (−) size particles are directly sent to the coarse grinder (rod mill).

FLOW CHART OF CLOSED Circuit:-




Crushing and Grinding Equipments and their Performance:-

(Theories of Comminution)

Comminution → is defined as the whole operation of reducing the iron ore to the size required for mechanical separation or metallurgical processing. It includes crushing and grinding. Jamal Sir

13/01/2014 Crushing and Grinding equipments and their performance (Theories of Comminution):-

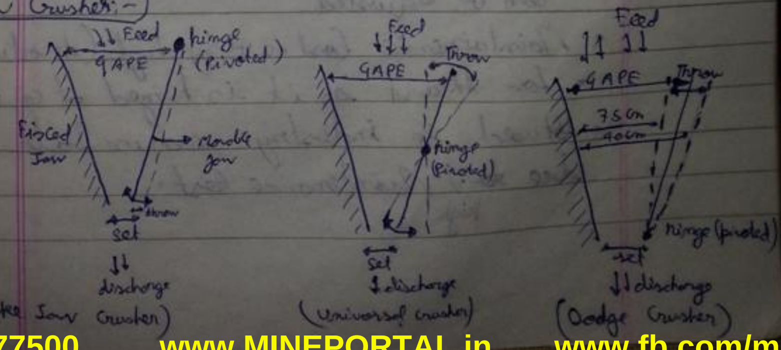
1.) Primary Crusher — Jaw Crusher
- Blake Jaw Crusher
- Dodge Jaw Crusher
- Universal Jaw crusher

— Gyratory Crusher.

2.) Secondary crusher and tertiary Crusher:-

→ cone crusher
- standard cone crusher
- short head cone crusher.

Jaw Crusher:-



## Characteristics of Dodge Crusher:-

It recieves feed of variable size, because the Jaw is pivoted at discharge point.
The throw of 20 cm.


### Advantages:-

Adv
- Feed of variable size
- Product is almost fix size
- Fixed Capacity (kg/hr). Cannot be altered. Hence limited application

disadv
- Limited Thrust imposed by moving Jaw. Decrease as we move down toward discharge point.

appl
Hence, because of limited capacity, it is used in laboratory.

## Universal Crusher:-

- Feed size is variable
- Discharges product of variable size. Can be adjusted
- Maintainence Cost is very high (disadvantage)
- Low thrust as it is hinged at centre
- Not used in industry more in lab due to high Maintenance Cost.

## Blake Crusher:-

- Feed is of fixed size
- Discharge is of variable size
- Thrust increases as we move toward discharge point
- High Capacity
- Widely used in labs and industry.

## Gyratory Crusher:-

23/01/2013

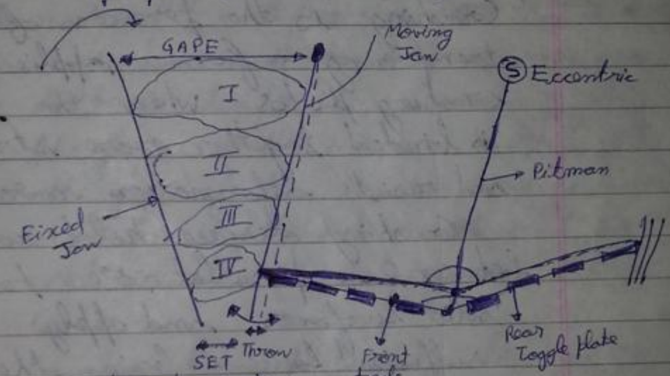
A J Sir

## Blake Jaw Crusher:-

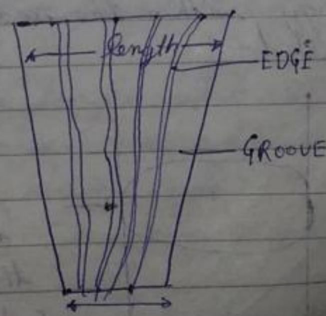
2 Types:-

1) Double Toggle jaw crusher
2) Single Toggle jaw crusher

→ Basic purpose of crusher is size reduction




Side sectional view

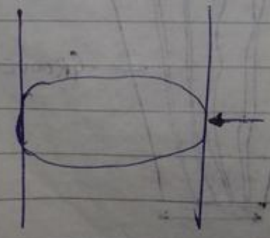



FRONT VIEW OF JAW

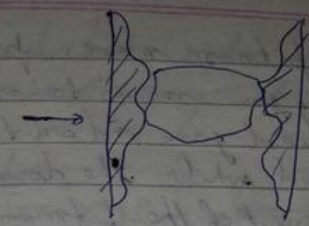
Crushers may be used to reduce the size, change the form of waste material so that they can be easily used; or to reduce the size of rock ore so that pieces of ~~different~~ separate composition can be differentiated for mineral processing processes.

Crushing is the process of transferring a force applied by crushing plates where the rock is binded together more strongly and resists deformation more.

Crushing devices hold rock between 2 parallel or tangent solid surfaces and apply sufficient force to bring the surface together to generate enough energy within the material being crushed.



if surface of crushing is smooth then there is area contact and resultant product has mixture of coarse and fine particles with higher % age of fines



→ If surface of crushing is corrugated then point contact takes place and mainly coarse particles are produced.

The material (rock/ore) is fed into the crusher with the help of conveyor belt or dumpers depending upon the gape of the crusher. Generally the gape of the crusher ranges upto 1m or slightly more ~~and~~ and the set is also ranging from 25-35 cm.

Crushing takes place when the angle is obtuse (maximum) between the togging place.

When the toggle plate with the help of eccentric moves upward ~~then~~ (making obtuse angle between the toggle plates), crushing takes place.

The successive reduction of size takes place as the pitman moves up and down with the help of eccentric.

→ As the pitman moves up the moving jaw moves towards the fixed jaw and crushes the material while the downward movement of the pitman takes the moving jaw away from the fixed jaw.

→ The movement of the pitman is due to the horizontal movement of the eccentric.

→ As a reduction in size of ore material, the volume of material in the crushing chamber is increased. Hence the process of crushing should be adjusted in such a way that the rate of feeding should not be more than rate of discharge. In such situation chances of breakdown of crusher is there due to burning of motor. To avoid this problem the throw of the crusher is adjusted accordingly. Obviously more throw (amplitude) of the crusher will give higher rate of production (capacity of crusher is increased) but the disadvantage is that more throw causes excessive production of fines and valuable is also lost in case of fines (as in case of gold).

Page No. :
Date :

The reduction ratio of the crusher is in the range of 3:1 to 5:1.

Specification:-

1220 X 915 mm → mouth area of the crusher.

gape    length of plate (l)

Theoritical capacity $= 0.6 \times l \times s$

(s) Set = 125 mm

Capacity of crusher = 265 – 295 tons per hour.

27/01/2014

AKS sir

and
a pulp
of galena
cut the
quartz
times
with
calculated
2 3.94
two is

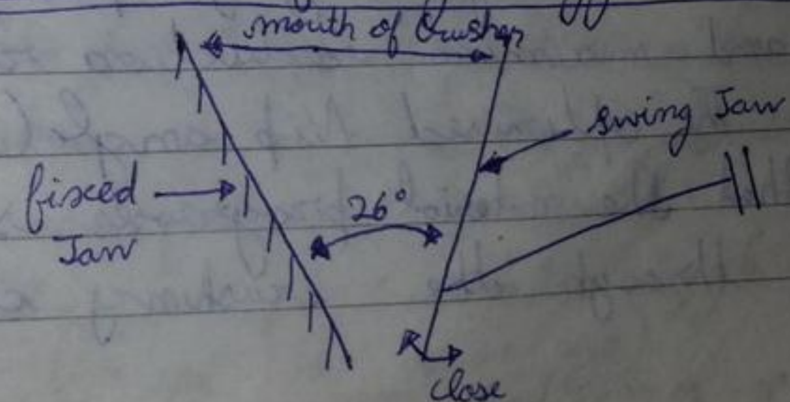
... to increase the effect of size on the separation.

20/2/14. and 25/2/14. | AJ Sir

Different type of Crushers:-

(1) Double toggle Jaw Crushers
(2) Single toggle Jaw Crusher

Characteristic of Single Toggle Jaw Crusher:-



- It is high strength, low weight crusher
- Frame consists of two side plates of rolled steel, hollow casting at front frame end and moving jaw which gives high rigidity by weight ratio $\left( \gg \frac{\text{Rigidity}}{\text{wt. ratio}} \right)$
- Large radius transition area reduces stress concentration and welds are positioned in low stress area.
- The advantage of welding frame is that it equally strong in all direction and ensure excellent durability against shock load. Thus, minimising the risk of failure on the main frame; As with a bolted construction.

**Advantage :-**

- High Capacity
- High reduction of feed
- ~~Low jaw plate wear~~ (?)
- large feed acceptance capacity

- The deep symmetrical crushing chamber maximises feed size, capacity, volume and maximum reduction ratio.
- The optimised Nip angle (26°) ensures that the material progresses smoothly down through the crushing chamber to enable

high reduction, productivity and utilisation of jaw plates.

— The movement of swing jaw, forces in horizontal and oblique, therefore less chocking problem.

## Specification Of Single Toggle Jaw Crusher:-

| | |
|---|---|
| Crushing speed | 300 rpm |
| Feed opening | 800 x 550 mm to 1500 x 1300 mm |
| Depth | 1400 mm |
| Shipping volume | 10 $m^3$ |
| close setting set | 50-175 mm |
| Total weight | 9900 kg |
| Motor power | 55 KW |

**Benefits:-**

1.) One piece frame of great strength
- heavy, fully welded, stress relieved

2.) Even distribution of crushing forces

3.) Protection of Swing jaw holder and main frame jaw location (replicable jaw backing plates)

4.) Extended life of toggle and toggle seat.

Suitable for "hard brittle material" like limestone, coal, Pb-Zn, Granite including platy and foliated mineral

5) It is cheaper (Double toggle are 50% costlier of the same size)

6.) High Capacity 7.) High reduction of size.

8.) Large size acceptance capacity.

~~Advantages~~

⇒ Jaw crusher can be installed in U/G mine also

**Disadvantages:-**

1) increased wear of Jaw plates
2) Direct attachment of swing jaw to eccentric imposes high degree of strain of drive shaft causing high maintenance problem.

① limited Capacity : under its capacity range our requirement fits then always prefer Jaw crusher

NOTE ⇒ Installation of Gyratory crusher is always U/G but JC can be installed at both U/g or Surface and now-a-days always ST JC is used.

| Types of Crushers | Reduction Ratio | Applications |
|---|---|---|
| Jaw Crusher | 3-5 | Mining, quarrying material, sand, gravel (Hard and soft material, Dry and wet, elastic |
| Gyratory Crusher | 4-7 | Mining, quarrying material, sand, gravel (Hard and soft ores, Dry and wet and not for flatty, and lamillar ores) |

| | | |
|---|---|---|
| Cone Crusher | 3-5 | quarrying material, Sand and gravel |
| Compound Crusher | 3-5 | mine and Building material |
| Horizontal Shaft Impactor | 10-25 | quarried ores, Sand, gravel, Recycling |
| Vertical Shaft Impactor (Shoe and Anvil) | 6-8 | Sand gravel, Recycling |
| Vertical Impact (Autogenous) | 2-5 | quarried ore, Rock, Sand, gravel |
| Mineral Sizer | 2-5 | Mining |

## GYRATORY CRUSHER

A gyratory crusher is similar in basic Concept to a Jaw crusher, consisting of a conical head, Both surfaces are typically lined with manganese steel surfaces. The inner cone has a slightly circular movement but does not rotate; the moment is generated by eccentric arrangement, not axial, but instead it is gyratory motion. As with the Jaw Crusher material travel downwards between 2 surfaces (Jaws) being progressively crushed until it is small enough to fall out through the discharge opening (set.

A gyratory crusher is one of the main types of primary crusher in coal and ore processing plants. Gyratory crushers are designed by either by gape or mantle diameter or by the size of the ~~the~~ recieving opening.

Gyratory Crusher can be used for primary or secondary crushing. The Crushing action is caused by closing of the space between mantle line (crushing head) mounted on the central Vertical Spindle and the concave liners (fixed) mounted on the main frame of the gyratory crusher. The gap is opend and closed by the eccentric sleeve on the bottom of the ~~[illegible]~~ spindle that causes the Central Vertical Spindle to Gyrate. The Vertical spindle is free to rotate around its own axis. On the basis of spindle size a gyratory crusher may be short shaft suspended gyratory crusher meaning that the main shaft is suspended at the top and that the eccentric is mounted above the gear. The short shaft design has superceeded the long shaft design in which the eccentric is mounted below the gear

⇒ Material size → 3-10 cm

⇒ No choking problem as the motion is gyratory

04/03/2014.

A J Sir

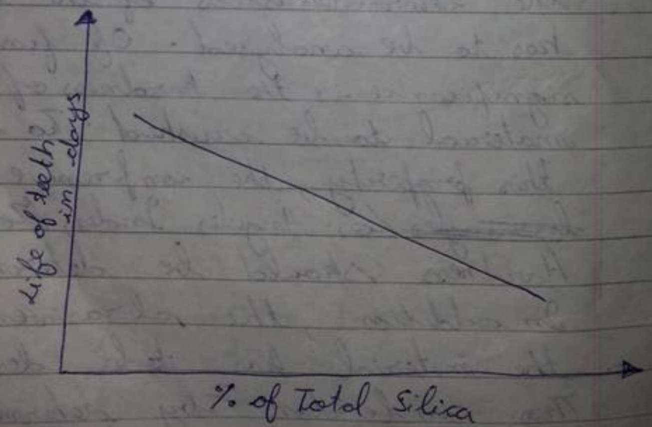
## Selection Criteria for Primary Crushers:-
## (Comparison of Jaw and Gyratory Crushers)

Selection depends on:-

1> Characteristics of Rock
2> Size of material comming from the mine
3> Type of material (brittle, slabby, minreal)
4> Capacity

The physical properties of ore and raw materials required for different mining and mineral based industries differs at a wide range. Before choosing a crusher for a certain application for mine and quarry and specially the characteristics of the ore has to be analysed. Of fundamental significance is the hardness of the material to be crushed. To describe this property, the compressive strength, ~~Los-angles~~ Los-Angeles Index, Mohs Hardness should be determined. In addition, the abrasiveness of the material has to be described. This can be done by determining the silica content, the free quartz content and the abrasion index. Of the same importance is to express the stickiness (clay mineral) of the material. For this reason, the moisture, clay content and shear test has to be investigated. Based on above values and characteristics of ore and raw material, the crushers are being selected for a particular Industry.

Life of Teeth in shearer
" " " Surface mines
" " " Shovel bucket
" " " Dragline bucket



Visit → (Thyssenkrupp Fördertechnik)

1) Feed size
2) Installation Cost
3) characteristics of ore/coal/raw material
4) capacity.

Feed Size:-
Crushers range in size upto gapes of 1830 mm and can crush ore with top size of 1370 mm at a rate of upto 5000 t/hr with a 200 mm set. Power consumption is as high as 750 KW on such crusher. Large gyratories often dispense with expensive feeding mechanism and are often fed direct from trucks/conveyor belts. They can be operated satisfactorily with the head buried in feed. Although excessive fines may have to be scalped from the feed.

Jaw crushers tend to be used where the crusher gape is more important than the capacity (to avoid need of secondary blasting). Gyratory crusher in general is used where high capacity is required since they crush on full cycle and they are more efficient than Jaw crusher.

Installation Cost:-

The installation Cost of Gyratory crusher is much higher than jaw crusher. Gyratory crusher is almost always installed below the surface and have limited movement option whereas jaw crusher can be installed over the surface and below the surface. and can move from one place to another place with a little cemented foundation.

Characteristics of ore/coal/raw material:-

The ore and raw material vary from mine to mine and within mine also. The type of material being crushed vary from brittle to elastic. Jaw crusher perform better than gyratory on clayey plastic material due to their greater throw. Gyratories have been found suitable for hard,

04/03/2

brittle and abrasive material and they tend to give more granular cubic product.

## Capacity:-

The capacity also plays an important role in selection between jaw and gyratory crusher.

A simple relation suggested by Taggart:

If t/hr. $< 161.7\,(\text{gape in m})^2$
use a jaw crusher

$<500$ t/hr $\rightarrow$ always Jaw Crusher

500 – 700 t/hr $\rightarrow$ go for Jaw crusher/ gyratory crusher

$>700$ t/hr $\rightarrow$ go for gyratory crusher face of the screens.

(Add to earlier notes)

**Working of Single toggle Jaw Crusher:-**

* The swing jaw suspended from the eccentric shaft moves towards the fixed plate as well as in the vertical direction
* The ~~E~~ elliptical movement of the swing jaw assists in pushing the rock through the crushing chamber, hence making them high capacitive.

- It is usually choke fed and the Jaw movement makes it self-feeding
- It is used for heavy-duty work on tough ores like taconite.

(AKS Sir) 10/3/2014.

are also possible. coarser separations

Jamal Sir

Secondary Crushers / Tertiary Crusher:-

Cone Crusher
- Standard Cone Crusher
- short head cone Crusher (Tertiary Crusher)

Roll Crusher

Impact Crusher

Secondary Crushers are much lighter than the heavy duty primary Crusher. Since they take the primary crushed ores as feed so the maximum feed size will normally be less than 15 cm in diameter and these feeds are freed from wooden material, metal scraps and clay and slimes. Hence it is much easier to handle the feed of secondary crusher.

ROM → // → PC → SC → TC

grizzly (getting slightly less than gape of P.C.) → 1) protects the hopper of PC 2) efficiency of PC improved (no jamming)

TC ↓ grinding mill

Similarly the transportation and feeding arrangements serving the crushers do not need to be as rugged as in Primary Crusher (Such grizzlies are not required for S.C.). Secondary Crushers also operate with dry feeds and their purpose is to reduce the ore to a size suitable for grinding. In those cases where size reduction can be more efficiently carried out by crushing, there may be a tertiary crushing stage before the material is passed to the grinding mill.

Rod mill acts as a Tertiary Crusher also :- Because of the wedge formation

by 2 rods and large fragment, the small particles are not crushed to fine size and so material remains at coarser size. So Rod Mill is a Tertiary Crusher also.

Tertiary Crushers are of the same design as secondary, except they have a closer set. The Bulk of Secondary crushing of metalliferous ore is performed by cone crushers, although roll crushers, impact crushers, hammer mill are also used for some specific purposes.

**Simons Cone Crushers:-**

They are modified gyratory crusher. The essential difference is that, the shorter spindle of the cone crusher is not suspended as in the gyratory but is supported in a curved universal bearing below the gyratory head or cone.

Since a large gape is not required, the crushing shell or bowl flares outwards which allows for the swell of broken ore by providing an increasing cross-sectional area towards the discharge end. The cone crusher is therefore an excellent arrested crusher. The flare of the bowl allows a much greater head angle than in the gyratory crushers, while retaining the same angle between the crushing chamber.

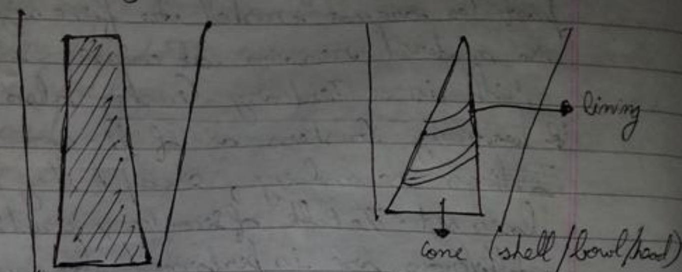



FIG1:- Gyratory Crusher.

FIG2:- Cone Crusher.

This gives the cone Crusher, a high capacity since the capacity of a gyratory crusher is proportional to the diameter of the head. Unlike a gyratory crusher which is identified by the ~~diameter~~ dimension of the feed opening and the mantle diameter, a cone crusher is rated by the diameter of the cone lining.

Cone Crusher range in size from 559 mm to 3.1m and have capacity upto 1100 tonnes per hour with a discharge setting of 19mm. There are 2 simons cone crusher (3.1m, each with capacity of 3000 T/hr) have been installed in an iron ore plant in South Africa.

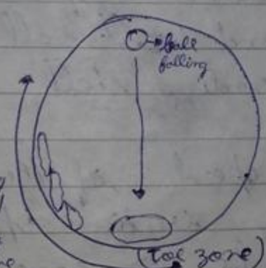
01/04/2014

Jamd Sir:

ROM → when ore is in the mine
feed → when that ore is used in processing plant.

**Grinding:-**

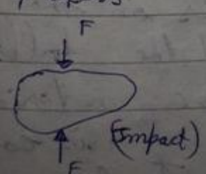
Material is generally crushed upto 250mm. Grinding starts from 5mm to 250mm (feed size). Materials can be grinded even upto micron size (upto 40 μm). ~~size (~~ Grinding is done for liberation, But excessive fine size is not preferred because energy consumption is very high and the process becomes uneconomic.




Tumbling mill

grinding effected in only this zone (if you look at the mechanism) so grinding is a probabilistic process

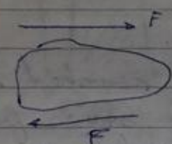
**Forces on Particles**




Coarse and fine particles present in product.

F are equal and opposite (compression)


when forces are oblique
Then product has coarse particles
(chipping)




(Abrasion)

when forces are parallel and opposite.
the product has fines.

When the mill is running at the <u>critical speed</u> then no grinding takes place because there is no relative displacement of charge and ball and wall of the grinding shell.

When the speed of the mill is less than critical speed then there can be 2 cases:-

1.) The balls rises to the topmost level and falls on the toe zone and the balls fall on the toe zone material and grind them. This is called Cataracting. The forces are compress

and so product has coarse and fine particles. The speed is called cataracting speed (70% of critical speed)

2) The ~~balls~~ balls and material rise along one side of the mill ~~vessel~~ walls and slides back to the toe region again. In such a case the materials are subjected to abrasion (forces are equal and opposite) and the product has only fines.

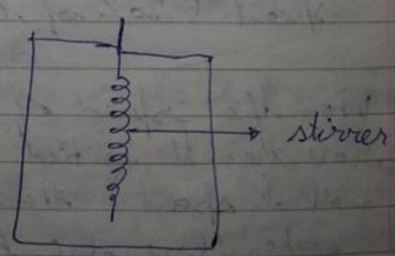

This process is called cascading and the speed is called cascading speed (30% of critical speed)

When the speed of the mill is more than the critical speed (super critical speed) then also grinding takes place due to abrasion, as the balls move along the mill wall but ~~no~~ corrosion of the balls and ~~the~~ mill wall liner ... ball and wall liner consumption is high.

**NOTE:-** But these concepts are only applicable for non sub-sieve/ sub-micron particles (> 40 µm).

grinding mill → Rotating / Tumbling mill
→ stirring mill

In tumbling mill the whole shell is rotating and grinding can be done in wet or dry condition, while ~~at~~ in stirring mill there is a stirrer where moves the charge withing the grinding shell and grinding is always done in wet condition)



Grinding is the last stag in the process of comminution. In this process the particles are reduced in size by abrasion and impact either dry or in wet condition. It is performed in rotating cylindrical steel vessels which contain a charge of loose crushing comminuting bodies (quartz, pebbles, iron balls), the grinding medium, which is free to move inside the mill. Thus comminuting the feed. Tumbling / Rotating mill are typically employed in the mineral industry for grinding between 5 - 250 mm and are reduced in size to between (40 - 300 μm). Whereas in stirred mill, the mill shell with either a vertical or horizontal orientation, is stationary and motion is imparted to the charge by the movement of an internal stirrer. Fine grinding media inside the mills are agitated / rotated by a stirrer. Stirred mills find application in fine ($< 15 \mu m$) and superfine grinding of material needlessly. Over grinding reduces the particle size of the subse-

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Date :

quently liberated major constituents and may reduce the particle size of the minor constituent below the size required for most efficient separation. It has been estimated that 50% energy consumed in U.S. mills is used in comminution.

In a survey it has been pointed out that average energy consumption in concentration was 2.2 KWh/t for crushing and 11.6 KWh/t for grinding and 2.6 Kwh/t for flotation. It has been observed in a experimentation that 19% extra energy is consumed in grinding 1 screen size finer in a $\sqrt{2}$ screen series (difference betwen aperture size is $\sqrt{2}$ in consequetive screens)

11/03/2014 SR Sir

Heavy Medium Separation: (Gravity Concentration)



Also known as Dense Medium Separation or sink ...

# Jaw Crushers:-

**Theoritical Reduction Ratio** → Theoretical reduction ratio ~~of the~~ is the ratio of the feed end called "GAPE" to the maximum opening at the discharge called "SET".

**Theoritical Capacity** → It is defined as the product of the integrated volume of the stream of the crushed material passing the discharge opening per unit of the time and the density of the stream.

Affected by:-

1.) Area of discharge opening
2.) characteristics of rock
3.) nip angle
4.) shape of jaw plates
5.) Method of feeding
6.) Size reduction
7.) Moisture.

Empirically, Theoretical capacity = 0.6 × L × S

(tons/hr.) — Theoretical capacity
length of plate (inch) — L
set (inch) — S

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**Reduction-Ratio (80)** → is the ratio of the theoritical square mesh opening that would pass 80% of the feed and the discharge product respectively.

It reduces the inaccuracy, introduced in the calculation of the limiting reduction ratio, by the presence of a small portion of coarse slabby material.

---

## Role of Rougher- Scavenger cell:-

# Grinding:-

→ Most energy - ~~[illegible]~~ intensive process of Mineral processing
→ last stage of comminution
→ Particles reduded in size by abrasion and impact either in dry or wet suspension in water.
→ Rotating cylindrical steel vessel containing charge of crushing bodies - The grinding medium - which is free to move inside the mill causing comminution (→ Probabilistic in nature)

→ Acc. Motion imparted to charge

**Tumbling mills**

- ~~Action~~ mill shell rotated
- motion imparted to the charge via the mill shell
- grinding medium may be steel rods, balls or rocks itself.
- Feed size → 5-250mm
- Product size → 40-300 $\mu m$

**Stirred mill**

- Horizontal or Vertical mill shell (stationary)
- An stirrer or agitator stirrs the fine grinding media
- Product size.
  - → 15-40 $\mu m$ (fine grinding)
  - → <15 $\mu m$ (ultra fine grinding)

~~To~~ Problems of Under grinding:-

1.) Product is too coarse
2.) Low liberation
3.) Inefficient separation
4.) ~~Low~~ Poor recovery and low enrichment ratio in Concentration

Problem of overgrinding:-

1.) unnecessary reduction in size of gangue
2.) Over-reduction of size of values
3.) ~~Ineffic~~ ~~Mass~~ Due to large scale fine production, values lost in fines
4.) Energy wastage.
5.) Additional time required.
~~Screening efficiency reduces~~

(19% extra grinding energy Consumed to grind one screen size finer in $\sqrt{2}$ series of ~~scre~~ screens)

Purpose of grinding:-

1.) Mostly, to cause liberation of valuable.
2.) If hydrometallurgical process of separation is used, then, to increase surface area of values.

NOTE:- Mill

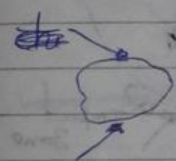
NOTE:- Mill charge = grinding medium + Ore
+ water

## Types of grinding forces:-

1) 

**Impact / compression**

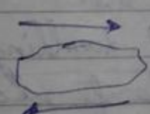
- Forces applied normally to particle surface
- Product has coarse + fine particles

2) 

**chipping**

- Forces are oblique
- Product has coarse particles

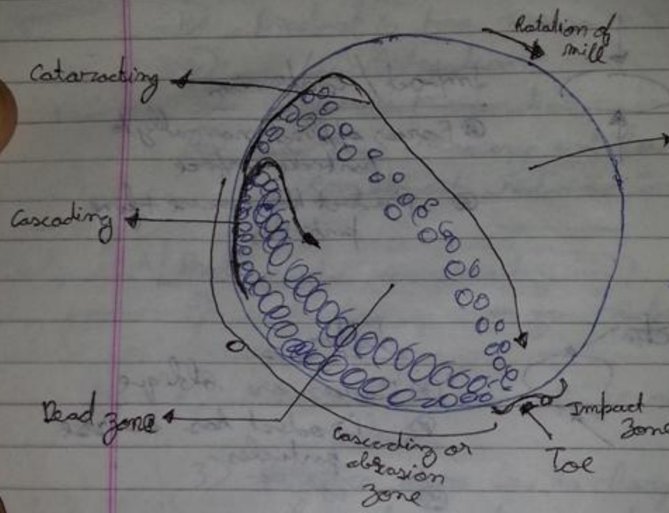
**Abrasion:-**

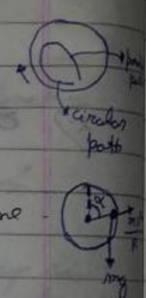
3) 

- Forces are parallel and opposite
- Product has fines only.

⟹ Type of forces applied depends on
1) speed of mill rotation
2) shell liner structure.

# Motion of charge in Tumbling mill:-




(*) Distinctive feature of tumbling mill → is the use of loose crushing bodies, which are large, hard and heavy in relation to ore particles but small in relation to ~~ss~~ volume of mill.

(*) The motion of the ~~medium~~ charge has 2 paths → lifting section near shell liner is circular
↳ drop back to the toe is parabolic

(*) Due to motion and friction of mill shell, the grinding medium is lifted along the rising side of the mill shell until a position of dynamic equilibrium

$\frac{mv^2}{R} = mg$

is reached beyond which the particles cascade and cataract down the the free surface of other bodies, about a dead zone, where little movements occurs, down to the toe of the mill charge.

## Mill speeds:-

The speed at which mill is run affects
1) product size / type of product
2) liner wear.

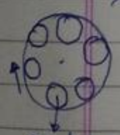
~~when the~~ Critical speed of a mill:-

$$N_C = \frac{42.3}{\sqrt{D-d}} \text{ rev/min}$$

where $D \rightarrow$ ~~dia~~ mill diameter
$d \rightarrow$ ball / rod diameter.

### Case I:-

when speed of mill = critical speed.




- centrifuging of ~~particles~~ medium takes place.
- no relative displacement of ball and wall of the mill
- No grinding takes place.

### Case II:-

when speed of mill < critical speed

(a) At very low speeds / smooth liner:-

mediums rises along the rising side of the mill wall and tends to roll down ~~the~~ the toe of the mill ~~charge~~. In such cases material

is subjected to abrasion only.
→ Product has increased fines and slimes.
→ Increased liner wear
This is called Cascading.
Cascading speed = 30%-50% of critical speed.

(b) ~~At~~ At higher speeds:—
medium is projected ~~of~~ clear of the charge to describe a series of parabolas before landing ~~landings~~ on the toe of the charge. The forces are compressive and so the product has a mixture of coarse and fine particles. There is reduced liner wear. Speed should be set in such a way that medium does not fall ~~medium~~ beyond the toe and damage the liner.
Cataracting speed = 70% of critical speed.
This is known as Cataracting.

Case III:—
At super critical speeds (speed of mill > critical speed)

grinding takes place due to abrasion as balls move (relative to it) along the mill wall
Corrosion of ball and mill liner is high so ball and mill

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liner consumption is high.

* Mill is generally run at 50-90% of the critical speed, Increase in Tumbling speed increases capacity but efficiency increase little beyond 70–50% of critical speed

## Types of mill:-

Tumbling mills are 3 basic types:

1.) Rod mill
2.) Ball mill
3.) Autogenous and ~~semi~~ semiautogenous mills.

Structurally, each type of mill consists of a horizontal cylindrical shell, provided with renewable wearing liners and a charge of grinding medium. The drum is supported so as to rotate on its axis on hollow trunnions attached to the end walls. The diameter of the mill determines the pressure that can be exerted by the medium on the ore particles and, in general, larger the feed size, the larger needs to be the mill diameter. The length of the mill along with its diameter, determines the volume and hence the capacity of the mill.

The feed material is usually

fed to the mill continuously through one end trunnion, ~~although~~ the ground product leaving via the other trunnion. All types of mill can be used for wet or dry grinding by modification of feed and discharge equipment.

Mill Liners:-

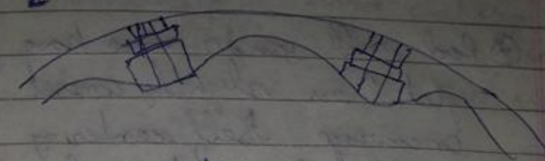
* The internal working faces of mills consists of renewable liners, which must withstand impact, be wear resistant and promote the most favourable motion to the charge.

* Shell liners have an endless variety of lifter shapes. ~~Smooth~~ liners

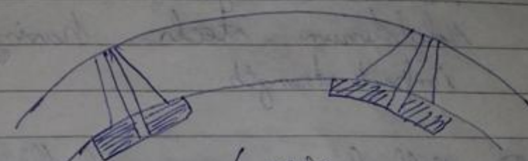
Disadvantage of Smooth liners:-

1.) increase abrasion
2.) more fine production
3.) High metal wear.

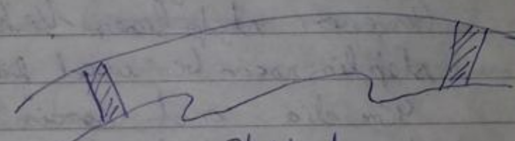
Hence the liners are shaped to provide lifting action and to add impact and crushing. The common shapes are :-



wave.



Lorain



Stepped

Shiplap

(*) The liners are attached to the mill shell and ends by forged steel countersunk liner bolts.

(*) liners are major cost in mill operation efforts to increase liner life are being made.

## Rod mill liners:-

* Rod mill ends ~~are~~ have plain flat liners slightly coned to encourage self centering and straight line action of rods. They are made of Mn or chrome Molybdenum steels having high impact strength.

* Mill liners are of alloyed steel and of wave type.
However ~~step liner~~ Ni hard step liners can be used for rods upto 4cm dia and Lorain liners of high carbon steel can be used for coarse grinding.

## Ball Mill liners:-

* Ball mill ends have ribs to lift the charge with the mill rotation. They prevent excessive slippage and hence increase liner life. They are made of white cast Iron, alloyed with Ni or other wear resistant material. They can also be made up of rubber.

* Ball mill liners are made ~~up~~ of hard cast iron when ball dia > 5cm or cast Mn steel or cast chrome steel when smaller balls are used. Lorain ~~liners can be used f~~ liners ~~to~~ of high carbon steel can be used for coarse grinding.

## Rubber liners:—

* Rubber liners have replaced steel ~~in~~ ~~in~~ in several applications.
* Advantages:—
  1. Longer lasting
  2. Easier and faster to install
  3. Lower noise pollution

* Limitations in applicability:—
  1. floatation ~~reagents~~ cells
  2. ~~For~~ ~~where~~ Cannot be used where temp > 80°C
  3. ~~where~~ high capacity mills (thicker than steel so reduces mill capacity)

* To reduce rapid wear of rubber liners magnetic metal liners can be used.

liberation

6/1/2014

AKS Sir

→ Mineral is naturally occuring inorganic homogeneous solid substance having fixed chemical composition and very often fixed crystal structure (changes in case of isomers)

→ ore is natural aggregation of mineral from which metal or metallic compound can be extracted profitably or economically

→ Rock is natural aggregation of mineral, in ~~which~~ the form they occurs in nature.

Crushing (Comminution or size reduction)

(+) (−) → particles that pass

particles that are retained in the screen

sizing or screening

if required size not obtained

If required size is obtained

## Sizing, Screening or ~~Sc...~~ Sieving

Sizing is the process of ~~dev...~~ ~~divi~~ dividing a mixture of different sizes of particles into groups or grades each of which is more uniform in size of particle than is the original mixture.

Limiting Screen (− particles) → the screen through which the particles have passed is called limiting screen and that which has retained them is sometimes called the retaining screen. (+ve particles)

(+) SCREEN

(−)

**Close sizing:-**

When the apertures of limiting and retaining screens are fairly in close size, the size product is short range and is known as close sizing.

**Oversize and Undersize**

Materials that fails to pass through a given screen is referred to as oversize or (+) of that screen and that which passes through the screen opening is referred to as undersize or (−) material for that screen.

**Sieve Scale:-**

It is the list of aperture of successively smaller screen in a step sizing operation.

**Sieve Ratio:-**

It is the ratio of the aperture of a given screen in a given sieve scale to the aperture of the next finer screen.

## %age of opening:–

It is the ratio of the combined area of the openings to the ~~of~~ total area of the screening surface.

## Dry screening:–

refers to the treatment of a material containing a natural amount of moisture or a material that has been dried before screening.

## Wet Screening:–

It refers to an operation in which water is added to the material being treated for the purpose of washing the fine material through the screen.

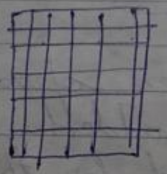
## Electrostatic bunching:-

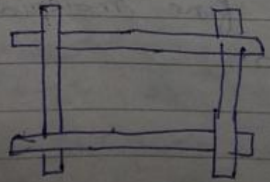
Flocculation of a particle during dry screening due to binding electrical forces at their surfaces is known as electrostatic bunching.

## Mesh:-

The aperture framed by the wires of a sieve opening. With square woven sieve, the number of wires per linear inch defines the mesh.

For example 30 mesh (30#) means that there are 30 wires per linear inch





Square mesh.

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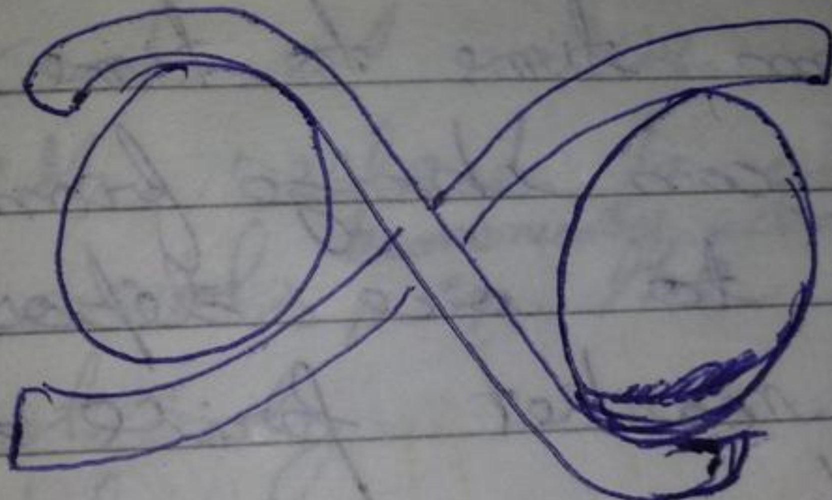


Circular mesh

SR Sir

13/1/2014.

AKS Sir

Near mesh:—

Near size grains close in cross-section to a specified screening mesh which tend to blind apertures and slow down sizing are known as near mesh.

Ring Size:—

A term for particle size where the pieces of ore is too large for screening. It refers to the diameter of the gangue or ring which can be sliped over it. Different Countries employing different standards like ASTM (American standard testing of materials), BSS (British standard sieves), IMM (Institution of mining and metallurgy, U.K.), ISA (Indian standard analysis, India), AFNOR (standard in france) and DIN (In germany).

Purpose of screening:—

1.) To retain oversize in a given section or circuit and thus prevent it from being ~~freed~~ ~~feed~~ fed to a machine not suitable; dealing with it.

2.) To cut off the fine end from the crusher feed and thus save power and prevent over-grinding so increasing their capacity and ~~eff~~ efficiency.

3.) In certain Industries where product size falls a part of final product specifications, screens are used for commercial grading to seggregate products for meeting these specifications

eg.) To grade broken rock products into commercial sizes as for ~~a~~ road metal, ballast, concrete aggregate, sands and the light materials.

4.) To prepare a closely sized feed to a concentrating process

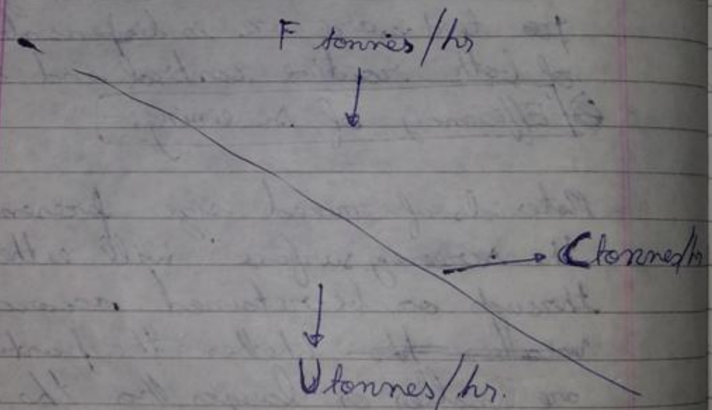
eg.) In case of gravity concentration process, crushed ore are above 1 or 2 mm divided into a series of product by screening. Such a grading of crushed ore, into fractions for feed to the individual concentration machines enables each machine to be adjusted and operated for better separations than would be the case with unsized feed to these machines.

5.) In laboratory testing of ores and mill products, seggregation of the material into different size fractions for separate testing facilities, analysis of results; losses and inefficiencies in both comminution and concentration to such an extent that sizing test are an indispensable part of both routine control and research.

## Efficiency of screening:-

Materials of mixed size presented to the screening surface will either pass through or be retained according to ~~wether the~~ whether the particles are smaller or larger than the governing dimensions of the apertures. The efficiency of screening is determined by the degree of perfection of separation of the material into size fractions above or below the governing dimensions of the aperture. An efficiency equation can be calculated from a mass balance across a screen as follows:-

F tonnes per hour feed is and ~~U tonnes of~~ U tonnes per hour is passed over the screen and C tonnes per hour is retained on the screen. Consider a screen onto which there is a feed of F tonnes per hr.




MASS BALANCE ON SCREEN

C tonnes per hr. overflows from the screen and U tonnes per hour is the rate of underflow. Let f, c, u be the fraction of material above the cut point in the feed, overflow and ~~and~~ underflow respectively, which can be accurately determined in the laboratory taken 100% efficient.

The mass balance on the screen is

$$F = C + U$$

The mass balance of the ~~oversize~~ ~~under~~ oversize material is :-

$$Fx_f = C x_c + U x_u$$

The mass balance of the undersize material is:-

$$F(1-f) = C(1-c) + U(1-u)$$

Hence:-

$$\frac{C}{F} = \frac{f-u}{c-u}$$

The recovery of oversize material into the screen overflow is

$$\frac{Cc}{Ff} = \frac{c(f-u)}{f(c-u)} \rightarrow (1)$$

and the corresponding recovery of undersize material in the screen underflow is :-

$$\frac{U(1-u)}{F(1-f)} = \frac{(1-u)(x-f)}{(1-f)(x-u)} \rightarrow (2)$$

20/01

From equation (1) and (2) measure the effectiveness of the screen in separating the coarse material from the underflow and the fine material to the overflow. A Combined effectiveness or overall efficiency (E) is then obtained by multiplying the 2 equations together and E is equal to:-

$$E = \frac{x(f-u)(1-u)(x-f)}{f(x-u)^2 \cdot (1-f)}$$

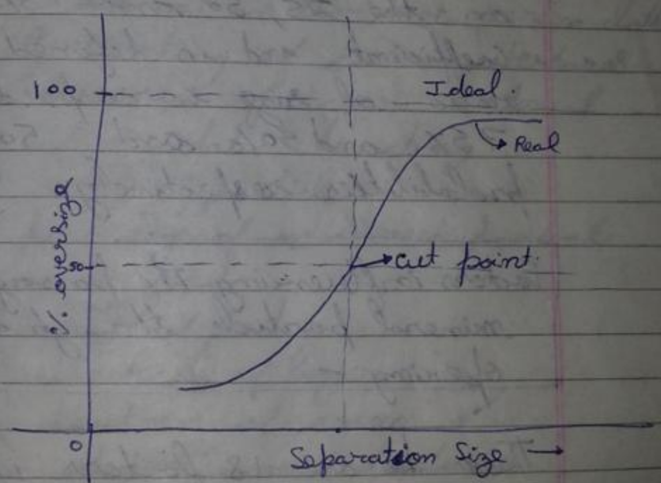
If there are no broken or deformed aperture, the amount of coarse material in the underflow is very low and infact zero (i.e. $u=0$)

in which case the formula for fine recovery and for the overall efficiency reduces :-

$$\therefore E = \frac{(c-f)}{c(1-f)} \quad \text{---} (3)$$

20/01/2017

AKS Sir




Partition Curve for Screening :-

The partition curve for the separation is drawn by plotting the partition coefficient defined as the % feed of each fraction reporting to the oversize product against the geometric mean size on a log scale. The separation size or cut point is obtained at 50% probability, that is, the size at which a particle has equal chance of reporting to the undersize or oversized product. The efficiency of separation assumed from the ~~stiffness~~ steepness of the curve. The sharpness of the separation is based on the 25, 50 and 75% partition coefficient and is defined as the ratio of size corresponding to 75% and 50% and 50 and 25% probabilities respectively.

**Factors influencing the passage of a mineral particle through a screen opening:-**

There ~~is~~ are 18 factors influencing the passage of the mineral particle through a screen opening. They are:-

1) ratio between cross-section of a particle and of mesh

2) ~~ratio~~ % age of screen area open.

3) angle of incidence of feed
4) efficiency of spread of feed over screen area
5) Kinetic energy of particle approaching screen opening
6) Moisture of ore feed
7) stickiness of particle and aggregated particles
8) pressure of particles riding ~~att~~ above the next screen cloth.
9) ~~B~~ Blinding of screen apertures
10) Corrosion of screen material
11) electrostatic bunching
12) shape of particle
13) percentage of near mesh particle in the feed
14) ~~weight~~ rate of feed
15) thickness of layer.
16) tautness of screen
17) shape of screen apertures
18) Motion imparted to the particle by screen vibration

Efficiency varies between 60-80% and increases with 1) the percentage of screen open to passes of undersize
2) the smoothness and freedom ~~for~~ from blinding of the screen wires.

3.) The suitability of the shape of aperture to the average particle shape under treatment.
4.) Increased transit time

However efficiency is adversely affected by 1.) increasing the rate of feed
2.) increase in %age of near mesh grains
3.) increase in thickness of bed which hinders presentation of particles
4.) lack of liveliness of the screen cloth in responding to the vibrating impulses.
5.) increased moisture in the feed

The efficiency can also be calculated by :-

$$R = \frac{100c\,(f-t)}{f\,(c-t)}$$

$$k = \left(\frac{c-t}{f-t}\right)$$

where $R \rightarrow$ recovery
$f, c, t \rightarrow$ are % size of feed, concentrate and tailings

This formula ~~wit~~ together with that for ratio of concentration, K can be used to show the relative amounts of sand discharged and overflowed

Precautions for efficient screening operations:-

1.) There should be good tension of screen cloth in the frame to give efficient transfer of the vibrating strokes from mechanism via cloth to load.

2.) The combined effect of vibration, speed and amplitude together with ~~flow~~ slope of screen should be adjusted in such a way that the material remains well ~~steered~~ steered and running freely.

3.) feed should be delivered throughout

the entire width of the screen with adequate gentleness to avoid wear.

4) In case of wet sizing the feed should be slurried at a liquid solid ratio of 2:1 and flushed gently and uniformly

5) When oversize in the product is intolerable, precautions should be taken against delivery of oversize material caused due to unnoticed rupture of screen. This may be achieved by duplicating the same mesh on a double deck machine.

6) The vibrating ~~sto~~ ~~stakes~~ strokes should be disturbed quite evenly over the whole area to ensure sufficient ~~causing~~ tossing of the feed and to avoid overstress at a point, line or node

7) ~~Ee~~ In installation, consideration should be given to convinience of maintainance and replacement

(S) Set = 125mm

Capacity of crusher = 265 – 295 tons per hour.

27/01/2014. AKS Sir

Types of Screens :-

There are many different types of industrial screens which may be classified as either stationary or moving screens.

Stationary screens further divided into:-

1.) Grizzley
2.) Static ~~sieve~~ sieve.
3.) Perforated plate
4.) wire cloth

Moving screens are divided into:-

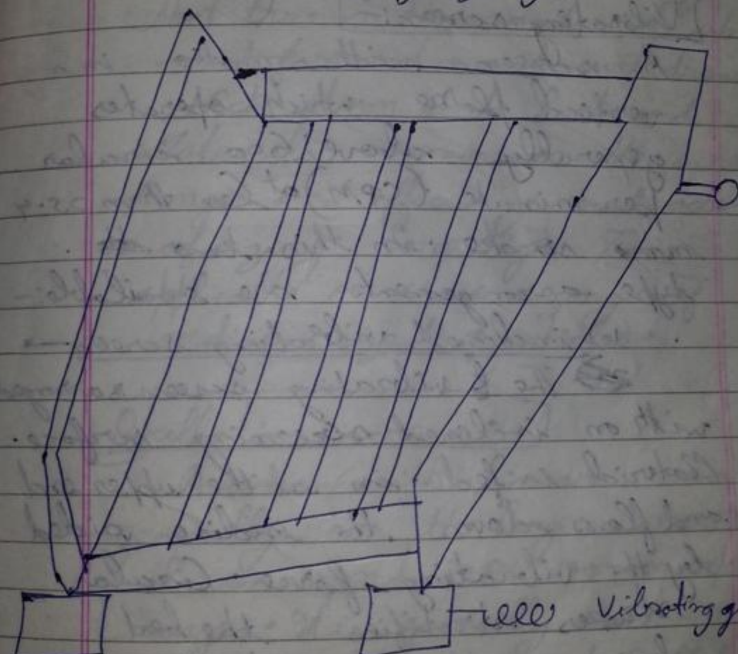
1.) Moving Grizzly
2.) Shaking, gyrating and pulsating screens

3) Vibrating screens
4) trommel or revolving screen

<u>Grizzly</u> → It consists of a number of parallel rods, bars or rails with a uniformly clear openings often tapered from feed to discharge end at an angle to the horizontal usually 20°–50° to provide self cleaning characteristic. It is generally employed in very coarse material. Some grizzly's employed in chains instead of bars and some are shaken or vibrated mechanically to help the sizing and to aid in the removal of the oversize. The most common use of grizzlys in mineral processing is for sizing the feed to primary crushers. If the primary crushers has a 10 cm product then the feed is passed over a grizzly with a 10 Cm spacing between the bars

in order to scale up or remove the undersize.

The size of particle screened on grizzly can be as large as 300mm size or small as 20 mm. The capacity which can be upto 1000 tons/hour is proportional to the area of grizzly.



Vibrating grizzly

Static Sieve:-

This consists of a set of parallel profile bars or wires positioned at right angle to line of flow and usually

sloped at incline of 45° or more to the horizontal. Bars may form a flat, curved or multi slope surface. They are used for size separation and scaling entering in range of 2 mm and finer.
~~In vibrating~~

## Vibrating screen:-

A screen with motion in a vertical plane which operates generally above 600 circular per minute (CPM) at less than 25.4 mm stroke. In this two type arrangements are available:-

1:) inclined vibrating screen →
The vibrating screen is arranged with an inclined screening surface. Material is fed in at the upper end and flows down the incline aided by the vibrating force. Circular strokes stratifies the bed bringing fine down to the screen surface. This is applicable in high capacity units for separation of a wide range of particle size and also used for scaling and

~~gas~~ trash removal.

2) horizontal vibrating screen → A vibrating screen arranged with a horizontal screening surface. Material is fed in at back end and ~~as~~ is moved over the length of screen by a +ve pulsating stroke that throws the material up and forward and withdraws deck down and backward. Materials remains on the screen longer and efficiency and accuracy of sizing are high. This is applicable in close sizing of medium sized particles.

Oscillating screens :-

A screen with linear motion generally in the larger strokes and slower speed i.e. 100-400 rpm range. It is generally used in -13mm to +60# range and light free flowing materials can also be separated at 74 μm and less.

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## High Speed Screen:-

A Relative term referring to the operating frequency of a screen generally applied to those operating in excess of 3000 rpm or cycle per minute (CPM). Vibrator or excitor may be mechanical or electromagnetic. This is used for fine and ultrafine screening.

~~Reciprocating screen:-~~

28/01/2014. S R Sir



Importance of Mineral Screening:-

10/2/2014

AKS Sir

## Reciprocating Screen / ~~sat~~ shaking screen:-

A Screen with substantial linear motion in the plane of main frame. Its stroke is normally in the range of 25-102 mm with speed varying from 30 to 200 cpm. Unit is slightly inclined and may be suspended from rods or cables or supported from base by durable flat spring. It is used for both conveying and size separation. It is ~~less~~ low capacity and high maintainance and good for accurate sizing of large lumps.

## Revolving Screen:- / Trommel

One of the oldest screening device is the trommel which is slightly inclined, rotating cylindrical screen which can be used wet or dry. Material is fed in at one end of the drum, Undersize ~~fin~~ material passing through the screen aperture and the oversize material

Comming off at the opposite end. They may be arranged in concentric series, with the coarset discharging its undersize into consequetively finer trommels. In this trommel which has a series of concentric cylinders with the coarset screen at the centre such that the coarset fraction is removed first. It can handle material from 55 mm down to 6 mm

and even smaller sizes can be handled under wet conditions. ~~and these~~ They are widely used in grading of sand and ballast. Trommels are cheap, vibration free and robust but have poor capacities. The screen revolves at low speeds usually 15 - 20 rpm. These are also used for scrubbing and washing of wet and sticky materials as sand and gravels in wet process.

feed

to

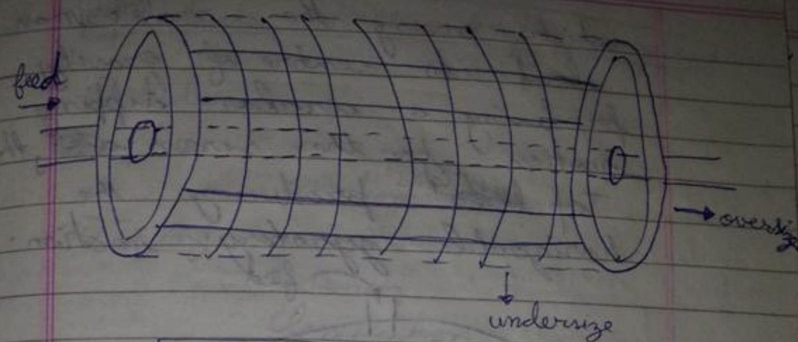



FIG:- Trommel Screen

## Gyratory Screens:-

These types of screens which imparts gyratory motion through out the whole screen cloth is becomming widely used for fine screening. The basic components consists of a nest of ~~screens~~ sieves supported on a table which is mounted on springs on a base. Suspended from beneath the table is a motor ~~which~~ with double shaft extensions which drives eccentric weights and is doing so as to effect horizontal gyratory motion; Vertical Motion is imparted by bottom ~~loads~~ weights ~~of gravity~~

which swing the mobile mass about its centre of gravity producing a circular tipping motion to the screen, the Top weights producing the horizontal gyratory motion.

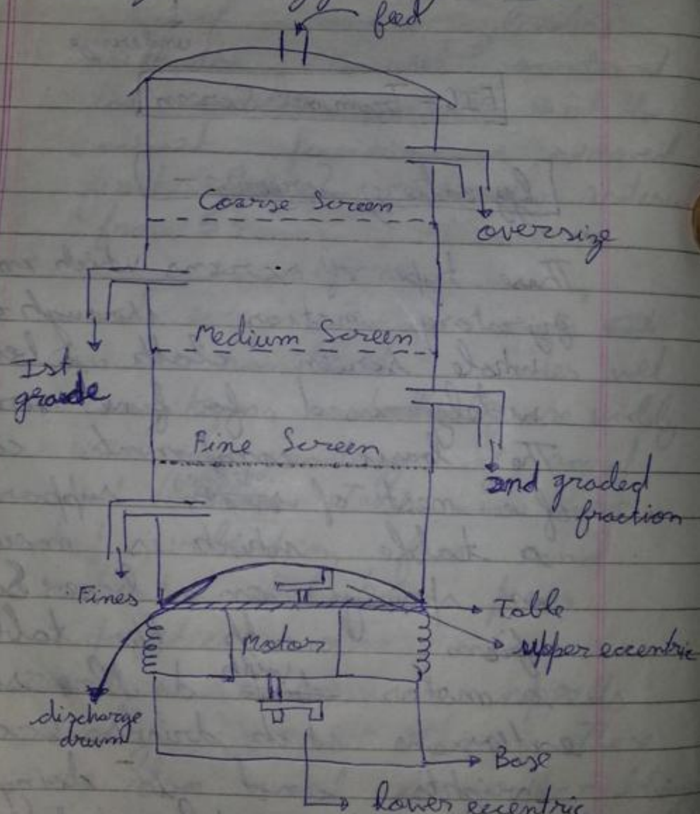



FIG: Gyratory Screen

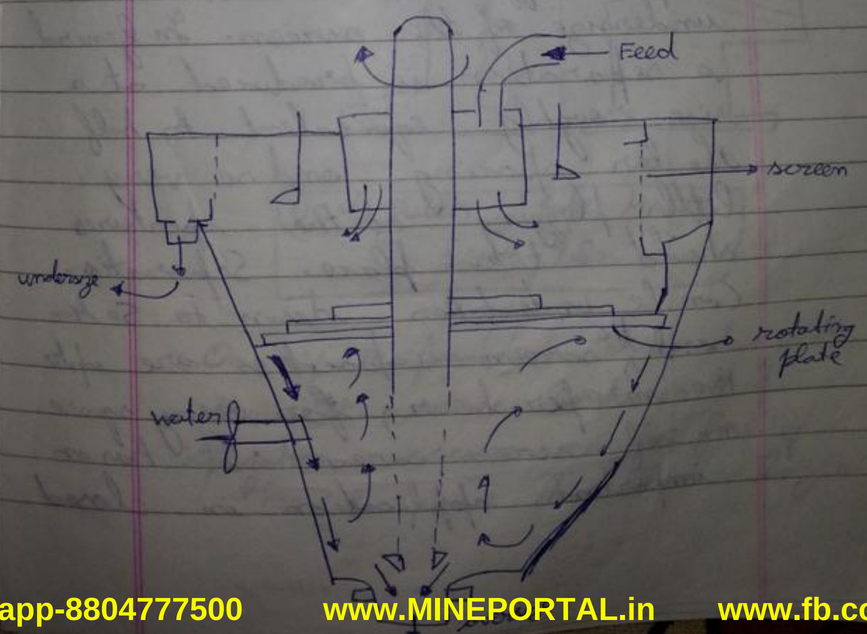
Only method is handsorting of belt conveyor material before the material is being fed to the crusher.

17/02/2014.

AKS Sir

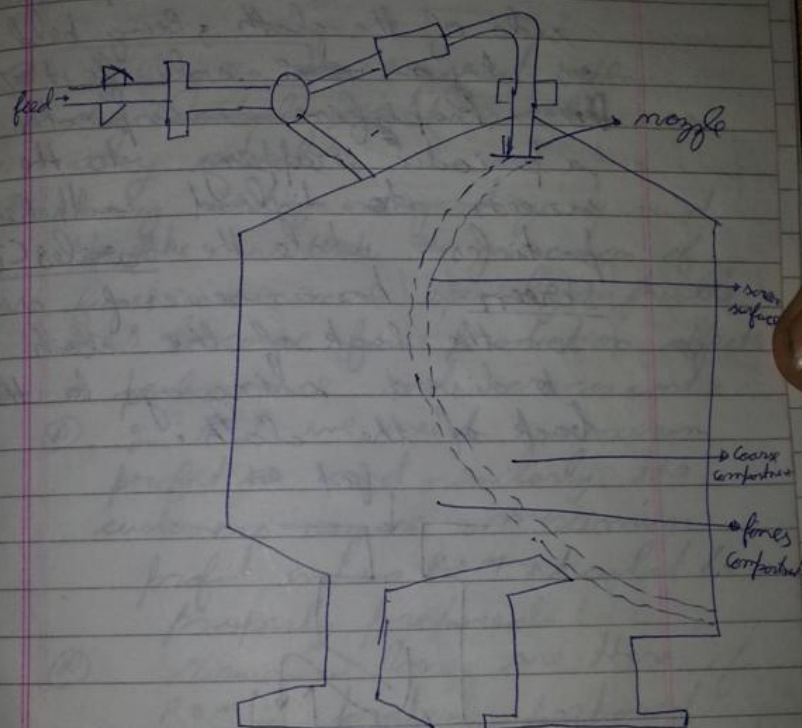
## HUKKI SCREEN :-

Hukki screen employs a combination of classification and screening and has been used in grinding circuits. It consists of an open stationary vessel with a cylindrical top section and a conical base. The top section includes a cylindrical screen. Feed enters centrally at the top and is distributed inside the cylindrical screen by means of a low speed rotating mechanism. Wash water is introduced into the conical section. The undersize passes through the cylindrical screen which consists of wedge bars into a collecting laund whilst the over size fraction is discharged through the apex.



## Sieve Bends:-

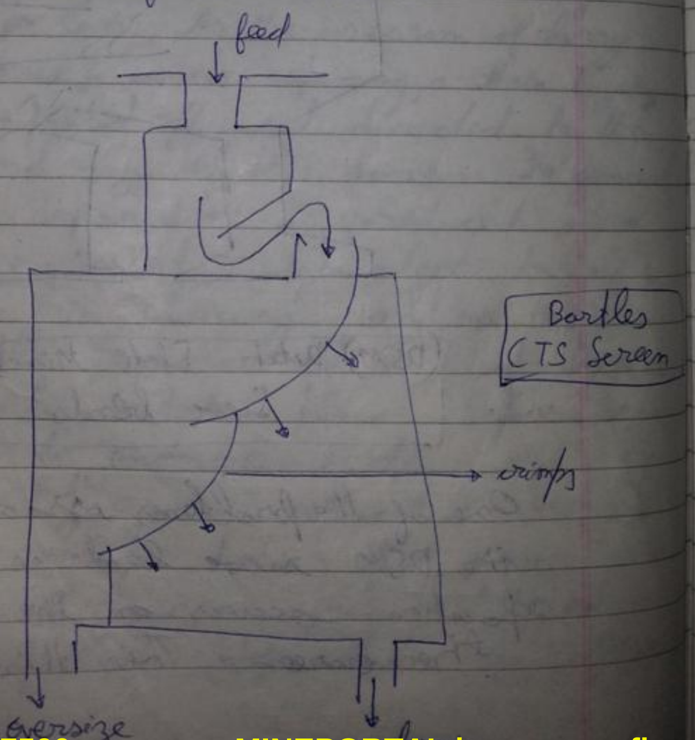
Static screens are also known as sieve bends and ~~are~~ is widely used in mineral industry for very fine wet screening process. It has a curved screen composed of horizontal wedge bars. Feed slurry enters the upper surface of the screen tangentially and flows down the surface in a direction perpendicular to the opening ~~w~~ between the wedge ~~b~~ bars. As the stream of slurry passes each opening, a thin layer is peeled off and directed to the undersize of the screen. In General a separation is produced at a size roughly equivalent to half the bar spacing and so very little plugging of the apertures should take place. Separation can be undertaken down to 50 Mm and the screen capacities are upto 180 $m^3$ per hour, for every square m of screen area. It has an important application in closed circuit grinding of heavy mineral ores.



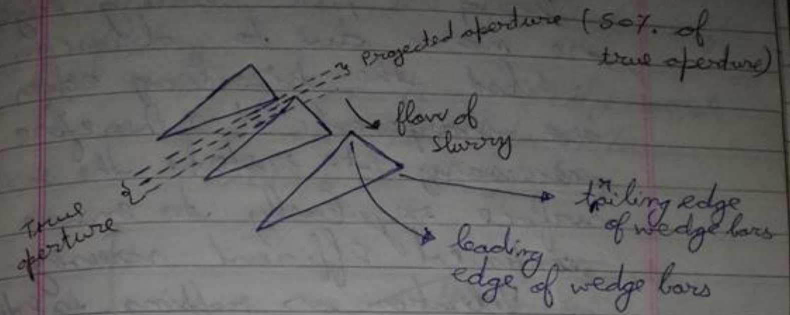

(DSM) Dutch State Mines Sieve bends

One of the problems associated with the DSM sieve bends is that separation occurs on the face of the screen. This thin layer of the pulp which have been passed through the apertures tends to continue down back the convex side of the cloth, being held on by a ~~due~~ wall effect - The Dorr Rapifine incorporates a periodic rapping to the screen to dislodge adhering particles while the Bartles CTS Screen has a series of crimps on the back of the cloth to divert clingings to the back of the cloth.

Need of preparation of ROM



## Sieve Bends :-




A sieve band is an inclined, curved, wedge wire screen with slot openings of the screen arranged perpendicular to the direction of flow of slurry. As slurry flows over the sieve bend, thin layers of fluid are "shaved" from the slurry by the openings in the screen surface. The fine particles in the slurry are carried by the flow passing through the screen apertures and thus removed from the main slurry stream.

The projected screen aperture, by virtue of design of sieve bend is 50% of the actual width of the slots. Sieve bends therefor have a cut-point equal to half the actual screen slot apertures.

During use, the leading edges are worn due to abrasion whilst the trailing edges are sharpened. It is therefore necessary to rotate the screen surface regularly to ensure continued efficient screening.

Vibration or rapping is employed to ensure that screen apertures are not blocked by near size particles and to remove clingings from the undersurface of the screens.

(Add to earlier notes)

Working of Single toggle Jaw Crusher:-

and can be sold in the market as well. Due to less production of fines, losses in the tailings is also low.

---

24/2/14.

AKS Sir

Classification → It is a method of separating mixtures of minerals into 2 or more products on the basis of velocity with which the grains fall through a fluid medium. This is usually water and wet classification is generally applied to mineral particles which are considered too fine to be sorted efficiently by screening. Since the velocity of particle in a fluid medium is dependent not only on the size but also on the specific gravity and shape of the particle. There are two laws of classification namely

1. stokes
2. Rittingers - Newton law

Both have been proposed for the terminal velocity of the particle. Stokes law is derived on the assumption that only the frictional forces retard the motion of the body and that there is no turbulent resistance. However Rittingers law is derived on the assumption that the resistance is entirely turbulent and neglects the effect of friction. Since small particles causes viscous resistance and larger particles causes turbulent resistance. Hence the fine particles obey stokes law and bigger particles obey rittingers law. According to ~~#~~ stokes law for settling of fine particles under free settling condition the terminal velocity (v)

$$V = \frac{2}{9} r^2 g \left(\frac{\Delta P - \Delta f}{\mu}\right)$$

$$= K r^2 (\Delta P - \Delta f)$$

$$K = \frac{2}{9}\left(\frac{g}{\mu}\right)$$

$\Delta P$ = specific gravity of particle
$\Delta f$ = specific gravity of fluid
$r$ = radius of particle
$g$ = gravitational constant
$\mu$ = coefficient of viscosity

stokes law

According to Rettinger's law

Terminal velocity $v_e = \sqrt{\frac{8}{3Q} g \cdot \frac{\Delta P - \Delta f}{\Delta f} \cdot r}$

$$v_e = K\sqrt{r(\Delta P - \Delta f)}$$

Q is ~~[illegible]~~ coefficient 0.4 ~~[illegible]~~
or 2.5

→ stokes law may also be defined as that in viscous flow the terminal velocity varies as the square of the particle diameter

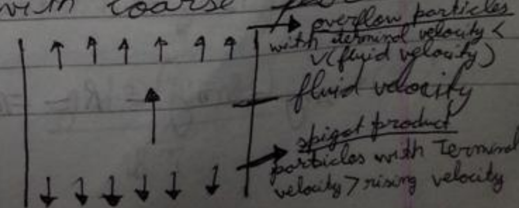
$$V = K d^2 \rightarrow (1)$$

d → particle dia

→ rittingers Newton law may be defined as that in turbulent flow the terminal velocity varies as the square root of the particle diameter.

$$V = K\sqrt{d} \rightarrow (2)$$

→ Both the laws of resistance imply that extremely small particles reach a velocity almost equal to their ultimate velocity in an extremely short time whereas large particle require an appreciable length of time. It can be regarded that very small particles settle at the rate of the terminal velocity from the start to their fall but this is not with coarse particles



## Free Settling:-

In case of free settling condition, it refers to the sinking of particles in a volume of fluid which is large with respect to the total volume of the particle. Hence particle crowding is negligible. For well dispersed ore pulps, free settling predominates when the % of solid by weight is less than about 15. Consider a spherical particle of diameter 'd' and density $D_s$ falling under gravity in a viscous fluid of density $D_f$ under free settling condition i.e. ideally in a fluid of infinite extent the particles is acted upon by the three forces.

1.) gravitational force acting downward
2.) an upward Bouyant force due to the displaced fluid
3.) A drag force R acting upwards

The equation of motion of the particle is:-

$$mg - m'g - R = m\frac{dx}{dt}$$

$m \rightarrow$ mass of the particle
$m' \rightarrow$ mass of the displaced fluid
$x \rightarrow$ particle velocity
$R \rightarrow$ Resistance
$g \rightarrow$ acceleration due to gravity

→ when the terminal velocity is reached $\frac{dx}{dt} = 0$

$$R = (m - m')g$$

$$R = \frac{\pi}{6} g d^3 (D_s - D_f) \rightarrow (2)$$

→ Stokes assumed that Drag force on a spherical particle to be entirely due to viscous resistance, and the expression

$$\boxed{R = 3\pi d \eta v} \rightarrow (3)$$

$\eta \rightarrow$ fluid viscosity
$v \rightarrow$ terminal velocity

Hence by substituting eq (2) in eq (3)

$$v = \frac{g d^2 (D_s - D_f)}{18\eta} \rightarrow (4)$$

The above is By stokes law when $d \leq 50$ Mm

→ Where as Newton assumed that drag force was entirely due to turbulent resistance and gave the expression

$$R = 0.055\pi d^2 v^2 D_f \rightarrow (5)$$

and Substituting this value in eq (2) we get the equation of turbulent velocity

$$v = \left[\frac{3g d (D_s - D_f)}{D_f}\right]^{1/2} \rightarrow (6)$$

The above from Newton's law when $d \geq 0.5$ cm

3/03/2014 (AKS Sir)

Terminal velocity by newton's laws:-

$$v = \left[\frac{3gd (D_s - D_f)}{D_f}\right]^{1/2} \rightarrow (6)$$

for turbulent resistance.

Stokes law is valid for particles below 50 micron in diameter and newton's law holds for particles larger than 0.5 cm in diameter. Thus there is an intermediate range of particles which correspond to the range in which most wet classification is performed. The stokes law for a particular fluid can be simplified.

terminal velocity $V_S = K_1 d^2 (D_S - D_f)$ --- (7)

and newton's law can be simplified to:-

terminal velocity $V_N = K_2 [d (D_S - D_f)]^{1/2}$ --- (8)

where $K_1$ and $K_2$ are constants

and $(D_S - D_f)$ is known as the effective density of a particle of density $D_S$, in a fluid of density $D_f$.

Both the laws show that, the terminal velocity of a particle in a particular fluid is a function only of the particle size and density. It can be seen that 1) if 2 particles have the same density then the particle with ~~the bas~~ which has large size has the higher terminal velocity and 2) if the 2 particles have the same diameter then the heavier particle has the higher terminal velocity.

$\boxed{\text{Equal Settling:-}}$

Equal settling of particles:- Consider 2 mineral particles having the density $D_a$ and $D_b$ and have diameter $d_a$ and $d_b$ falling in a liquid of density $D_f$ at exactly the same settling rate. Their terminal velocity must be same. Hence from Stokes law:-

$$d_a^2 (D_a - D_f) = d_b^2 (D_b - D_f)$$

and hence

$$\frac{d_a}{d_b} = \left(\frac{D_b - D_f}{D_a - D_f}\right)^{1/2} \quad \text{--- (9)}$$

This expression is known as free settling ratio of 2 minerals that is the ratio of particle size required for the 2 minerals to fall at equal rates.

Similarly from the newton's law, the free settling ratio of large particles is:-

$$\frac{d_a}{d_b} = \left(\frac{D_b - D_f}{D_a - D_f}\right) \quad \text{--- (10)}$$

The general equation for free settling ratio can be deduced from the above 2 equations:-

$$\frac{d_a}{d_b} = \left(\frac{D_b - D_f}{D_a - D_f}\right)^n \quad \text{--- (11)}$$

where $n = 0.5$ for small particles ($< 50\mu m$)
$n = 1$ for large particles ($> 0.5 cm$)

The value of $n$ which lies in between 0.5-1 range for intermediate size particles. ($50\mu m - 0.5 cm$)

## For Hindered settling:-

As the proportions of solid in the pulp increases, the effect of particle crowding becomes more apparent and the falling rate of the particle begin to decrease. The system begins to behave as a heavy liquid whose density is ~~tat~~ that of the pulp rather than that of the ~~clear liquid~~ carrier liquid. Hindered settling conditions now prevail; the approximate falling rate of particles is:-

$$v = k\left[d\,(D_s - D_p)\right]^{1/2} \quad \text{--- (12)}$$

where $D_p$ is the pulp density, $k$ is a constant, ~~D~~ $d$ is particle diameter and $D_s$ is density of particle.

This is important in classifier designing.
Hindered settling reduces the effect of size while increasing the effect of density on classification. The hindered settling ratio can be

derived from ~~above~~ equations:-

For equal settling →
$$\frac{d_a}{d_b} = \left(\frac{D_b - D_p}{D_a - D_p}\right) \quad \text{--- (13)}$$

Example:-

Consider a mixture of galena, density = 7.5 and quartz, density = 2.65 particles, classified in water. For small particles obeying stokes law the free settling ratio from the above equations is:-

$$\frac{d_a}{d_b} = \left(\frac{7.5 - 1.0}{2.65 - 1.0}\right)^{1/2} = 1.985$$

i.e a small particle of galena will settle at the same rate as a small particle of quartz which has a diameter 1.99 times as large.

For larger particles obeying newton's laws for the same mixture the free settling ratio is:-

$$\frac{d_a}{d_b} = \frac{7.5 - 1.0}{2.65 - 1.0} = 3.94$$

The free settling ratio is therefore larger for coarser particles than for fine particles. This means that the density difference the mineral particles have a more pronounced effect on classification at coarser size ranges.

In case of hindered settling ratio for the same mixture, galena and quartz for the pulp density $D_p = 1.5$

$$\frac{d_a}{d_b} = \frac{7.5-1.5}{2.65-1.5} = 5.22$$

for larger particles

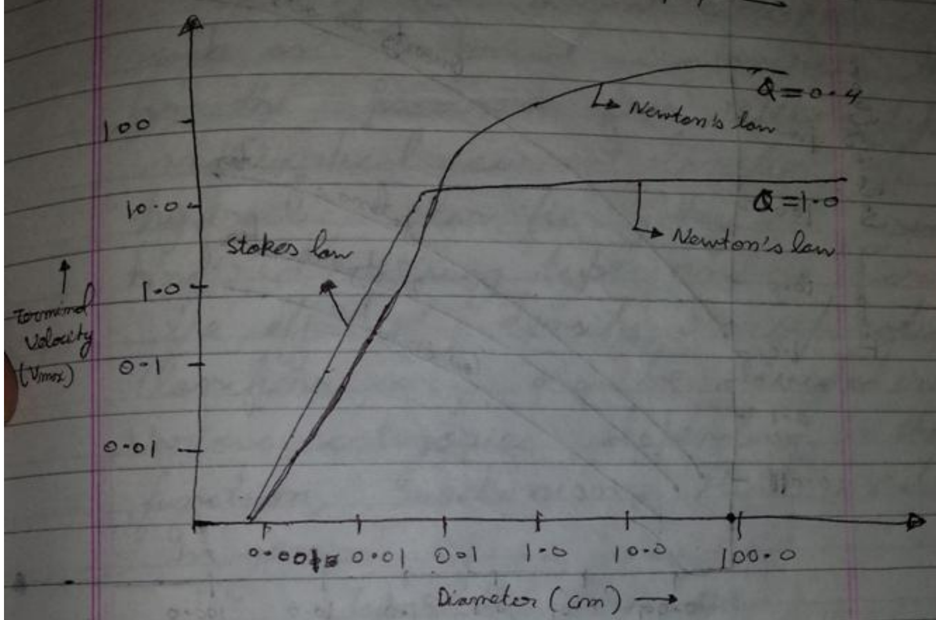
20/2/14.

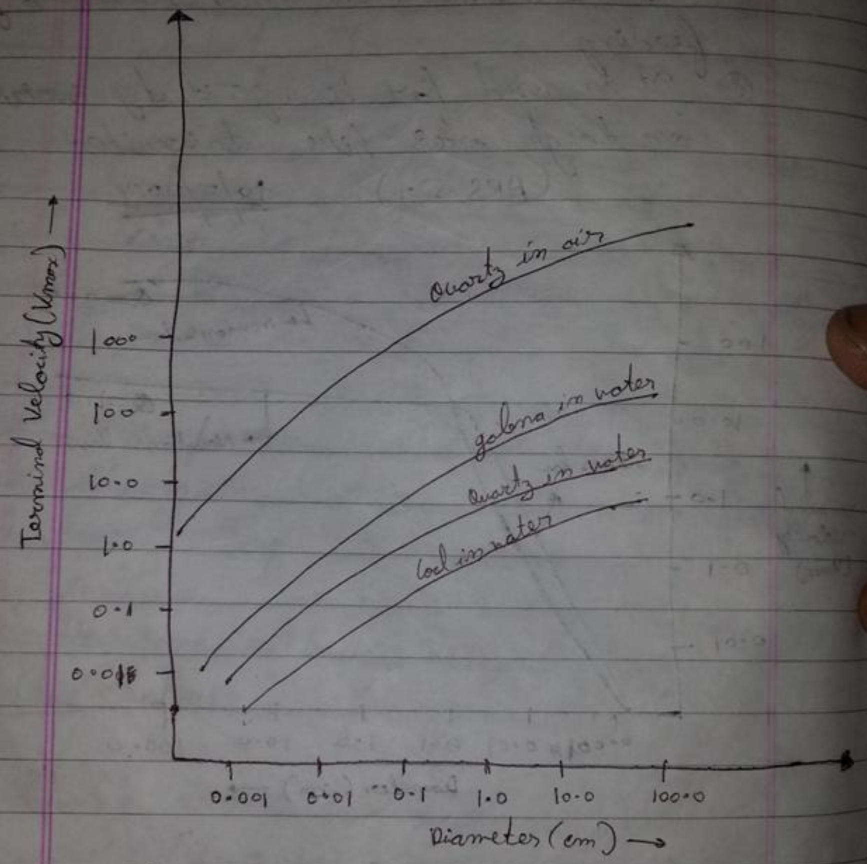
When the mixture of quartz and galena particles settling in a pulp density 1.5, the particle of galena will thus fall in the pulp at the same rate as a particle of quartz which has a diameter 5.22 times as large. This compares with the free settling ratio calculated for turbulent resistance 3.94. The hindered settling ratio is drops greater than the free settling ratio and denser the pulp, greater is the ratio of the diameter of equal settling particles.

The greatest hindered settling ratio that we can attain theoretically is around 7.5. Hindered settling classifiers are used to increase the effect of density on the separation where as free settling classifiers are used for relatively dilute suspension to increase the effect of size on the separation.

20/2/14 25/2/14 A.S. Sir

... for heavy-duty work on tough ores like taconite.
(AKS Sir) 10/3/2014.




Terminal Velocity (Vmax) →
1000
100
10.0
1.0
0.1
0.001
Quartz in air
galena in water
Quartz in water
Coal in water
0.001
0.01
0.1
1.0
10.0
100.0
Diameter (cm) →

31/03/2014. (AKS Sir)

# Types of Classifiers:-

Classifiers may be grouped into 2 classes depending on the direction of flow of the carrying current.
1.) Horizontal current classifiers such as mechanical classifiers, they are the ~~free set~~ free settling type and 2.) Vertical current classifier or hydraulic classifier, they are usually hindered settling type and so increase the effect of density on separation.
Classifiers may also be divided into various categories depending on their function, mechanism, fluid used.

In general :-

**Types of Classifiers**

- Sorting Classifiers
  - Launder Type
  - Cylindrical type
  - Trapezoidal Tank type
  - Hydro tator type
- Sizing classifiers
  - Non-mechanical
    - Surface sorting
      - Pyramidal
      - Cone
      - Sluice
      - Thickening
    - Hydraulic
    - Hindered settling
  - mechanical
    - Overdrain classifier
    - Rake classifier
    - Bowl classifier
    - Spiral
    - Multi[illegible]
  - Pneumatic classifier
  - cyclones
    - Hydrocyclone
    - Aircyclone
    - Cynocone

Hydrocyclone:-

It is a continuously operating classifying ~~that~~ device that operates on centrifugal force to accelerate the settling rate of particles. It is one of the most important device used in the mineral processing industry. It has proved extremely efficient at fine separation sizes. It is also used in ~~[illegible]~~ increasingly in closed circuit grinding operations and has found many other uses like desliming, degritting and thickening. It has also found wide acceptance recently for the washing of fine coal. It Consists of a conical shape vessel open at its apex joined to a cylindrical section which a tangential feed inlet. The top of the cylindrical section is closed with a plate through which passes an axially mounted overflow pipe. The pipe is ~~standar~~ extended into the body of cyclone by a short removable section known as Vortex finder which prevents shortcircuiting of feed directly into the overflow

The feed is introduced under pressure through the tangential entry which imparts a ~~[illegible]~~ swirling motion to the pulp. This generates a ~~[illegible]~~ Vortex in the ~~[illegible]~~ Cyclone with a low pressure zone along the Vertical axis. An air core developed along the axis normally connected to the atmosphere through the apex opening, but in part created by dissolved air coming out of solution in the zone of low pressure. The classical theory of hydrocyclone action is that particles within the flow pattern are subjected to two opposite forces, an outward centrifugal force developed accelerates the settling rate of particles thereby separating particles according to the size and specific gravity and Faster settling particles move to the wall of the cyclone where the velocity is the lowest and migrate to the apex opening. Due to the action of drag force, the slower settling particles move towards the zone of low pressure along the axis and are carried upward through the vortex finder to the overflow.

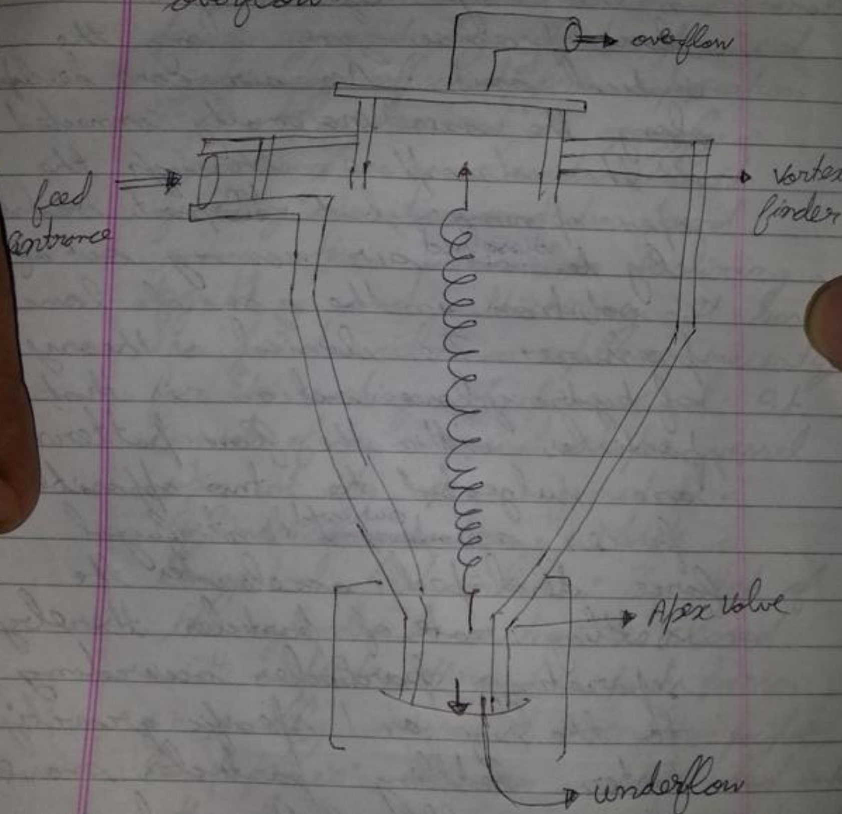



FIG:- Hydrocyclone

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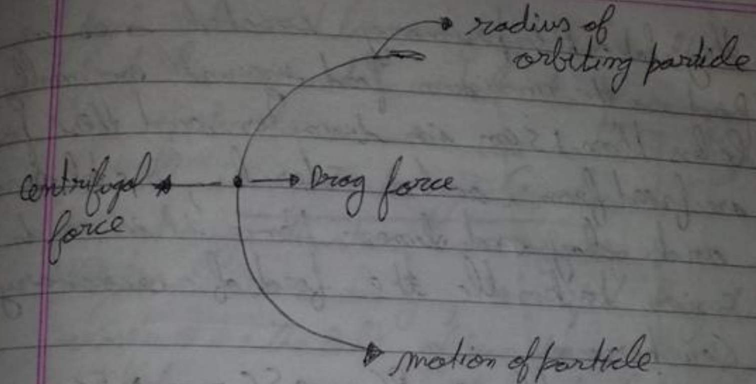



FIG - Forces acting on an orbiting particle in hydrocyclone

Hydrocyclones are almost universally used for classification between 150 and 5 μm, although coarser separations are also possible.

Jamal Sir

Secondary Crushers / Tertiary Crusher :-

Standard cone Crusher

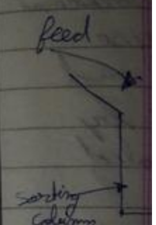
Cone Crusher — short head cone Crusher (tertiary crusher)

07/04/2014.

AKS Sir

**Hydraulic classifier →** These are characterized by the use of water, additional to that of the feed pulp introduced, so that its direction of flow opposes that of the settling particles. They consist of a series of sorting columns through each of which a vertical current of water is rising and particles are settling out. The rising current are graded from a relatively high velocity in the first sorting column to a relatively low velocity in the last. Very fine slimes, overflows the final sorting column. The size of each successive vessel is increased but crossectional area of column remains unchanged throughout column. This is Because the amount of liquid to be handled includes all water used for classifying in the previous vessel. They may be free or hindered settling types.

The greatest use for hydraulic classifiers in the mineral industry



is for sorting the feed to certain gravity concentration process.

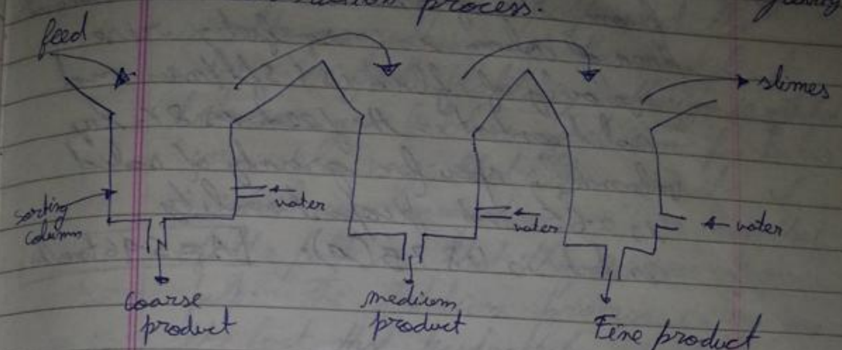



FIG:- Hydraulic Classifier

## Performance of Classifier:-

The performance or capacity of a classifier is directly proportional to 4 factors i.e.

1.) Cross-sectional area of sorting column (A)
2.) The rising velocity (V) of the fluid in the sorting column
3.) The pulp density ~~or~~ solid content of the feed by volume denoted by ($\gamma$)
4.) Specific gravity of the solid denoted by $\rho_s$

The Capacity of classifier is:-

$$C = a A V \gamma \rho_s$$

Q.) Calculate the capacity of a classifier from the furnished data. Crossectional Area of column is 10 sq feet, rise velocity of fluid is 1.5ft/min and solid content in the feed is 8% by volume, specific gravity of solid is 2.65 and proportionality constant is 1.875 (a). $\boxed{\text{Ans}= 5.96 \text{ tons/hr}}$

Q.) Spherical particle of quartz 15 μm in diameter are to be settled from their mixture with water. The specific gravity of quartz is 2.65 and the viscosity of fluid is 1 cp, settling time is 1 min. How height should be the chamber to allow settling of these particles.

~~10~~ Ans = (12 X 10$^{-9}$ cm)

Flotation:-

It is the most widely used method of wet concentration of ores for separating the valuable constituent from the worthless gangue. The process is primarily based on surface phenomena. In this the adhesion to air of some particles from a pulp and the simultaneous adhesion of other particles to water. In froth flotation, adhesion is effected between gas bubbles and ~~some~~ small particles in such a way that the sp. gravity of mineral air association is less than that of the pulp so that they rise in that pulp. The flotation process relies on the fact that hydrophilic particles are wetted by water whereas hydrophobic are wetted by oil or air bubbles. Therefore if air bubbles are introduced into an aqueous slurry, the bubbles adhere to the hydrophobic solid particles.

## Operational principles of flotation:—

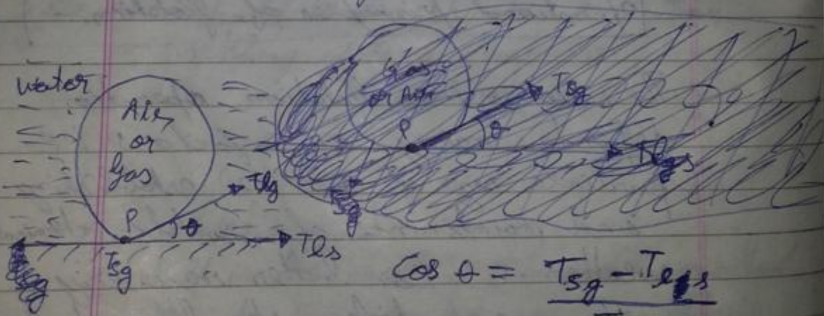
The success of the flotation operation depends mainly on 2 factors i.e. 1) particle size of ore 2) establishing and maintenance of suitable chemical weather. For better recovery the ore particles should not be over grinded. It should be in fixed intermediate size range. It should not be lower than 5-10 μm size and

80% of the feed is passed through a particular size.

## Pulp conditioning and pulp density:-

For better results the pulp density should not be more than 30-35% by the weight of solid. For the success of flotation operation, addition of optimum quantities of reagent are very essential. Little excess or lower values will have either beneficial or sometimes adverse effects.

## Contact Angle:-




$$\cos\theta = \frac{T_{sg} - T_{ls}}{T_{lg}}$$

$T_{sg}$ – Surface tension of solid gas

$T_{ls}$ → Surface tension of liquid solid

$T_{lg}$ → Surface tension of liquid gas

$\theta \rightarrow$ Contact angle

The contact angle may be used as some indication of the floatability. If the contact angle is 0° or very small then water will tend to displace air at the solid surface, thus the surface becomes wettable and the mineral is non-flotable.

→ Flotability ~~decrea~~ increases and wettability decreases with increase in $\theta$.

→ The term $(1-\cos\theta)$ has be suggested as flotability factor.

It can be concluded that the greater the contact angle, the greater is the work of adhesion between particle and bubble i.e. minerals with high contact angle are said to be aerophilic and they have a higher affinity for air than of water.

~~Theoretical capacity and reduction ratio of crushers, Feed size~~

16/04/2014

AKS Sir

(i) PH regulator:- Use of pH regulators are made to increase the attraction of collectors towards the surface to be floated. $H^+$ and $OH^-$ ions alter the mineral surface hydration due to adsorption on mineral. limes — $Na_2CO_3$, $Na_2SiO_3$, $NaOH$, $NH_4OH$ - These are the reagents which are used for alkaline ~~mineral~~ medium. Acids → $H_2SO_4$, $HCl$, Oxalic acid are used for acidic medium. Generally for oxide minerals acidic medium is used and for sulphide ~~med~~ mineral alkaline medium is used. Flotation is carried out in alkaline medium as most of collector including xanthate are stable in these conditions, And corrosion of cells, pipe work is also minimised.

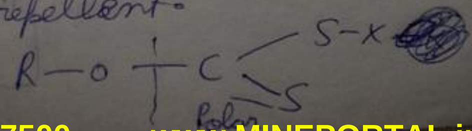
(ii) Collector :- These are organic substances which act selectively on the surface of certain mineral particles and form a thin coating by adsorption on the mineral surface to render them water repellant or air adherent. The characteristic feature of collectors are:-

(a) Complex molecular composition

(b) Asymmetrical structure

(c) consisting of two parts differing in properties i.e. polar and non-polar.

The non-polar part is always a hydrocarbon group ~~or~~ a chain and posses a water repellant property where as polar group have the property to react with water and ~~will~~ adsorb on mineral surface. This condition makes the mineral surface water repellent.

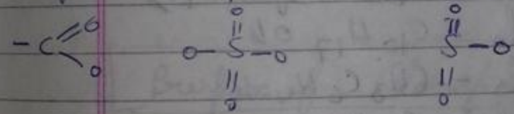


where X is Na or K

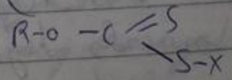
$R = C_2H_5$ Potassium ethyl xanthate.

Collectors

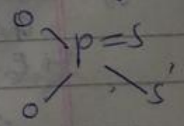
- non-ionizing (liquid non-polar hydrocarbons which do not dissociate in water)
- Ionizing
  - Anionic
    - Oxyhedral (Based on organic and sulpho acid group)
      - Carboxylic
      - Sulphate
      - Sulphonate



    - Sulphydryl (Based on Bivalent sulphur)
      - (Xanthates)



      - (Dithiophosphates)



  - Cationic (cation is water repellent based on pentavalent nitrogen)

Cationic $\rightarrow$ $[R-NH_3]^+ Cl^-$ ; $[R_2NH]^+$ ; $[R_3-N]^+$ ; $[R_4-N]^+$

## Frothers:-

These are the reagents of surfactants type of low solubility and surface tension which increases the life of the bubbles produced. These are hetropolar surface active substance which are adsorbed at the air water interface due to its surface activity and ability to reduce water surface tension. It also reduces the speed of bubble movement in the pulp and thus the bubble content with mineral particles is more, which result in better conditions for attachment of mineral particles.

ex: The most active frother consist of hydroxyl (-OH), Carboxyl (-COOH), Carbonyl (-CO), Nitrogen (-N), amino (-$NH_2$), sulpho group (-$SO_2OH$, -$OSO_2OH$). Among these hydroxyl are most common (for ex.)

terpinols - $C_{10}H_{17}OH$

Cresols - $CH_3C_6H_4OH$

alcohols - $C_5H_{11}OH$

→ For sulphide mineral pine oil is used which contains 44% terpinols.

→ For oxide minerals hydroxyl, alchohol, aromatic, wood tar, phenols are used as frothers.

→ Extra :- ←

**Purpose of Screening :-**

(a) To retain oversize in a given section or circuit and thus preventing it from being fed to a machine not suitable for dealing with it.

(b.) To remove undersize from the feed to a crushing machine set to treat bigger lumps

(c.) To grade rock into specified sizes

(d.) to present a correctly sized feed to a concentrating process.

**Purpose of Classification / Sorting :-**

(a) Separate ore into relatively course and fine fractions by exploiting difference in settling rates

(b.) Split a long-ranged feed into fractions settling equally.

(c.) Close grinding mill circuits so that no particles escape from them in to the concentrating section of the plant until they are reduced to desired size

(d) Remove or seggregate slimes

(e) Regulate [illegible] fed to a process

Circular mesh

07/01/2014 $\boxed{\text{SR Sir}}$

Contained value per ton > (Total extraction + losses cost of metal + other cost) / t

the value of metal contained in 1 ton of material/deposit mined out

→ mining cost
→ metallurgical cost
→ refining cost
→ processing cost.
→ installation cost
→ infrastructure
→ maintenance cost.

⇒ Profit is the main consideration to start ~~the~~ mining of a deposit.

⇒ To know the contained value → we should know about the grade of ore and price of metal in the market

From time to time → any deposit can change from simple deposit to ore deposit depending on the market price of the deposit.

Q) Calculate the contained value. A deposit contains 1% of Cu, 0.01% Mo if metal price of Cu = ₹400/Kg and ₹1000/Kg is the market price of Mo.

A) In 1 ton deposit

10 Kg of Cu → value is 4000 ₹

0.1 Kg of Mo → value is 100 ₹

∴ Contained value of ore = 4100 ₹

if deposit has

0.001% of Ag — ₹30000/Kg

0.00001% of Au — 3000000/Kg

$$\therefore \text{Contained value} = 4100 + \underbrace{300₹}_{Au} + \underbrace{300₹}_{Ag}$$

= 4700 ₹

So contained value is calculated with respect to all important economically extractable metals in the deposit and not only w.r.t. primary metals.

08/1/2014. SR Sir

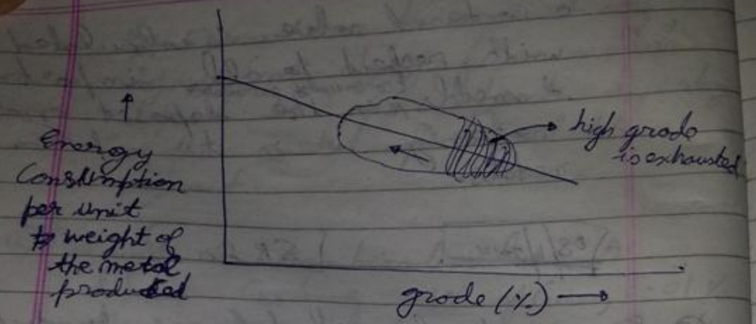
(*) In conventional method of ore production, we extract metal from ore deposit (primary source).

(*) Metals are also extracted from non conventional methods, non conventional source like sea beds, earth's crust, or by recycling of used metals.

(*) recycling of waste metal gives increased production of metal at a very low cost because mining cost becomes zero.

(*) Non-conventional sources like in sea beds, off grade deposits are future source of metals. (low % grade of metal)

(*) off grade deposits at present technology are not used as metals can't be extracted economically. We have to develop a cheaper technology to lower the cost of production to exhaust the deposits.




(*) Earlier the wastes deposited from mines had a very low grade %. Now-a-days these wastes are used to produce metals.
# Today's waste is tomorrow's resource.

(*) Even a high grade ore is not a gaurentee to start mining.
A high grade ore ~~should~~ can be suitable for mining but it may not be suitable for processing. We have to develop a suitable method of processing the ore also.

In future high grade will be exhausted and large off grade deposits will be used for metal extraction.

Deposits $\xrightarrow{\text{Mined}}$ ROM ore ~~[illegible]~~

Broken material carried to the surface.

1.) It is not uniform in size, even after advanced technology and optimisation of blasting results. Very fine to very large sometimes even boulders.

2.) Grade of ROM is not uniform, poor grade in most of the cases

3.) Presence of impurities → harmful impurities
→ advantageous impurities, if this is more, then we can get additional benefit from the ore by selling them, if separated. If not separated, the main consumer is charged more.

4.) Presence of more than one values, sometimes the ore may contain more than one valuable metal (ex.) W with Mo content
Pb-Zn with Ag content
Pb-Zn with Cu content

These metals are also processed and separated from the ore and can be sold to other consumers.

To meet the ~~cost~~ Customers requirement, so preparation of the ore is to be done and that preparation should be simple, cheap, less polluting, efficient and the chemical identity of the the mineral should not change. This preparation of ore is called mineral processing.

**Need of Customers:-**

1.) They need a uniform size
2.) They need a high grade.
3.) Presence of minimum impurities.
4.) In case of complex type of deposit where more than one ore is present, all the values have to be separated so that is can be supplied to different customers.

**Reason for these demands:-**

Customer is metallurgical plant

1.) To maximise the productivity of metal production
2.) Requirement of production of metal at lower rate
2.5.) They want to produce purer metal or good quality metal
3.) Minimum environmental problem during smelting
4.) Minimum losses of values
5.) Minimum energy consumption requirement

21/01/2014:

[S.R Sir]

## Need of Mineral Processing

→ Mineral processing is done for preparation of raw material as required by the customers. The chemical identity of the ore is not changed only some physical processing is done.

→ We need uniform size so that air can pass through all areas of blast furnace.

→ In case of hydrometallurgical process like leaching, leaching rate depends on surface area. More is the surface area, more is the leaching rate. Hence a finer ore size is necessary.

→ In the steam engine, coarser coal was required but in thermal power plants, finer size is required. It is the duty of the processing engg. to prepare the required size, upgrade the grade, increasing the contained value of the ore.

→ Impurities are removed. ⊛ In Iron ore impurities like phosphorus, sulphur, Alumina, silica, Manganese which may be available in ROM. These will affect the strength properties of material, more fuel will be needed in the blast furnace. To make the process cheaper easy, impurities should be removed.

⊛ In coal if ash content is high then the cost of energy production is high. Although fly ash has got binding property and is used in cement and brick making industry. But if flyash production is very high then its effective utilization is not possible and additional cost of fly ash handling arises.

→ In case of complex deposit where more than one value of metal exists. (Pb-Zn) or (Pb, Zn and Cu). All the values need to be separated and need to be supplied to v.customers. separate

Advantages w.r.t Customers:-

→ Supplying proper grade; minimum impurities;
→ Energy consumption will be reduced in processes
→ Transportation Cost is reduced
→ Reduced cost in environmental problems:
  - lot of gangue and slag need to be safely disposed
  - Dust need to be removed; less fly ash produced
  - Air dust has to be treated properly.

Advantages w.r.t. Mines:-

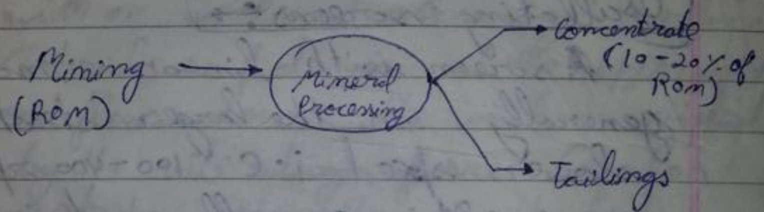
→ The tailings of mills serves as backfilling material.

→ Waste can be sold to other customers – Road building, brick making or electromagnetic. This is used for fine and ultrafine screening.

~~Reciprocating screen~~

28/01/2014 SR Sir

## Importance of Mineral processing:-




Ore consists of valuable mineral and non valuable minerals (waste). Waste has to be separated by using mineral processing.

Concentrate is sent to the customer which is usually the metallurgical plant/power plant, etc.

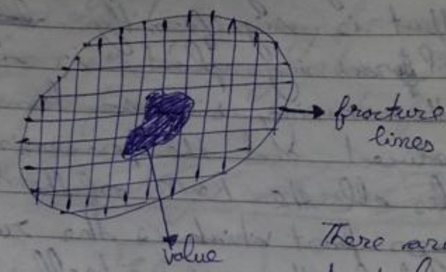
If the grade of ore meets the requirement of the customer then the ~~ROM~~ ROM is directly sent to the customer.
But if the grade is low then the material is sent through the processing plant ~~and~~ but the transportation cost of this high grade processed output is significantly ~~large~~ low.
~~But~~ ~~So~~ Processing plant is always at the mining site so transportation is reduced and the processing plant handles all the ROM of the mine and the major part which is the reject is utilized by the mine itself as filling material.
The high grade form is only 20% of the ROM and so for the same transportation cost we can sent higher quantity of processed material to the metallurgical plants located far away from the mines.

## Major Operations in Mineral Processing.

1) Liberation – freeing of the valuable ~~materi~~ mineral from the gangue

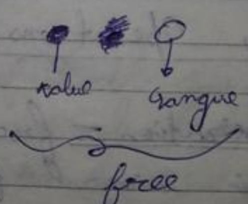

• Concentration is not possible until the valuable mineral is freed from the gangue material binded with it.

operations used for liberation is Communition. Communition is done by crushing and grinding. Communition is the process of size reduction. Some supporting operations like sizing is also done.



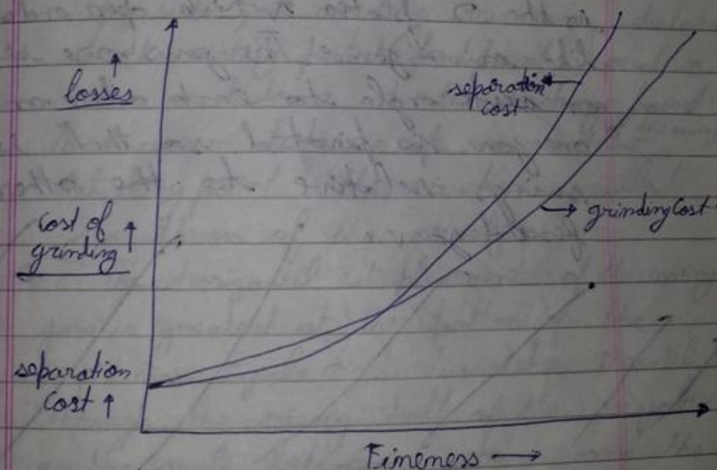

There are many particles in which value ~~ore~~ and gangue are in the locked form:—

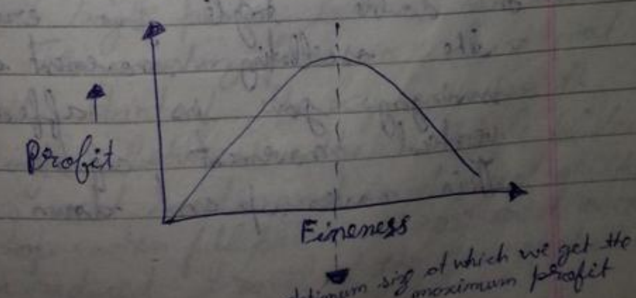

The smaller the size the better is the liberation.



Aim is not to get fully liberated particles (because it will require very fine size) but to get optimum liberation.

At very fine size, cost of communition is becomes very high, large fine production so ~~suppression~~ separation cost is also very high, ~~suppression~~ separation efficiency is also very low, losses will be very high.



If in the concentrate, is 100%
liberated then grade is maximum
but it is not possible practically.

Aim → to get liberation as
coarser as possible (cost of grinding
is less, cost of separation is less, losses
are less)

AJ Sir   30/01/2014.

Primary Crusher → Jaw crusher :→
Distinctive features of jaw crusher
is the 2 plates which open and shut
like animal jaw. The jaws are set at
an acute angle to each other and
one jaw is pivoted so that it

11/02/2014

SR Sir

## Operations in Mineral processing:-

1.) Liberation
- crushing
- grinding

2.) Sizing
- Screening
- Classification

3.) Concentration
- Sorting
- Gravity Concentration
- Flotation
- Magnetic Separation
- High tension separation
- Agglomeration

4.) Dewatering
- Sedimentation (Thickening)
- Filtration
- Drying.

## Sizing:-

If requirement of customer is particular size and grade is not important then sizing operation is done. For sizing screens are used and then since efficiency of screening falls rapidly ~~at~~ with increase in fineness so for fine separation we use classifiers.

Classifiers work on settling rate of particles.

Classifiers can also be used for Concentration process if size is controlled earlier then we know that higher specific gravity material settles fast and hence this method can be used for concentration also.

Concentration:-

After the liberation of ore and gangue we can separate by a number of separating processes.

→ In case of coal (oil agglomeration) is used as concentration operation.

→ Agglomeration in metallurgical industries is used for getting fines of suitable size, not for concentration process.

Dewatering:-

In pulp from concentration there is 20% solid content rest is water. It has to be separated and reused maximum ~~so~~ to reduce dependence on extra water and to reduce ~~the~~ practice of its discharge into streams thereby polluting it.

of total
80% water is removed & by sedimentation
About 50% pulp solid content is obtained after sedimentation.

Then filteration is done followed by drying process. Some moisture still remains in the ore.

Purpose of dewatering:-

→ removing water
→ effective re-utilization of recovered water
→ control water pollution by avoiding disposal of contaminated water.

## CONCENTRATION:-

Depending on some physical properties some particular method of concentration is opted.

Sorting → Based on visual examination of particles (color, lustre, shineness)

2 types:-
(a) hand sorting
(b) Mechanized or mechanical/electronic sorter

→ one of the earliest method but due to large scale mining and fine dissemination the ore is crushed to finer sizes. So hand sorting is not possible because fine separation is difficult and time taking and labour availability is a problem and costly. So it is not used much except in small scale mines and where labour is cheap.

* Generally ~~is~~ on both sides of a belt conveyor, people stand and examine each particle passing by. It is done for timber removal or removal of unexploded material mixed in ROM as it may cause explosion in crushing chamber.

→ By mechanized sorting materials like uranium, gold, copper may be separated based on some special distinctive properties. ex) uranium is sorted based on radioactive emissions

Gravity Concentration →

To have an idea ~~where~~ ~~at~~ whether the particles can be separated by gravity concentration or not, we find concentration criterian (C.C.)

$$C.C. = \left(\frac{D_h - D_f}{D_l - D_f}\right)$$

$D_f$ → sp. gravity of fluid
$D_h$ → sp. gravity of heavy minerals
$D_l$ → sp. gravity of lighter minerals

If $C.C. > 2.5$, specific gravity concentration will be ~~easil~~ easier.
sp. gravity method preferred because it is cheaper, less polluting, simple

If $C.C. < 1.25$, the use of gravity is not preferred except on lab scale ~~as~~ as it is very time consuming.

$1.25 < C.C. < 2.5$ then ~~you~~ efficiency of gravity method decreases as C.C goes below 2.5..

Methods of gravity separation:-

(a) Jigging
(b) Tables (ex.) Wilfrey table)
(c.) spirals
(d.) cones
(e) Heavy-medium separator (coarser size)
(f.) sluice

finer size

Step:-

1.) first find C.C. and see feasibility of gravity method

2.) Then find size of liberation
3.) Then crush it to that size
4.) See size of feed material for concentration and ~~so~~ then select fine method ~~•~~ if materials are fines.

Froth - floatation:-

→ Based on surface properties of minerals

→ use some chemicals to make surface of minerals air-avid (hydrophobic)

→ then the required minerals can be floated by use of frothers

Magnetic Separation:-

→ Based on magnetic properties, magnetic materials like magnetite can be separated from non-magnetic materials

High Tension Separator:-

→ Based on conductivity of materials, conducting and non-conducting materials can be separated.

12/02/2014

SR Sir

## Removal of Harmful material from RoM :-

~~ective~~ Harmful impurities if not removed affect life of equipment of processing plant and affect the processing operations and their efficiency. Hence they increase the cost of processing.

### Types of harmful Impurities:-

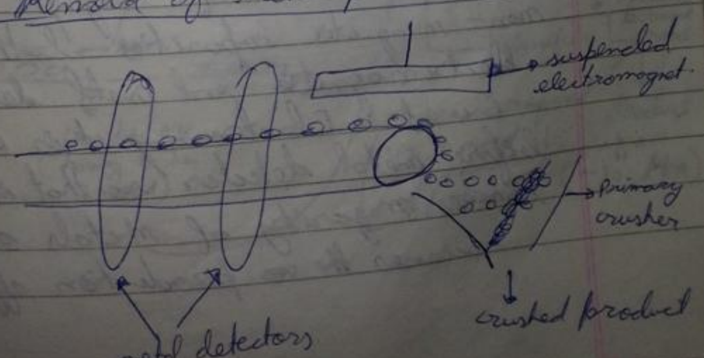
1.) Metal pieces → my come from broken tools, may be ferrous or non-ferrous metal
2.) presence of wood → In U/G mines wooden props may be ~~burried~~ buried in the RoM.
3.) unused explosives and their ~~cartiges~~ Cartridge
4.) Slimes or ultrafine particles or ~~a~~ presence of clay

### Effect of these harmful impurities:-

* presence of metal pieces may affect the crusher, it may damage it, jam it, so it has to be removed prior its entering into the crusher chambers

* presence of explosives can cause explosion in crushing chambers
* presence of wood chokes the opening of the screens, its presence in the flotation cell absorbs the reagents ~~f~~ of the flotation cell so high reagent consumption is there and hence this increases the cost of reagents. It may choke the part of flotation cell. It may decompose ~~the~~ in the flotation cell and depress the values and cause movement of values into the tailings.
* Slimes/clay chokes opening of the screens. It unnecessarily consumes the reagents of the flotation cell. It affects the performance of gravity concentration process.

## Removal of Metal pieces:-



But in case of ore having magnetic properties like Magnetite or in case metals are non-magnetic in nature.

- Metal detectors are used (based on electrical conductivity of the materials)

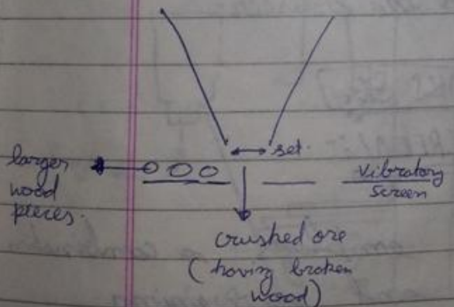
Ore has less conductivity compared to metal due to low grade and so if conductivity fluctuation is very high then above a fixed limit the 1st metal detector signals and stops the belt conveyor. Then by hand picking, metal pieces are removed.

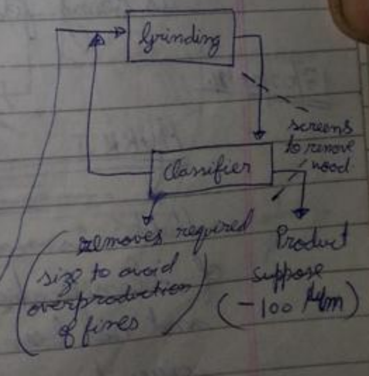
In case of mixture of magnetic and non-magnetic impurities both Electromagnet and metal detectors are used. Electromagnet is used before metal detector so that it removes majority of metals and increases the production efficiency

larger wood pieces

## Removal of wood:—

wood when enters the crusher, most of it is flattened, only few are broken into pieces.
So best method to remove the pieces is to put a vibratory screen below the crusher having aperture slightly more than the set size of the crusher. So all the crushed ore is passed through while most of the wood is removed, only a small part of wood which is crushed is passed through. Its removal is also essential. Then the next process is grinding and the remaining wood is removed in the grinding circuit.



we will ~~only~~ analyse the size of product of grinder and fix screen of that aperture over which wood overflows.

But wood which are crushed to about 100 μm then a screen is used after the classifier so that wood material further overflows from it ~~and~~ but very small size wood still passes on to the concentration processes.

Removal of explosives:-

Only method is handsorting of belt conveyor material before the material is being fed to the crusher.

7/02/2014.

AKS Sir

HUKKI SCREEN:-

26/03/2013

SR Sir

## Preparation of ROM:-

* Washing → Required when ore ~~contails~~ contains slimes or clay material.

Need of preparation of ROM:

* During crushing and grinding we need to take care that the generation of fines is minimum specially in friable ores ~~be~~because fine production affects performance and increases cost.
* In M.P. we need maximum profit ~~so~~ and similarly the customers require maximum profit and so ROM should be properly prepared.
* Minimum losses are there if ROM is properly prepared.

## Main operations:-

- Liberation
- Concentration
- Dewatering → thickening, filtration, drying

Removed water is reused in processing plant and reject in the form of pulp is disposed in nearby area.

ROM
↓
Comminution → gives liberation by crushing and grinding. But along with it sizing unit is essential

sizing — screening (coarser)
sizing — classifiers (fines)

↓
Concentration → Depending on the physical properties of a particular concentration method is selected.
↓
Product Handling (Dewatering is main)

seams or vein type deposits

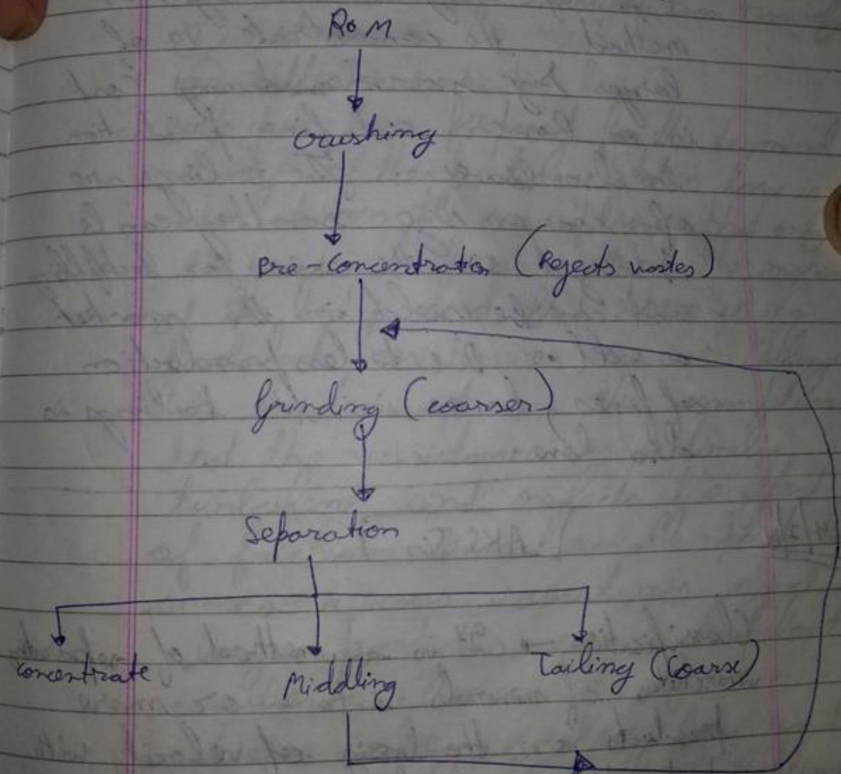
ROM
↓
Crushing
↓
(+) Screening → it is necessary to ensure larger particle does not enter grinding unit thereby increasing cost of grinding
↓ (−)
grinding
↓
(+) classifier
↓ (−)
Concentration

concent

## Ways of preparing:-

1.) washing -

2.) pre-concentration → Due to high mechanization in mining ROM is highly diluted; In thin seams or vein type deposits. In such cases pre-concentration is used to remove the waste material as coarser size, economically.



Coarser grinding is cheaper so it is used so if liberation size is 75Mm then by coarse grinding 500 Micron size is obtained so some required size material is obtained in the form of concentrate and major ~~size~~ portion is obtained as middlings which is recirculated to grinding unit. By this method the concentrate is of larger size so dewatering cost is ~~so~~ lower and fines production is also lower. The tailings are of coarser size so they can be utilized in the mines for backfilling and can be sold in the market as well. Due to less production of fines, losses in the tailings is also low.

---

24/2/14.

$\boxed{\text{AKS Sir}}$

Classification → It is a method of separating mixtures of minerals into 2 or more products on the basis of velocity with

crusher/
gyratory crusher

> 700 t/hr → go for gyratory crusher

04/03/2014. ~~Pre~~ SR Sir

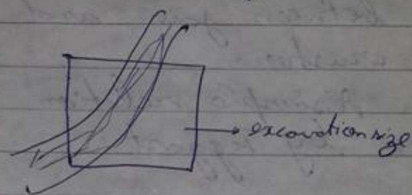
~~Pre~~ Pre- Concentration:-

→ This is gaining importance due to mining of low - grade deposits now-a-days.

Purpose → To reject waste materials from ROM at coarser size before starting main treatment process. Major part of waste is removed.

Applicability Conditions:-

1.) Particularly in metal mine when deposit is vein type




2.) If pre-concentration is done in u/g then hoisting cost is reduced a lot, pollution on surface is less as waste is directly used for backfilling.

3.) In open cast with large mechanization mining thin seams requires pre-concentration

→ In these crushing is not necessary before pre-concentration, we can directly opt for pre-concentration.

→ If the ROM is in coarsely aggregated form then crushing is required before pre-

Advantages of pre-concentration:-

1) allows high grade feed to concentrator, processing cost reduced

2) recovery and grade of the concentrate will be high

3) It reduces comminution cost which is considered to be one of the most energy consuming process. We have to grind a lower amount of feed.

4) Reagent cost will be reduced because less amount of the material is to be processed.

5) The mining reserves is increased because we can lower the cut-off grade of the ore.

6) In case of coal, pre-concentration helps in getting the final product where only slight reduction of ash content is ~~reduction~~ required. Seperate benificiation plant is not necessary.

Types of pre-Concentrators/
Methods of pre-Concentration:-

→ Simple and cheap methods are used.

1.) Gravity method (heavy medium separation process) is most popular used when amt. of material to be handles is very large, popular in base metals)

2.) Sorter (mechanized electronic)
It is a dry process. ~~used for~~ Based on colour, lustre — Photometric Sorter
↳(washing is also required)

Based on radioactivity — radiometric Sorter

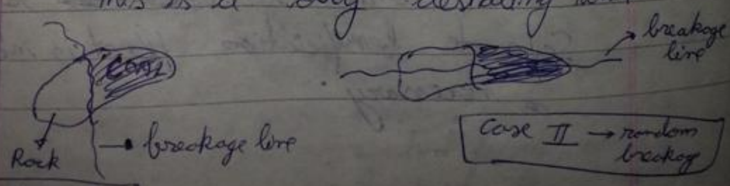
3.) Crushing and Screening → Based on the differential breaking characteristic of the value in comparison to the rock. (Rotary Crusher is used)
Name:- (Bradford breaker)

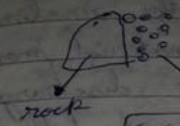
In case of coal:

value → Coal

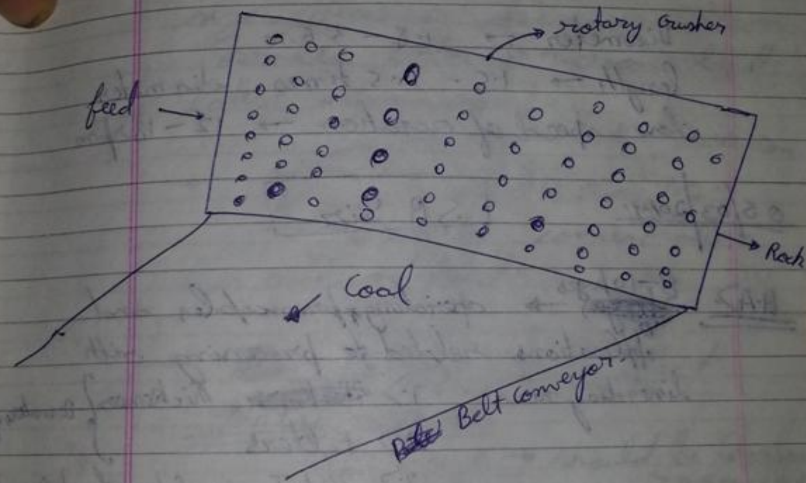
gangue — shale

This is a dry deshaling unit

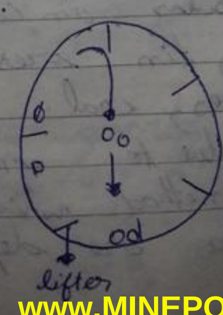





$\boxed{\text{Case III}}$ → In such cases opt for rotary crushers




rotary crusher looks like a trommel. It has a thick metal perforated casing.




⇒ Due to falling of material, coal breaks into smaller size.

The crusher is slightly inclined so that the falling material moves ~~ahe~~ ahead towards the discharge end. After 2 to 3 times of fall when the coal size is less that the diameter of the perforation then the coal is obtained on the belt conveyor.

Coarse grinding

Diameter → 1.8 – 3.6 m
length → 1.5 – 2.5 times diameter
slow speed of rotation → 12 – 18 rpm.

05/03/2014.

SR Sir

H.A. 8–10 pages → operating principles and applications related to processing with line diagrams
1) ~~thickener~~ thickener } Dewatering
2) Filters
3) High Tension Separator } Concentration

Gravity Concentration:-
→ oldest method of concentration
→ ~~popul~~ popular in case of coal, iron, tungsten, tin ores, chromite ores, oxidized ores, coal.
→ declined due to introduction of floatation method which is popular for complex ore deposits.

→ simple, cheap, environmentally free, cost of equipment is low, operating cost is low, can be used as a pre-concentration operation also

→ effective for coarser particles ~~with~~ with reduction in size efficiency decreases. It can handle upto 50 Micron by the latest advancement.

→ If C.C. (concentration criterion) is less than 1.25 then gravity concentration is not adopted.

→ ~~The~~ Factors that affect gravity method:

(i) size → should be coarser > 0.5 mm size

~~(ii) Specific gravity~~ But if it is used for finer size upto 50 Micron then centrifugal force has to be applied for fast settling by use of centrifugal cyclones.

(ii) specific gravity → There should be sufficient difference between the specific gravities. In a close size range material, specific gravity is the only dominating factor

(iii) → Presence of slimes (< 10 Micron) → affect the gravity process badly so their removal is important. So desliming method is adopted by hydraulic classifier or hydrocyclones.

ore is friable → hydraulic classifier used

ore is harder → hydrocyclones are used

→ Presence of slimes affects the viscosity of fluid used for concentration thereby affecting sharpness of separation/efficiency of separation.

(iv) The particles should be closely sized so that ~~sp~~ gravity is the dominating factor.

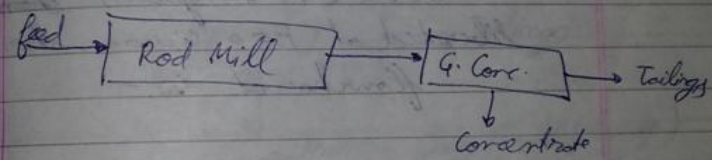
(v) liberation at Coarser size → The values should be liberated at coarser size

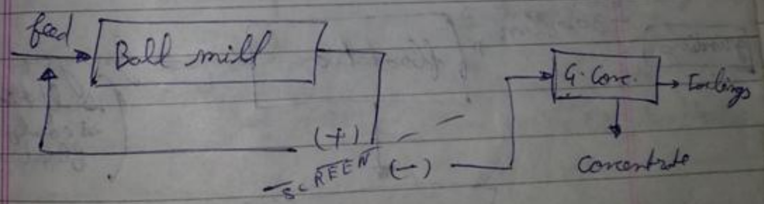
$\boxed{\text{Preparation of feed for gravity process:-}}$

1) Generally crushing and screening is adopted if ore is liberated at Coarser size.

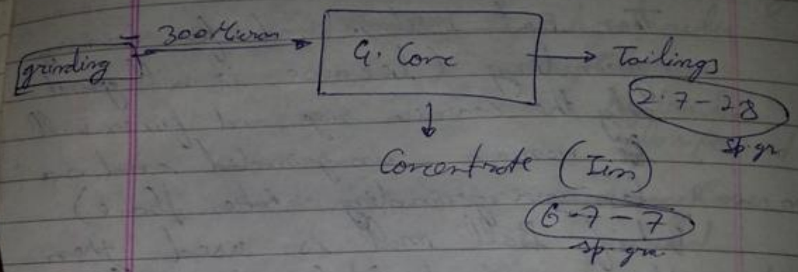
2) If liberation takes place at finer size then grinding is used also.

Then Rod mill is used for Primary grinding (because it will grind only the coarser size and finer will ~~be~~ remain ungrinded and so less overgrinding takes place)
But if Ball mill is used then the circuit should be closed by screens to avoid overgrinding.

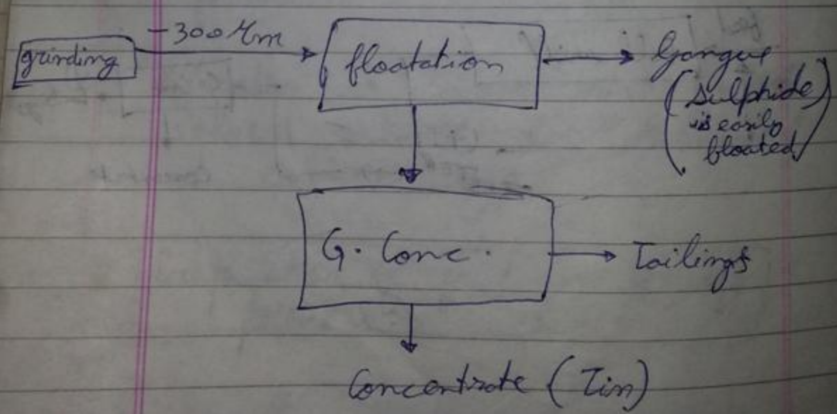


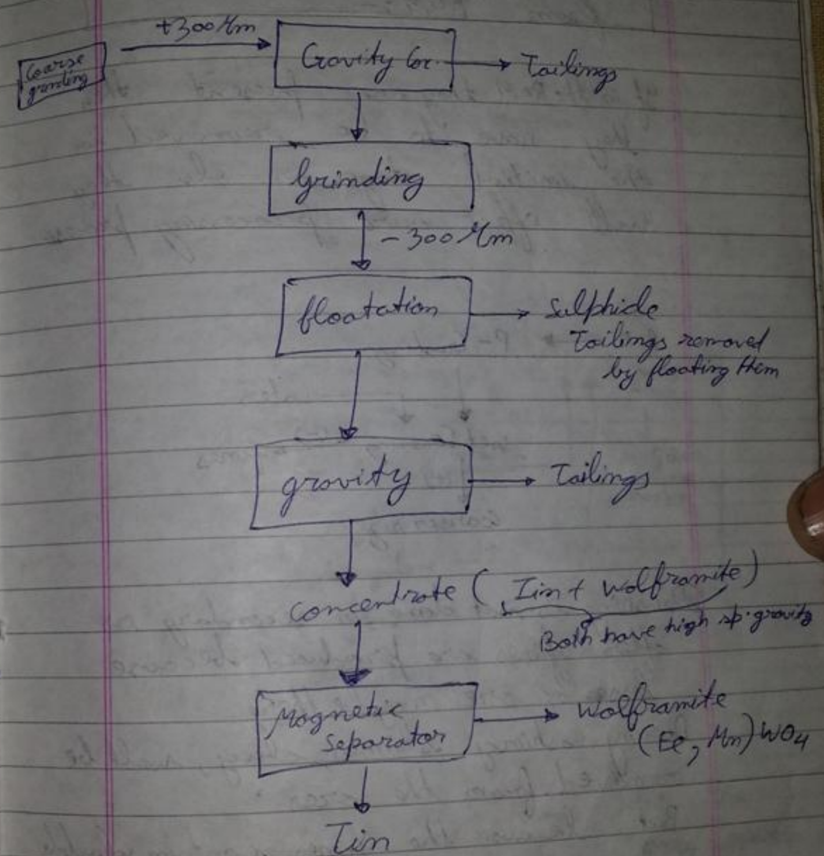
* Consider an ore of tin liberated at 300 Micron with simple gangue.




* But if ore consists of tin and other valuable (like tungsten) ~~then~~ both liberated at 300 Micron then the flowchart is:–



(*) But if ore has tin, wolframite and sulphide values, all liberated at 300 μm then flowchart becomes as follows:-



/10/14 SB Sir.

## Removal of Ultrafine particles from ROM:—

If in the ROM they are present then they have to be removed in the initial stage or else they will effect our processing process.

ROM ⟶ P-Crushing

↓ ← water

wet Screening $\xrightarrow{(-)}$ fines

↓ (+)

coarser size

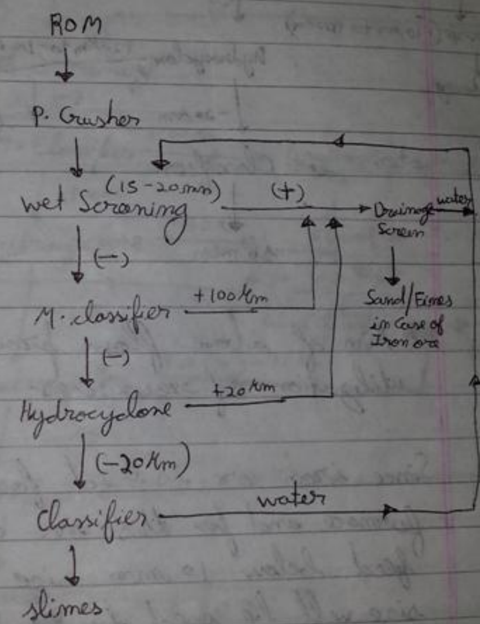
* Washing is not done in secondary or after fines are produced because loss of ore may be there

During washing slimes, clay, will be removed from the ores.

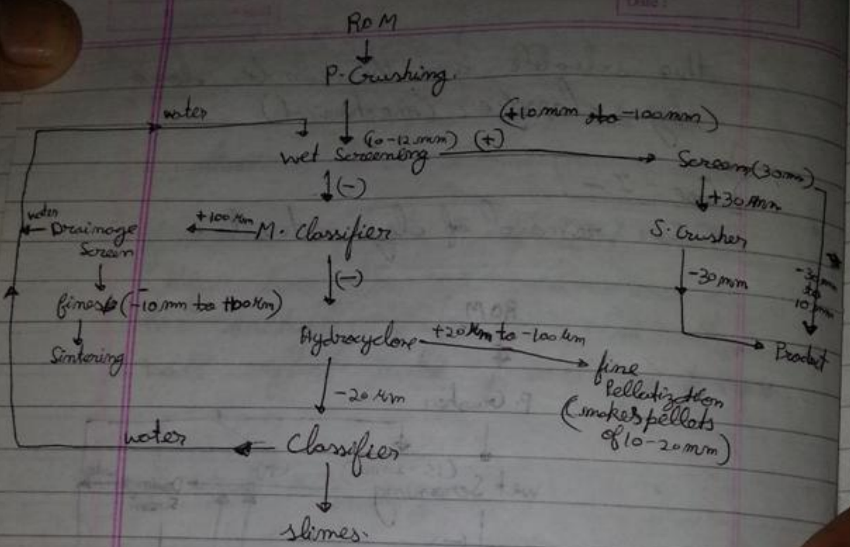
But because the fines contain valuable along with clay so size of screen is (15-20) mm. product size is -15 to -20 mm. Since these fines contain values so next step is to recover this valuable and this can be done by classifier (mechanical)

**Case - I :-**

For removal of clay material




**Case II :-** In case of iron ore, the requirement of size is more. It only needs washing after Primary Crushing.

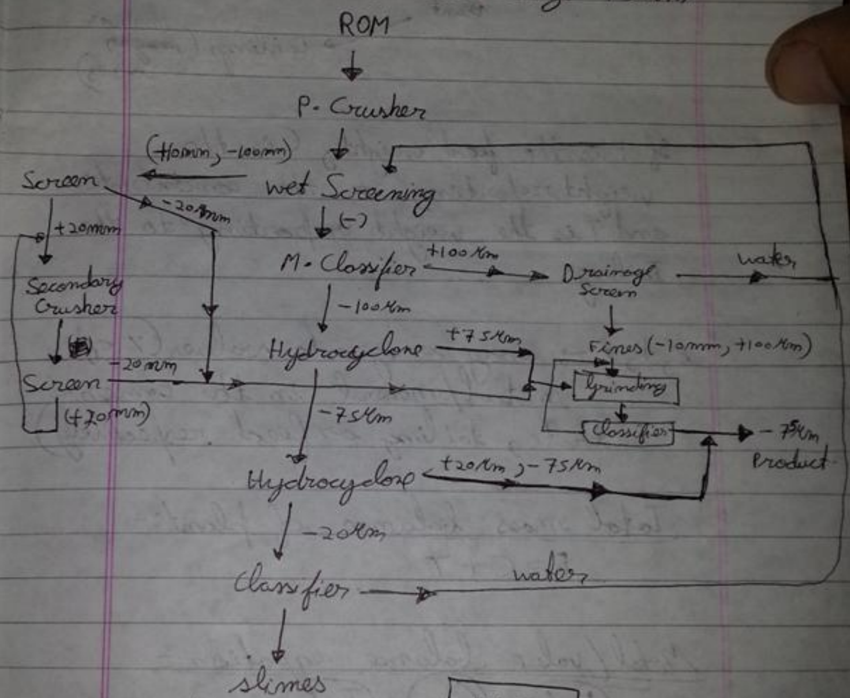



⇒ Aim of above flow process is maximum utilization of resources.

Since iron ore is used for ~~f~~ blast furnace and for this we cannot feed below 10 mm size. So +10 mm size will be used by ~~the~~ Blast furnace while earlier -10 mm size ~~was~~ was dumped nearby the mines but now due to metallurgical advancements we use sintering (the method of agglomeration ~~aggregating~~) upto 150 μm size. The ~~a~~ ~~#~~ -150 μm size can also be used by aggregating them (Pelletizing).

**Case III :-**

when we need liberation of values : Suppose Copper ore has liberation size 75 μm.




SRSM

19/02/2014.

## Evaluation of Plant's Performance

Recovery → The % of the total metal contained in the ore that is recovered in the concentrate.

In case of non-metallic ores, it refers to the total mineral contained in the ore that is recovered in the concentrate.

Feed ⟶ Plant ⟶ Concentrate (major values)

Plant ⟶ Tailings (minor values)

If F is the feed weight, C is the weight reporting to the concentrate and T is the weight reporting to the Tailings.

c, t, f → assay or grade values (% of metal/mineral in the concentrate, tailing or feed respectively)

Total mass balance of plant:-

$$F = C + T$$

Metal/value balance equation:-

$$\underbrace{F \cdot f}_{\text{Total metal in feed}} = \underbrace{C \cdot c}_{\text{Total metal in concentrate}} + \underbrace{T \cdot t}_{\text{Total metal in tailing}}$$

Solving above equations we get:-

$$F \cdot f = C \cdot c + (F - C)t$$

$$\text{or } F \cdot f - F \cdot t = C \cdot c - C \cdot t$$

$$\text{or } F(f-t) = C(c-t)$$

$$\text{or } K = \frac{F}{C} = \frac{c-t}{f-t}$$

$$\text{Recovery } (R) = \frac{C \cdot c}{F \cdot f} \times 100$$

$$\therefore R = \frac{c(f-t)}{f(c-t)} \times 100$$

⇒ In plants, the weight measurement is very difficult, to calculate recovery but if we go for analysis of feed, concentrate and tailing then also we can calculate recovery.

Ratio of Concentration (K) = It is the ratio of the weight of the feed (head grade) to the weight of the concentrate.

Ratio of Enrichment → It is the ratio of the grade of concentrate to the grade of the feed.

$$\boxed{R.E. = \frac{c}{f}}$$

Q.) If 249.2 tons of the concentrate are produced assaying 42% of the metal from a head grade (feed) of 3.5% leaving tailings of 0.79%. Calculate the recovery, ratio of concentration and ratio of enrichment.

$F = ?$

$f = 3.5\%$

$C = 249.2\,T$

$c = 42\%$

$T = ?$

$t = 0.79\%$

$$F = 249.2 + T$$

$$\frac{3.5F}{100} = \frac{42 \times 249.2}{100} + 0.79T$$

$F = ?$ $T = ?$

$\boxed{\text{After Calculation, results are reported in a Material Balance table or Metallurgical Balance Sheet:-}}$

| Items | Weight (tons) | Assay (%) | Wt. of Metal (tons) | Distribution of Metal (%) |
|---|---|---|---|---|
| Feed | 3790.3 | 3.5 | 132.7 $\xrightarrow[\text{as}]{\text{taken}}$ | 100% |
| Concentrate | 249.2 | 42 | 104.7 | 78.89 |
| Tailings | 3541.1 | 0.79 | 28.0 | 21.1 |

Q.7 A plant processes 210 tonnes of the material during the 1st shift assaying 2.5% of the metal to produce a concentrate 40% of metal, a tailing 0.2% metal. In the 2nd shift it processes 305 tonnes of material assaying 2.1% metal and produces a concentrate 35% metal and 0.15% in tailings. Find out the composite metallurgical balance sheet of the 2 shifts.

| Items | wt (tonnes) | Assay (%) | wt. of Metal (tons) | Distribution of metal (%) |
|---|---|---|---|---|
| $\boxed{\text{1st Shift:-}}$ | | | | |
| Feed | 210 | 2.5 | 5.25 | 100% |
| Concentrate | 12.136 | 40% | 4.854 | 92.46% |
| Tailing | 197.86 | 0.2% | 0.396 | 7.54% |

2nd Shift :

| | | | | |
|---|---|---|---|---|
| Feed | 305 | 2.1% | 6.405 | 100% |
| Concentrate | 17.066 | 35% | 5.973 | 93.255% |
| Tailings | 287.934 | 0.15% | 0.432 | 6.745% |

Composite

| | | | | |
|---|---|---|---|---|
| Feed : | 515 | 2.263% | 11.655 | 100% |
| Concentrate | 29.202 | 37.076% | 10.827 | 92.896% |
| Tailings | 485.794 | 0.170% | 0.828 | 7.104% |

25/02/201

Q1) A
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SRS37

Q1) A Concentrator is fed 1000 T/hr of ore assaying 10% Galena. It produces a Concentrate assaying 80% galena and tailings assaying 0.19% Galena. What are the flow rates of tailings and Concentrate streams and also Calculate the recovery and loss of Galena in the concentrate as well as tailings respectively.

$F = 1000\ T/hr \qquad f = 10\%$

$c = 80\%$

$t = 0.19\%$

$$R = \frac{c\,(f-t)}{f\,(c-t)} \times 100 = 98.33\%$$

$$\therefore R = \frac{c}{f} \cdot \frac{C}{F} \times 100$$

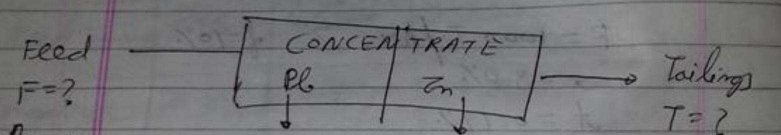
$$\Rightarrow C = \frac{F \times 98.33}{8 \times 100} = 122.9\ T/hr$$

$$1000 = 122.9 + T$$

$$\therefore T = 877.1\ T/hr$$

$$\text{Loss} = 100 - 98.33 = 1.67\%$$

Q.2) A lead-Zn ore containing 5% lead and 7.5% Zn is treated to produce lead concentrate assaying 50% lead and 5% Zn and a Zn concentrate assaying 10% lead and 50% Zn and tailings 1% lead and 1.5% Zn. Calculate the Recovery of lead in lead concentrate and Zn in Zn concentrate.




$f_{Pb} = 5\%$

$f_{Zn} = 7.5\%$

$C_{Pb} = ?$

$c_{Pb} = 50\%$

$c_{Zn} = 5\%$

$C_{Zn} = ?$

$c_{Zn} = 50\%$

$c_{Pb} = 10\%$

$t_{Pb} = 1\%$

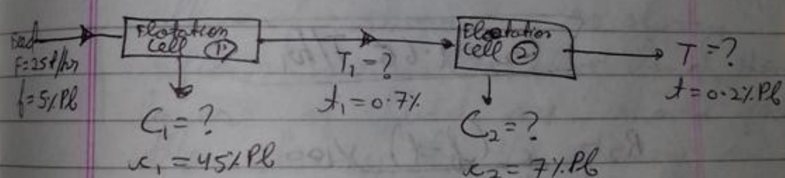
$t_{Zn} = 1.5\%$

NOTE:- In lead concentrate, Zn is waste and vice-versa

$$R_{Pb} = \frac{c(f-t)}{f(c-t)} \times 100 = 81.63\%$$

$$R_{Zn} = \frac{c(f-t)}{f(c-t)} \times 100 = 82.47\%$$

Q-3) 25 tonnes/hr of ore containing 5% lead is fed to a bank of floatation cells. A high grade concentrate is produced assaying 45% lead. The high grade tailing assay 0.7% lead and feed to low grade cell which produces a concentrate grading 7% lead and low grade tailing containing 0.2% lead. Calculate the wt. of the high grade and low grade concentrate produced per hour and the recovery of the lead produced in bank of floatation cells.




$F = 25\,T/hr$ $\quad f = 5\%$

$C_1 = ?$ $\quad c_1 = 45\%$

$T_1 = ?$ $\quad t_1 = 0.7\%$

$$F = C_1 + T_1$$

$$45(25 = C_1 + T_1) \rightarrow (1)$$

$$25 \times 5 = 45\, C_1 + 0.7 T_1 \rightarrow (2)$$

$$40 \times 25 = (45 - 0.7) T_1$$

$$\boxed{T_1 = 22.57\ T/hr}$$

$$\boxed{C_1 = 2.43\ T/hr}$$

$$R_1 = \frac{c\,(f-t)}{f\,(c-t)} \times 100 = 87.35\%$$

For 2nd Cell tailings of first cell will become feed:-

$\therefore F_2 = 22.57\ T/hr \qquad f_2 = 0.7\%$

$$7(22.57 = C_2 + T) \longrightarrow (1)$$

$$22.57 \times 0.7 = C_2 \times 7 + 0.2T \longrightarrow (2)$$

$$(7-0.7)(22.57) = (7-0.2)T$$

$$\boxed{T = 20.91\ T/hr}$$

$$\boxed{C_2 = 1.66\ T/hr}$$

$$R_2 = \frac{c\,(f-t')}{f\,(c-t')} \times 100$$

$$= \frac{7\,(0.7-0.2)}{0.7\,(7-0.2)} \times 100 = 73.53\%$$

$$\text{Total } C = C_1 + C_2 = 2.43 + 1.66$$
$$= 4.09\ T/hr$$

$$\boxed{\text{Total Recovery} = \frac{C_1 c_1 + C_2 c_2}{Ff}}$$

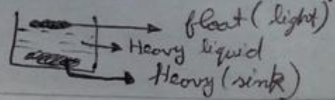
that ... in grinding 1 screen size finer in a $\sqrt{2}$ screen series. (difference between aperture size is $\sqrt{2}$ in consequative screens)

11/03/2014 SR Sir

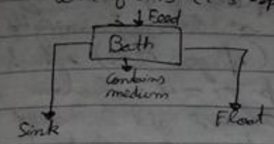
Heavy Medium Separation: (Gravity Concentration)

→ Also known as Dense Medium Separation or (sink and float) method.
→ It is one of the simplest process utilizing only the specific gravity difference.
→ using a simple medium whose gravity is in between the sp. gravity of minerals to be separated.
→ Simple water is not used in this case ~~between~~ because the values have sp. gravity more than 4.5 and gangue have sp. gravity around 2.5 – 2.6
→ The particles that are lighter will float in comparison to heavy which sinks.

(ex) Suppose a mixture of sand and cock, sand will sink and cock will float.



→ Bath can be trough type, cone types, cyclones. Its size depends on amount of feed to be handled. Size refers to mouth size. The Bath contains the medium which is not water because medium sp. gr. should be in between (2.6 – 4.5) ex) For coal, medium of sp-gravity = 1.55 is used coal floats (1.3 sp. gr).




In case of metals → sink is valuable mineral, and float is rejects. (sp. gr. of medium = 2.8)

In case of coal → sink is gangue and float is coal (sp. gr. of medium = 1.55)

Lab Scale:– Heavy organic liquids can be used. Earlier $H_2SO_4$ was diluted and used but since $H_2SO_4$ is dangerous and ~~not~~ corrosive so we shifted to organic liquids like Bromoform (sp. gr. 2.89), $CCl_4$ (sp. gr = 1.5), toluene (sp. 0.9), ethylene bromide, etc.

- Bromoform (sp. gr. 2.9) can be used for coal also by diluting it with $CCl_4$ to get sp. gr. around 1.5
- method is very efficient and maintaining a specific gravity for a longer time and obtaining such specific gravity is easy. We get a clear cut (sharp) separation of particles.

In Industry → organic liquids is not used because of the cost. In lab the results are accurate and less requirement of liquid is there so we use organic liquids. In industries solid particles are maintained in suspension state at weight % less than 15% of the solid. To get desired specific gravity of fluid, solid of high specific gravity is used so that amount of solid required is less. This specific gravity medium can be maintained easily for a longer time. This is our separating fluid.

Earlier sand was used to prepare fluid for separating but due to low sp. gravity, large amount of sand was used so to avoid such huge quantities consumption we use magnetite (in case of metal/coal) Now-a-days which has a high specific gravity (We can

obtain fluid of sp gr. 2.8 easily from magnetite.)
For the case of ore, the solid used is Ferro-silicon (84% Fe and 15-16% Si) alloy is used. We can easily maintain a fluid of sp gravity around 3.2. Solid should be 15% or less by weight % age.
Other metals used are Pb (sp. gr. 7.5) which can be used for a liquid of sp. gr = 4. Galena is also used but not preferred because it is soft and will change into fines because of which losses of it will be very high.

**Properties of medium considered for ~~selection~~ selection of solid:-**

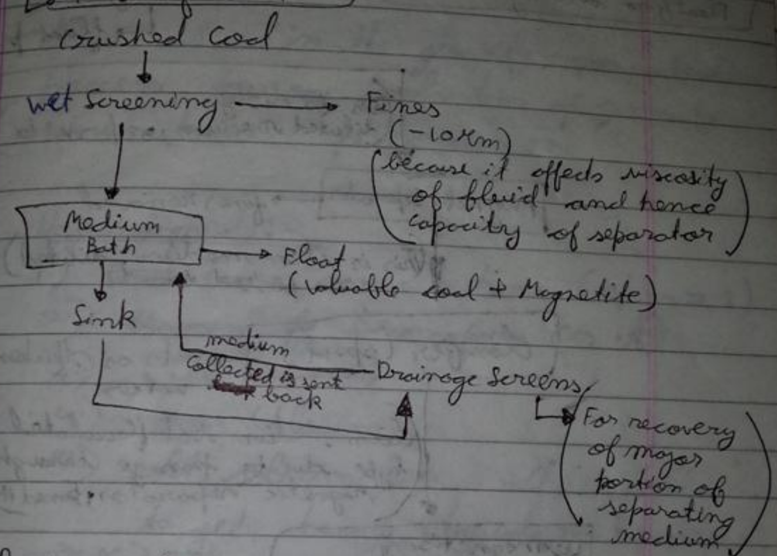
1.) Hardness of solid → Solid should be harder so during the use ~~fo~~ less degradation of medium takes place.
2.) It should be easily available
3.) It should be cheap
4.) High sp gravity media.
5.) Non-reactive and if it is lost in the product, it should not affect quality of product
6.) The media should be easily recovered (the solid is lost during its usage). In case of magnetite, magnetic separation can be used for recovery (it is cheap) but in case of galena, costly froth floatation is used for recovery and while use, galena may be oxidized, which consumes more reagents.

(*) In case of ore, HMS can be used as a pre-concentration. When mining vein type deposits or coarsely aggregated form, we can reject major portion of gangue with minimum amount of losses. By use of HMS for preconcentration, we can save a huge amount of cost of concentration, only a small plant can be for concentration for recovery of same amount of values.

## Steps:-

① Ore has to be properly prepared. There should be no slimes or fines before entering the bath. Washing is done to remove slimes.

### In Case of Coal:-




After Drainage even some medium is left which is removed by washing of float and sink from drainage screen. This medium obtained is dirty, diluted medium containing coal fines and extra water so it has to be cleaned and proper specific gravity has to be reestablished.

## Recovery of Medium By Washing of Float and Sink:-

Sink from drainage Screen $\xrightarrow{\text{water}}$ wet Screening → Sink product

Float from drainage Screen $\xrightarrow{\text{water}}$ wet Screening → float product

→ Media

(This is dirty diluted medium, so passed to)

Magnetic Separator → fines removed

(This is clean medium; diluted) so passed to

Classifier (spiral) → acts as thickener, removes water

(Clean medium but flocculated type due to passage through Magnetic separator, so passed through)

Demagnetising Coil → Causes freeing of the medium

This is the clean medium of required specific gravity which is freed

It is sent back to the medium bath.

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01/04/2014

SR Sir

## Heavy Liquid Test:-

→ Main use is in the gravity concentration process for ~~ea~~ evaluation of gravity concentrator performance.

Heavy liquids:-

1.) ~~Brot~~ Tetra bromo ethane (sp gr = 2.9)
2.) ~~Bromof~~ Bromoform (2.89)
3.) $CCl_4$ (1.5)
4.) ~~Bp~~ Chlorine
5.) Salt solution like $ZnCl_2$, $CaCl_2$ to get heavy liquids can be used.
6.) Toluene (0.84)

Generally organic liquids are preferred one, because inorganic liquids can contaminate the product so the products has to be washed / rinsed to remove the contaminants while organic liquids evaporate after the test is over so no washing is required.

## Information obtained from this test:-

1.) To determine the feasibility of heavy medium separation process on a particular ore

This is a simple lab test to know whether HMS can be adopted for a particular ore or not.

2) To determine the optimum/economic separation density.
3) To assess the efficiency of an existing heavy media circuit ~~separation~~ ~~process~~ by using the simple sink and float test.
4) To examine the suitability of the pre-concentration process before adoption of the main concentration operations.
5) To examine the ~~po~~ washability characteristics of the given coal samples in case of coal preparation.
6) This test can also give the idea about selection of the type of the separation process.

In case of coal preparation → The quality of the coal is fixed depending on requirement of customer (powerplant, blast furnace). The ash content is fixed depending on customer.
1) From the washability characteristics

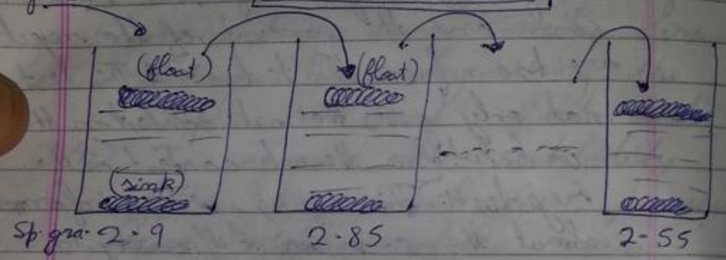
| Sp. gravity fraction |
|---|
| 2.55 / -2.55 |
| 2.60 / -2.60 |
| 2.65 / -2.65 |
| 2.70 / -2.70 |
| 2.75 / -2.75 |

This test gives us the idea what should be the sp. gravity of the medium sho be maintained in the Heavy medium bath to achieved the required ash content in the coal. 2.) On that sp. gravity, what will be the yield of the clean coal and the amount of the rejects are known from this test. 3.) This test not only gives the ash content in the coal but also the ash content in the rejects. 4.) This gives us the information about the ease or difficulty in preparation of coal. Test gives the efficiency of plant performation (separation plant).

| Sp. gravity fraction | % wt. | Cumulative weight % | Assay (% of metal) | Distribution (% of metal) | Cumulative distribution (% of metal) |
|---|---|---|---|---|---|
| 2.55 / -2.55 | 1.57 | 1.57 | 0.003 | 0.04 | 0.04 |
| 2.60 / -2.60 | 9.22 | 10.79 | 0.04 | 0.33 | 0.37 |
| 2.65 / -2.65 | 26.11 | 36.90 | 0.04 | 0.93 | 1.30 |
| | | | | | 2.00 |
| 2.70 / -2.70 | 19.67 | 56.57 | 0.04 | 0.70 | 3.81 |
| | | | | 1.81 | |
| 2.75 / -2.75 | 11.91 | 68.48 | 0.17 | 3.32 | 7.81 |
| 2.80 / | [illegible]0.92 | [illegible] | 0.34 | | |

| | | | | | |
|---|---|---|---|---|---|
| 2.85/-2.85 | 7.87 | 87.27 | 0.37 | 2.60 | 9.73 |
| 2.90/-2.90 | 2.55 | 89.82 | 0.3 | 2.96 | 12.69 |
| +2.90 | 10.18 | 100 | 9.6 | 87.31 | 100 |

**Lab method.**




Given:- Data is for tin ore:

1.) Weigh the ore accurately
2.) Crush the ore below 1 inch size
3.) Take 1 kg of sample and feed the ore to 1st media bath
4.) Float of 1st bath transferred to next bath
5.) So we get a series of products.

**Conclusion** → We get the value distribution in different sp. gravity range

→ What sp. gravity of medium should be maintained to get a particular quality of product

Pr-SP-SP

→ We can decide whether pre-concentration process should be adopted before the main concentration unit.

Suppose we take a liquid of sp. gravity 2.75 then % of float (rejects) is 68.48% and % of sink (values, so it is heavier) is 31.6% approximately and the amount of values lost in the rejects is only 3.8%. so if this amount of loss of value is acceptable then we can go for pre concentration. This reduces 68.48% of the weight forwarded for main concentration process and so our concentration process becomes cheap enough and economic. If this reduction in cost is such that loss of 3.8% of values is acceptable then we opt for HMS process as a preconcentration process with sp-gravity of liquid a 2.75.

02/04/2014

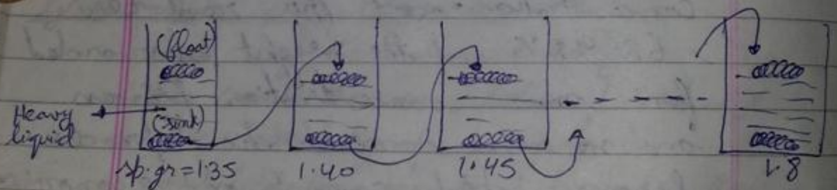
SR Sir

## Washability Characteristics of the coal:-

1.) To design a coal preparation plant
2.) To improve performance of coal washing plant.

This is important for coal because mostly Coal is benificiated by gravity method because it is simple, cheap and easy.

In the lab, simple sink and float test is performed:-




Pure coal specific gravity is 1.3
Select the complete range of sp. ~~Sp~~ gravity covering the entire range from coal to shale with a difference of 0.05. Take 1kg ~~co~~ crushed Coal sample and feed to 1st ~~bath~~ bath.

> NOTE:- As ash content increases the sp. gravity increases.

We require coal of a particular ash content ex> coking coal has ash content 17 to 18%.

In 1st bath → pure coal is obtained as float. Sink is higher density material and transferred to next bath and continue to do so.

⇒ In this way we get a series of floats of different specific gravity.

⇒ Specific gravity of liquid can be maintained by organic liquids and in lower range the liquid is diluted by toluene (sp. gr 0.89)

→ Find the exact weight of floats and the last product (sink). Weigh them accurately after drying.

→ Then find out the ash content in each sample.

Take one gram of sample from each product, ~~crush~~ dry and crush below 60 # size and put it in a crucible and to keep it in a ash furnace, all coal part will burn away in the furnace and the mineral left is the ash which will not burn. The crucible is kept for an hour or so in the furnace at 815°C depending on the quality of coal ~~in the~~ and when the weight ~~remains~~ becomes constant then this is the weight of ash in the sample. Weigh it very accurately.

# WASHABILITY DATA

| 1.) sp. gravity fraction | 2.) wt. % | 3.) ash % | 4.) ash product (Column 2 × Column 3) | Cumulative float: 5.) ash | Cumulative float: 6.) weight % | Cumulative float: 7.) ash % (column 5/column 6) | Cumulative Sink: 8.) ash | Cumulative Sink: 9.) weight % | Cumulative Sink: 10.) ash % (column 8/column 9) | 11.) ± 0.1 sp. gravity material | 12.) Ordinate (D) = a + b/2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| -1.35 | 44.2 | 4.3 | 190 | 190 | 44.2 | 4.3 | 1498 | 100 | 15.0 | — | a=0 22.1 |
| -1.40 | 24.2 | 9.6 | 232 | 422 | 68.4 | 6.2 | 1308 | 55.8 | 23.4 | — | 56.3 |
| -1.45 | 11.4 | 16.2 | 185 | 607 | 79.8 | 7.6 | 1076 | 31.6 | 34.1 | 45.5 | a=68.4 b=11.4 |
| -1.50 | 6.0 | 23.7 | 142 | 749 | 85.8 | 8.7 | 891 | 20.2 | 44.1 | 23.3 | 82.8 |
| -1.55 | 3.9 | 30.3 | 118 | 867 | 89.7 | 9.7 | 749 | 14.2 | 52.7 | 13.0 | 87.8 |
| -1.60 | 2.0 | 37.6 | 75 | 942 | 91.7 | 10.3 | 631 | 10.3 | 61.3 | 7.4 | 90.7 |
| -1.70 | 1.5 | 43.3 | 65 | 1007 | 93.2 | 10.8 | 556 | 8.3 | 67.0 | 1.4 | 92.5 |
| -1.90 | 1.4 | 53.1 | 74 | 1081 | 94.6 | 11.4 | 491 | 6.8 | 72.2 | — | 93.9 |
| +1.90 | 5.4 | 77.3 | 417 | 1498 | 100 | 15.0 | 417 | 5.4 | 77.2 | — | 97.3 |

a = Cumulative float wt % down to sp gravity being considered

b = wt % of material in gravity fraction considered

Column 6.

ex) Sp. gravity is 1·45 :-
Material on 1·45 + 0·1 = 1·55 → 89·7
Material on 1·45 − 0·1 = 1·35 → 44·2

Material ±0·1 at 1·45 = 89·7 − 44·2
= 45·5%

03/04/2014.

SR Sir

5 important curves are drawn for washability analysis:-

(i) yield curve [yield-specific gravity curve] - It is a plot of "cumulative float weight percent" against 'specific gravity' i.e. column 6 vs column 1

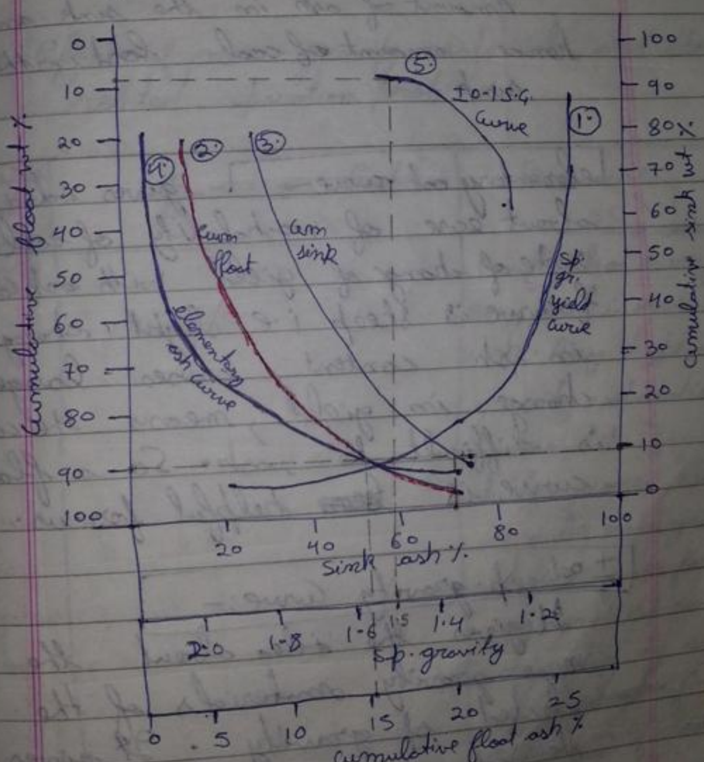
(ii) Cumulative float curve [cumulative float-ash curve] - It is a plot of "cumulative float" vs "ash percent" i.e. column 6 vs column 7

(iii) Cumulative sink [cumulative sink-ash curve] - It is a plot of "cumulative sink wt. percent" vs "cumulative sink ash%" i.e. column 9 vs column 10.

(iv) elementary ash curve - It the plot between the ordinate "D" vs ash percent (direct)" i.e. column 4

(v) ± 0·1 sp. gravity distribution curve — It is the curve of "± 0·1 value" vs "Cumulate float wt. percent" corresponding to sp. gravity i.e. column 11 vs column 1

**Importance of each:—**



yield curve → To take maximum yield of required quality what should be the sp. gravity of the liquid.

Cumulative float-ash →
we get amount of cleans (float)

Cumulative sink-ash →
Amount of ash in the sink and hence amount of coal lost in the sink.

Elementary ash curve → gives idea about ease of washability of coal i.e. rate of change of yield with ash content. If curve is steep i.e. slight change in ash content causes large change in yield, means the coal is difficult to wash. So a flat curve is ~~[illegible]~~ helpful for us.

±0.1 sp. gravity curve:-
It gives the idea about the near gravity materials of the selected sp. gravity. It gives the idea of the midding. If the coal is fully liberated [coal (1.3) and shale (1.7)] then we can get separation of coal very easily. But if coal has lots of

inherent ash which is in finely dissiminated form then crushing cannot fully liberate the coal so large amount of midlings are formed. These midlings are near gravity material having sp. gravity close to sp. gravity of liquid used (generally 1.5).

Table:- Effect of near-gravity materials and the related separation problems:-

| wt. % within ±0.1 sp. gravity (near-gravity materials) | Separation Problem | Remarks |
| --- | --- | --- |
| 0 - 7 | simple | Beneficiation is very easy, coal is easier to wash. Any type of gravity separation process like jigs, tables, cones, spirals can be employed. Choice goes for jigs and spirals depending on size of ~~product~~ feed. Spirals → If coal has lot of fines. Jigs → If ~~product~~ feed is coarser size |

| | | |
|---|---|---|
| 7–10 | Moderately difficult | HMS is costly so simple, cheaper process should be adopted. |
| 10–15 | difficult coal | Even this coal can be treated by all process depending on size of feed [ Jigs, spirals, cones, etc ] |
| 15–20 | very difficult | HMS process is used. It is efficient because we can maintain a fixed sp. gra. of liquid for a longer time. In other processes the loss of coal is very high |
| 20–25 | exceedingly difficult | Only solution is HMS but with proper automation the operating variables have to be controlled. |

| | | |
|---|---|---|
| 72.5% | formidable (very-very difficult) | More sophisticated control measure are to be opted to get maximum yield |

Q) Why Indian coal is most difficult coal to wash??

Ans) After crushing we get very high near gravity materials.

Coal Beneficiation Practice in Indian Industry:-

Coal contains coaly matter and mineral matter (converted to ash). Indian coal is one of the most difficult coal from washing point of view. We use HMS process as the only process for benefitiation.

In general HMS process is costly.

Impurities in coal

- intrinsic form (locked during formation of coal, finely disseminated form needs ~~crushing~~ grinding to separate efficiently but grinding is costly, only crushing is done.
- extrinsic form (free form mixed during process)

Metallurgical plants use coking coal [with ash content 17-18%].
If ash content increases then more coke is required for production of unit weight of metal so production cost increases so quality has to be strictly followed.
Our ROM coking coal contains roughly 35-40% which cannot be used unless ash content is reduced.

⇒ Non-coking coal is cheap so its benefeciation should also be cheap.

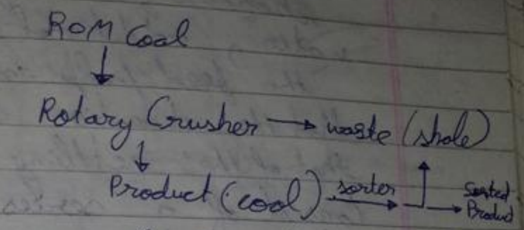
→ Benefeciation of non-coking coal:- ←

advantages of use of beneficiated non-coking coal by power plants:-

1.) energy content of coal increases so less amount of coal consumed
2.) fly ash generation is lower so environmental problem is less
3.) Handling of waste is easier
4.) Maintainance of machines is lower

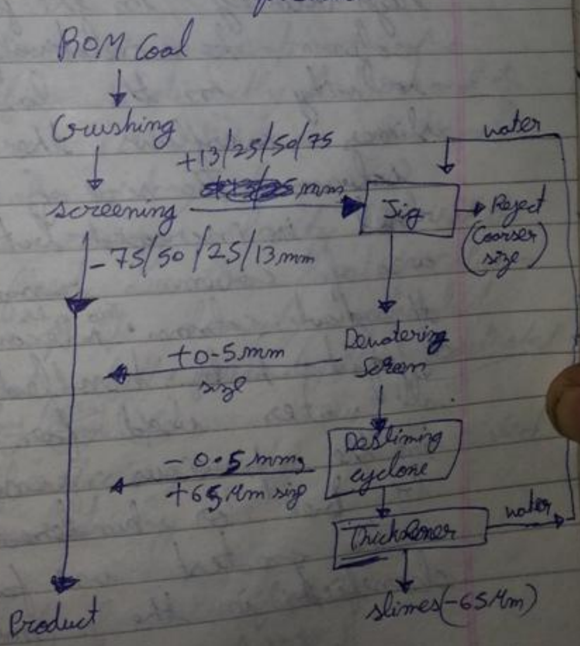
(*) If power plant is at mine site

then ~~to~~ it can ~~be~~ use ROM directly or a simple benefeciation process can be adopted :-




Product can further be passed through a mechanised sorter also to further reduce ash content.

(4) General benefication process where ash content requirement is about 34%



09/04/2014.

SR Sir :-

**Coking Coal Beneficiation:**

→ essential because of the requirement of a particular quality of the coal.

→ In the Blast furnace, ash content should ~~not be less than~~ be around 17 - 18%.

Indian washeries can be divided into 3 main groups:-

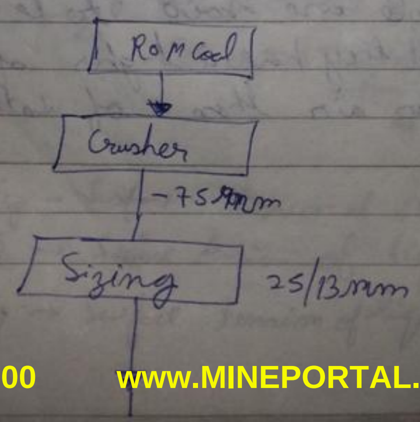
(i) where the coal is slightly easy to wash or moderately difficult

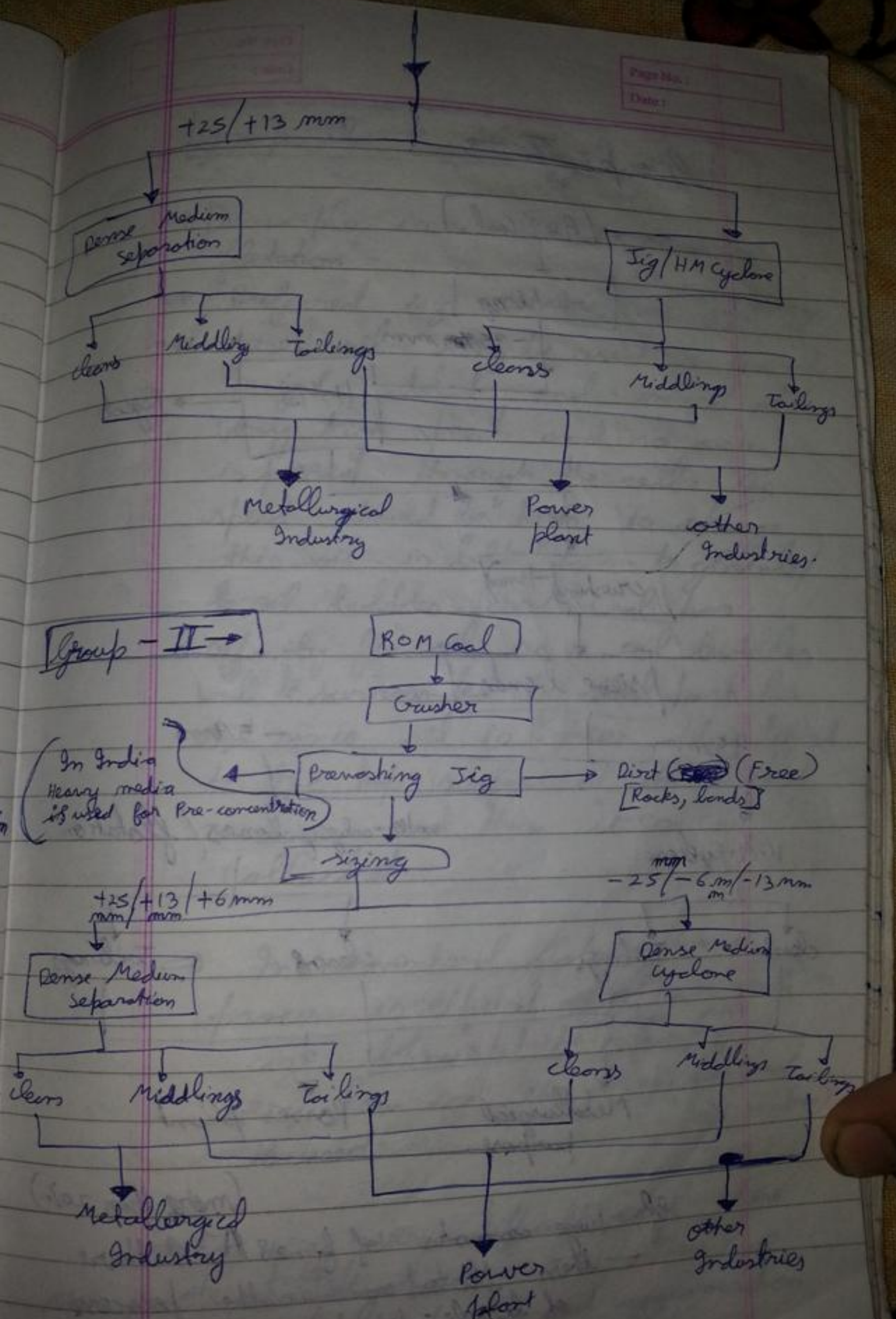
(ii) difficult coal is washed

(iii) Very - Very difficult coal

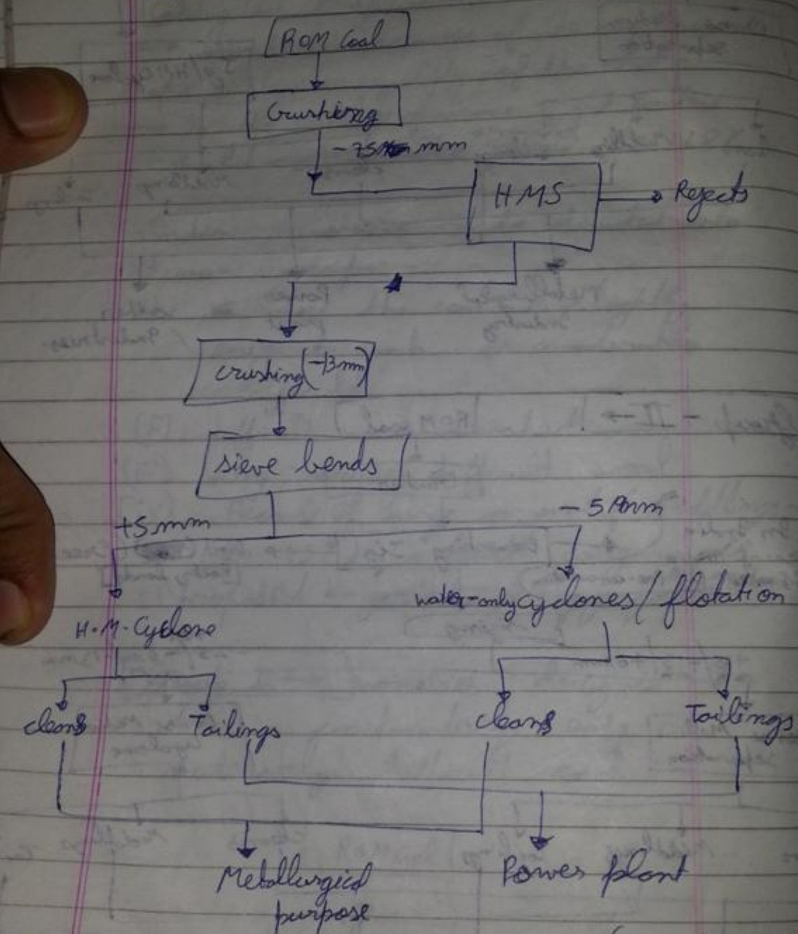
(iv) Because of large amount of middlings (40 - 45%), a fourth category ~~is~~ proposed — ~~geotechnical aggregation~~ oil agglomeration

**Group I** → washeries designed to treat comparatively easy or moderately difficult coal :-




+25/+13 mm
Dense Medium separation
Jig/HM Cyclone
cleans
Middlings
Tailings
cleans
Middlings
Tailings
Metallurgical Industry
Power plant
other Industries.
Group - II →
ROM Coal
Crusher
Prewashing Jig
Dirt (Free)
[Rocks, lands]
In India Heavy media is used for Pre-concentration
sizing
+25 mm/+13 mm/+6 mm
-25 mm/-6 mm/-13 mm
Dense Medium separation
Dense Medium cyclone
cleans
Middlings
Tailings
cleans
Middlings
Tailings
Metallurgical Industry
Power plant
other Industries

Group - III →




If huge amounts of fines (more than 20%) is there — then flotation is the process of beneficiation

Group - IV → oil agglomeration

⇒ Principle is similar to that of flotation.

⇒ Preferred size — ~~(...)~~ upto zero size range

⇒ diesel oil may be used or Pine oil may be added and mixed at very high speed and no air is passed through the cell. The speed should be high to change this oil in bulk form to globule/ & oil bubbles form. Coal has affinity for oil so oil bubbles will be surrounded by coal particles and since oil is lighter, it is lifted to the top surface of the liquid medium and then it can be collected.

⇒ In conventional flotation → the process is efficient ~~(...)~~ for 200 - 350 μm size below which and above which recovery is very low so the above method (agglomeration) is used.

⇒ For very - very difficult coal where near gravity particles ~~(...)~~ are 30-35% then we should opt for jig and agglomeration together.

The coarses is treated by jig and the wastes are reduced in size (below 100 $\mu m$) and then go for oil agglomeration process. The coal from jig can be of the quality with 20% ash (because recovery is poor below this ash level) and then the coal from oil agglomeration will be of the quality around, 10% ash and then blend the coal from the 2 processes to get coal of required quality with around 17% ash.

10/04/2014.

SR Sir

Plant Practices:-

Operating steps and sequence of operation:-

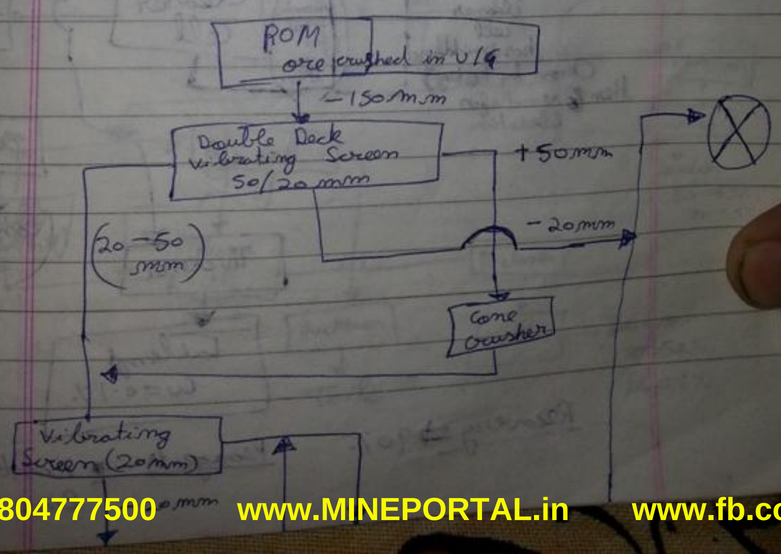
1.) Crushing or Size Reduction Section
- Consistings of grinding mills and size control by screens.

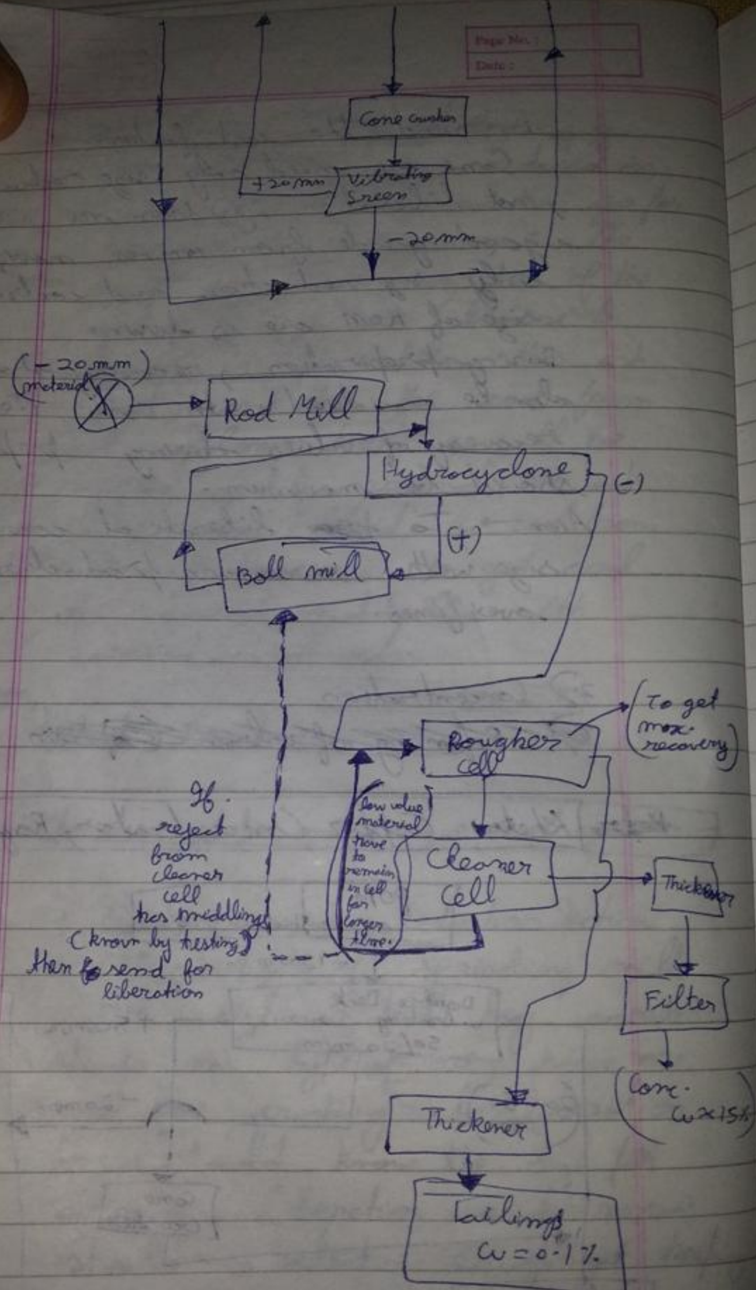
Depends on type of ore, some ore need fine crushing for liberation. So we should know the size for optimum liberation and so we should select equipment keeping

in mind the cost factor.
Some ore need only size reduction, not liberation eg.) iron ore, we have a good grade from mines now, so only size reduction and control of size of ROM ore is done.
During preparation, recovery should also be considered with cost. The recovery of values during preparation should be maximum.
Aim → To ~~free~~ liberate at coarser size with minimum production of over fines.

2.) Concentration
~~Refining of values Caption~~

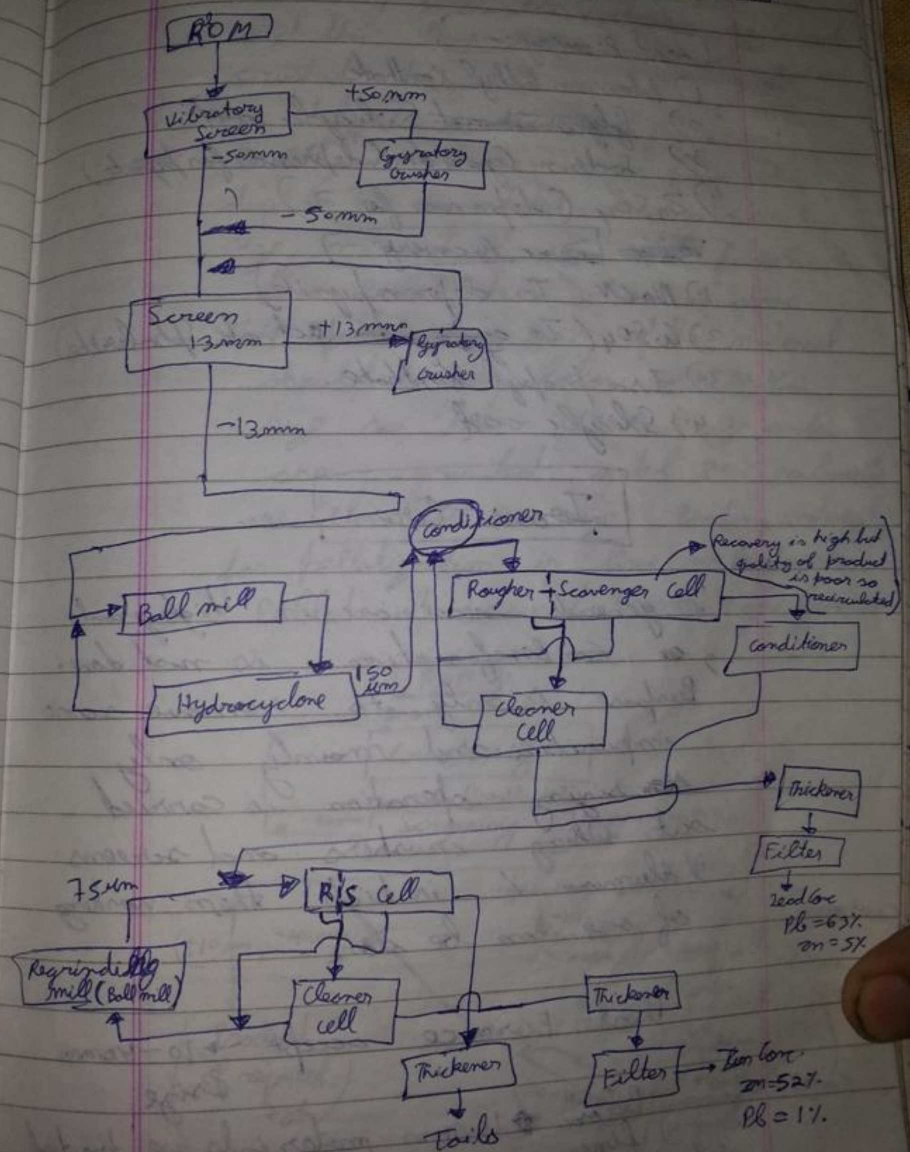
~~Kstr~~ Khetri Copper Concentrator, Rajasthan:-






Recovery ⇒ 90%. Reagents → Xanthate
Pine oil

Lead-Zinc Ore → Jawar mines



Differential flotation:- → (float one value at a time)

Lead Recovery:-

1.) Potassium Ethyl Xanthate
2.) ~~Glycoric acid~~ Silicylic acid
3.) Sodium Cyanide (depressor for pyrite)
4.) $ZnSO_4$ (depressor for Zn)

~~Zinc~~ Zinc Recovery:-

1.) NaCN (To depress pyrite)
2.) $CuSO_4$ (To ~~aggregate~~ activate Sphalerite)
3.) Iso-propyl Xanthate
4.) Silicylic acid

Iron - Ore

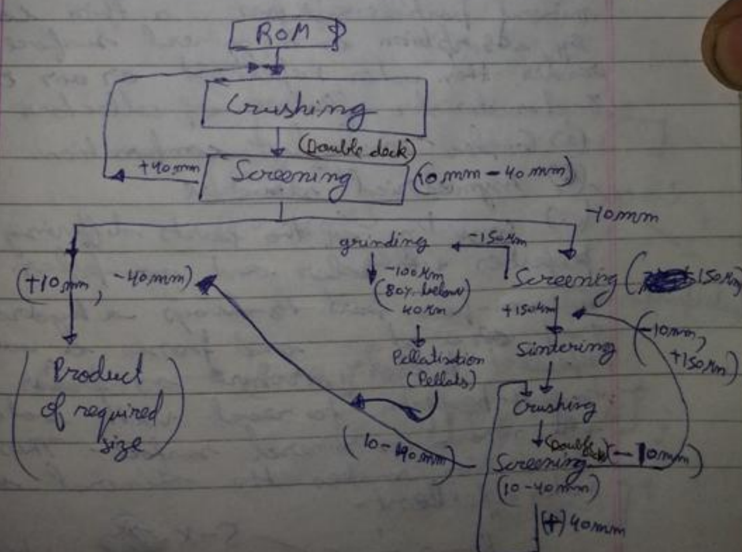
In general since ore is high grade, Beneficiation is not done. Purpose is only to remove some impurities and mainly only sizing operation is carried out using crushers and screens. If Alumina % is high then washing of ore can be done.

Blast Furnace accept → 10-40mm size

Below 10 mm materials are treated fines

~~From 10 to 150~~ Upto 150 μm size, material are sent to sintering plant, the materials agglomerate and then these bigger sizes are again crushed to get (10-40 mm) size to be utilized in the Blast furnace.

→ All iron ore mines have blue dust (70% Haematite) having < 40 μm size and lot of iron ore fines < 150 μm then Pellatization of ore is done. For pellatization 80% of the material should be below 40 μm size so below 150 μm size materials are reground until 80% materials are below 40 μm size. Binding material for pellatization is lime or Bentonite. Pellets of around 40mm are formed.



Q:) Feed preparation for gravity Concentration is necessary, why??

Ans) 1.) Comminution is important for proper liberation of the values. Without proper liberation, efficiency of separation remain low.

~~2) Primary can be done by rod mills~~

2.) In case of fine liberation sizes, the necessity of secondary crushers arise. It should be carried out by ball mills closed with screen to avoid excessive over-grinding resulting in fines. Because fines reduce the efficiency and sharpness of separation by gravity method to a large extent.

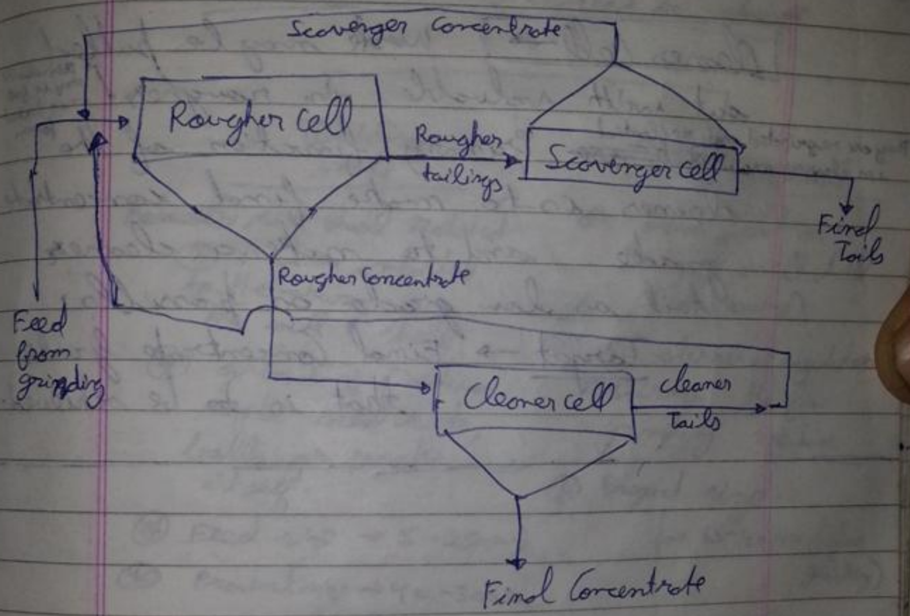
3.) Gravity separators are extremely sensitive to slimes, which increase the viscosity of the slurry and hence reduce sharpness of separation and obscure visual cut-points. ex) For de-sliming, hydrocyclones or hydraulic classifiers can be used.

4.) By screening the feed the size variable can be removed, and density variable accentuated and so the success of gravity method can be ~~need~~ felt.
eg.) The feed to jigs, cones, spirals should ~~if pos~~ be screened before separation and each fraction should be treated separately or else light big particles are not efficiently separated from heavy small particles.

5.) One of the most important aspects of gravity methods is correct water balance within the plant. Almost all gravity concentrators have an optimum feed pulp density, and relatively little deviation from this density causes rapid decline in efficiency. Accurate pulp density control is essentiale
eg.) Hydrocyclones or thickeners may be used to maintain correct feed pulp density.

... of the limiting reduction ratio by the presence of a small portion of coarse slabby material.

## Role of Rougher - Scavenger cell:-




Rougher Cell → Primary function is to make a tail as low grade as possible with a concentrate grade that is acceptable to the cleaner circuit

Target → Trade off between concentrate grade and recovery.

**Scavenger cell →** Last chance ~~for~~ to recover values before the pulp leaves the concentrator. It is highly reagentized and so concentrate is pulled off much faster ~~rate~~ than in roughers.

Primary function of scavenger ~~Primary function~~ ~~R.o.f.~~ cells is to make a final tail as low grade as possible.

<u>Target</u> → Maximize recovery

**Cleaner Cell →** Waste may be pulled out with valuable in roughers. This valuable may be free or in locked form.

They are reground and refloated in cleaner circuit ~~which are~~. Primary function of the cleaner is to make final concentrate grade and to make a cleaner tail as low grade as possible.

<u>Target</u> → Final Concentrate grade that is to be achieved.

IMPORTANT NOTES

## Jig:-

→ Oldest method of gravity concentration suitable for coarser particles from size (10 mm to 50 mm). It can also treat upto 0.5 mm.

→ Performance of Jig is influenced by:-

screening is done to divide feed into categories

1.) closeness of particle size (Particles should have a closed-size range)
2.) Effectively treats even if sp. gra. difference is very less (0.5 difference)
3.) Suitable for treatment of coal, Pb, Au, Sn, Mn etc.

→ Major Problem in jig is caused by presence of slimes → they effect capacity of jig, separation quality, etc.

**Advantages of Jig:-**

- Simple
- Cheaper
- For a given size, its capacity is high

HMS is efficient but it is costly so Jig is preferred.

**IMPORTANT NOTES**

→ Major Components of jigs:-

1.) Screen → may be fixed or movable screen
2.) Hutch → space below the screen which helps in Collection of Concentrate
3.) Ragging material → above the Screen we put few layers of heavy coarser minerals or steel/nickel shots etc.
4.) water → Introducing the water in the hutch area in addition to the water which is available in the feed slurry.
5.) Providing the motion/pulses to the water. (diaphragm or plunger is there)

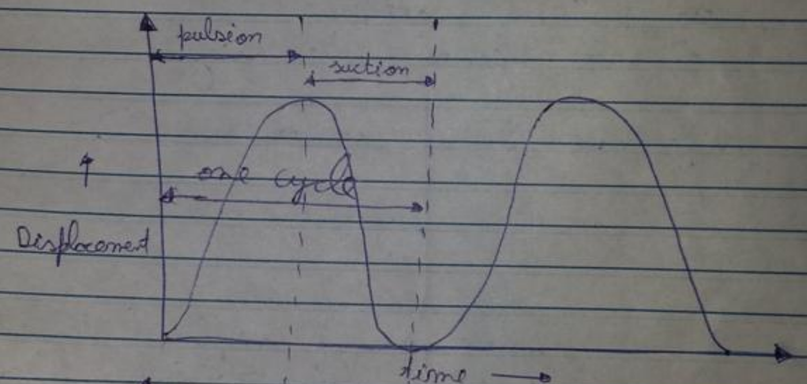
Principle :-

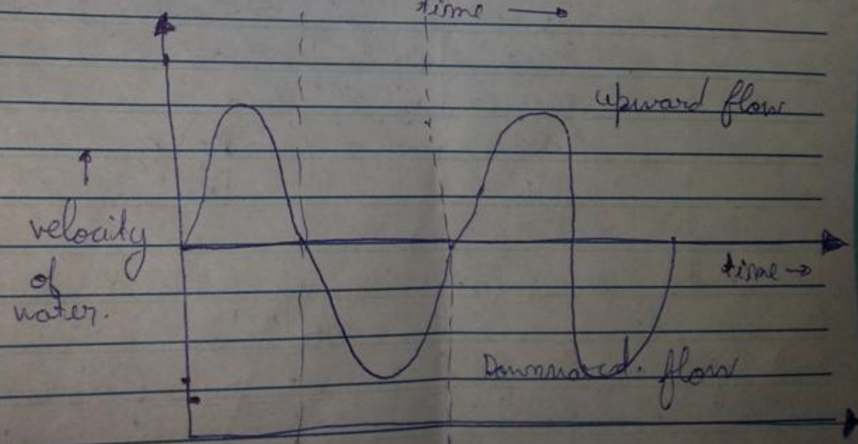
→ minerals of different sp. gr. are separated by a pulsating current of water which dilates the materials and allows them to settle so as to cause a clear stratification.

**IMPORTANT NOTES**

Frequency of pulsion and suction:-
50 - 300 cycles/min.

$\boxed{\text{Movement of plunger:-}}$



**IMPORTANT NOTES**

Settling of particles is based on 3 phenomenon :-

1) Differential Initial acceleration
2) Hindered Settling
3) Consolidation Trickling.

Differential Initial acceleration :-

$$m \frac{dx}{dt} = mg - m'g - D$$

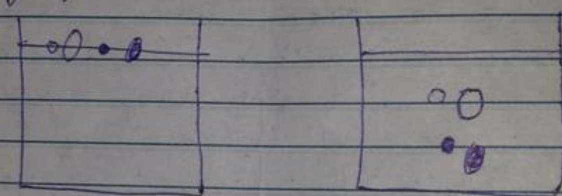
$m \rightarrow$ mass of solid
$m' \rightarrow$ mass of displaced liquid.
$D \rightarrow$ Drag force $= 0$ initially at start of motion
$x \rightarrow$ velocity of particle.
$D_f \rightarrow$ Density of fluid

$$\frac{dx}{dt} = accel = \left(1 - \frac{D_f}{D_s}\right) g$$

⇒ Initial acceleration of particle depend on density only and not on size; so if duration of fall is short and frequency of cycle is very high then settling

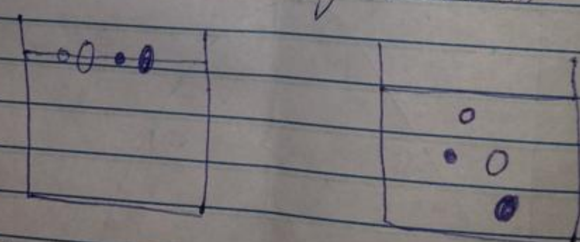
IMPORTANT NOTES

of particles depends on initial acceleration only. So if a short high frequency jigging cycle is operated then small heavy particles will be separated from big lighter particles.



**Hindered Settling:-**

After sufficient time of settling, the particles fall with their terminal velocities in a hindered settling condition.

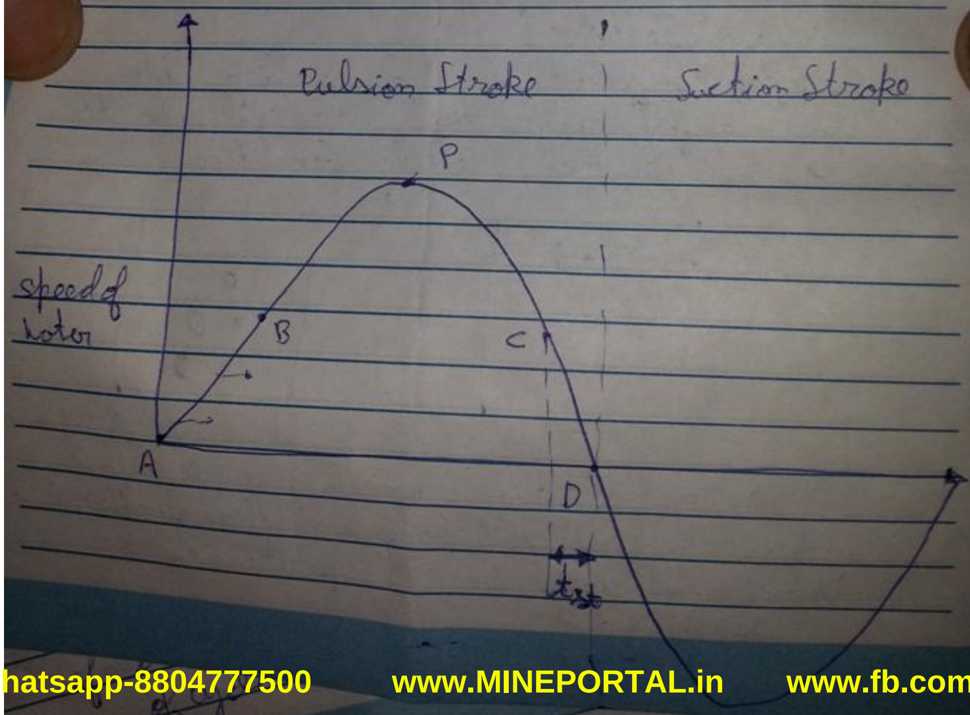


Hindered Settling has a marked effect when there is long and slow strokes are there and help in separation of coarser particles.

IMPORTANT NOTES

Consolidation trickling:-

At the end of pulsion stroke, the bed of coarser materials interlock and form a bed and the smaller heavier particles trickle through the interstices of the ~~heavy~~ Coarser particles due to gravity. If consolidation trickling lasts for long enough then efficiency of recovery of smaller heavier particles is improved.



**IMPORTANT NOTES**

~~At B~~ From A to B → Bed of material is loosened.

From B to P ~~to~~ C → The materials dilate in an upward flow of fluid. Lighter material report to tailings by overflowing.

At C → Coarser heavier material begin to settle

From C to D → Settling of particles takes place.
Time of settling = $t_{st}$

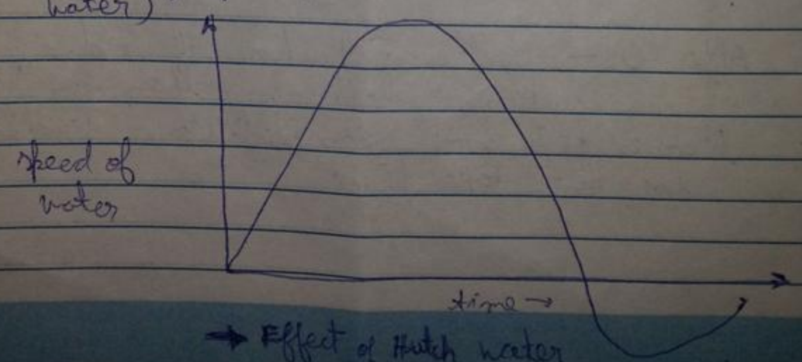
At D → Compaction of bed starts and Consolidation trickling takes place

After D → Full compaction of bed, if suction cycle is long then ~~con~~ bed becomes tight and consolidation trickling does not take place.

## IMPORTANT NOTES

If the pulsion cycle = suction cycle then consolidation trickling is not allowed because bed becomes tightly packed.

But if Hutch water is introduced from below (a constant volume of water with upward flow) then the suction cycle is reduced (it can be eliminated as well) and the pulsion stroke becomes longer and slower. Due to reduction of suction stroke, severe compaction of bed is avoided and consolidation trickling is favoured. But loss of fines is increased due to longer pulsion and higher peak velocity of pulsion water (due to hutch water)



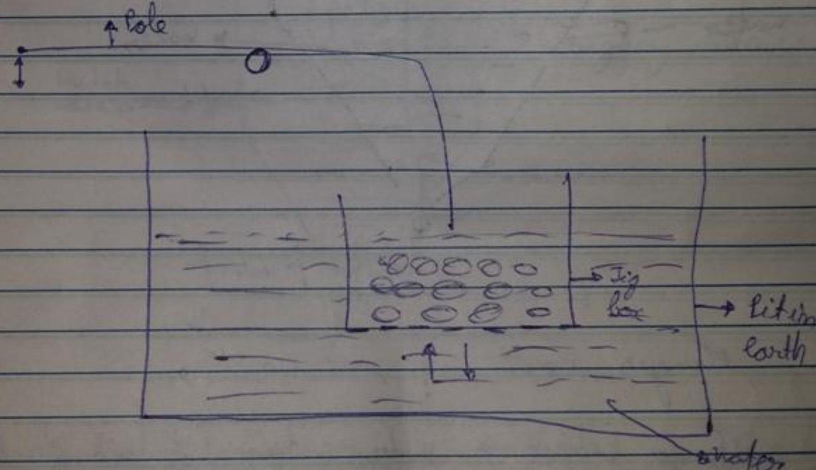

→ Effect of Hutch water

IMPORTANT NOTES

NOTE:-

If peak velocity is too high then the lighter particles report to tailings but separation of heavy smaller particles from lighter larger particles is not possible

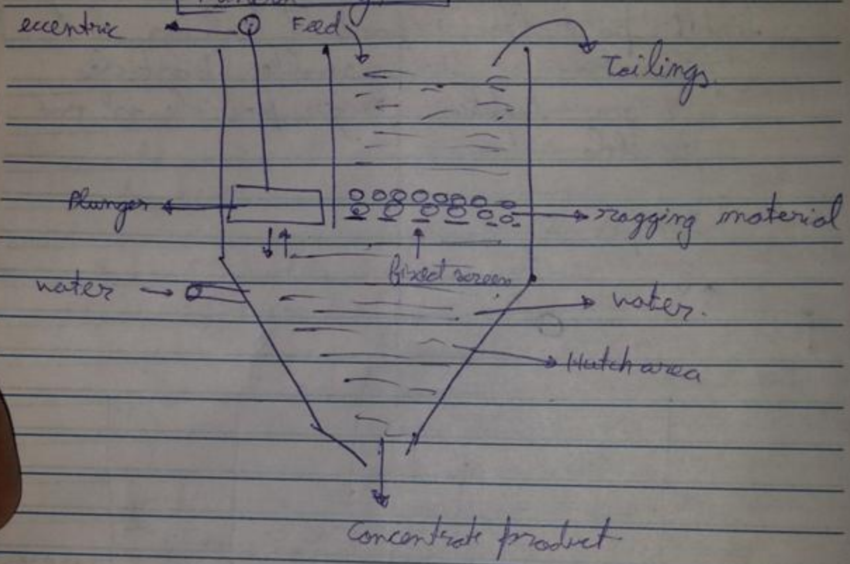
Simple Jig:-




Raising and lowering of Jig box causes pulsion and suction resulting in separation.

**IMPORTANT NOTES**

Mineral Jig:-




Plunger moves up and down.

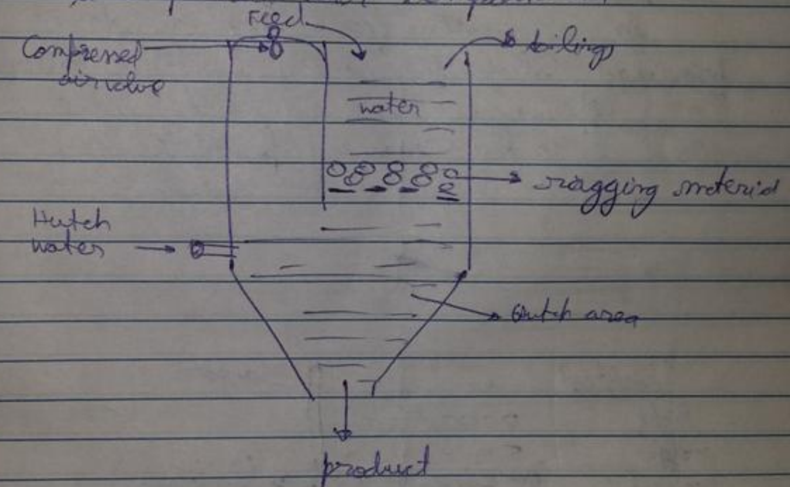
plunger moves { down → water enters (pulsion stroke)
up → water sucked out (suction stroke)

Feed    Recovery = 85-90%.

IMPORTANT NOTES

Coal Jig (Baum Jig)

Pulsion and suction strokes provided by a compressed air compartment.



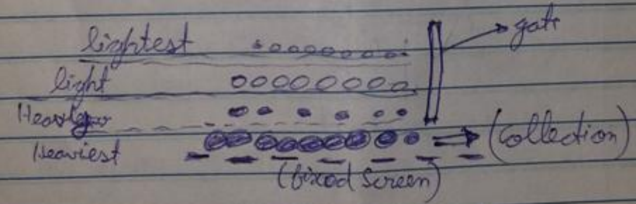

Batac Jig → Jigs are wider so single entry of compressed air does not provide uniform pulses and suction so separation of fines is affected so in place of single entry, multiple entries of compressed air is there at regular intervals.

IMPORTANT NOTES

## Collection of Concentrate:-

1.) Through the screen → if feed size is small

2.) Above the screen → if screen is smaller in size than feed then a gate is provided above the screen with a bottom opening. As more and more feed enter, the heaviest particles are tapped off over the screen.

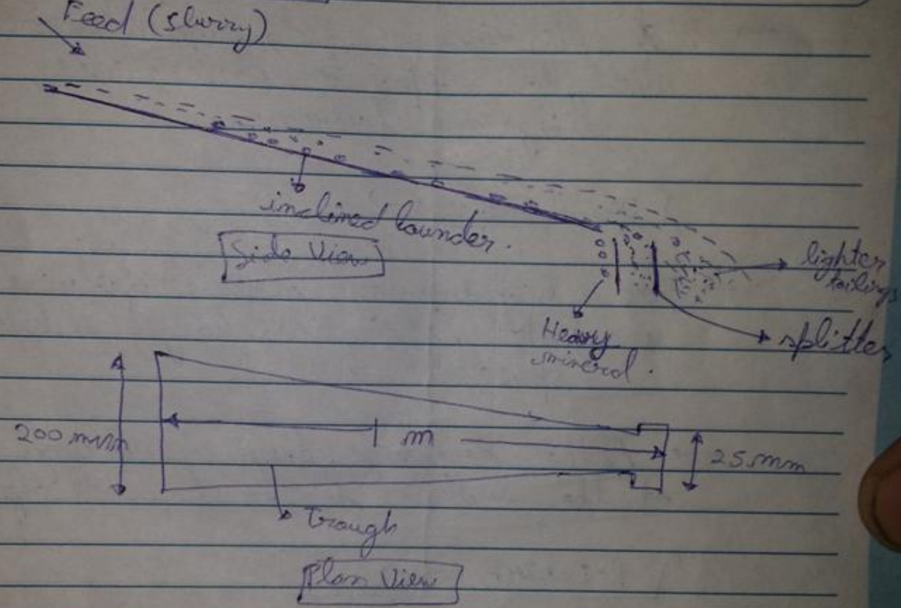



## Use Of Ragging Material:-

→ Provides an immobile bed of coarser material which ~~to~~ keep the bed loosened and provide interstitial space for small heavy particles to trickle during consolidation of bed.

IMPORTANT NOTES

Pinched Sluice:-




→ Suitable for fine particles like Beach Sand ~~etc~~, tin ore, etc.

→ As the feed slurry is fed onto the incline, stratification takes place heavier particles settle while lighter overflow.

IMPORTANT NOTES

→ At the discharge end, splitters are used to separate concentrate, midlings and tailings.

Disadvantages:-

→ For a high capacity a series of sluices are kept so requires larger installation space.

→ At the discharge, there is mixing at the walls due to the wall effect.

Reichert Cone:-

→ Suitable for size range (100 μm - 3 mm)

→ Suitable for ores like beach sand, Haematite, coal etc.

**IMPORTANT NOTES**

Feed = 50 - 65% solid by wt.

Capacity = 65-100 t/h

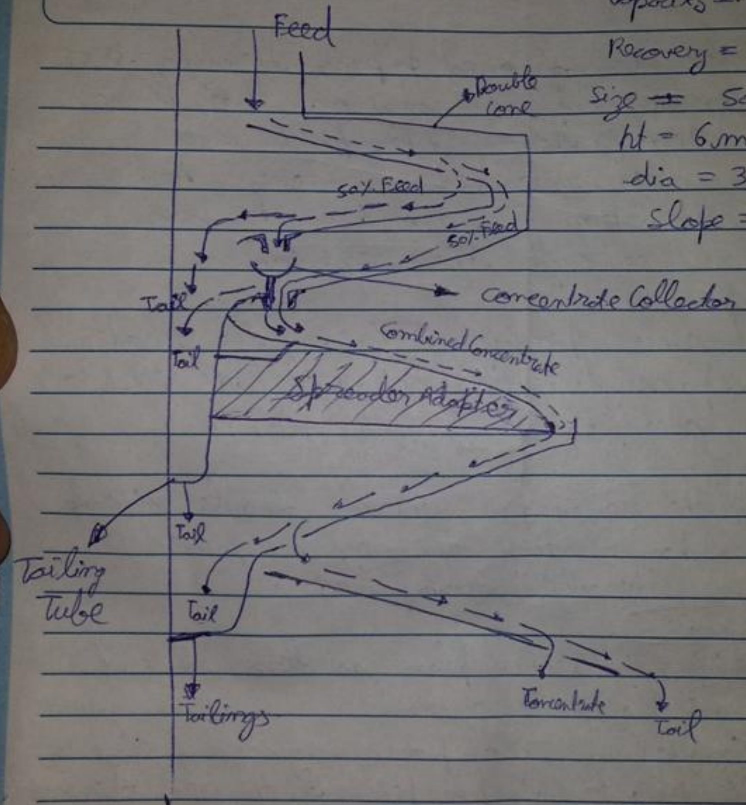
Recovery = 85-90%.

Size = 50 µm - 600 µm

ht = 6 m

dia = 3 m

Slope = 17°



## IMPORTANT NOTES

→ Materials allowed to pass through inclined plane and on that plane stratification takes place and concentrated material is in the bottom and allowed to pass through the next cone.

→ At each opening 50% of the material passes through it and the rest 50% overflows.

→ If the tailings contain valuable minerals then they are again passed through another cone.

$\boxed{\text{Advantages:-}}$

1.) It is in the vertical plane so lesser space of installation is required

2.) Simple and no power required, only the feed has to be pumped to the feed opening at the top.

3.) Effective and high recovery of 85-90%

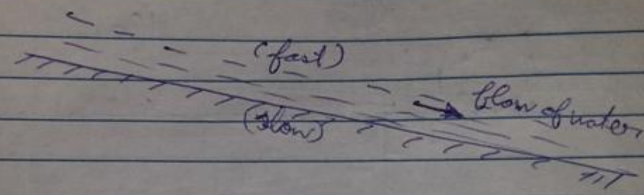
4.) High Capacity

5.) Environment friendly

6.) Since there is ~~not~~ no wall effect so mixing is less

IMPORTANT NOTES

~~Wilfley~~ Tables:- → (efficient for fines)




→ Water layers in contact with the deck move at lower speeds that water layers at the top. So smaller particles moves slowly and larger move at a faster rate.

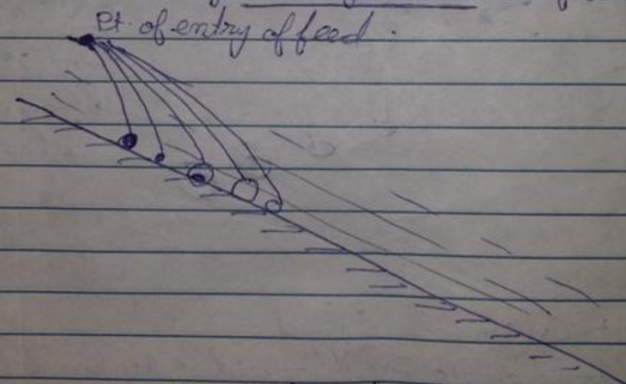



FIG → Heavy particles falls rapidly hence they are drifted less

**IMPORTANT NOTES**

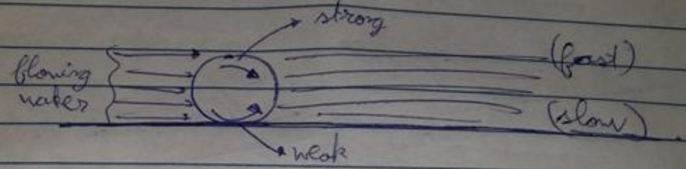



FIG → Effect of various forces of flowing water. -

→ Also Heavier moves slowly while lighter moves faster.

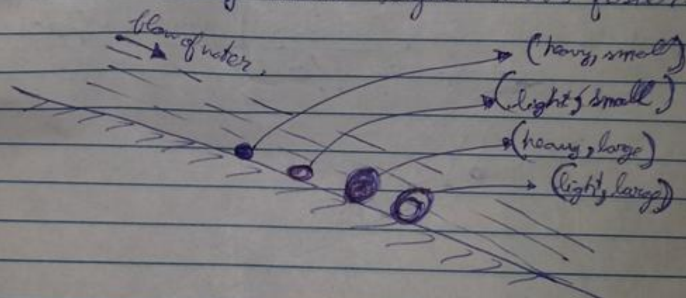



FIG → Combined Effect.

→ Tables are based on the above concept. They have a longitudinal motion and wash water flows across the tables. Each particle has 2 components of ~~forces~~ motion :- (i) due to longitudinal motion, it moves forward while (ii) in a ⊥r direction a velocity is imparted due to the wash water flow. Hence the resultant motion of particle is in the diagonal direction from the feed end to the concentrate corner. As the particles move diagonally, they fan out and the various sized materials are collected at the various discharge ends of the table. But this separation phenomenon of flowing fluid requires a single layer of the feed. This is not practically possible so a wilfrey table with riffles is used for multilayered feed. Vertical stratification takes place between the riffles and various layers are washed out to different locations at the edges of the table as the material moves forward due to the longitudinal strokes of the table.

IMPORTANT NOTES

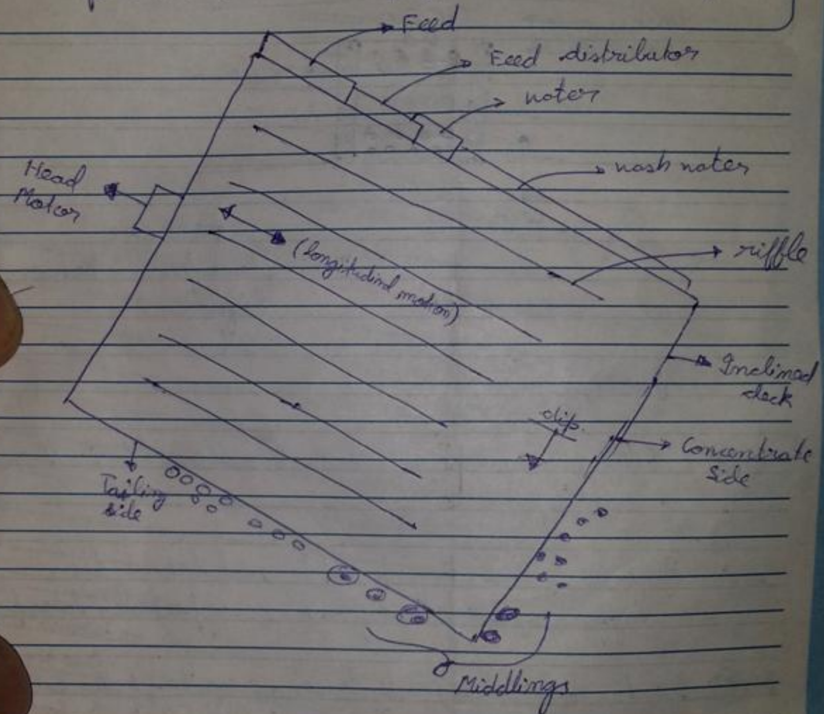
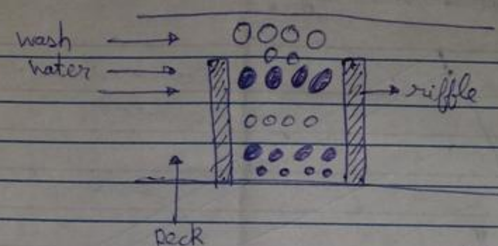



FIG:- Wilfrey Table

IMPORTANT NOTES

## Wilfrey Table:-




VERTICAL
FIG:- Stratification Between Riffles

**Working:-**

* Riffles are tapering towards one end (i.e. Their height decreases)

* Riffles have certain height and behind the riffles, ~~the~~ stratification of particles takes place

* Due to the longitudinal movement of the Tables the particles move forward along the riffles and are spreaded between the riffles.
As the height of riffles decreases continuously, the lighter materials are washed by the overflowing wash water and report to the tailings While the heavier particles continue to move in the longitudinal direction and report to the Concentrate side.