Extraction Material and Powder Technology

First year

Material science branch

Applied science department

By

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Extraction material and powder technology

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- Extraction of metals from Halides (U, Pu, Th)
- Precious metals (Au, Ag, Pt)
- Powder technology

References

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- "استخلاص المعادن الحديديه واللاحديديه" ا.م.د. ابراهيم محمد منصور و م نوال عزت عبد اللطيف
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Extractive metallurgy

Introduction

The history of man can be broadly classified into three divisions, namely:

1- **The Stone Age**: where the old man used the non-metallic material like stone and quartz to manufacture his own tools like cutting tools, weapons and for making fire.
2- **The bronze age**: the transition from the stone age to metal age brought about the discover of the copper in around 8000 B.C.-can be consider one of the most significant phases of human history. The copper age was followed by the bronze age as it was discovered that by adding the Arsenic to copper and to tin will increase the mechanical properties of copper around 4000B.C.and this was the beginning of bronze age. The bronze was used in huge quantity to manufacture special tools beside its use in manufacturing weapons.
3- **The Iron Age**: the iron metal was faster oxides by appearing free with air and humidity, so it is appear in nature as oxide which means that too much processing should be made to get it; like melting in high temperature. That was the reason for its late discovery till 3000B.C.
   The Iron Age was very important as its extension to our age.

The precious metals (silver &gold) was known earlier in the 12000B.C.,but its use was limited to jewels and commercial aspects.

-from 1700-1800D.C. new metals were discovered

(Co, Pt, Zn, Ni, Bi, Mn, Mo, Te, Wu, Zr, Ti, Be, Cr)-

_from 1800_1900D.C. another metals were discovered like (Ta, Os, Pa, Ph, K, Na, Ba, Ca, Mg, Sr, Ce, Li, Cd, Se, Si, Al, Th, V, La, Ra, Rb, In, Ac, Po, Ir)

Source of metals

Three main sources of metals and their compounds are the earth's crust, the sea, and scrap metal, the most important one being the earth's crust. The sea, which cover more than 70 %of the earth surface, contain, on an average, 3.5%of dissolved solids. In the future, metal could be extracted by deliberately cultivating specific marine organisms which would concentrate one or more elements within their bodies by inherent biological activity. In addition, metal are also found in deposit of nodules which cover large areas of the sea floor.

Finally, scrap metal is becoming increasingly important, and a freely available source of metal in view of the rapid industrial growth all over the world. (The metal recovered from scrap metal are called *secondary metals*), infect we may envisage situation where metal manufacturing processes would virtually refine and recycle increasingly huge quantities of metals which are periodically used and discarded. For instance, in current steel- making processes a significant portion of the "charge" consists of scrap metal.

1-Earth's crust

The most common element in the nature that is representing in the earth's crust are formed from molten rock (magmas). Magmas are the source of the igneous rock, which is represent the organs of other type of rocks. From these rocks the earths crust are formed with a thickness about (33 km).

The rock that formed the earth crust can be classified into three types:

1- **Igneous rock**: is formed through the cooling and solidification of magma.
2- **Sedimentary rock**: is a type of rock that is formed by sedimentation disintegration of material at the Earth's surface and within bodies of water. The disintegration occurs by withering or corrosion.
3- **Metamorphic minerals**: are those that form only at the high temperatures and pressures associated with the process of metamorphism. These minerals, known as **index minerals**

Table 1 lists the relative abundance of the 45 most prevalent elements in the earth's crust. The first (8) elements account for more than (98 %); of which nearly (75 %) is composed of only two elements, oxygen and silicon.

2- Sea as source of metals

Sea water can be considered a dilute solution containing valuable minerals and chemicals compound. About (70) elements have so far been discovered in sea water .table (2) gives the values of the relative abundance of some of these elements. Since the seas form one continuous, nearly homogenous body of water, these values are, remarkably, the same all over the globe.

It should be noted that the values of the relative abundance of the element given in table (2) differ from those given in table (1) for the earths crust as a whole. This is primarily because solubilities in silicate solution, which form the earth crust, are basically different in sea-water.

Although sea-water all over the earth is nearly homogeneous, there is a localized concentration of some elements in the organisms. For example, algae, a kind of seaweed, contain a very high concentration of iodine. Other sea organisms may contain element such as (Ba, Co, Cu, Pb, Ni, Ag and Zn)

Trillions of tons of nodules are scattered across the ocean floor. These nodules whose principal constituents are (Mg, Ni, Fe, Cu, Co)

3- Scrap:

Definition of mineral and ore

A ***mineral*** is a natural inorganic compound of one or more metal in association with nonmetal such as oxygen, sulphur, and the halogens. A mineral has a fixed composition and well-defined physical and chemical properties.

An ***ore*** may be defined as a natural occurring aggregate or a combination of minerals from which one or more metal or minerals may be economically extracted.

The first stage in the winning of the ores is o fined them. In ancient times, some minerals must have been spotted on the earth's surface itself because of their striking physical characteristics such as vivid colors and crystalline shapes, where those hidden under the soil would have remained unnoticed. Therefore, scientific methods are necessary for an accurate location and a quantitative estimation of mineral deposits. The principle methods employed in extraction are generally based on the magnetic, electric and electromagnetic properties of the ore bodies.

1- **Magnetic methods:** which is based on the fact that magnetic ore deposits disturb the earth's magnetic field in their vicinity. Instruments such as magnetometers are of detecting buried deposits of magnetite (an iron ore) and nickel and cobalt-bearing ores. Indirectly, they also help in locating alluvial deposits of gold and platinum which often contain abundant grain of magnetite.
2- **Electrical methods:** This is based on the differences between the electrical conductivity of certain ore deposits and those of the surrounding rocks. These methods are recommended particularly for certain sulphide minerals which have remarkably high conductivities-often several

thousand time higher than the conductivity of the surrounding rock. Conductivity measurements, therefore, directly indicate both the presence and magnitude of the ore deposits.

3- **Electromagnetic methods:** it provide comprehensive on the position and shape of electrically conducting ore bodies hidden beneath the earth's surface. Such data are gathered by sending electromagnetic waves over area, and then recording the secondary field reradiated by the conducting ore bodies. Electromagnetic methods fined ready application even in mountainous regions, deserts, snow-laden, ice-covered lakes, and areas covered by nonconducting surface rock strata.

<u>The physical and chemical characteristics of ore</u>

Ore as in mined may be very large up to several meters but the maximum size of deep-mined ore must be much smaller to reduce handling problem. Ore should consist of valuable minerals and gangue with a minimum of (country rock). Often the rock can be eliminated by hand picking at the mine head. Tables accompany the valuable minerals, being either partly replaced country rock or an agglomeration oh other minerals deposits simultaneously with the mineral of major interest.

The ore can be dividing into several types:

- The ore is almost a single pure crystalline mineral in very extensive deposits. This case is rare though important, for example, gold metal.
- In a general case a vein contains several minerals in banded array, the bands of the valuable minerals being sandwiched between layers of, for example, quartz, pyrites, fluorspar.

- The valuable mineral occupies fissures in anther mineral which may be the original country rock or an earlier filling of the vein.

The type of dispersion is important as it determined the size to which grinding must be carried out to expose the mineral particles to chemical action or as that they can readily be distinguished by physical characteristic as predominantly valuable mineral or gangue.

Chemically, an ore may contain three groups of mineral:

1- Valuable minerals of the metal which is being sough.
2- Compounds associated metals which may be of secondary value.
3- Gangue mineral of no value.

The valuable mineral fall into one of the following groups:

1- Native metal

Apart from the precious metals gold, silver and platinum metals, mercury and little copper, occurrences of native metal are rare. Some native iron of magmatic has been found. Native metal is seldom pure, but occurs rather as an alloy. It is more likely to be found as filament or flakes than massive.

2- Oxides

These are often the result of oxidation of sulphides and if found in veins may gradually give way to sulphide as the veins are worked downwards. A few oxides do occur as primary deposits, notably (Fe_3O_4) in the magmatic stage and (SnO_2) and (TiO_2). Complex double and multiple oxides like niobite and tantalite are found in pegmatitic veins. These are all resistant to chemical attack and are frequently recovered beach sands and river gravels.

3- Oxy-salts

Secondary sulphates and carbonates are obviously members of this group, but it contains also many compounds of magmatic origin-silicates, titanates, spinels, etc., some of which be described as mixed oxides. Some of these, like zircon ($ZrSiO_4$) and the complex rare earth phosphates occur finely disseminated in granites and similar rocks but are naturally concentrated in placer deposits and in beach sands with other similarly chemically unreactive minerals.

4- Sulphides

The last major class of ore mineral is probably the most common and is usually found on the sites at which it was deposits. Minerals in this group associate in families with iron almost always present thus lead and zinc are often found together, and lead is seldom found without some sliver. Cadmium is found associated with zinc, iron with copper, copper and iron with nickel and nickel with cobalt. Platinum occurs commonly with copper and nickel.

5- Arsenides

This group is of minor significance except for its nuisance value. Arsenides or more often sulpharsenides occur in association with the corresponding sulphides in some cobalt, nickel, copper and lead ores and arsenates may occur among their oxidized deposits. The presence of these obviously affects the value of the deposits. The most important arsenide is sperrylite ($PtAs_2$), the form in which platinum occurs when magmatically deposited with nickel sulphide.

The evaluation of ore deposits

Unless a mineral deposit can be worked with profit it would not be designated an ore by miners, but a deposit which can be worked with profit at one period in history need not be profitable at another period.

The credits associated with the minerals deposit are the sum of the ***"values"*** of metals and non-metals (e.g. sulphur) which can be extracted from it and sold.

The ***"costs"*** involved are those of exploration, mining, concentration, transportation, waste disposal, extraction, refining, and marketing, research and administration.

If the ***"values"*** exceed the ***"costs"*** by a reasonable amount the deposit is workable ore.

Several considerations should be taken to evaluate the ore deposit and can be divided into two groups:

1- Geological considerations: can be summarized to:
   - a- The size, the shape and the deposit ore
   - b- The concentration of the of the metal or the metals into the ore
   - c- The amount of the material which could be found in the ore deposit and the ability to extract them as byproduct like gold and silver, or gangue mineral in ore.

2- Non geological consideration: can be summarized to:
   - a- The cost of mining operations, which consist of mineral extractive
   - b- The cost of concentration processes, the chooses of concentration process depend on ore nature and gangue mineral.
   - c- The cost of transport waste away from working position.

d- The cost of assisting materials which is association in extraction process
e- The amount of energy needed in the sum of the free energy of the reduction of the compound of the metal as found in the ore to the metallic state. And the energy required for all mechanical and heating processes which it may be necessary to carry out.
f- Workers: the cost of the workers are different from location to another (from country to another) and almost unskilled workers were used in mining operations, but in some cases it was necessary to used a skilled workers In extraction operation.

The mining operation

By whatever methods a deposit is discovered, and after a full geological survey made to determine the workable ore. Then mining operation is commenced.

An ore body is mined by a method appropriate to its size, shape, and depth below the surface.

1- Open pits:
The simplest methods apply to deposits which outcrop over a large area. The ore being broken with explosive and shoveled into trucks. If the ore lies deeper below the surface but is extensive horizontally, open cast mining proceeds by first clearing the over-burden to form a wide trench at one edge of the deposit.
2- Under-mine
Most mining operations involved going underground. Again there are a number of methods available depending on the size and shape of the deposit.
a- Closed under-mine: massive deposits extended horizontally would be mined by the "room and pillar" method.

b- If the deposit extend vertical, a vertical shift is cut alongside it and horizontal galleries are driven across at various levels to the vein. The mineral content of the vein above each access point and up to the one above it is blasted down and taken out to the shaft.

Method of Benefication

All metal extraction techniques are developed to produce a particular type of raw materials or a particular combination or raw materials. Whether or not a particular raw material is suitable for a giver extraction technique depends on both the physical nature of the ore and its chemical composition. Therefore, it is apparent that most of ores and minerals require some treatment before they can be processed either in increase their chemical purity or to better utilize their physical properties so as to facilitate the extraction of the metal.

The first process most ores undergo after they leave the mine is mineral dressing (processing), and ore dressing or ore beneficiation.

Ore dressing is a process of mechanically separating the grains of ore minerals from the gangue minerals, to produce a concentrate (enriched portion) containing most of the ore minerals and a tailing (discard) containing the bulk of the gangue minerals. These process a physical and chemical treatment or a combination of the two which aimed to altering the physical and chemical nature of the mineral so that the final combination of the minerals can be economically treated for metal extraction.

Mineral dressing is the processing of row materials to yield marketable products and west be means that not destroy the physical and chemical identity.

In general these processes can be summarized as below

Comminution	→ Crashing	
	→ Grinding	
Sizing	→ Sorting, screening	
	→ Hydraulic classification	
Concentration	→ Gravity	→ Heavy media separation
		→ Jigging
		→ Tabling
	→ Magnetic separation	
	→ Electrostatic separation	
	→ Flotation	
Dewatering	→ Sedimentation thickening	
	→ Filtration	
	→ Drying	
Agglomeration	→ Pelletizing, nodulizing, sintering	

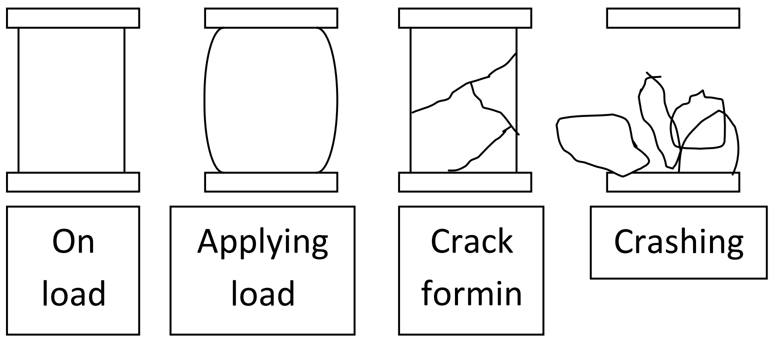
1- Comminution

Since most ore minerals are usually finely disseminated and intimately associated with gangue minerals, the various minerals must be broken apart (freed) or “liberated” before they can be collected in separate products. Therefore, the first part in any ore dressing process will involve the crushing and grinding (which is also known by a common name called “comminution”) of the ore to a point where each mineral grain is practically free.

Basically comminution serves two purposes:

1- It detaches dissimilar minerals particles from each other.
2- Liberate the valuable components and it produced small-sized mineral particles which are more suitable than large-size ore for subsequent beneficiation operations.

Crushing and grinding are usually carried out in a sequence of operations by which the lump size is reduced step by step. These processes occur by applying energy or force on the ore to be crashing until reached a critical point and then it will be crashed.



There are 3 stages of ***crushing*** and 2 stages of ***grinding***

The crashing stages are:

1- ***Primary Crushing*** (coarse crushing): In primary crushing, ore or run-of-mine ore (up to 1 m in size) is crushed down to about 10 cm and it is done in a jaw or gyratory crusher.
2- ***Secondary Crushing*** (intermediate crushing): In this case, ore is crushed from 10 cm to less than 1 – 2 cm size; for this purpose jaw, cone or roll crushers are used. These secondary crushers consume more power than primary crushers.
3- ***Tertiary Crushing*** (fine crushing): By tertiary crushers ore is crushed from 1 – 2 cm to less than 0.5 cm. Short head cone crushers, roll crushers, hammer mills can be used for this purpose.

The grinding stages are:

1-***Coarse Grinding***: Rod mills are generally used as coarse grinding machines. They are capable of taking feed as large as 50 mm and making a product as fine as 300 microns.

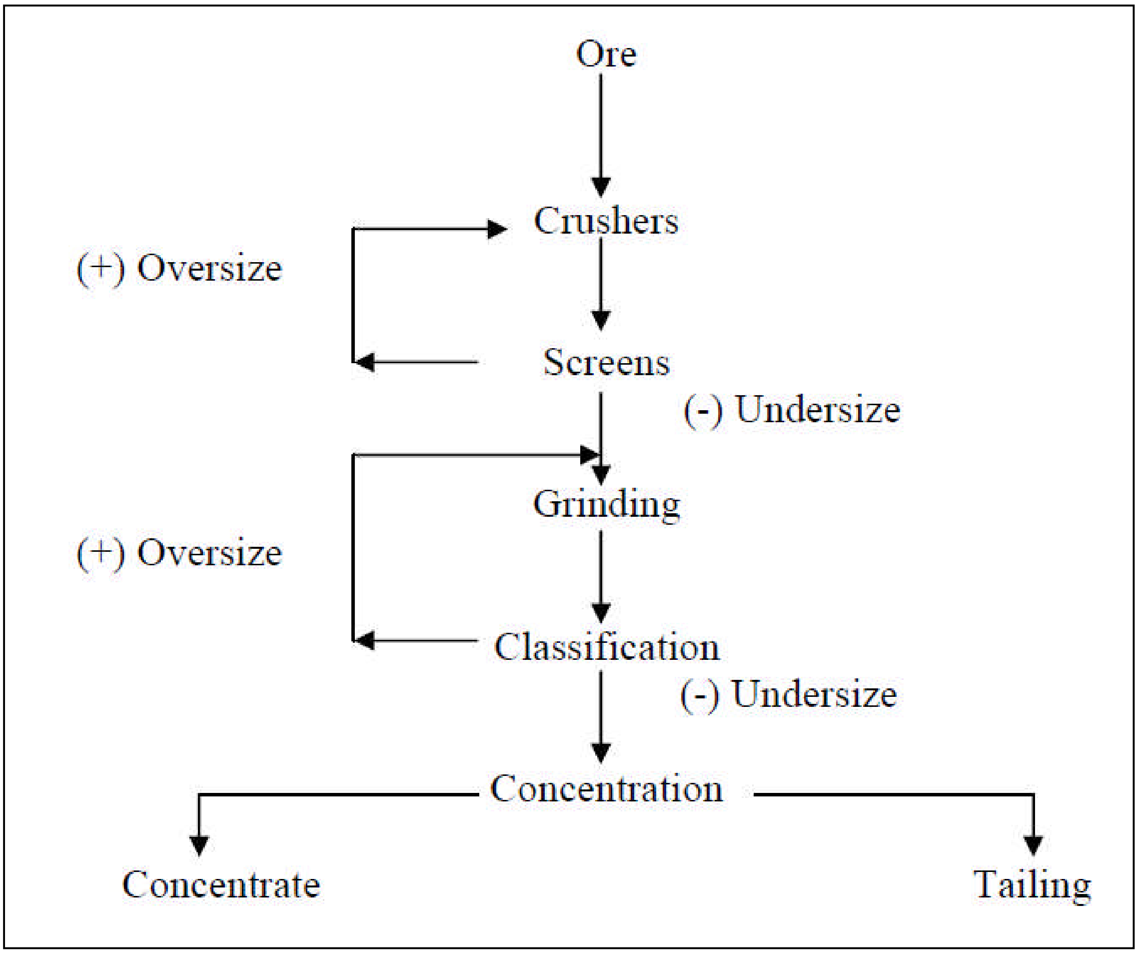
2-***Fine Grinding***: Fine grinding, which is the final stage of comminution, is performed in ball mills using steel balls as the grinding medium. The ball mill, after feeding 0.5 mm material may give a product that is less than 100 microns. Grinding is usually done wet.

The principle purposes of grinding are:

1- To obtain the correct degree of liberation in mineral processing.

2- To increase the specific surface area of the valuable minerals for hydrometallurgical treatment; i.e. leaching

Mineral processing combines a series of distinct unit operations. The flow sheet shows diagrammatically the sequence of unit operations in the plant.



A simple flow sheet of a mineral processing plant

Crusher and Grinder

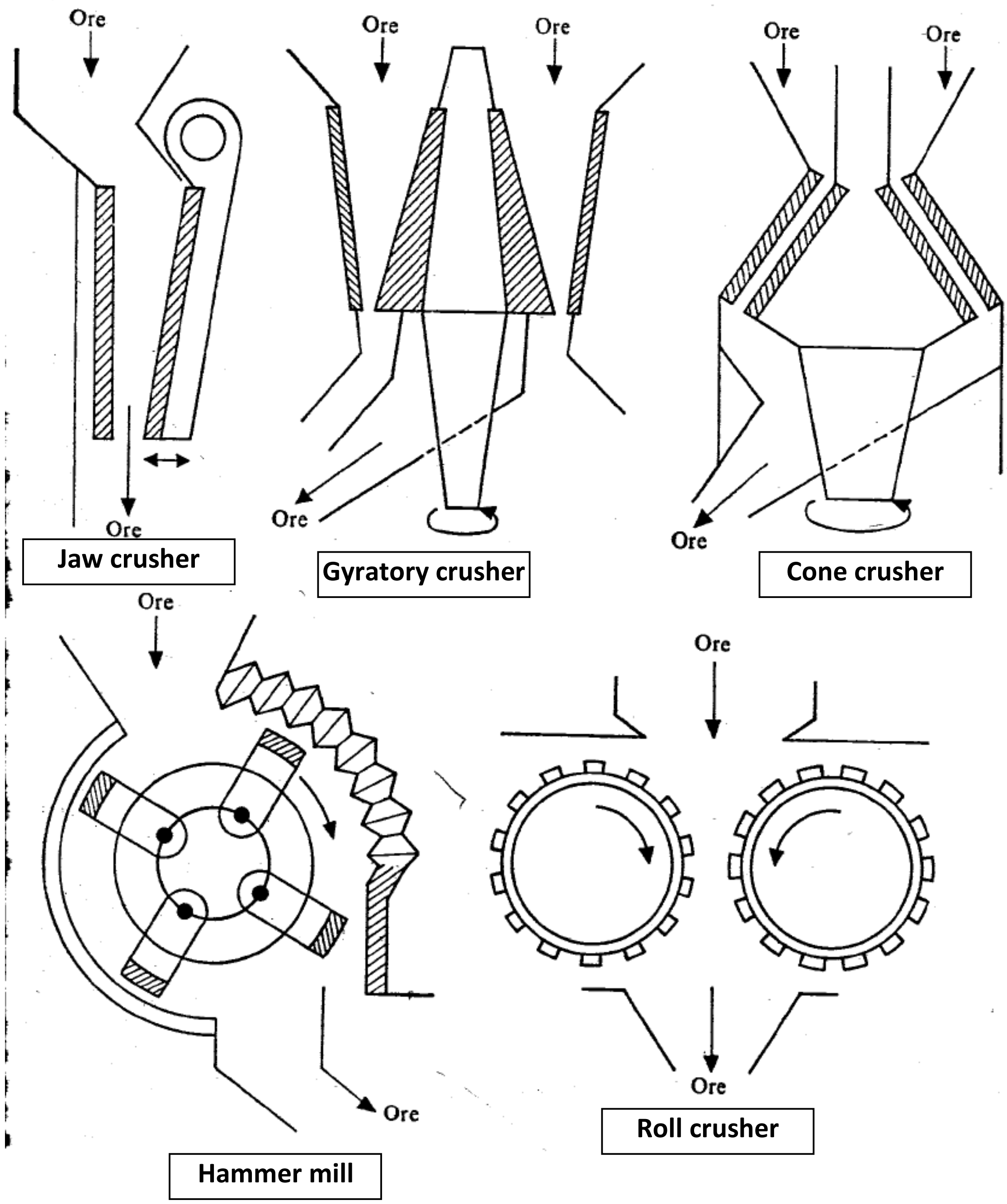
Machines such as jaw crusher, gyratory crusher, and rolls carry out the crushing of an ore as it mined. In most of these machines the ore is crushed in a wedge-shape space between two hard crushing surfaces one fixed and the other moving. The smaller fragments of the crushed ore particles are collected as they fall through an opening provided in the machine.

In jaw crusher ore is squeezed until it breaks and the fragments fall down to a narrower part of the wedge to be squeezed again, repeatedly, until they can escape through the minimum gap at the bottom. Its capability of processing up to 500 tons of ore per hour and reduction ratios range from 4 to 10 in the biggest machines.

The gyratory crusher is similar in effect, but the relative motion of the crushing face is due to the gyration of the eccentrically and some tangential force is applied in the case as well as simple squeeze. Its capability of processing up to 5000 tons of ore per hour. Gyratories operate best on hard, brittle materials and do not work well on soft pr plastic minerals like clay while jaw crusher can deal these material mach better.

Rolls draw the ore lumps down into the gap between them and, after one nip, discharge the product. With a given roll diameter and set there is maximum size of lump that will be drawn in. With smooth rolls this limit the reduction ratio to about 3:1, but using slugger rolls which have ridges or knobs on the roll faces, the reduction ratio can be raised above 4:1. These are used on iron ore which are usually cohesive but not very hard. Fracture of ore between rolls is again mainly by squeezing and must occur by stages as the material is drawn into the narrowing space. Interaction between ore particles is much less than in jaw and gyratory crushers and the proportion of fines produced is smaller.

Secondary reduction would be carried in a cone crusher, by cone, or in a hammer mill. Of these the cone crusher is the most commonly used on ores. It is similar to the gyratory, but it self –cleaning because the gap widens to let the product fall through after the nip has been made. The inner cone sometimes rotates on an eccentric axis instead of gyrating. Hammer mills are used mainly for breaking weak, brittle materials like coal. The materials is fed through a hopper into the bath of the flying hammers which are freely swinging in smaller machines but fixed rigid with the rotor in the largest size. The ore lumps are broken by the impact fracture mechanism either when hit by the hammer, or on subsequent collisions with the impact plates enclosing the working space, with other lumps or with another hammer. Its capacities range up to 2000 tons per hour and reduction ratio can be as high as 40:1.



Grinding, a process that is slower than crusher, is usually carried out in a ball mill or in equipment similar to it, namely, a tube mill, a pebble mill, or a rod mill. These mills are closed chambers containing hard balls, rode or pebbles, which are used in grinding. Since the operating mechanism of the each of these grinding mills is similar, we discuss only the ball mill. The ball mill is rotated in such a manner that the ball rise along the walls and then either roll down or throw themselves on the ore particles, which leads to fragmentation by grinding. In this rotating mill, the ore particles are subjected to various forces which cause fracture such as:

(1) Cataracting (impact with balls, rods, or pebbles),
(2) Cascading (attrition among rolling ball),
(3) Interparticle collisions and rubbing,
(4) Frictional force at the lining of the mill.

It should be noted that if the speed or rotation of a mill is too high, then centrifuging takes place. As a result, the contents of the mill simply stick to the inner rotating surface, and there is hardly any grinding. Conversely, if the speed of rotation is too slow, then cataracting dose not occur, and the particles and balls simply roll down the inner surface. In such a situation, only limited grinding takes place as a result of cascading. A successful grinding operation aims at a suitable speed among the various operation forces.

Size of particles

In an ore benefication methods, when ore are subjected to force in order to reduce their size by crushing and grinding. It's necessary to identify the particle size of the products by sizing and classification methods.

Size is usually signifies the narrowest regular aperture through which a mineral particles can pass. Such a criterion may be suitable for a regularly shape polyhedron, especially a sphere, where the diameter is obviously the size, weal in the case of long-rod shape particles is meaningless.

When particles are sized into fraction using sieves, every fraction has bigger and smaller particles with upper and lower limits. The average size of particles in a fraction can calculated the mean of the upper and the lower level.

The determining the size of single particle in laboratory can occur by several methods. The common procedures are by microscopic and macroscopic observation to obtain the dimensions of a single particle. The volume "V" of the particle having dimensions "a,b,c" can be obtained from the equation

$$V_{(a,b,c)} = \frac{\pi d^2}{6}$$

Where "d" is the diameter of a single particle by assuming the particle is spherical.

The other sizing technique that using in the laboratory is sieving. A standard sieve is made of square mesh whose aperture size vary in geometry. The aperture sizes used in a sieve range from (37μ) upwards. In the longest series, standardized mesh size extend from 3 to 400. The mesh number specifies the number of square apertures per linear inch (25.4 cm) a standard size scale, called the "Tyler" series, and is given in table below. There are other systems of grading aperture size like ASTM and BS.

Table 2

The Tyler Standard Series for Screen Analysis

	Aperture Size		Tyler Mesh #
	Millimeters	Microns	
↓ √2 series	26.67	-	-
	18.85	-	-
	13.33	-	-
	9.423	-	-
	6.680	-	3
	4.699	-	4
	3.327	-	6
	2.362	-	8
	1.651	-	10
	1.168	-	14
	0.833	833	20
	0.589	589	28
	0.417	417	35
	0.295	295	48
	0.208	208	65
	0.147	147	100
	0.104	104	150
	0.074	74	200
	0.052	52	270
	0.037	37	400

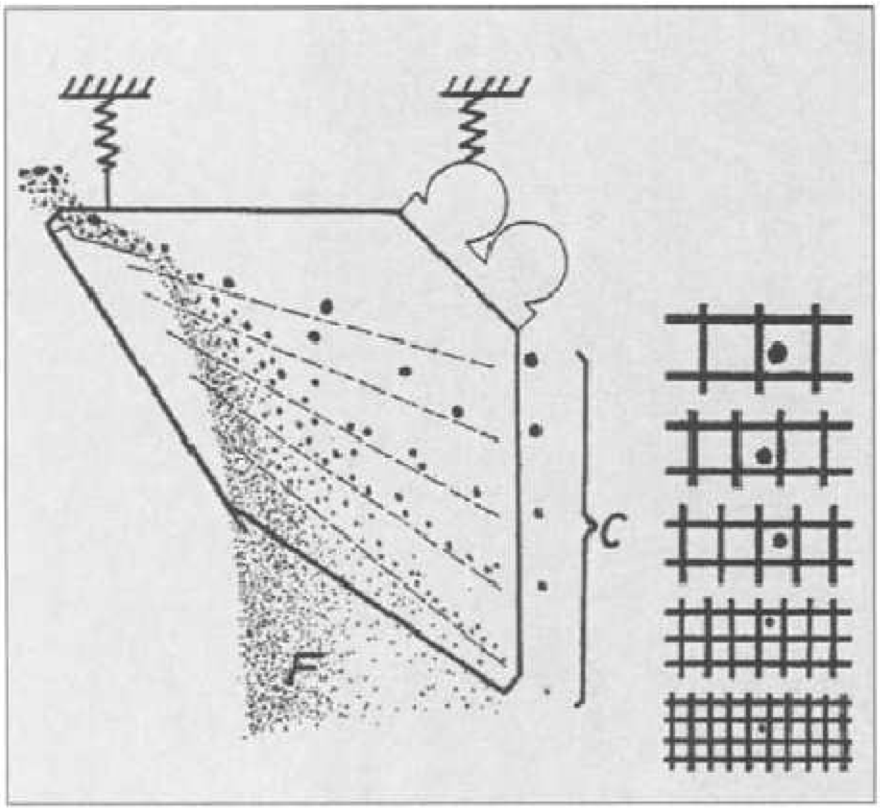
The term 'mesh" is normally reserved from small aperture size. From bigger particles, screens may be made with any size of opening and down to about (50 mm).

Sizing

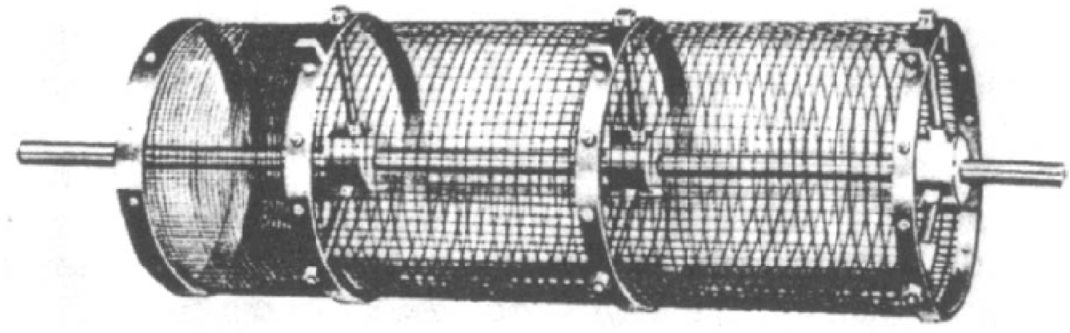
Most unit processes are designed to treat over certain size ranges. Thus the raw material must be chosen by proper selection process. It can be divided in two methods.

- Sorting or hand-picking: this method yields particles, approximate diameter range (40-500 mm) which are not only ideal for certain unit process but may also a high concentration of mineral.
- Screening: it more scientific than sorting, where the basis of separation is the particles size, as indicated by standardized apertures. In this way the particles can separated into two groups, namely, oversized and undersized.

The chief types of industrial screen



Grizzly screen



Trommel screen

Capacity of screen

The capacity of a screen primarily depends on the following factors:

1- The area of the screen surface;
2- The size of the opening on the screen surface;
3- Characteristics of the ore such as specific gravity, moisture content, temperature and the proportion of fines;
4- The type of the screening mechanism used.

Since the capacity of a screen depend directly on both the area of the screening surface and the screen aperture, it is expressed as (tons/ft^2) or (tons/m^2) screen aperture per (24 hr). The table below gives the approximate capacity range of certain type of screens:

Type of screen	capacity range per (24 hr) per (mm) aperture	
	tons/ft^2	tons/m^2
Grizzly	1-5	0.1-0.5
Trommel	0.3-2	0.03-0.2
Shaking screen	2-8	0.2-0.8
Vibrating screen	5-20	0.5-2

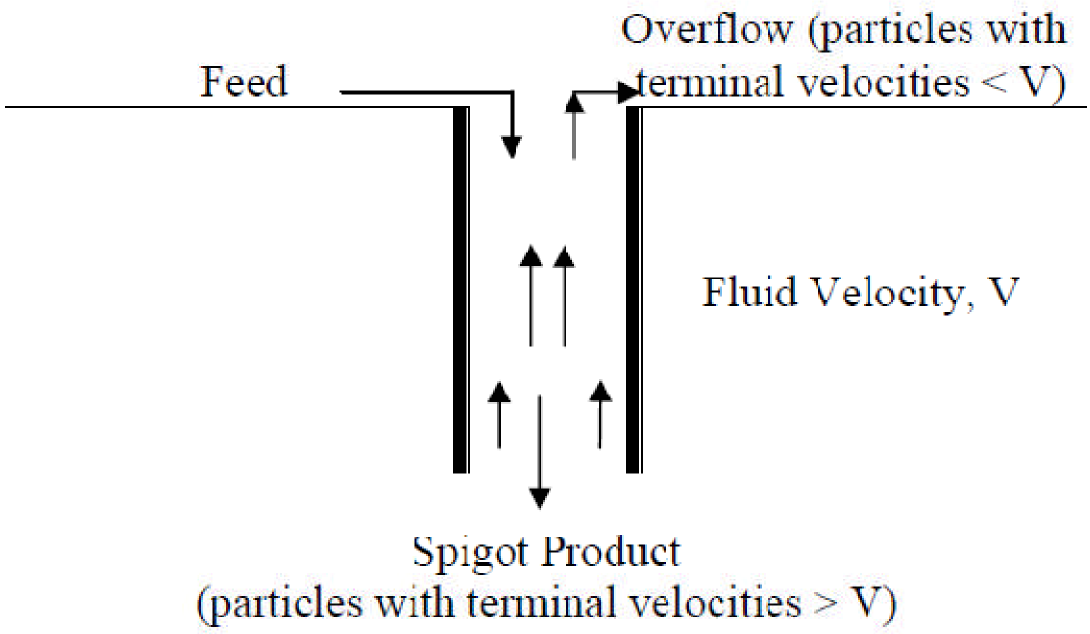
Classification

Classification is a process by which particles of different sizes and specific gravity are sorted out into uniform groups. Classification differs from sizing in two ways:

- First: it is normally applicable to a very low range of particle size i.e., 65-200 mesh (208-74 µm).
- Second: it separation the particles on the basis of their densities. Thus, if the particle sizes are comparable, then, the settling velocities of heavier and lighter particles would be difference, leading to a possibility of separation and concentration.

In general, classification depends on the settling rate of the individual particles in a fluid medium (usually water). Further, the difference in the settling rate between particles of different sizes and/or different specific gravities is the controlling factor in classification.

In which a fluid is rising at a uniform rate (Figure below). Particles introduced into the sorting column either sinks or rise according to whether their terminal velocities are greater or lesser than the upward velocity of the fluid. The sorting column therefore separates the feed into two products an overflow consisting of particles with terminal velocities lesser than the velocity of the fluid and an underflow or spigot product of particles with terminal velocities greater than the rising velocity.



There are two main kinds of settling, namely, *free settling* and *hindered settling*.

Free settling: take place when the individual particles settle free, i.e., unhindered by other particles through a medium of still water or against a rising current of water.

Hindered settling: As the proportion of solids in the pulp increases, the effect of particle crowding becomes more apparent and the falling rate of the particles begins to decrease. The system begins to behave as a heavy liquid whose density is that of the pulp rather than that of the carrier liquid; hindered-settling conditions now prevail. Because of the high density and viscosity of the slurry through which a particle must fall in a separation by hindered settling

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 conditions, i.e. ideally in a fluid of infinite extent. The particle is acted upon by three forces: a gravitational force acting downwards, an upward buoyant force due to the displaced fluid, and a drag force (D) acting upwards. The equation of motion of the particle is

$$F = (m - m')g - D$$

Where (F) the summation of acting force, (m) is the mass of the particle, (m') is the mass of the displaced fluid. The main part of the equation is the drag force (D) which is directly depend on the settling rate of the particle, and can be calculated from

$$D = C_D A(D_f V^2)/2$$

Where (V) the relative velocity between the particle and the fluid, (A) the cross section area of the particle, (C_D) the drag force index.

The settling of a particle in water depends on several factors:

- **Specific gravity**: a particle that has higher specific gravity than anther particle settles faster when other parameters such a size are comparable.
- **Shape**: a rounded particle settles faster than a long narrow grain of a flat grain.
- **Size**: a large particle settles faster than a small one.

- **Air bubbles**: a particle that does not retain adhering air bubbles settles faster than one dose.
- **Density of liquid**: the settling rata of a particle is higher in a lighter than a heavier liquid.
- **Viscosity**: the settling rata of a particle is higher in a less viscous medium than in a more viscous one.

Types of classifier

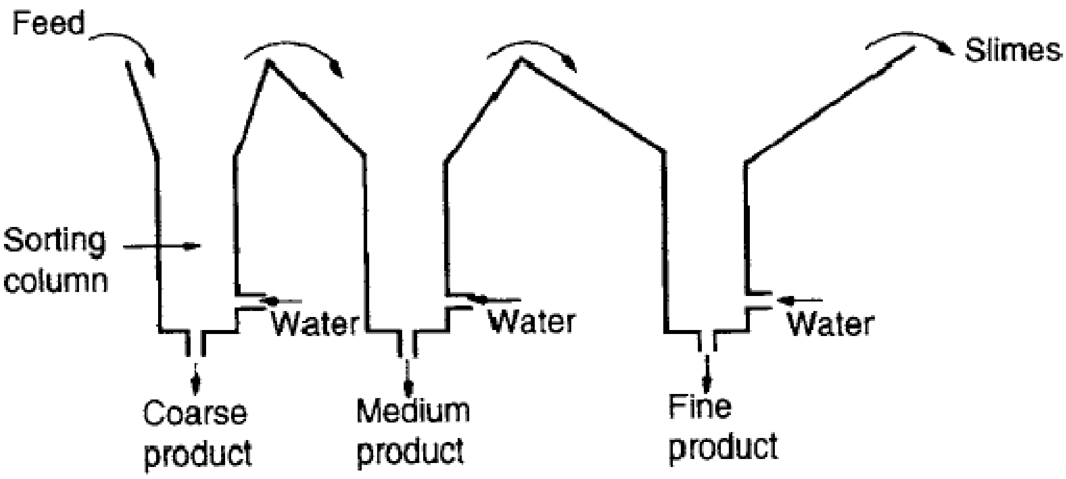
They may be grouped, however, into two broad classes depending on the direction of flow of the carrying current.

- **Horizontal current classifiers** such as mechanical classifiers are essentially of the free-settling type and especially the sizing function;
- **Vertical current** or hydraulic classifiers are usually hindered-settling types and so increase the effect of density on the separation.

Hydraulic classifiers

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 normally consist of a series of sorting columns through each of which a vertical current of water is rising and particles are settling out (the fig below)

The rising currents are graded from a relatively high velocity in the first sorting column, to a relatively low velocity in the last, so that a series of spigot products can be obtained, with the coarser, denser particles in the first spigot and the fines in the

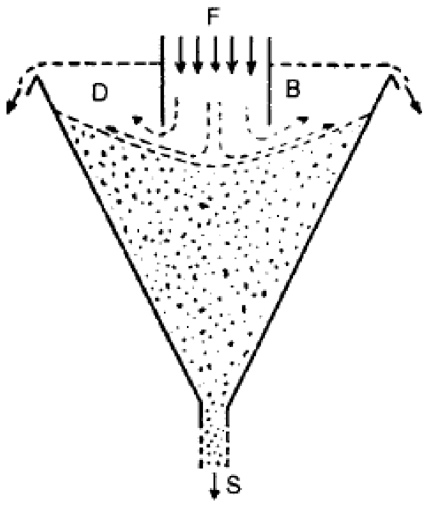


Principle of hydraulic classifier

latter spigots. Very fine slimes overflow the final sorting column of the classifier.

Settling cones

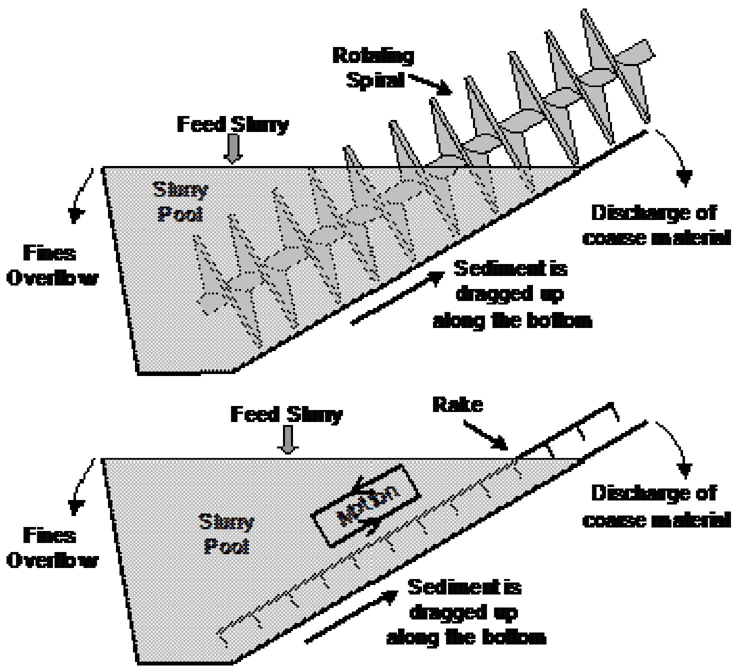
These are the simplest form of classifier, in which there is little attempt to do more than separate the solids from the liquid, i.e. they are sometimes used as dewatering units in small-scale operations. The principle of the settling cone is shown in Figure. The pulp is fed into the tank as a distributed stream at F, with the spigot discharge S initially closed. When the tank is full, overflow of water and slimes commences, and a bed of settled sand builds up until it reaches the level shown. If the spigot valve is now opened and sand discharge maintained at a rate equal to that of the input, classification by horizontal current action takes place radially across zone D from the feed cylinder B to the overflow lip. The main difficulty in operation of such a device is the balancing of the sand discharge and deposition; it is virtually impossible to maintain a regular discharge of sand through an open pipe under the influence of gravity.



Settling cone operation

Mechanical classifiers

Mechanical classifiers such as the spiral and rake classifiers work in a similar fashion in that both drag sediment and sand along the bottom of an inclined surface to a higher discharge point on one end of the settling chamber. The primary difference in the two systems is the mechanism by which the settled material is moved up the inclined surface (see figure). Spiral classifiers are generally preferred as material does not slide backwards which occurs in rake classifiers for separation of finer material.



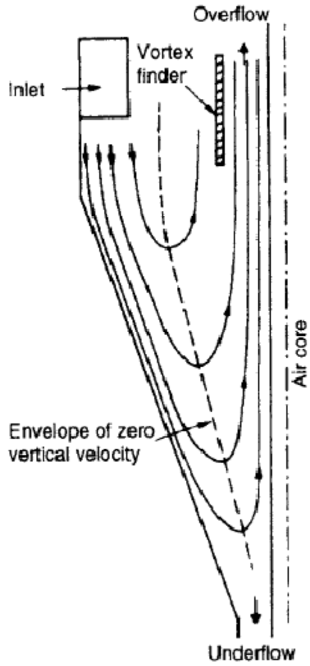
Principle of mechanical classifier (Spiral and rake)

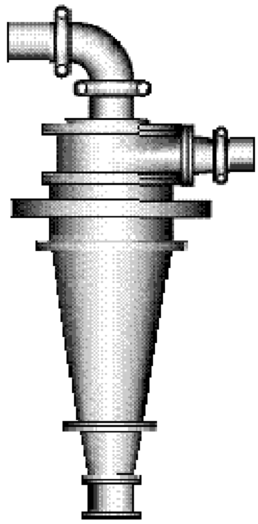
when the rakes are lifted between strokes. This also allows spiral classifiers to operate at steeper inclines producing a drier product. The spiral classifier also produces less turbulence in the settling pool allowing for separation of finer material.

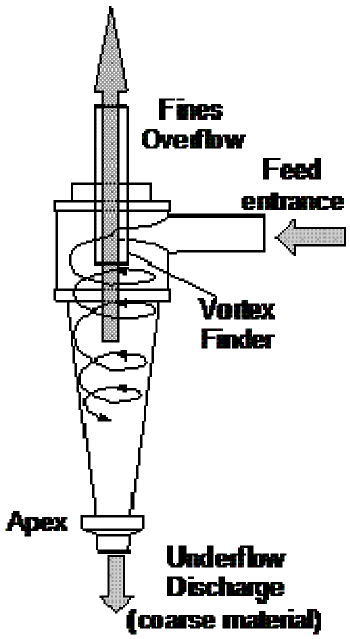
Hydrocyclones (Cyclones)

This is a continuously operating classifying device that utilises centrifugal force to accelerate the settling rate of particles. It is one of the most important devices in the minerals industry, which has proved extremely efficient at fine separation sizes. It is widely used in closed-circuit grinding operations. The main advantages of cyclones is that they have large capacities relative to their size and can separate at finer sizes than most other screening and classification equipment.

The separation mechanism in hydrocyclones relies on centrifugal force to accelerate the settling of particles. The slurry enters the cylindrical section tangentially above a conical section. The velocity of the slurry increases as it follows a downward helical path from the inlet area to the smaller diameter underflow end. As the slurry flows along this path, centrifugal forces cause the larger and denser particles to migrate to the fluid layer nearest the wall of the cone. Meanwhile, the finer or lower specific gravity particles remain in, migrate to, or are displaced toward the center axis of the cone. As the swirling slurry approaches the underflow tip, smaller and lighter material closer to the center reverses its axial direction and follows a smaller diameter rotating path back toward the top overflow discharge pipe.







Principle of Hydrocyclones

Heavy media separation

Is a special classification process which depends exclusively on the specific gravity of a particle. In this operation the particle size is not important. Generally, the comminuted ore (after the fine size have been removed from it) is put into a fluid whose specific gravity lies in between the specific gravities of the two mineral that are to be separated from each other. For example the densities of most metallic oxides lie in the range (3.5-4.5 g/cm^3) silica the main component of gangue having a density of (2.65 g/cm^3). Therefore, during heavy media separation in a liquid whose density is approximately (3g/cm^3) the metallic oxides sink but silica floats. Such a liquid can, however, be obtained by suspending fine, dense particles in water. Typical examples are galena (lead sulfide) (effective specific gravity of medium 4.3 g/cm^3) and ferrosilicon (effective specific gravity of medium 2.5-3.5g/cm^3).