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Separation of beach sand minerals

A.S. SIDDIQUI, A. K. MOHAPATRA and J. V. RAO
Indian Rare Earths Ltd., OSCOM, Chatrapur, Orissa, India

ABSTRACT

India has a vast resource of beach sand minerals along the Eastern and the Western coastal lines. The Beach Sand Minerals are usually heavier due to higher specific gravity and because of this property these are also known as Heavy Minerals. The Heavy Minerals are themselves a mixture of a variety of minerals like monazite, ilmenite, rutile, zircon, silimanite, garnet etc. These minerals are available in nature in the range of 75 to 500 Microns and can always be classified in the fines category. Preliminary extraction of these minerals is done by dredging of the raw sand along a pre determined dredge-path. The dredged minerals are processed in a floating Concentration poant where these minerals are subjected to gravity separation technique in spiral concentrators. The enriched concentrate ppgradation plant located near Mineral Separation plant to increase the concentration up to about 95-96 % HM so that it will ready for processing in the Mineral Separation Plant for individual separation.

In addition to gravity separation techniques, other techniques such as high tension seprartion, magnetic separation, flotation techniques etc. are adopted in the Mineral Separation Plant to separate the individual minerals. These heavy minerals have wide field of application in plint iondustries, ceramic industries, electronic industries, abrasive industries etc.

In this paper, the author have tried to present briefly the nature of formation of the beach sasnd deposits containing the heavy minerals, the mining activities undertaken and the preliminary separation in the wet plants to discard the gangue minerals at the site of mining itself, and then the various processing techniques involved in the separation of the individual minerals. At the end, emphasis is given to the environmental impact of beach sand mining and processing activities.

Key Words : *Frontal dunes, Rear dunes, Concentration, Dredge, Cutter-ladder, Surge bin, Pontoon.*

INTRODUCTION

Extensive beach sand deposits are located along the coastal lines of the eastern and the western parts of India. Out of the total world deposit of about 2500 Million tons, India has a share of about 10-11%i.e. about 275 million tons. Beach sand deposits are the major source of beach sand minerals, commonly known as Heavy Minerals. The heavy minerals derive their name because of their higher specific gravity compared to quarts which is the gangue mineral. The heavy minerals are themselves a mixture of a group of heavier minerals such as ilmenite, rutile, zircon, monazite, sillimanite, garnet etc. The ratio of these individual minerals in the deposit varies from place to place according to the natural process of formation and the provenience of the deposit and accordingly determines its economic value.

In India major beach sand deposits are found in the states of Tamil Nadu, Kerala, Orissa and Andhra Pradesh. Manavalakurachi of Tamil Nadu, Chavara in Kerala, Bhimlipatnam in Andhra Pradesh and Chatrapur in Orissa, Indian Rare Earths Ltd, a Govt. of India Undertaking functioning under the Dept. of Atomic Energy, is actively engaged in beach sand mining and processing in India. Kerala Minerals and Metals Ltd., an undertaking of Kerala State Government, is also engaged in beach sand industry in a small way in the state of Kerala. Other countries like Australia, USA, South Africa are the leading producers of beach sand minerals in the world.

GEOLOGY

In India, the heavy minerals are found in Placer deposits formed along the coastal stretches. The origin of the deposit belongs to the parent rock types available in the Eastern ghat and the Western ghat Mountain ranges which contain these minerals in very low concentration to call for profitable extraction. The main source rocks are Khondalites, Charnockites, Gneiss, Granites, Laterites, Sand stones etc. When the source rocks are subjected to weathering processes, the minerals are liberated from it and transported downword by running water and rivers. A tropical climate with heavy rainfall assists in the weathering process. The liberated minerals transported downword are deposited at the sea shore in an unsorted condition

The actual sorting and concentration takes place due to the actions of two principal agents i.e. action of waves and surfs and the action of the wind. Ocean waves and surfs play predominant role in the concentration of the heavy minerals. A breaking wave takes all the fore-shore minerals to the beach but the back wash carries only the lighter minerals back to the sea. Repeated action of waves results in sorting and the concentration of heavy minerals in Beach Placer deposit. After the concentration is over, action of the wind further enriches the

concentration by blowing away the finer and the lighter sand particles thus leaving the in-situ deposit rich in heavy minerals.

MODE OF OCCURRENCE

The occurrence of the beach sand deposit is usually in the form of Dunes along the shore lines of the sea. The deposits in the vicinity of the sea shore are coarse grained having highest degree of concentration and are known as frontal Dune Deposits. Some of the finer heavy minerals are sometimes blown away from the frontal dunes and move towards the intermediate leeward side until it is obstructed. When these minerals are deposited in the form of dunes in the rear side of the deposit these are called as Rear Dune Deposits. The concentration of heavy minerals, grain size and the mineral composition in the dune deposits vary across the width of the deposit due to the variation of the velocity of wind at different times and also the variation of the ground water table in the locality.

MINE PLANNING

Mine planning activities cover two important aspects in the total mining operation. The first aspect deals with the prospecting and exploration and the deposit evaluation. The selection of equipment, sequence of extraction of minerals in short term and long term period are determined from the data obtained during preliminary investigation. The second aspect covers wide number of current mining activities such as providing support facilities to the operating personnel, guiding the operating personnel by providing information related to production activities, rehabilitation of the mined out area by systematic plantation etc. Laying of road and power lines ahead of the dredge movement is also an important planning function.

Planning of dredge - path is a very important activity which helps the operating people in monitoring the production schedule in monthly as well as yearly basis. Dredge - path planing is based upon a number of data such as production target, dredging area, height of the deposit, dredging depth desired, grade of minerals available in the area, behaviour of the ground water table etc. The focus of the planners is always to utilise the maximum land available and guide the dredging personnel to minimise losses that may arise due to encroachment of tailings on the virgin area and also between successive runs that the dredge takes in the deposit (Fig. 1).

MINING ACTIVITIES

In general, wet method of mining is adopted for extraction of heavy minerals as it is more advantageous to deal with concentration process in slurry form. Dredging is the most suitable method of mining of the beach sand in wet form

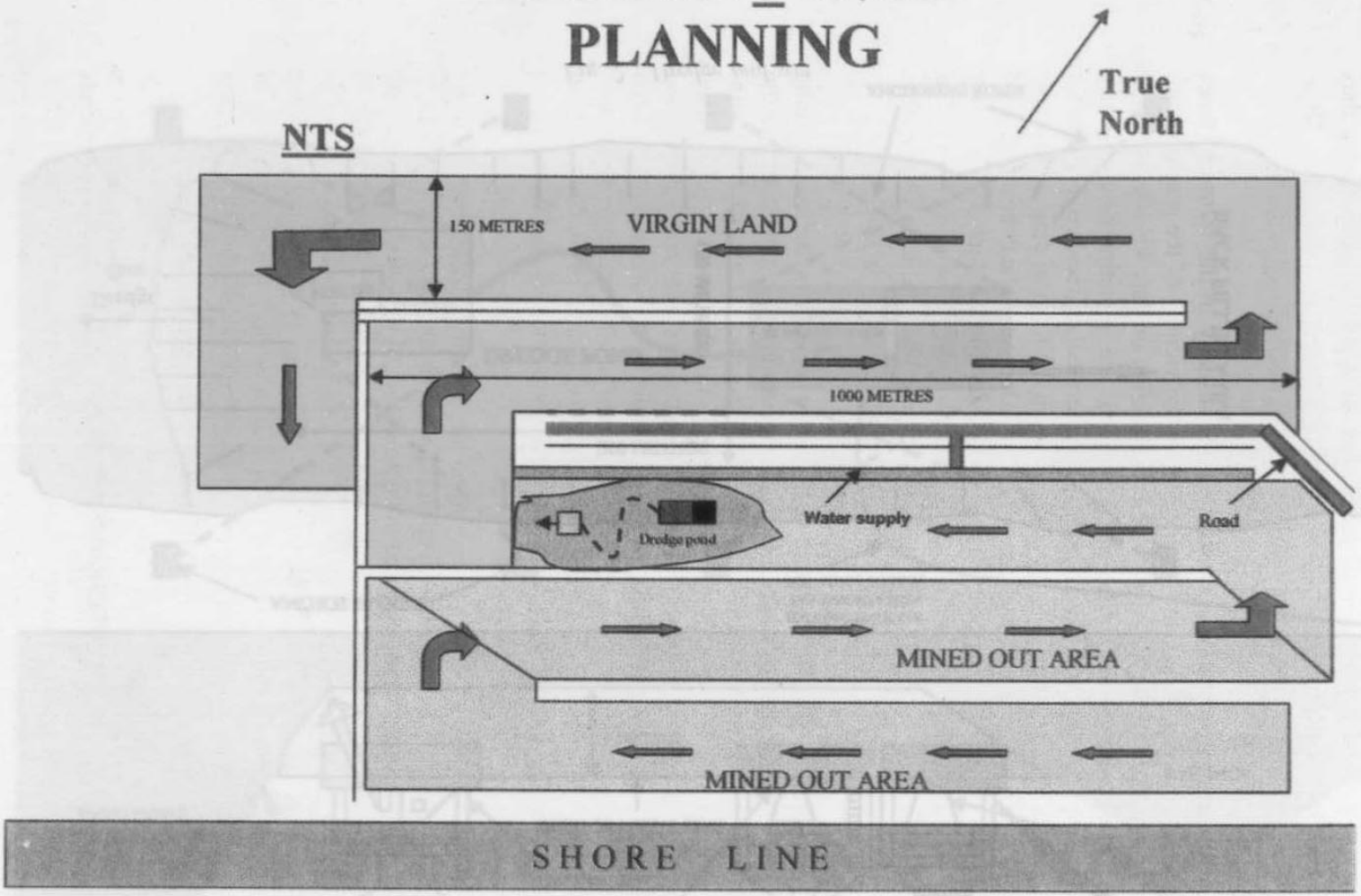

Fig. 1 : Dredge-path planning

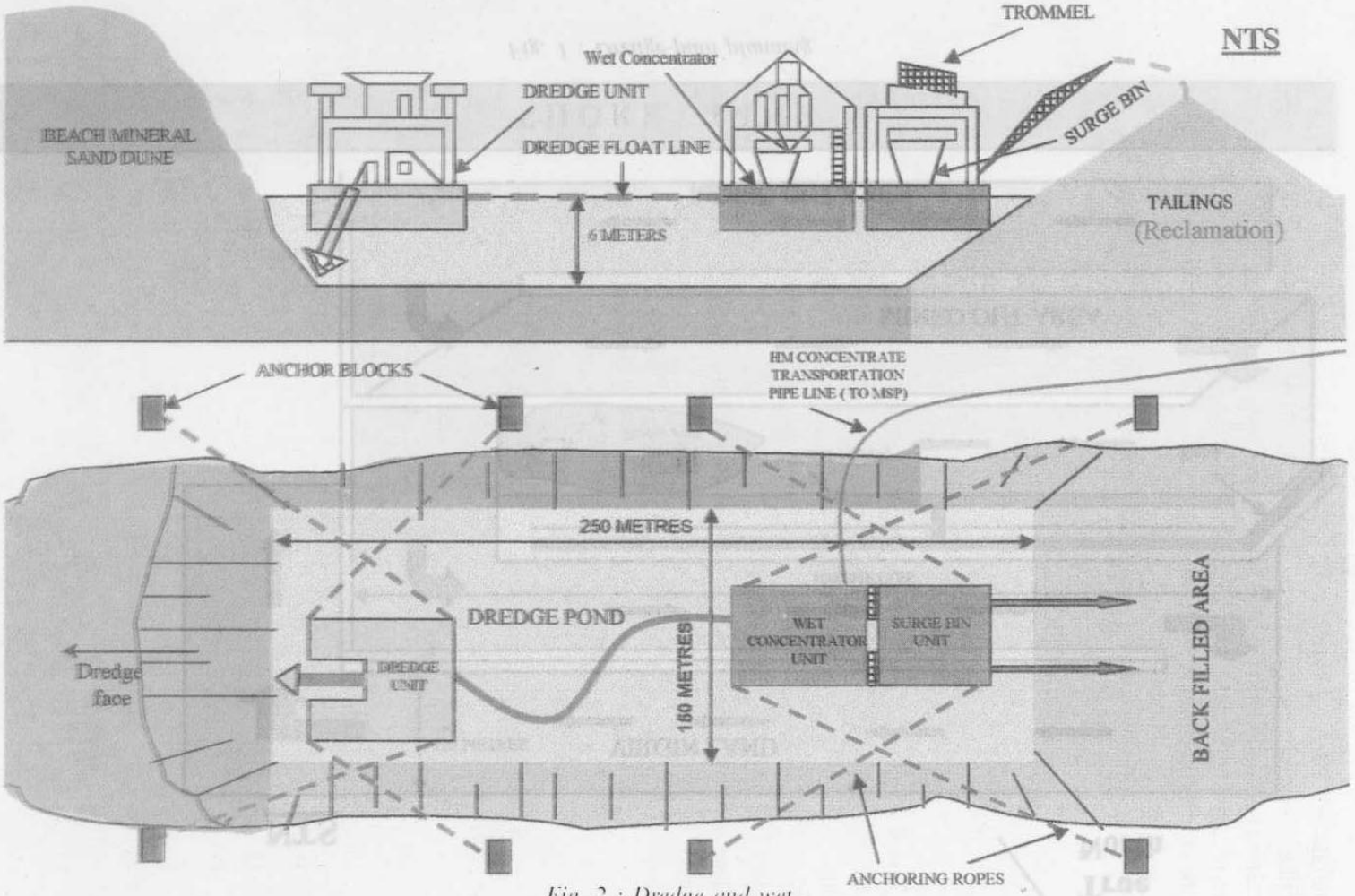

Fig. 2 : Dredge and wet

minerals. The dredge consists of a cutter-ladder unit, a dredge pump and all ancillary equipment mounted on a floating pontoon. The operation of the dredge is carried out along the front bank of the pond and the tailings of the dredge sand, after processing, is directed back into the rear portion of the pond for back filling of the mined out area.

The dredged sand in slurry in firm is pumped to a Trommel Screen to remove any over sized material including roots, pebbles, stones encountered while dredging. The screened material is collected in a surge bin mounted on a floating pontoon. The purpose of the surge bin is to ensure that a constant pulp density is maintained to the concentrator unit irrespective of the fluctuations that may arise in the course of dredging. A constant pulp density of 35% to 40%wt/wt is ideal for efficient separation in the spirals.

The material from the surge bin is pumped to a Concentrator Unit mounted on a floating pontoon. It mainly consists of a number of Spiral Concentrators, pumps with motors and bins or tanks. The concentrator plant utilises the principle of gravity separation for upgradation of heavy minerals from the bulk of the raw sand and discards the gangue minerals at the site itself (Fig. 2).

The spiral circuit has different stages like Rougher Circuit, Secondary Rougher Circuit, Cleaner Circuit (Fig. 3) depending upon the feed grade and the upgradation desired for final product. The final concentrate, which is about 85-90% HM, is pumped to the Mineral Separation Plant in slurry form through a series of booster pumps.

A typical analysis of the Raw Sand mined by dredging and the final concentrate (by%wt) is given in Table-1 for comparing the performance of the concentrator plant..

Table 1 : Mineral composition

Minerals	Raw Sand (%by wt)	Concentrate (%by wt)
Heavy Minerals	20	90
Ilmenite	9	50
Garnet	6.0	25
Rutile	0.4	2
Zircon	0.3	1.5
Sillimanite	3	8
Quartz	79.5	10
Others	1.3	3.5

SEPARATION OF INDIVIDUAL MINERALS

The heavy mineral concentrate obtained from the Dredge and Wet Concentrator Plant still contains about 10-12% i.e. the gangue minerals. This must be minimised to maximum possible extent before feeding to the Mineral Separation Plant so that the equipment of MS Plant give the desired performance. For this reason, the concentrate is further treated in a Concentrate Upgradation Plant where the grade of the concentrate is enriched to about 95 to 96% heavy minerals.

The concentrate so obtained is stock piled and dried to remove the moisture content to about 5-6% to improve the operational efficiency of dryers of the Mineral Separation Plant where individual separation of heavy minerals is carried out.

The minerals produced from the Concentrate Upgradation Plant contain heavy minerals in different proportions with different physical properties as mentioned in Table - 2.

Table 2 : Physical properties of minerals

Minerals	Physical properties
ILMENITE	Electrically conducting and strongly magnetic
RUTILE	Electrically conducting and non-magnetic
ZIRCON	Non-conducting and non-magnetic
SILLIMANITE	Non-conducting and non-magnetic
MONAZITE	Non-conducting and weakly magnetic
GARNET	Non-conducting and magnetic
QUARTZ	Non-conduction non-magnetic and lighter than other constituents

Various separation techniques are utilised in the Mineral Separation Plant and depending upon the physical properties of the individual minerals, they separate out from one another (Fig. 4). Some of the commonly adopted techniques are described briefly as follows :

High Tension Separation

High Tension Separation are used mainly for separation of conducting from non-conducting minerals. The concentrate which is heated to bone dry (about 120-150 degree Celsius) in rotary dryer is fed to High Tension separators (HTS). These separators have a vertical configuration with single/double electrode system. The electrodes are charged with D.C. current and the rotors (drums) are

driven by A.C. motors. Ilmenite and Rutile which are electrically conducting lose their charge and report in conducting fraction due to centrifugal force of the drum. The non-conducting particles acquire the charge and pin to the drum. A.C. electrode is provided at the bottom of the drum to neutralise the charge of non-conducting particles and they are simultaneously brushed off from the drum and collected in a separate channel.

Magnetic Separation

The Magnetic Separators utilise the magnetic susceptibility of minerals for their separation. Induced Roll Magnetic Separators are most commonly deployed equipment for magnetic separation of Ilmenite from Rutile and Garnet from Monazite. In this separator, magnetic flux is developed by applying D.C. current through the coils provided in the equipment which in turn induces magnetic flux in the rolls which are driven by A.C. motors. The magnetic minerals cling to the rolls where as the non-magnetic minerals are thrown away due to the centrifugal force of the rolls. The non-magnetic minerals are collected in a hopper and the magnetic minerals are brushed off at the other end of the rolls and are collected in a separate channel. The equipment may be in the configuration of single start or double start depending upon the quantity to be handled and can be installed as single stage or multiple stage based on the quality requirement.

After separation of the conducting and the magnetic minerals like Ilmenite, Monazite, Rutile and Garnet by a series of High Tension Separators and Magnetic Separators, the remaining part is enriched in non-conducting and non-magnetic minerals, viz, Sillimanite, Zircon and Quartz. These minerals are separated from one another by utilising their properties of difference in specific gravity in Gravity Separation techniques.

Gravity Separation

The specific gravity of Zircon, Sillimanite and Quartz is 4.7, 3.25. and 2.65 respectively. The total materials are fed to Spiral concentrators in the slurry form and then the final concentrate so obtained is again treated in the Wet Tables. Zircon is collected as concentrate and Sillimanate and Quarts are collected as tailings. Zircon is then dried and taken as a product after required cleaning of conducting, magnetic and low specific gravity minerals which are often found as impurity in Zircon.

However, Gravity Separation technique is not applicable for separation of Sillimanite from Quartz as the concentrate criteria of the two minerals is below 1 i.e. they have a very low difference in specific gravity for effective separation by Gravity Separators. Hence flotation technique is adopted for separating these two minerals.

Flotation

It is a physico-chemical process of separation of the minerals. In this process, Sillimanite and Quarts are conditioned in alkaline solution of pH 9.0 to 9.6 using Soda -Ash as reagent. Sodium Silicate is used to depress the Quartz and Oleic Acid as a collector to froth the Sillimanite. This process is carried out in two-stage conditioning. Thereafter, the conditioned material is taken to flotation cells where air is injected through blowers to form froth. Sillimanite is attached to air bubbles and gets lifted up as froth. Quartz, which is not affected by the air bubbles goes down as Sink. This process is carried out in a number of stages depending upon the feed grade and the desired final grade of the product.

Although the individual minerals are separated by the above techniques in different equipment, there are various other auxiliary equipment which are used in different stages for improvement of quality of the products and also achieve optimum recovery. The function of these equipment are briefly described as follows:-

Electrostatic Plate Separators

These are generally vertical type of equipment where electrodes are provided in the shape of a plate and D.C. voltage at about 22 to 30 Kv is passed through the plate. When feed material is passed through the plate, the conducting minerals are lifted towards the conducting hopper and the non-conducting minerals gravitate downward and are collected in the non-conducting hopper. This operation is carried out in a number of stages and is usually installed in conducting -cleaner and mid scavenger operations. These equipment are mainly used to separate fine conducting minerals like Ilmenite and Rutile from the coarse mineral i.e. Garnet.

Air Tables

These are vibrating tables made of wooden decks. Air is blown in to the table deck which has a cloth on it. These tables are moved to and fro at a high frequency by a driving arrangement. This gives vibratory motion to the table and the heavier minerals like Monazite and Zircon are separated as Concentrate. Air tables are generally used in the final stage of the upgradation of the products. Lighter minerals which escape as impurity in Monazite and Zircon products are removed in these equipments.

Cross - Belt Magnetic Separations

These are high intensity lift type magnetic separators used to separate feebly magnetic minerals like leucoxene from the non-magnetic product like Rutile. In this equipment, the product is allowed to pass through a main belt and a number

WET CONCENTRATOR

FLOW SHEET

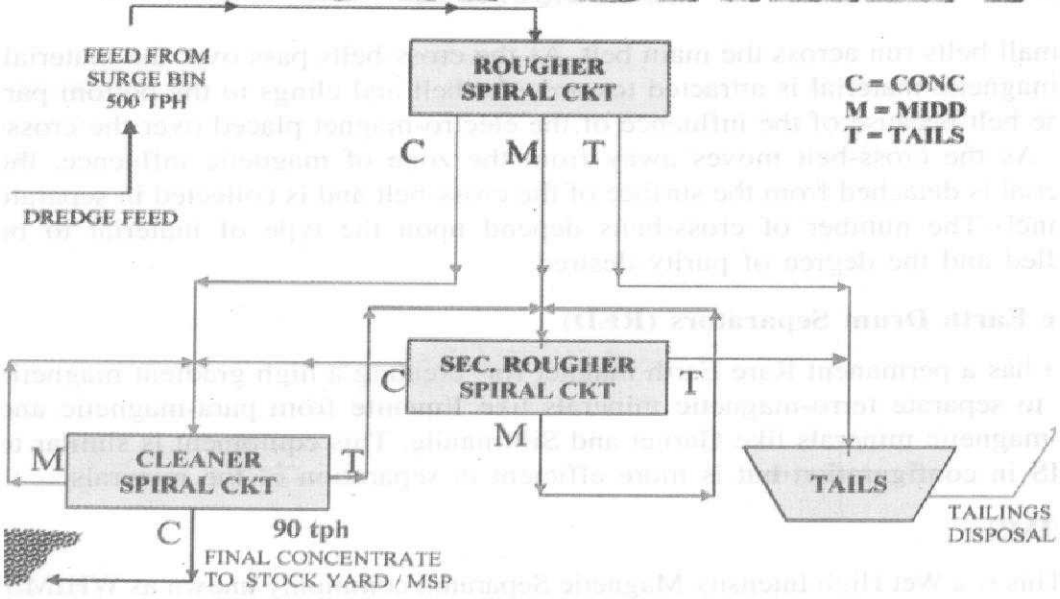

Fig. 3 : Flowsheet of wet concentrator

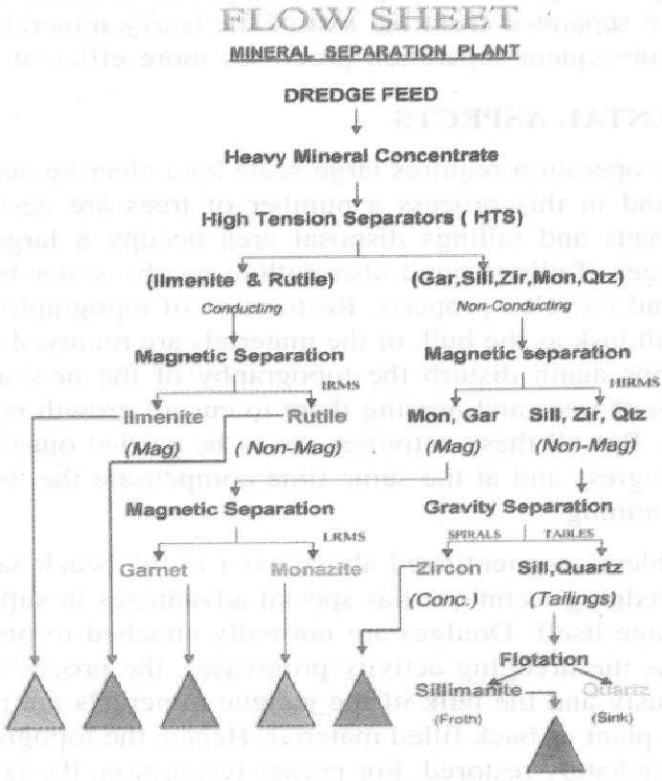

Fig. 4 : Flowsheet of mineral separation plant

of small belts run across the main belt. As the cross-belts pass over the material, the magnetic material is attracted towards the belt and clings to the bottom part of the belt because of the influence of the electro-magnet placed over the cross-belt. As the cross-belt moves away from the zone of magnetic influence, the material is detached from the surface of the cross-belt and is collected in separate channel. The number of cross-belts depend upon the type of material to be handled and the degree of purity desired.

Rare Earth Drum Separators (RED)

It has a permanent Rare Earth magnet for creating a high gradient magnetic flux to separate ferro-magnetic minerals like Ilmenite from para-magnetic and non-magnetic minerals like Garnet and Sillimanite. This equipment is similar to IRMS in configuration but is more efficient in separation of the minerals.

WHIMS

This is a Wet High Intensity Magnetic Separator, commonly known as WHIMS, which works in Wet application in pre-concentration of heavy minerals. When slurry is passed through this equipment, magnetic minerals like Ilmenite (and also Garnet) are separated from the rest of the heavy minerals at the first stage itself making subsequent separation processes more efficient.

ENVIRONMENTAL ASPECTS

Any mining operation requires large scale land clearing activities by dozing, levelling etc. and in this process a number of trees are destroyed. The waste dumps, haul roads and tailings disposal area occupy a large amount of land cleared from trees. Tailings pond also pollute nearby water bodies if the water is not treated and recycled properly. Restoration of topography of the mined out area is a difficult task as the bulk of the materials are removed to far away places and waste dumps again disturb the topography of the new areas in course of time. Plantation of trees and nursing them to ensure growth is a costly and time consuming job. But all these activities are to be carried out to keep the mining operation in progress and at the same time compensate the degradation of land caused due to mining.

All the problems as mentioned above exist in the beach sand mining operation also but dredging technique has special advantages in supporting the nature in its design stage itself. Dredges are normally attached to processing plants as integral part. As the dredging activity progresses, the processing is also carried out simultaneously and the bulk of the gangue minereals are pumped out in the rear side of the plant as back filled material. Hence, the topography of the mined out area is immediately restored. For proper restoration, the tailings stackers are

provided with wire ropes attached to the winches to allow vertical movements so that stacking can be made to desired height depending upon restoration need of the topography. Handling of the tailing over a long distance is eliminated in the mining stage which is the starting point of the whole processing operation. The small amount of tailings generated in the Mineral Separation Plant are pumped to some of the small ponds left intentionally in course of mining. The sand bed in the pond works as a filtering agent and the clean water is collected from the pond and again utilised as process-water. Thus, chances of pollution of tailings water to nearby water bodies is eliminated.

In Beach Sand Deposits, the beach areas are devoid of thick density of vegetation due to saline climatic conditions and only a few species like cashew, casurina, coconut trees survive in this climate. These trees are planted in the mined out area and nursed till they achieve full growth in a more thicker density. Hence the areas which were dry and devoid of any tree before mining operation, look green after the trees are grown in the mined out areas. This further improves the ecology of the surrounding area and prevents migration of sand dunes due of wind.

During mining operation, Monazite is taken out from the raw sand and the mined out area becomes deactivated and more environment-friendly to the local inhabitants from problems of radio-activity. In this way, the beach sand mining activities are completely supportive to the environmental aspects and often termed as eco-friendly system of mining.

USES OF HEAVY MINERALS

The heavy minerlas have wide field of application in various industries. Some of the important uses are given below:-

Ilmenite - It is mainly used in the manufacture of titanium dioxide pigment. It is used in paint, plastic and paper industries. It is also used for production of titanium metal used in air - craft industries.

Rutile - It is used in welding electrodes and also for the production of titanium dioxide pigment, titanium metal/sponge etc.

Sillimanite - It is mainly used in the manufacture of refractory bricks for high temperature applications.

Zircon - It is used in foundries, ceramics and refractory industries. It is also used in the manufacture of metals alloys and chemicals, it has also wide application in high tech industries for production of artificial diamond, structural ceramics, nuclear industries etc.

Garnet - It is used in abrasive industries, for polishing TV tubes, for sand blasting and also for water jet cutting and water filtration purposes.

Monazite - It is used as fuel for the nuclear reactors. It is also used in the manufacture of detergent chemicals, gas-mantles, permanent magnets, colour TV tubes and fluorescent lights. It has also wide application in the production of Rare Earth chemicals etc.

CONCLUSION

In Beach placer deposit, the heavy minerals are always available in the size range of 75 to 500 microns in the form of sand and is often termed as Beach Sand Deposite. Hence the cost of crushing, milling, screening etc. is not incurred for liberation of the minerals from the gangue. Most of the heavy minerals have direct applications in industries and the operation of agglomeration, done in the conventional fines, is not required in case of heavy minerals. Nevertheless, the beneficiation process for separation of individual heavy minerals is not a very simple one as it looks at the first instance. The flow sheet adopted for separation of individual minerals vary widely according to the composition of minerals and the technology deployed and is selected only after thorough study and test works for a particular application. As the cost of production and the quality of the products finally determine the share of the market, great care must be taken in the selection of technology, flow sheet and reliability of equipment which will produce higher out put at a lower operating cost and at the same time meet internationally accepted quality of the products. Because of the wide field of application in hightech industries, the heavy minerals have a promising future and a good source of earning foreign exchange for the economic growth of our country.

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