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Indian Bureau of Mines
Nagpur

Slurry Transportation in Indian Mines

GOVERNMENT OF INDIA
MINISTRY OF MINES
INDIAN BUREAU OF MINES
Nagpur

Slurry Transportation in Indian Mines

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PREFACE

The present bulletin on "Slurry Transportation in Indian Mines" is the fortieth bulletin brought out by Indian Bureau of Mines.

After second World War hydraulic sand winning, handling and transport systems have been successfully experimented in the coal mines in Jharia & Raniganj areas. Hydraulic transport of tailings is being done in the mines of KIOCL, HCL, HZL, SAIL, HGML etc. Thus in India hydraulic transport of solids is not a novelty.

Normally, the better quality deposits which are more accessible are the first to be exploited, while the deposits which are not amenable to beneficiation are neglected. Kudremukh was one such project where there were no transportation facilities. The latest developments in slurry transportation of solids and beneficiation of ores have made this huge deposit economically viable. In order to transport beneficiated iron ore from Kirandul village of Bailadila iron ore sector in Madhya Pradesh to Pellet Beneficiation Complex, Vishakapatnam, the ESSAR Steel Ltd has initiated to lay a long distance slurry pipeline of 268 km. To implement the project, approval is awaited from government. Besides, slurry transportation is also used in some small mines while levigating clay.
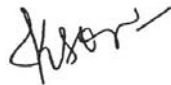
India has vast reserves of iron ore. With depletion of high grade ore, low grade ores have to be mined and beneficiated. Presently, only lumpy ores are being used in large quantities and fines which are more than half of the country's reserve do not find utilisation owing to high rail and road freights. The pipeline transport require less capital investment & operation cost and therefore can be largely beneficial to the steel industry.

Transport of mineral in slurry form in pipelines not only makes the project cost effective with no spillage but also environment friendly as it do not affect environment in any way once pipeline is laid. Other mode of transport system on land affects the environment in one or the other way.

In this bulletin, advantages, disadvantages, basic operations, factors to be considered and slurry transportation system at some Indian mines have been discussed based on the information obtained from various public and private organisations wherever slurry transportation is in practice.

It is hoped that the bulletin shall be useful to personnel in the industry who are interested in the application of slurry transportation.

Nagpur
Dated : 26-05-2001

(K. S. RAJU)
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CONTENTS

INTRODUCTION

Mined out material needs transportation to the actual site of consumption or sale or export. For this different methods are available. Pipeline transportation is well known for fluids like petroleum and natural gas. For solids and comparatively heavier solid minerals, Slurry Transportation System is adobted. Solids with low specific gravity like potash, coal etc. do not pose any serious problems. Several long distance pipelines for transportation of solids are in operation since fifties. But, minerals with higher specific gravity and abrasive in nature like iron ores do present some difficulties in designing the pipeline mode of transport. River Savage in Tasmania near Australia was the first to have a long pipeline of 100 km laid for the purpose of transport of 2 million tonnes per annum of iron ore in the form of slurry from the mine head at long plains to Port Lata. After this project, the movement of iron ore fines in slurry form are finding increasing application in many parts of the world.

In India, after Second World War, several hydraulic sand-winning, handling and transport systems were successfully experimented, installed in various coal mines.

Hydraulic transport of tailings was introduced in Kolar Gold Mines and at Jaduguda Uranium Mine, for filling underground voids. Transportation of fine material through pipeline over short distance is being practised in beneficiation plants at several places in the country.[1]

The cost of transportation of raw materials from the source to their ultimate destination has a bearing on the final cost of product. Kudremukh is an example of a prospect which was once rejected for lack of transportation facilities and for every low concentration of iron in the ore. But with the developments in slurry transportation of solids and beneficiation of ores, this huge deposit became economically viable. Iron ore concentrate is transported in slurry form through pipeline for a distance of 67 km.

A recent and encouraging development in slurry transport through pipes is the envisaged project in which iron ore concentrate would be transported through cross country slurry pipeline over a distance of 268 km passing through three states, i.e., Madhya Pradesh, Orissa and Andhra Pradesh. For this project, the zero point will be Kirandul Village in Bailadila Iron Ore Sector in Madhya Pradesh and destination will be Pellet Beneficiation Complex of Essar Steel Ltd at Vishakhapatnam in Andhra Pradesh. Pre-construction activities have been completed for this project which is scheduled to be completed in 18 months.

In subsequent chapters, the Bulletin discusses : Theory (Ch.2); Basic Operations (Ch.3); Criteria—Pipeline Designing (Ch.4); Characteristics (Ch.5); Case Studies (Ch.6) and Future Outlook (Ch.7).

THEORY— HYDRAULIC TRANSPORT SYSTEM

Hydraulic transport system is a method of transporting solid material through a liquid carrier. The solid may be :-
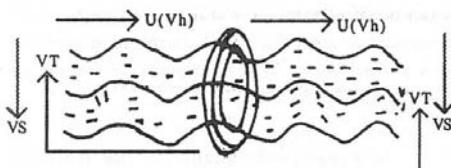
a) in a suspended state;

b) pulverulent, granular or coarse materials commonly used in construction and mining industry;

c) fibrous materials or wood chips for use in paper making etc.

The theories relating to this transportation system are discussed below.

2.1 Theories on Hydraulic Transport System

LIFT FORCE THEORY

While transporting ores (crushed/ground) which are denser than water, they have to be kept in suspension in carrying stream during actual movement. The material is carried by the flowing water through the pipeline by "lifting force". The lifting force is created due to the difference in the static pressures between the velocities in various sections of the stream. This is achieved by the velocity of the transporting medium which normally is water. In an open channel flow, the velocity is maximum at the top and minimum at the bottom. It has been found during studies that 'lift force' is proportional to the velocity of the stream in the pipeline. When the velocity of the stream in the pipeline is low the lift force will not the adequate to move the material. Consequently the material to be transported will cease to be in suspension and start settling at bottom, creating pipeline jams.

TURBULENCE THEORY

The solid material to be carried in the pipeline has to be kept in suspension as stated in (A) above. This is achieved by making the stream in the pipeline turbulent. In turbulent flow, solid particles take a wavy path due to a vertical component 'VT' and Horizontal Velocity 'U' as shown in Figs. 2-1 & 2-2.

VT – Vertical Component
VS – Settling Velocity
U(Vh) – Horizontal Velocity

Fig. 2-1 Turbulence Flow
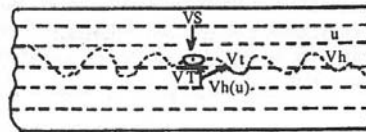
VT – Vertical Component
VS – Settling Velocity
Vh(u) – Horizontal Velocity
Vt – Resultant Component/Turbulence Velocity

Fig. 2-2 Turbulence Flow

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Minimum possible velocity of the stream which keeps all the particles in suspension is called 'Critical Velocity' (Vc)'. Velocities less than Critical Velocity cause pipeline jams, while higher velocities cause energy losses. For flow at critical velocity, i.e., transportation in suspension the *Turbulence Velocity* (Vt) should be equal to the *Settling Velocity* (VS) or (Vt = VS). Settling velocity which means constant terminal velocity of free falling particle in water is determined by knowing the weight of the solid particle, weight of the volume of water displaced by the particle and viscous resistance to motion of particles in water. By studies, it is found that turbulence velocity 'Vt' is a function of U (or Vc for optional regime of flow) i.e. Vt = VS (Vc). (Figures. 2.1 and 2.2).

GRAVITATIONAL THEORY

The flow of slurry can be by gravity or by pumping. According to gravitational theory, the most important parameter is "Hydraulic gradient" i.e. resistance to motion per metre length of pipe or channel. The requirements of hydraulic transport by gravity are :

i) Volume of concentration, i.e., ratio of solids in slurry should be as high as possible. High concentration reduces quantity of water to be pumped and decreases pipe wear per tonne of solids under transportation.

ii) Velocity of slurry should be as low as possible but above critical level.

iii) Diameter of a pipe is important parameter for regulation of velocity and should be judiciously chosen in given system.

2.2 Problems

Formation of cavitation, jamming and bursting of pipeline are major problems in this type of transport system. Air pockets may be formed at the bend of pipeline and these may cause drop in pressure and local concentration of heavier particles. Some of the solids which cannot be carried by the designed velocity will settle down. The stream immediately behind the air pocket, accelerates these deposited solids from rest at the expense of a part of kinetic energy as a result of which velocity further drops and ultimately falls below the critical level, leading to further deposition of solids. The process repeats till pipeline gets chocked and jammed. The chances of jamming increase with the increase in quantity of air in the stream.

It is essential to maintain feed rate of slurry at an optimum value as calculated from the installed pipe diameter. A decrease of velocity below the critical level, caused by reduced slurry fed into the pipeline would lead to jams.

In cold countries/regions, freezing in winter poses a serious problems. Burying of pipeline below the frost line is an answer but advantage of rotation is lost. For uninterrupted operation due to other adverse factors, solids have to be of very fine size particularly in long pipeline.

2.3 Types

Solid - liquid mixtures can be prepared and transported in various ways depending on specific gravity, size of particles and their distribution, dissolving and separation characteristics of solids in liquid used which for all practical purposes is water. Whatever may be the mode and type of pipeline to be economically successful, it must fit into the overall system. Broad classification of various hydraulic transport system is as follows :

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HYDRAULIC TRANSPORT SYSTEM

Between 0.2 & 2 mm by either suspension or saltation	Saltation Coarser than 2 mm or low velocity	Suspension finer than 0.2 mm or high velocity	Solutions			Sediments
			Non-settling	Stabilised	Settling	
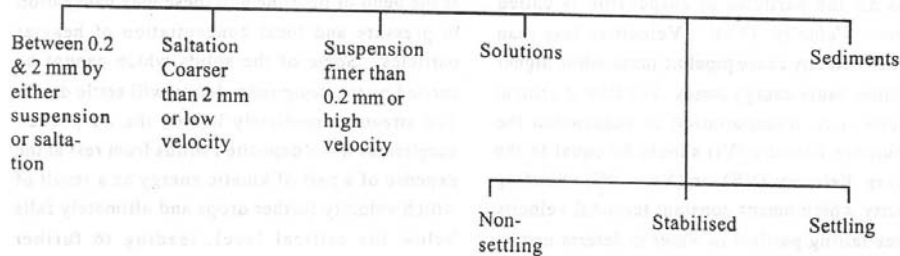
Where heavy material is mixed with water or another liquid, mixtures could be :

a) Homogenous - when particles size is very fine.

b) Heterogenous - coarse particles exceeding a few tenths of millimetre.

2.3.1 Homogenous Mixtures (Slurries)

Solid particles in slurries govern the viscocity of conveying fluid and such mixtures have distinct plastic properties. Near the state of rest, the medium behaves as solid and solid particles are able to settle down. Flow cannot occur until there is a certain internal shear stress. When flow occurs, if it is a laminar flow, apparent viscosity varies with velocity and if it is turbulent flow then mixture behaves as a Newtonian fluid. A Newtonian fluid is one which exhibits direct proportionality between shear stress and shear rate in a Laminar flow, the ratio between shear stress and shear rate being the viscosity of fluid.

Such slurries can be transported equally well under laminar and turbulent conditions if materials are very fine, i.e., under 5 micron, such as collodial clay e.g. bentonite. If materials to be conveyed are from a crushing mill and

contain some particles upto 0.1 to 0.2 mm but with an appreciable proportion of materials finer than 50 micron, transport should take place in turbulent flow.

2.3.2 Heterogenous Mixtures

In such mixtures grains do not affect viscocity of the conveying fluid. Behaviour of flow follows the patterns given below :

1. In suspension

   If grains are fine, i.e., less than 0.2 mm or if flow velocity is high.

2. In saltation

   If grains are coarser, i.e., more than 2 mm or if flow velocity is low.

Materials of sizes between 0.2 mm and 2 mm depending on flow velocity may either be transported in suspension or saltation.

These motions in a duct may have transport of two types :

a) First type has a forced flow condition. No grain is able to remain stationary in

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the pipe and all move forward along the flow.

b) Second type has transport with deposit formation.

This has a state of equilibrium between the flow and materials conveyed. Liquid flow may not be sufficient to keep average velocity in the pipe above the critical deposit forming velocity. The conditions are unstable if pumping plant has wrong characteristics. This may result in complete blockade of the pipe.

Non-settling slurries are preferred due to low power consumption. Variation in distribution of size of particles and/or chemical treatment is practiced to obtain stabilised slurries from settling slurries.

BASIC OPERATIONS

Basic operations involved in a slurry transportation system are Slurry Preparation and Slurry Pumping.

3.1 Slurry Preparation

Preparation of slurry normally involves both size reduction, i.e., crushing and grinding and slurrification of the ground product by the addition of the liquid, generally water. Slurrification is carried out by wet grinding process. The crushed ores is fed into the grinding mill and water is added during the process. This gives slurry. Chemical additives is also some times used to the slurry for preventing corrosion in the pipeline and improving the characteristics of the slurry being transported.

3.2 Slurry Pumping

Machines used for pumping the slurry are :

a)   Piston/Plunger type pumps.

b)   Centrifugal pumps and turbine pumps.

c)   Jet pumps (rarely used).
Capacity of the pumps will depend upon the quantity to be transported.

3.2.1 Pipe and Pipeline

The size of the pipe depends upon the quantity of the material to be transported. The material of the pipe should have high resistance to abrasion, corrosion, high strength and ductility. The specification of the pipe should be such that it could be laid easily and subsequently maintained economically.

3.2.2 Protection of Pipeline

The corrosion and erosion are two main factors affecting the slurry pipeline. The corrosion affecting the pipeline is both external and internal. External protection is given by various surface treatments while internal corrosion is prevented/restricted by means of mixing chemicals into the slurry. In order to prevent the abrasion, the pipeline is rubber lined. If it is not lined, sufficient margin is given in the wall thickness of the pipe to take care of normal wear[2]. In such cases thicker pipe wall will give more life to the pipeline. Life will also depend upon the abrasiveness of the material being transported. Wear will also be more with smaller pipe diameter compared with the quantity of material to be transported.

It is not possible to provide at economic cost a protective coating which will give permanent protection, hence cathodic protection is necessary to prevent exposed metal from corroding.

3.2.3 Pumping Stations

The number of pumping stations depend upon the terrain and the distance to be covered. Normally, the pumping stations are spaced at 100-150 km. If the pipeline diameter is small causing high rate of friction losses, the distance between the pumping station is kept less.

Pumping can either be done with reciprocating piston/plunger type pumps capable of giving high head or by a battery of centrifugal pumps in series. The slope of the pipeline carrying slurry under gravity would be such that the head gained is neutralised by the friction losses, thus, avoiding high exit velocity at the discharge end.

3.3 Slurry Utilisation

It is necessary to dewater the slurry to obtain the mineral in the form of cake for further application/ use. The main operations taking place at the terminal side of the slurry pipeline are: storage, thickening, dewatering and drying.

3.4 Instrumentation

For satisfactory operation of the system, it is necessary to install instruments at selected places on the pipeline to ascertain adequate information in respect of :

  a) Pipeline pressure

  b) Velocity of slurry flow and

  c) Concentration of solids.

PIPELINE PRESSURE MEASUREMENT

For pressure measurement Bourdon and diaphragm gauges are used. Suitable types of traps for removal of air and fine solids are used in conjunction with Bourdon gauges.

VELOCITY MEASUREMENT

Direct measuring instruments are not suitable for use on slurry pipelines as they are susceptible to blockage, wear or damage due to the presence of solids. Therefore velocity measurement is carried out by indirect (i.e. inferential) means. Common types of inferential meters are venturi meters, orifice plats, nozzles, dall tubes, electromagnetic flowmeters and rotameters. Thereafter no restriction to the slurry flow and may be installed in pipes at any gradient can be used for measurements an any non-magnetic slurry.

DENSITY / CONCENTRATION MEASUREMENTS

Instruments used for this purpose are counterflow concentration meter and gamma ray absorption meter. The concentration is also determined by measurements of conductivity (electrical) and by weighing[3].

Fig.No. 3-1 shows a schematic line diagram for transportation of iron ore slurry[2].
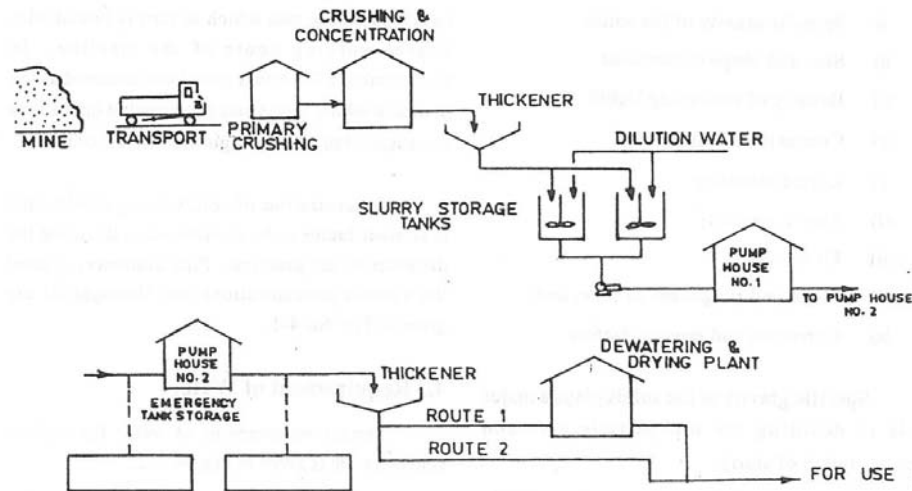

Fig. 3-1 Schematic Line Diagram for Transportation of Iron Ore Slurry

CRITERIA— PIPELINE DESIGNING

4.1 Design Factors

The major factor for designing the slurry pipelines is the nature of flow through the pipeline, i.e. whether the flow is homogeneous or heterogeneous. In homogeneous flow the solids are distributed uniformly throughout the liquid medium and the concentration of solids is high and the particle size is small. In heterogeneous flow, the solids are not distributed uniformly in the liquid medium and the concentration of solids is low and particle size is higher as compared to homogeneous flow. In addition to this, there are number of other factors which affects the slurry pipeline design. These are as follows : [2]

   i)   Specific gravity of the solids

   ii)   Size and shape of particles

   iii)   Density of conveying liquid

   iv)   Concentration of Solids

   v)   Liquid viscosity

   vi)   Slurry viscosity

   vii)   Flow rate

   viii)   Slope and roughness of pipe, and

   ix)   Corrosion and erosion factors

Specific gravity of the solids plays a major role in deciding the top particle size and concentration of slurry.

The transportation velocity is normally maintained around 1.7 m/sec depending upon the slurry viscosity. The velocity depends upon the maximum particle size. The main reason for keeping velocity on lower side is to minimise abrasion in the pipe. The velocity is chosen so as to keep the concentration homogeneous.

The quality of the slurry should be such that it should be restartable, i.e., when the pipeline shuts down, the solid particles should settle in such a way that the system can be restarted with ease by the flush water pump.

4.2 Pipeline Diameter

The pipeline diameter is decided on the hourly pumping rate which in turn is linked with annual working hours of the pipeline. In Kudremukh, 5760 hours have been assumed as the annual working hours since the mining operations are suspended during high monsoon months.

Concentration of solids being transported is another factor to be considered in deciding the diameter of the pipeline. Pipe diameters against the various concentrations and throughputs are given in Fig. No.4-1.

4.3 Requirement of Water

Annual requirement of water for various concentration is given in Fig.No.4-2.
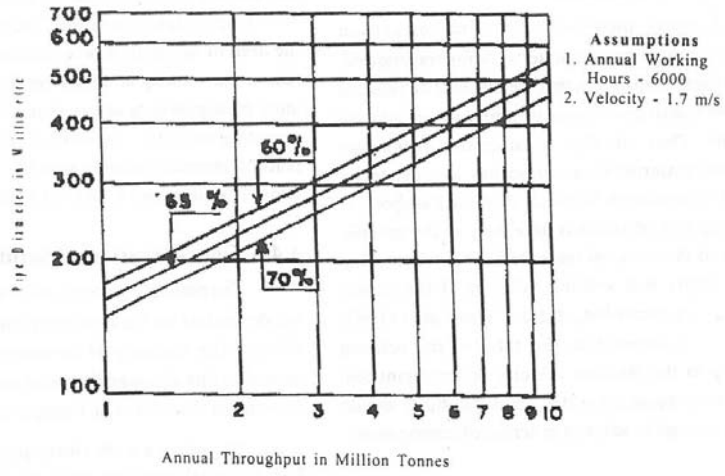
Technical parameters in designing slurry pipeline.
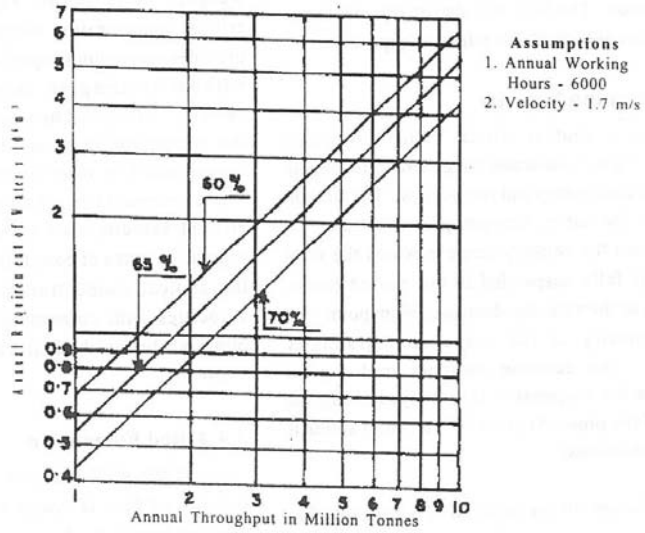
Fig. 4-1 Pipe Diameter Required with Various
Throughputs & Concentration

Fig. 4-2 Annual Water Requirement with Various
Throughputs & Concentration

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4.4.1 Slurry Fineness

A slurry pipeline system makes certain demands upon the solid material being transported. One of these demands is that the material be reduced to a fine consistency prior to introduction into the pipeline. Thus, the first consideration is whether the solid material in question has a consistency which is fine enough for slurry pipeline transport. A lower top size of solids is necessary as the specific gravity of the material increases. This relationship would imply that settling velocity of the coarse material is a controlling factor. Wasp et al (1963, 1967) have shown that the ratio of the settling velocity to the friction velocity is important and ranges from about 0.1 to 0.3. Thus, the slurry should be fine enough to achieve criterion of homogeneity.

Heterogeneous distribution results in higher frictional energy losses that would occur with homogeneously distributed system of smaller and/ or lighter solids at the same flow rate and concentration. The flow will also be less stable and will be more subject to the effects of pipe slope.

4.4.2 Pumping Velocity

This is another critical variable in slurry pipeline. Fig.4-3 illustrates the general relationship between pressure drop and rate of flow. The straight portion of the curve, between points 'A' and 'C' encompasses the velocity range in which the solid material is fully suspended in the carried liquid. However, as the velocity decreases from point 'A', the uniformity of the suspension gradually decreases. This decrease continues until at point 'C' where the suspension is conveyed along the bottom of the pipe. At point 'D', a bed of solids is found to be formed.

Although all the material is being moved in suspension until point 'D' is reached, it is not desirable for the solid particles to be dragged along the bottom of the pipelines. In addition, experiences with long distance pipelines indicated that this is the area of unstable flow conditions. It is for this reason the velocity at which the pipeline is operated must be somewhere above point 'C', the minimum operating velocity. Experience has shown that the practical operating velocity point 'B', will vary between 3 fps (91.4 cmps) and 6 fps (182.8 cm. p.s) fps.

4.4.3 Concentration of Solids

The pumping velocity and the critical velocity are dependent on the concentration of solids in the slurry. The viscosity of the slurry is also directly related to this although this relationship varies from material to material to be transported.

Experience with slurry pipelines indicates that the most practical concentration of solids is in the general area where a small increase in solids concentration causes a large increase in viscosity e.g. in Figure 4-4 a stage at around 50% solids by weight. It is at this region (the so called critical concentration range) that the slurry itself provides maximum support for the coarse particles without creating an untenably high critical velocity. As implied by viscosity curve, increasing the concentration of solids beyond the critical range results in sharp increase in pressure drop. More important, however, is that the critical velocity also increases sharply in this region. In terms of cost, this means that exceeding the critical concentration will require higher velocities with corresponding higher costs for pumping but with little real gain in increased capacity.

4.4.4 Bed Formation

If the solid particles are too large and the velocity of flow is low, a bed of deposited solid particles form at the bottom of the pipe partially restricting the flow. This reduces the efficiency and
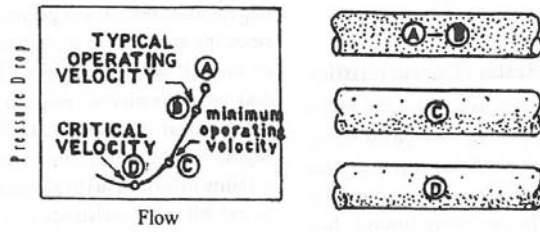
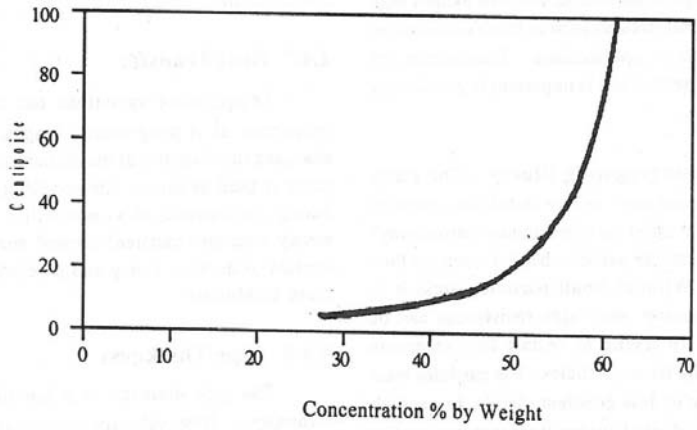**Fig. 4-3 Effect of Pumping Velocity on Pipeline Flow Conditions**
(Wasp et al. 1971)

Fig. 4-4 Effect of Solids Concentration on Slurry Viscosity
(Wasp et al 1971)

carrying capacity of the pipe and is clearly undesirable in a commercial pipeline. Variation in the specific gravity of the solid particles can also affect the bed height.

4.4.5 Shutdown and Restart Characteristics

When a slurry pipeline is stopped the solids will settle down on the bottom of the pipe assuming that the specific gravity of the solids is greater than that of the carrying fluid. In pipelines crossing hilly country, the solids can further move towards low points of the line profile. Three view points of this problem must be considered in order to arrive at a slurry composition which ensures that the pipeline can be restarted without difficulty.

Settled Bed Velocity : The particles must not be too small (less than, say, 0.1 to 1 micron range) or the settled bed viscosity will be excessive due to large inter particle forces. Moreover, the solids must not be too large or the settled bed will exhibit high yield and normal stresses such as those encountered in soil mechanics applications. Maintaining the fluidity of the settled bed is important to permit easy restart.

Stable, Non-segregating Slurry : The slurry concentration and particle size distribution must be selected so that large particles do not "settle away" and leave the smaller particles behind when the flow is stopped. Without small particles present to "lubricate" motion, very high resistances can be encountered on trying to restart line segments containing only larger particles. The particles must settle as more or less coherent cloud. In general, steep angles of pipe inclination require smaller particles size distributions to prevent this segregation of particles of different sizes.

Sliding or Slumping : If the pipe slope is too steep, the settled solids will not be held in a distributed way along the incline but will slide down into the valley sections. While such conditions may not necessarily create prohibitively large impediment, restart will generally be more difficult since the entire cross section of pipe at the bottom of the hill will be occupied by the solids. The maximum permissible slope to just avoid sliding is not necessarily related to the so called "angle of repose" of the solids. In contrast with the kind of stability described in (b) above, larger particles seem to exhibit more resistance to sliding of the settled bed than smaller particles.

4.4.6 Pipe Slope

Most of the discussion in (4.4.5) above also applies to this parameter. In general as pipe slope is allowed to increase higher concentration and finer solid particles will be necessary to provide the required characteristics. In hilly terrain, the allowable pipe slope will lower the cost of pipeline construction.

4.4.7 Heat Transfer

Temperature variations can affect slurry properties as it progresses along a pipeline by changing the viscosity of the carrier fluid, and when water is used as carrier, the possibility of freezing during shut downs is also a possibility. Appropriate steady state and transient thermal analyses can be applied to develop slurry and pipeline designs for these conditions.

4.4.8 Pipe Thickness

The pipe diameter is a function of solids throughput, flow velocity and costs. The wall thickness is decided by the pipeline pressure and allowance for erosion and corrosion. The normal economic range of wall thickness found in slurry systems is between 0.188 inch (0.477 cm) and 0.500 inch (1.27 cm). Heavier walls are feasible, but call for a premium both in first cost and in welding and

installation costs (0.750 inch i.e. (1.905 cm is usually the practical maximum). On the minimum side (other than manufacturing considerations), the limiting factor for buried pipe is usually external loading. Conventional rule of thumb is (outside dia/thickness) 128. The carrying capacity of a pipe is proportional to the 5/2 power of its diameter.

4.4.9 Corrosion

Corrosion can be controlled by the addition of certain chemicals to the slurry at the preparation plant and en- route. If corrosion is much reduced, low velocities and small particles sizes will cause very little erosion. The corrosion/ erosion allowance in pipe thickness should be heavier in the first few km. of the pipeline where free oxygen may be expected and where the particles have not been rounded by rubbing against each other. Any chemical additives should not be detrimental to the "hydraulic design" of the slurry.

As far as the design of a slurry pipeline is concerned, each slurry and situation is unique. No standard design procedure is available. Almost all the correlations are empirical and most of the data for design are based on experience and is often inadequate. Under these circumstances, it would appear that there is no better way for optimizing the various parameters of slurry pipeline design than a through investigation on laboratory and pilot plant scales.

CHARACTERISTICS

In a short span of two decades, slurry transportation of solids has scored over the other established modes of transportation viz. rail, road, aerial ropeway, conveyors, inland water ways, etc. The advantages and disadvantages have been given in following paragraphs.

5.1 Advantages of Hydraulic/ Slurry Transport of Minerals[1,2]

a) Low capital cost as compared to rail transport or road transport (a comparison is given below in Table - 1) is far more cheaper to operate and maintain. Its power requirement is very low.

Table No.1

Capital Cost of transportation of slurry through pipeline and other modes[2]

Distance (km)	Capacity (t/Yr)	Capital cost in million Rs.(approx.)		
		Slurry through pipeline	Railway	Roadway
100	1	23	127	97
	2	37	168	164
	3	44	200	231
	5	56	274	370

Note : Cost on the basis of level terrain (a comparison)

b) Fewer personnel are required to attend. Highly automated pipelines require relatively few operating and maintenance personnel.

c) Due to comparatively low capital and operational costs, development of minerals below the present cut off grade, previously considered uneconomical due to prohibitive costs can be reconsidered for exploitation. This is more applicable for undeveloped area having difficult terrain and inclement weather.

d) It eliminates dust hazard, air and noise pollution. There is negligible effect on the aesthetic of the surrounding area as the pipeline is buried or it may be quite inconspicuous. Thus, it is environment friendly system.

e) Space requirements are very much less. As normally the pipeline is buried, the land above it can be used again for agriculture.

f) It is particularly a boon for transportation under adverse conditions, across areas of thick jungles, across the ocean floor or over scorching deserts.

g) The system can be operated intermittently.

h) Slurry pipelines offer more economical service with the increase of volume to be transported. Unit cost of transportation decreases dramatically with the increase in the annual volume.

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i) It helps establishment of processing units, mineral based industries etc. in coastal area.

j) It is one of the safest and most reliable means of transportation having very few encumbrances.

k) Same pipeline can be used for oil, gas, water, and slurry transportation with slight modifications.

5.2 Disadvantages

a) All materials cannot be transported through pipeline as compared to rail and road transport.

b) It may become incompatible with any change in the existing system to be adopted in future.

c) Any change in the feed material or the relocation of the slurry preparation facility may pose difficulties.[1,2]

5.3 Conditions Favouring Pipeline Transport

a) Nature of terrain if rough and rugged, the investment cost for rail, road, conveyor etc. may be prohibitive. In such case, transport through pipeline shall get preference.

b) Advantage of gravity transportation is more in cases of high altitude difference between mine site and place of disposal viz. port or the steel mills. Operation cost due to gravity is very low as power requirement will be less and in some cases may even be nil.

c) Size of mineral particles should be very fine, the finer the better, because the material needs to be kept in suspension to have a stabilized slurry. The grind size may be as low as 100% minus 200 mesh, and 80-90% minus 325 mesh. Power requirements increase considerably if size is coarser and bulk density higher.

d) If the material to be transported is available in large quantities in the form of slurry as a part of the process itself.

e) Tonnage of solids to be transported should be large as the transportation cost comes down with the increase of volume of material.

f) Availability of water in large quantities.

g) Chemical characteristic of the material should be such that corrosive and other effects are not very harmful[1].

CASE STUDIES

6.1 Pipeline of Kudremukh Iron Ore Co. Ltd

In India, Kudremukh Iron Ore Mine, in Karnataka State is the only mine where iron ore concentrate in slurry form is transported through pipeline over a long distance. The deposit at this mine is known since 1913 and is principally magnetite. The deposit is in the Kudremukh-Aroli-Gangamula range in the Western Ghats of India and is close to the port of Mangalore on the western coast. Initially, this deposit was considered to be un-workable because there were no transportation facilities and the concentration of iron in the ore was very low. The development/advances in the techniques of beneficiation of low grade magnetite ore coupled with virtual reduction of transportation cost of solids in slurry/pulp form led to commercial exploitation of the deposit. The latest development in slurry transportation of solids and beneficiation of ores have made this huge deposit economically viable.

The iron ore is transported from the mine to the crusher by 108 tonnes capacity dumpers. The crushed ore is then transported to the processing (beneficiation) plant through a conveyor system. Subsequently, final product, i.e., concentrate in the slurry form is stored in two slurry storage tanks each of 4500 m³ capacity. The pipeline distance of transport from slurry storage tanks to the port handling plant comes to 67 km.[4] During normal operation, the pipeline carries 1115 m³/h of slurry equivalent to 1,500 t/h of dry ore. At present, about 6 million tonnes of concentrate is being transported with reduced pumping hours as against the designed capacity of 7.5 million

tonnes/year. One battery of pumps will receive slurry from either of the storage tanks. One flush water pump along with one standby pump is provided to flush the pipeline immediately after shut down. The pumping is started by water first and then gradually switched over to slurry. At normal shut off, the procedure is reversed i.e. water replacing slurry. In case of power failure the slurry remains in the pipeline. Restarting of the line is done by flushing water into the pipeline before the slurry is pumped.

The schematic diagram of the system showing concentration area, pump station, pipeline and terminal area is given in Fig. No.6-1.

The general topography along the pipeline route is characterised by a mine rising above river Bhadra-sub-basin, a rugged mountain ridge covered by dense forest and coastal plain leading to port facility. The maximum gradient of the route is 10%. The horizontal and vertical radius of curvature is 12.3 m and 9.7 m respectively.

6.1.1 Slurry Pipeline & Pump Details

1) Life : The life of the pipeline may be around 30 years.

2) Length : 67 km long 13.1 km upgradient from 802 RL upto 849 m RL (= 47 m head) and then by gravity to Mangalore Port (MSL).

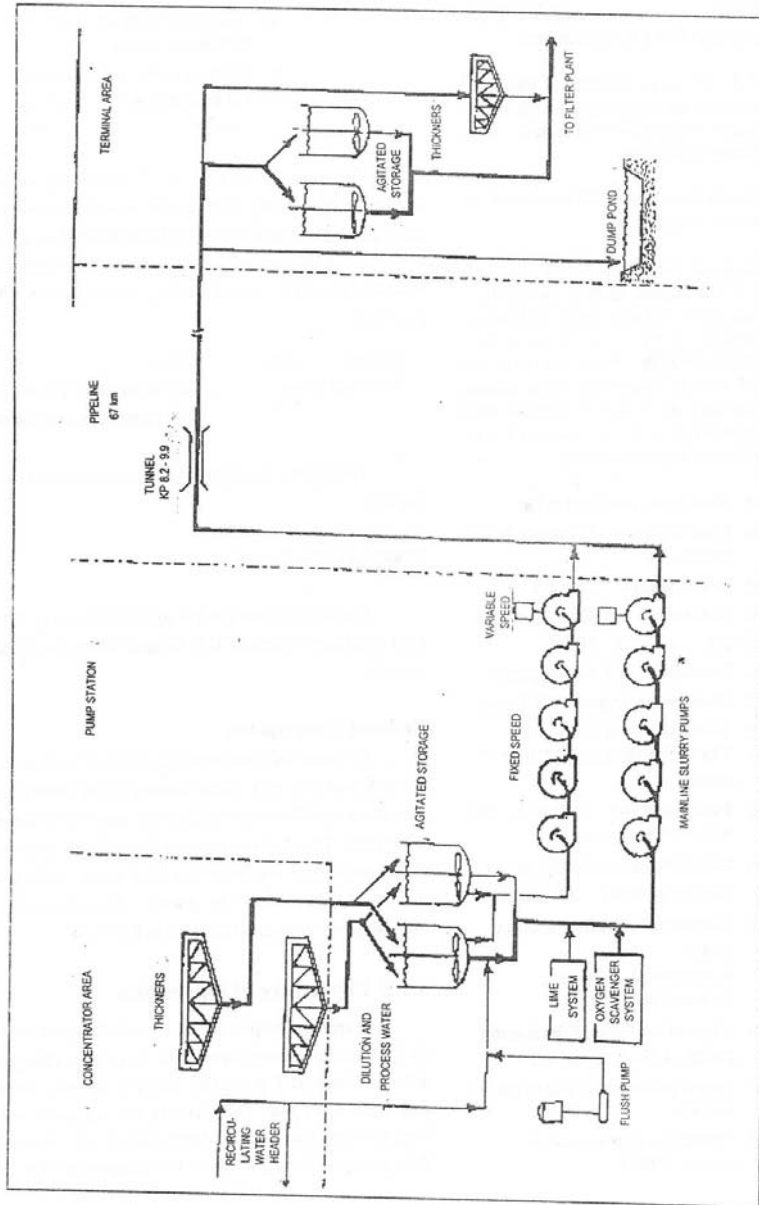3) Diameter : 18" dia upto 13.1 km (457 mm dia) 16" dia afterwards upto (terminal) 67th km (406 mm dia)

Fig. 6-1 Schematic Representation of Kudremukh Slurry Pipeline

4) Make : ERW, high wear resistant, Steel pipes, API 5 LX 52 standard

5) Capacity : 7.5 million tonnes / year of concentrate with projected life of 30 years 1300-1500 tph approx. with 60%-70% solids.

6) Thickness : Varies from 10.3- 18.3 mm based on slurry hydraulics.

7) Profile : Rugged terrain passing through 1.7 km tunnel, buried generally a minimum of one metre and above ground pipe is restrained and anchored at both portals at 12 metres intervals. Pipe routes marked at 4 km intervals and identified at 2 km intervals and kilometre post markers.

8) Operating Parameters :
a) Flow rate - 600-900 m³/hr
b) Flow Velocity - 1.8 m/sec to 2.8 m/sec.
c) Density/spgr - 1.8 - 2.2
d) % solids - 60-70
e) pH - 9.5 - 10.0
f) Pressure - 18.5-34 kg/cm²
g) Dissolved Oxygen - < 2.0 ppm
h) Wear rate - 8 mills/year
i) Time taken to reach M'lore - 7 hours
j) Particulate size - 325# 60 to 70% min, +100# 1% max.
k) Operating hours : 5760 per year
l) Design velocity : 2.8 m/sec
m) Horizontal centrifugal slurry pump
  a) operating : 5 Nos
  b) Stand by : 5 Nos
n) Vertical centrifugal flush water - pump : 1 No
o) Power required for slurry pump: 400 kW
p) Operating power load on slurry : 1900 kW
q) Power required for flush : 800 KW water pump
r) Storage tanks with agitator
  - at Kudremukh : 2 Nos
  - at Port : 2 Nos

The pipeline is buried 1-2 metre below the ground along most part of the route and passes through a tunnel, where it is laid above the floor along one side of the tunnel. It may be stated here that rotating pipeline buried underground may not be possible.

Length of tunnel .. 1.7 km
Size and shape .. 2.25 m wide x 2.25 m high with a semi circular ceiling

The slurry pipeline route map is depicted in Fig.6-2.

Gradient of the tunnel

The tunnel rising at 1% upto half the way from East and then falling at 1.57% upto West end of the tunnel.

Gradient of the pipeline

Elevation of pipeline increases by 47 m from the pump house to a high point located in the tunnel and then drops by 847 m (1.57%) from this point in the tunnel to the port. The slurry is pumped from the pump house to the high point and from this high point to the port facility, the slurry flows by gravity. Flow diagram of transport concentrate is depicted in Fig. 6-3.

6.1.2 Procedure of Operation

Water is pumped for two and half hours or till 18.5 kg/cm² pressure is reached. It is then changed over to slurry at 1.8 density initially for two hours and then with max 2.2 density till agitated tank become empty or density drops below 1.8. Water is then pumped for eight hours for flushing so that the
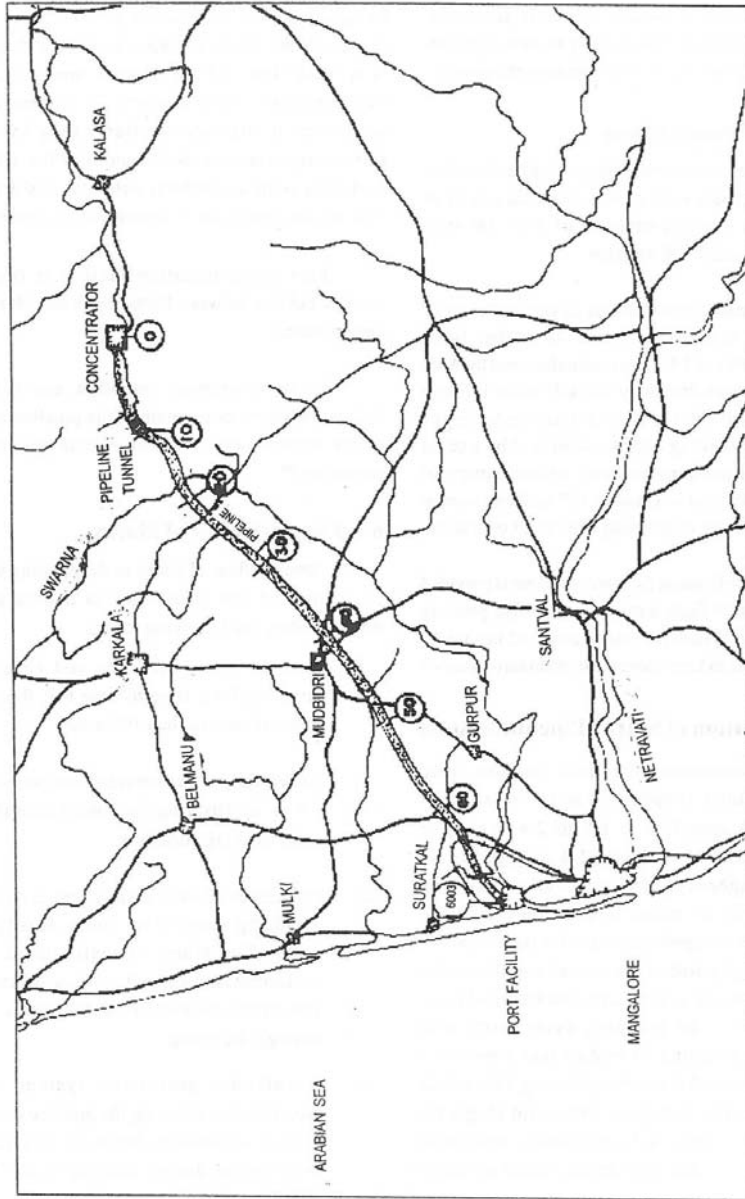
Fig. 6-2 Kudremukh Iron Ore Project – Slurry Pipeline Route Map

slurry in the pipe is cleared to avoid jamming. Scrapper pig is launched biannually to clear pipeline, internal scaling and to improve pipeline efficiency.

6.1.3 Slurry Pump House

Iron ore concentrate slurry is stored in two slurry storage tanks each of size 20 m dia and 18 m high having a working capacity of 4500 M^3 each equipped with a 250 kW agitator.

The pump house consists of two batteries of pumps. Each battery has 5 nos. of rubber lined centrifugal pumps of 14/12 size manufactured by Allis Chalmers and each driven by 400 kW motor through speed reducers at 550 r.p.m. At a time, one battery of pumps will be running and the other will be a stand by. The rated pumping capacity of one battery of pump is 1115 m^3/hour at a head of 137 m during normal operation on slurry containing 65% solid operation.

Water for flushing the slurry pipeline is provided by a high pressure flush water pump. A high pressure gland seal water system provides water at 42 kg/cm² for the pump glands to keep them clear of abrasive slurry[5]

6.1.4 Operation of Slurry Pipeline System

The maximum size limit for the solid particles in slurry is specified at 100 mesh. The flow velocity specified is 1.8 to 2.8 m/s. The operating velocity is about 2.4 m/s giving an average throughput of 1500 tph of dry solids. The ground profile of route is such that slurry is required to be pumped upstream for the initial 8.7 km upto a high point in the tunnel and thereafter the slurry flows by gravity upto the terminal point at Mangalore. The pumping cycle starts with initial water pumping to ensure that pipeline is full with water and then slurry having 55% solids is pumped. After pumping 55% solid slurry for two hours the density is increased, maximum being 70% by weight. During the initial period of

pumping the orifice station at Mangalore gives the necessary back pressure to ensure that there is no back flow. If the flow becomes slack, the pipeline gets filled with slurry. It is then flushed with water to displace the slurry fully by water. Instruments are provided to monitor the different variables such as density, velocity of slurry etc. The whole operation is controlled by computer .

Fast communication facility is provided through hot line between Kudremukh and Mangalore control room.

Under emergency condition, due to power failure the slurry can remain in the pipeline upto 24 hours without any harmful effects and flushed thereafter.[5]

6.1.5 Smooth Flow of Slurry

Smooth flow of slurry in the pipeline without plugging and the slack flow is maintained by implementing the following steps :

i)   Concentrate is screened and ensured by sampling from time to time that there is no material coarser than 100 mesh.

ii) The velocity is maintained above the minimum 1.8 m/ by ensuring that slurry pumps are in good working condition.

iii) Percentage of solid in the slurry is controlled by adding water if the slurry density is too high. The slurry is recirculated to the concentrate thickener if the density is too low. The control is exercised before slurry passes through the pump.

iv) A cathodic protection system is also provided. For reducing the pipeline corrosion, oxygen scavenging chemicals are injected in the pipeline during flushing cycle. Cobalt

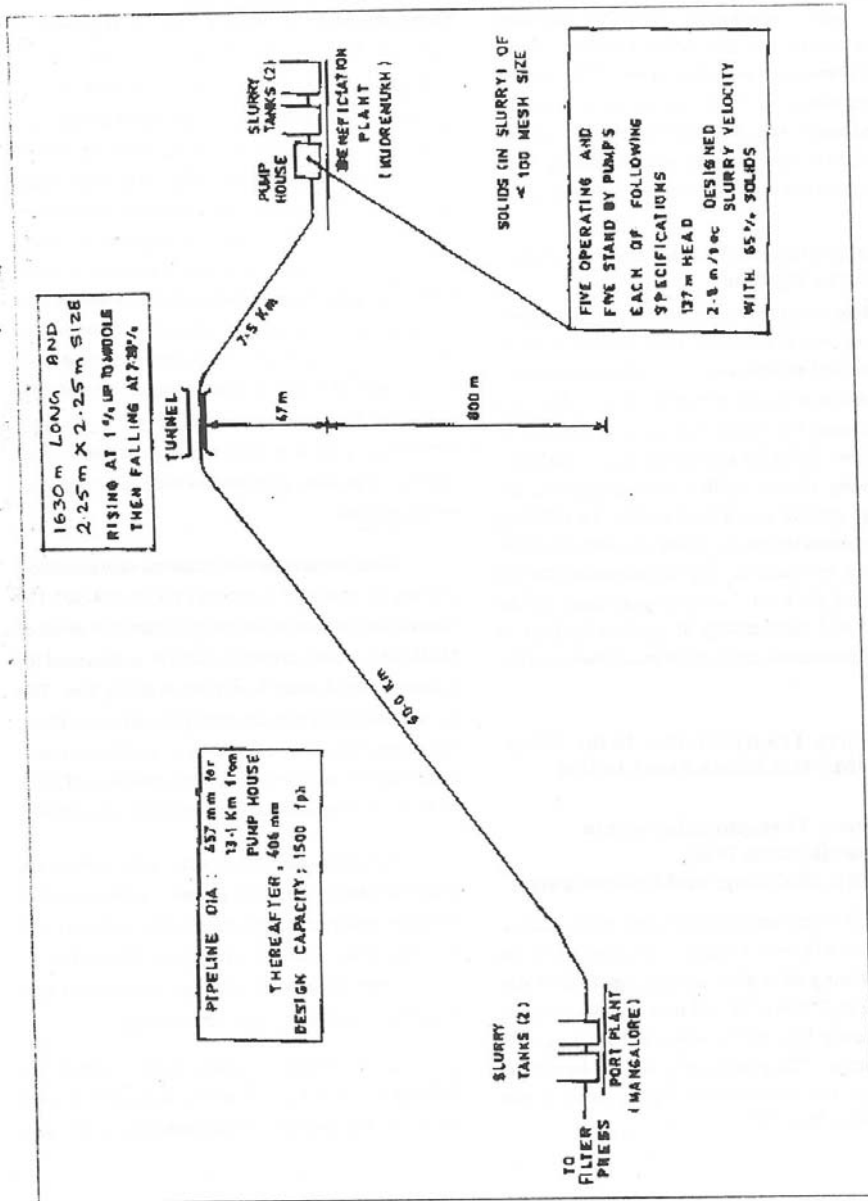Fig. 6-3 Pipeline Transportation of Concentrate from Kudremukh to Mangalore Port

(Courtsey : Mineservius, Nagpur)

sulphate and Sodium sulphate are the chemicals being used for the purpose of oxygen scavenging. Sodium sulphate maintains the pH value whereas cobalt sulphate is scavanging agent. The rate of application is 30 tonnes/month for sodium sulphate and 300 kg/month for cobalt sulphate. Some time lime is added during slurry pumping to maintain the slurry at 10.5 pH.

6.1.6 Inspection and Maintenance of the Slurry Pipeline

Because of the rugged terrain, forests, heavy rainfall and limited accessibility of the pipeline route inspection and maintenance of this pipeline is a big task requiring adequate attention. A helicopter has been provided for conducting aerial inspection of the pipeline. Since the system has been established well, giving almost trouble free operations, the helicopter service is required rarely. In addition, annual physical inspection along the pipeline is also undertaken by walking. The management has not confronted with any serious problems in the operation and maintenance of pipeline because of adequate inspection and regular maintenance of the system[5].

6.2 Slurry Transportation in the Mines of M/s Hindustan Zinc Limited

6.2.1 Slurry Transportation within Beneficiation Plant (Ore, Middlings and Concentrates)

Within the beneficiation plant, transportation of slurry in different sections of grinding, flotation and dewatering takes place through pipelines of size varying from 3" NB to 12" NB for a distance covering approximately 10 m to 150 m length at discharge side of the pumps. The pumps are generally horizontal centrifugal and vertical centrifugal pumps of size varying from 3" to 14".

6.2.2 Tailing Disposal System

Rampura Agucha Mine : The tailing generated from 4500 tpd Lead Zinc Ore Beneficiation Plant at Rampura Agucha Mine are taken to a thickener for dewatering. The settled tailing at a solid consistency of 32-35% (P.D) (1.30 to 1.32 kg/litre) are further taken to a neutralization tank having an agitator, where lime is mixed to raise the pH of plant tailings to 9.0 - 9.5. Tailing from this tank are disposed to tailing dam of 0.86 km^2 area located at a distance of about 800 m from plant through three 193.7 X 7.1 mm parallel pipelines (2 working + 1 standby). The tailing disposal system includes suction from lime treatment/ storage tank above tailing slurry pump, instruments and other facilities, approximately 2.0 km long distribution pipe line with toppings at 100 metres interval. The entire pipeline has been laid on trestles above ground.

There are three parallel batteries, each consisting of 4 nos. (3 working + 1 standby) VASA-HD-507-150 (Heavy duty horizontal centrifugal) pumps in series of MBIL/SALA make driven by 125 kW motors used for transportation of slurry from plant to tailing dam. The elevation of tailing dam top from ground level is 12 mt. The pumps have been provided to meet the total head requirement of 100.5 m (slurry) for a discharge of 218.6 m^3/hr slurry (normal flow) at a pressure of 14.3 kg/cm^2.

Automatic gland seal water arrangement has been provided in the slurry pumps. Instrumentation has been provided to measure the slurry density and flow rate in the pipeline. Automatic slurry shut-off valve is provided in the pipeline to prevent back-flow of slurry in case of power tripping.

The Rampura Agucha Plant tailings are difficult to settle and therefore, flocculent is used for enhancing thickener underflow density and also

to get clear overflow from thickener itself. A maximum of 30-35% solid consistency is achieved in the thickened tailings.

Cost of establishment of slurry transport system has been assessed to Rs 2.0 crores. The operating cost of slurry transportation including water reclamation has been assessed at Rs 9.70 per m^3 of slurry considering power, maintenance and manpower only.

Technical data for tailing slurry transportation at Rampura Agucha Mine is given below :

(A) SITE DATA

* Slurry Source Site : Tailings thickener underflow at concentrator after lime treatment
* Slurry Disposal site : Tailing Dam
* Elevation of pump discharge : GL 394.5 m
* Elevation of dam top : GL 406.5 m
* Proposed elevation of dam : Upto 418.5 m final in two stages
* Length of main pipeline : 0.8 km approx.
* Length of distribution line : 2.0 km approx.

(B) PIPELINE DATA

* Total length of pipeline: 2.8 km approx.
  Vertical - 15 mtr approx.
  Horizontal - 2000 mtr approx.
  Inclined - 650 mtr approx.
* Gradient of the pipeline : (i) for 630 mtr : 6-7° approx. (upward & downward)
  (ii) for 20 mtr : 40° (upward)
* Laying of main pipeline : Above ground on trestles
* Pipeline dia outside : 193.7 mm
* Wall thickness (Minimum) : 7.1 mm
* Material type : API 5L Gr.B, Seamless
* Hydrostatic test pressure : 1.5 times of system design pressure i.e. 14.3 kg/cm²

(C) MAIN LINE SLURRY PUMPS

* No. of batteries : Three
* No. of pumps per battery : Four
* Type/model/make of pumps : Horizontal, Centrifugal VASA HD-507-150 MBIL-SALA make
* Capacity of Pumps : 267 m³/hr.
* Head (M) : 52
* Sp. Gr. of slurry : 1.327
* Discharge pressure : 14.3 kg/cm²
* Design Pressure : 2.8 kg/cm²
* Seal Type : packing with gland seal
* Speed of impeller : 1095 RPM
* Motor KW, RPM : 125, 1500

(D) SLURRY DATA

* Solid : Lead-Zinc ore tailings
* Sp.Gr. : 2.8-3.0
* Particle size : 67.4% - 200 mesh
* Average particle size : 100 mesh
* Slurry density : 1.28 - 1.32 kg/litre
* Slurry flow :

  Normal : 218.6 m³/hr
  Maximum : 267.0 m³/hr
  Minimum : 167.0 m³/hr

* Pumping temperature : Ambient

Zawar Mines : Presently, tailings generated in the beneficiation plants at Zawar Mines are transported to tailing disposal section at a distance of

approximately 100 m by pumping through pipelines of size 8" NB. From the tailing disposal section, tailings slurry is transported to tailing dam situated at a distance of about 2.5 km through pipelines of size 8" NB. There are two pipelines one operating and one standby. The pumps used are horizontal centrifugal type, and there are two batteries each having 3 pumps in series.

Rajpura Dariba Mines : At Rajpura Dariba, the plant tailings are first pumped by two horizontal centrifugal type pumps in series to a battery of four hydrocyclones at a distance of 250 m through 8" NB pipes. There are two such batteries of pumps, pipelines and hydrocyclone batteries. The cyclone underflow falls into fill storage tank and overflow product gravitates through a 10" NB pipeline to tailing thickener at a distance of around 100 m. After dewatering, the thickener underflow slurry is pumped to tailing disposal system at a distance of 30 m and finally transported to a tailing dam, situated about 2.5 km away, by a battery of three horizontal centrifugal slurry pumps in series through 6" NB pipe lines. There are two such battery of pumps and pipe-lines.

Bandalamottu Lead Mine : At the 200 tpd Lead Concentrator at this unit, the slurry tansportation is done mainly for pumping the tailings from plant to Tailing Dam. Approximately 66,500 MT of tailings is being pumped to tailing dam annually.

The features are as below :

1.	Type of Slurry	:	Lead Tailings slurry
2.	Percentage of solids in slurry	:	30 to 35% of solids
3.	Pulp density	:	1.25
4.	% of Pb	:	0.25

5.	Quantity	:	66,500 t/year approx. 500 Cu.Mtrs/Day
6.	Pumps installed	:	2 Nos. 75mm Vacseal pumps: One No in operation and One as standby.
7.	Motor Particulars	:	50 HP; 1440 rpm; Power consumption : 2.5 kWh/t approx.
8.	Discharge pipeline	:	Initially 100mm dia pipeline for 75 mtrs. from 195 mRL to 209 mRL. Then the pipe line enlarged to 200mm dia for about 240 mtr. With a slope of 1:60 so that the slurry flow by gravity.
9.	Water consumption	:	About 2.3 kl/t of ore treated (430 m³/day) is being pumped to dam along with tailings. No water recirculation takes place.
10.	Capital cost	:	(a) Slurry pumping station : Rs 1.00 lakh approx. (b) Tailing pipe lines: Rs.0.25 lakhs approx.
11.	Operating cost per tonne of handling of tailing	:	Rs 10.50

6.2.3 Water Circulation System

1) Water recovered from tailing thickener overflow is pumped from thickener overflow sump to mill overhead water tank through pipe lines of size 6" NB to 8" NB covering a distance of approximately 500 m.

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2) In tailing dams, solid particles settle and water is recovered after filtration through pebble beds. The recovered water is pumped back to mill overhead water tank through 6" to 8" NB pipe lines covering a distance of 2.0 to 3.0 km.

6.2.4 General

* The reason for adopting this method of transportation is that it is the most economical way.

* No separate project cost of slurry transportation system is available as it is an integral part of the complete plant.

* No serious problem is faced with this system except for jamming of pipelines sometimes.

6.3 Ore/Tailing Transportation System at Khetri Copper Complex Concentrator Plant of M/s Hindustan Copper Ltd

The Concentrator Plant treats ROM and slag for copper recovery, by crushing, grinding, flotation, filtration & dewaterings.

ROM is drawn by stockpile feeders and is fed to crushers with the help of conveyor belts. After screening, the fine ore is filled in bunkers. In grinding section, fine ore is drawn by feeders and with conveyor belts fed to mills alongwith water. The ground ore is subjected to flotation after classification. The concentrate pulp and tailings thus generated in flotation are pumped to concentrate and tailing thickeners respectively.

The slurry transportation at KCC Concentrator is through MS pipe lines 350 mm dia and with centrifugal pumps of size 200/150 mm. The tailings collected in flotation section is first pumped to tailing thickener having dia of 77.5 mtrs. The thickened tailings from central cone are drawn through two parallel 200 mm pipelines to central sump. Tailings from Central Sump is pumped through one set of tailing pumps to tailing dam about 1.2 km away. There is no provision for recirculation system. There are two sets of tailing pumps. Each set is having 3 Nos. 200/150 mm Warman pumps in series (earlier 2 Nos.). Two parallel 350 mm delivery lines are connected to each set of pumps. The Warman pump has the capacity of 437 m^3/hr coupled with a drive motor of 125 kW. Generally, this kind of tailings are transported by pipe lines with the help of pumps. The water so reclaimed is reused in grinding operations. In general, problems faced are leakages in pipe lines and pumps, due to wear and tear and handing corrosive slurries at high pressure of 10 kg/cm^2, besides maintenance on pumps & motors in case of breakdowns.

6.4 Slurry Transportation in Chromite Ore Beneficiation Plant of Ferro Alloys Corporation Ltd, at Boula Chromite Mines in Orissa

6.4.1 Process for Adopting Slurry Transportation

The entire process of beneficiation is a wet gravity concentration at fine ground particles size (i.e., -1mm) in which, the media is water. As such, transportation of slurry through pipelines to different concentrating units is inevitable.

The system is resulting in following advantages/disadvantages.

A. Advantages

i)   Effective controll on spillage.
ii) Minimising water loss.
iii) Applicability of gravity flow of slurry wherever possible, avoiding pumping cost.

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iv) Maintaining pressure at various concentrating units.

v) Easy accessibility for handling/recirculation.

vi) Low cost of transportation.

B. Disadvantages

i) Jamming of pipe lines due to fast settling rate of solids.

ii) Corrosion of pipeline.

6.4.2 Details of Pumping Arrangement

a) Sumps connected by MS pipe lines in different gradients coupled with centrifugal pumps having rubber lining are running with electrical motor/V-belt drives.

b) Arrangement made for fresh water addition to the sumps to maintain required pulp density.

c) Pinch valves are fixed to the sumps to maintain slurry level in the sumps.

d) Dummy arrangements made at different points on the pipe lines for cleaning the jamming as and when required.

6.4.3 Recirculation of Water

a) The tailings from the concentration unit having pulp density of 1.06 are pumped to thickner through pipe lines, where, the solids settle down. The thickner overflow water is sent to Ground Water Reservoir by gravity flow and the thickner underflow (with 1.3. pulp density) is pumped to tailing pond.

b) Concentrate having pulp density at 1.25% is pumped to dewatering cones where, the concentrate settles down and the reclaimed water is pumped to Ground Water Reservoir.

c) The spillage water of the concentrate unit is collected in to a common drain and pumped back to thickner.

d) The supernatant water from the tailing pond after settling the tailings is pumped back to the ground water reservoir.

e) The seepage water from the tailing pond (if any) is collected in the sump, dug at the extreme end of the tailing pond and then is pumped back to Ground Water Reservoir.

6.4.4 Approximate Cost of Establishment of Slurry Transport

		Rs.in lac (Approx.)
a)	The installation cost of pump unit with drive	2.50
b)	M S pipeline of 4" dia for 10 m length	0.05
c)	Operational & Maintenance cost/one thousand m^3	0.30
	TOTAL	2.85

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CASE STUDIES

DETAILS OF SLURRY TRANSPORTATION IN COB PLANT

Sl. No.	Location of pump	Discharge point	HP	Dia of pipe	No. of bends	Pulp density of slurry	% of solids	Pipeline lay out in metres			Total
								Vertical	Horizontal	Incline	
1.	Rod mill discharge	Cyclone	75	100 mm	3	1.30	37	22	8	-	30
2.	Slime circuit	Rod mill cone	50	100 mm	2	1.10	14	10	-	190	200
3.	Middlings sump	Rod mill cone	20	100 mm	2	1.20	27	7	-	33	40
4.	Concentrate sump	Dewatering cone	1	75 mm	2	1.25	32	12	-	28	40
5.	Tailing sump	Thickner	40	150 mm	2	1.06	9	12	-	138	150
06.	Thickner underflow	Tailings pond	50	100 mm	3	1.33	40	4	100	126	230

DETAILS OF INCLINED PIPELINE

Sl. No.	From	To	Type of pump	Gradient of Inclined Pipeline		Total
				Upward Gradient	Downward Gradient	
1.	Rod mill discharge	Cyclone	VASA HD 455-100 Horizontal	-	-	-
2.	Slime circuit	Rod mill cone	VASA 284-100 Horizontal	15°-80m, 10°-110 m	Nil	190
3.	Middlings sump	Rod mill cone	VASA 284-100 Horizontal	10°-8 m, 30°-19 m, 15°-6 m	Nil	33
4.	Concentrate sump	Dewatering cone	SPV 263-80, Vertical	30°-10 m 10°-8 m 30°-10 m	Nil	28
5.	Tailing sump	Thickner	VASA 336-150 Horizontal	10°-138 m	Nil	138
6.	Thickner underflow	Tailings pond	VASA 336-150 Horizontal	10°-70 m	15°-56 m	126

m - metre

6.5 Transport of Slimes/Slurry in Bolani Ores Mines, Kiriburu Iron Ore Mine and at Meghahataburu Iron Ore Mines of Steel Authority of India Ltd

6.5.1 Transport of Slimes in Bolani Ores Mines

Run-of-Mine (ROM) is dumped in a Hopper (RL = 767 m) and crushed to -50mm. The crushed ore is conveyed through down hill conveyors to the Secondary Stock Pile (RL = 654 m) with a capacity of 35,000 tonnes. The total length of conveying from Primary Crusher Hopper to Secondary Stock Pile is 3908 metre. From Secondary Stock Pile the crushed ROM is reclaimed through Bucket Wheel Reclaimer and is processed either through a dry circuit or wet circuit in the screening plant. The finished product from both circuits are taken to Lump Stock Pile and Fines Stock Pile for despatches.

During wet processing, slimes to the tune of 25% of ROM is generated which is conveyed presently through a 350 mm dia pipeline to Old Tailing Pond at a distance of one kilometre. Under Modernisation Scheme, a New Tailing Dam is under construction and the entire slurry generated is to be conveyed through a set of two Tailing Pipelines covering a distance of 2 to 2.5 km.

No finished product in the form of slurry is transported in Bolani Ores Mines. However, some conveying of fines is done through open launders in the Ore Processing Plant. Distance covered is hardly 10-15 metres. The finished product from stock pile is reclaimed through a set of conveyors and is loaded directly into wagons for onward despatch.

Pumping Arrangement for Washing : Water for the Ore Processing Plant is pumped from River Karo and stored in the Make-up Water Tank at the rate of about 700 cu.m/hour. Pumping is controlled depending on actual requirement and storage capacity available. This is done through a pipeline of 550 mm dia.

Besides fresh pumping, reclamation of water (about 50%) is done through Thickener.

Problem Faced : In the Tailing Transportation, excessive wear of pipeline is being observed at sharp bends. Normal wear is observed at the bottom of Tailing Pipeline.

Schematic drawing showing various locations of operation and pumping system is given in Fig.6-4 and pumping system in Fig.6-5.

6.5.2 Slurry Transportation in Kiriburu Iron Ore Mine

The tailing produced from the ore processing plant after wet screening are conveyed through a 12 inch dia, 2 km long pipeline by gravity to a tailing pond. The tailing pond has a height of 29 m at which about 24 lakh cubic meter of tailing can be accumulated. The overflow of clear water is conveyed to the down stream side of tailing dam through a discharge tunnel at a gradient of 1 in 200. Filters have been provided to carry the seepage water and prevent erosion of soil or damage to over line structure from uplift pressure.

To ensure effective operation of the tailing, disposal system is modified and upgraded.

Salient feature of New Tailing Disposal System :

(A) SITE DATA

* Slurry source : Thickner under flow : 2 Nos
* Slurry Disposal Site : Tailing Dam : Cap - 2400000 m³
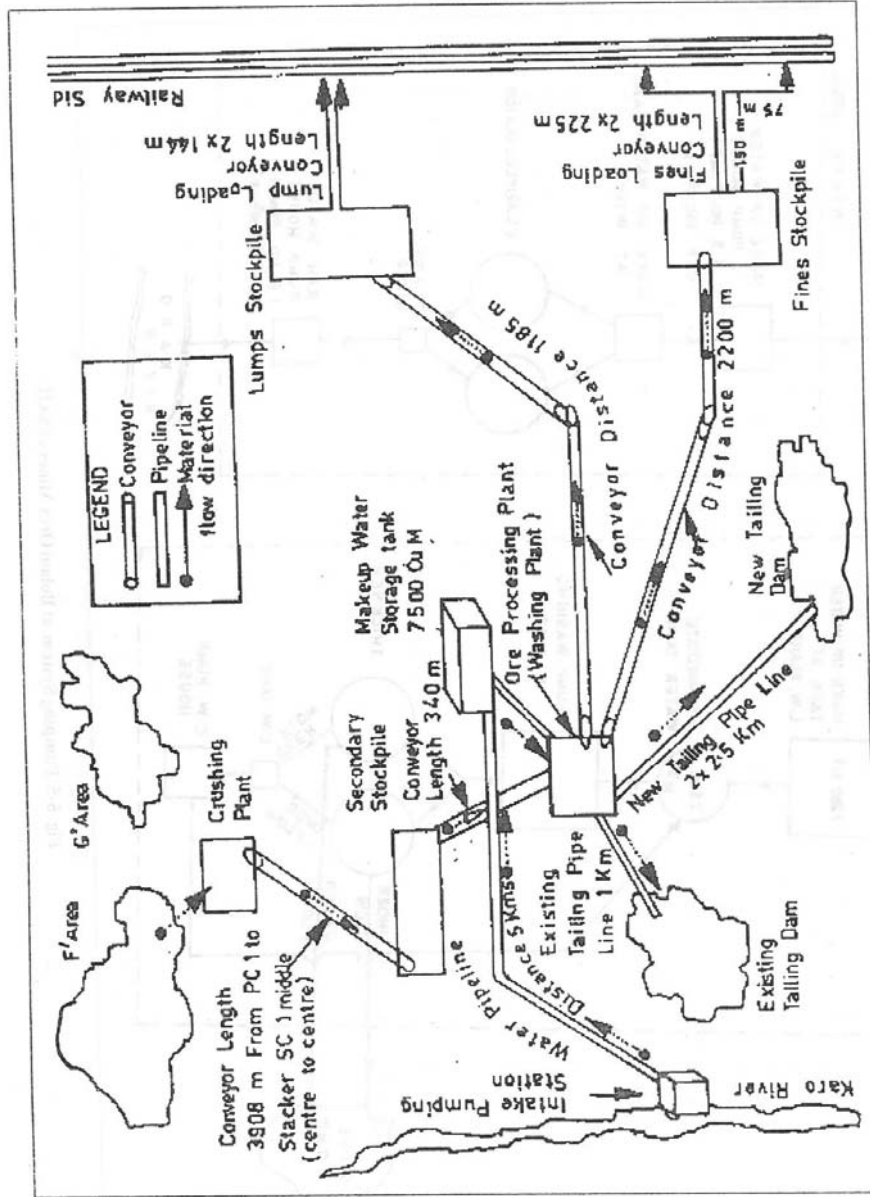* Elevation of pump discharge : 621 m
* Elevation of dam top : 622 m

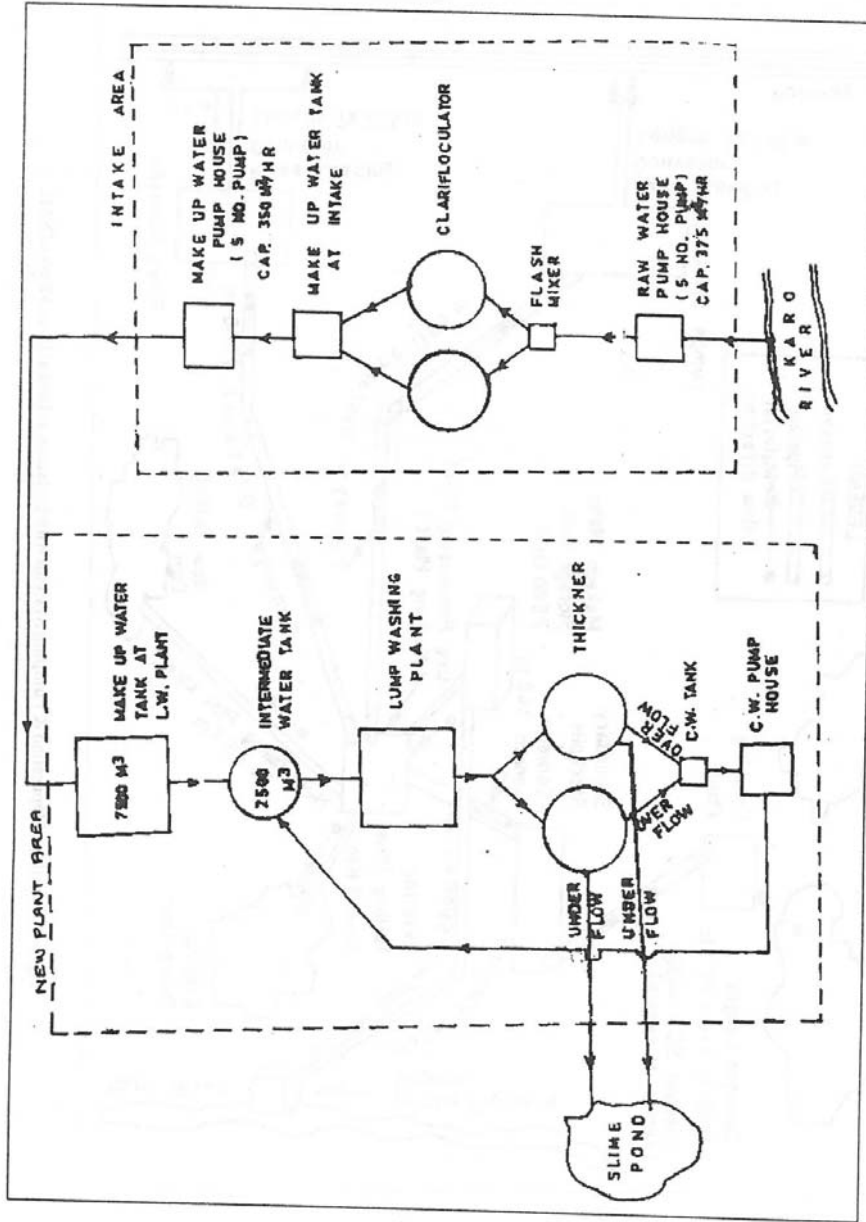Fig. 6-4 Location of Operation & Pumping Systems with Distances at Bolani Ores Mines of SAIL

Fig. 6-5 Pumping System at Bolani Ores Mines of SAIL

* Proposed Elevation
  of dam : 630 m
* Highest waer level : 620 m
* Cost : 330 lakh

(B) PIPELINE DATA

* Slurry Pipes
  Length of Pipe
  No.1 : 2280 m
  No.2 : 2630 m
* Pipeline dia out side : 250 mm
* Material type : M S
* Out of the total length
  how much is vertical,
  horizontal and
  inclined The gradient : Av. gradient of 1 in
  of inclination (upward   30 up to the distance
  and downward)   of 2398.57 m and 1 in
                          100 up to extended
                          length 350 m

(C) MAIN LINE SLURRY PUMPS

* Capacity of pumps : 500 m³/hr, 2 Nos.
* Head : 22 m
* Specific gravity of
  slurry : 1.87
* Motor power : 75 kW

(D) SLURRY DATA

* Solid : < 20%
* Specific gravity : 4.575
* Particle Size : +0.25mm - 1.32%
                  +0.15mm - 6.86%
                  -0.15mm - 91.68%
* Slurry Density : 1.84
* Slurry flow : 124 t/hr to 316 t/hr

One system will work all the time and other system will work as a stand by to ensure effective operation.

6.5.3 Slurry Transportation at Meghahatuburu Iron Ore

The slurry generated from the discharge of underflow of thickener is transported to the entry point of the tailing dam by means of pipeline of length 1300 metres. The diameter of the pipeline is 600 mm. The average slope of the pipeline is 1 in 22. The slurry alongwith water is transported by means of gravity action through the pipeline. The tailing dam is having a catchment area of 405 hectare and a capacity to accomodate 3.38 million cu.m. of slurry. Innumerable sand bags and gravels are laid down at the discharge point of the tailing dam, as filters, from where clear water oozes out. The approximate expenditure incurred for laying of slurry pipeline was Rs 45 lakhs.

6.6 Ore Processing at Pale Mines & Costi Mines of M/s Chowgule and Co. Ltd

6.6.1 Pale Mines

The Pale Mines of Chowgule and Co.Ltd. is operating Washing Plant, which consist of Vibrating Grizzley, Double Deck Screen, Impact Crusher and Spiral Classifiers to upgrade Iron Ore Fines, and to eliminate gangue minerals like alumina and silica.

PROCESS

ROM received at the Hopper either from Mines or from Stack Yard is handled by Vibrating Grizzley, eliminating +120 mm fraction. -120 mm is conveyed to Double Deck Screen having 50mm screen on top Deck and 10mm screen on bottom Deck with intense water spray on both decks. -120 + 50mm fraction is led to Impact Crusher and -50 + 10 mm fraction is taken out as Washed Lumps by special conveyor belt. -10 mm sized fines in slurry form are allowed into 2 nos. Spiral Classifier having end point at 0.15 mm size. So raked production is 'Washed Fines'. Overflow from both the Classifiers are tailings which are diverted to Tailing Pond.

TAILINGS TRANSPORTATION

Tailings are generated to the tune of 457 m³ per hour consisting 50 tons solids. Tailings Pulp

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Density is 1.35 kg/litre having solids 10.2% w.w. Tailings are initially collected to Junction Box and then are transported to Tailing Pond at a distance of 500 meters, under gravity through 12" pipe line inclined to Tailing Pond at static head difference of 5 meters.

Classifier overflow is treated by suitable flocculants like slaked lime, so that solids are settled within tailing pond area and clean water is percolated.

6.6.2 Costi Mines

Washing Plant : At Washing Plant, operation involves Wet Screening by Double Deck TRF Screen and 2 Nos. Spiral Classifiers. The overflow of the classifier is pumped to hydrocyclones of Cut-point, 325 mesh and overflow from the Cyclones flows by gravity to the Tailing dam at a static head difference of 15 mtrs. through UDPE pipe 8" dia to a distance of 100 m.

The Classifier overflow at 350 m³/hr and having pulp density of 1.1 kg/litre is pumped to hydrocyclone by 150 mm Slurry Pumps to a head of 15 m and at 1.2 kg/cm² Pressure. The underflow of the Cyclone with pulp density of 2.0 kg/litre is allowed to flow by gravity to a concentrate yard. The overflow of the hydrocyclone with pulp density of 1.04 kg/litre, with a capacity of 300 m³/hr flows by gravity to the tailing pond situated nearby.

Beneficiation Plant : The process at this plant is screening, grinding and hydrocyclonisation. The ground product from the Ball Mill (-1mm, 100% in size) is pumped to Primary Hydrocyclones consisting of 90 Nos. 100mm size Cyclones. These hydrocyclones handles 900 m³/hr, slurry at pulp density 1.2 kg/litre. Overflow from these goes to thickner under gravity at a density of 1.05 kg/litre. The overflow (capacity 850 m³/hr) having pulp density of 1.05 kg/litre flows down by gravity to the 40m dia thickner.

The underflow is subjected to second stage of hydrocyclonisation having 52 nos. of 150 mm size cyclone. These handle 700 m³/hr of slurry at 1.2 kg/litre p.d. The overflow is further recirculated through ball mill sump. The horizontal pan filter situated below, a concentrate at 8 to 10% moisture is transported to the concentrate yard through conveyors.

On settling of suspended particles in the thickness, clear water is recovered and is pumped back into the process. The thickener slurry settled at the bottom of the thickener, is pumped by 150 mm Slurry Pump to a distance of 750 m, at head of 45 m. The pulp density of the slurry 1.45 kg/litre, capacity 100 m³/hr in this process.

6.7 Slurry Transportation System at Codli Mines of M/s Sesa Goa Ltd

M/s. Sesa Goa Ltd is operating Iron Ore Beneficiation Plants since 1984. The plant has capacity of 550 tph. The tailing was to be transported to new tailing pond area which was about 1 km away. It was decided to shift the hydrocyclone to an elevated structure whereby the tailings of the second stage hydrocyclone overflow will be transported by gravity to tailing pond through the pipeline. Around 900 cubic metre/hour of hydrocyclone overflow, which contains about 8 to 9% solids is being transported through the pipeline. Floculants are dozed to the tailings and the clear water from the tailings pond is pumped back to the plant for processing.

The total cost of the system when introduced was around Rs 1.2 crores, which includes pumping system, pipelines, tailing pond and dam construction.

PROBLEMS FACED WITH THE SYSTEM

A combination of tailing pipe made of MS (ERW) and Hume pipe of dia.500 mm was installed from the hydrocyclone tower to the tailings pond.

The steel pipe was laid on trestles and steel structures wherever road crossing was involved and the hume pipe used on the ground. The hume pipes wherever, it was running full due to upward slope, the joints were leaking heavily which was subsequently replaced by MS Pipes. There are still some hume pipes which are installed for down gradient and are working satisfactorily. The tailing pipe was extended to the new tailing pond with the help of MS Pipe and finally through the open channel which is working satisfactorily. They did not face any problem except the initial leakage of slurry through the joints of hume pipe, which was overcome by replacing with MS Pipe.

TAILING DISPOSAL DETAILS

* Total length of tailing pipeline - 1.2 km

* Total length of tailing travel + Recirculation of water - 1.2 km + 3.3 km

* Pipeline diameter - 500 mm.

* Quantity of tailing : Solids 0.6 million tonnes/ year, slurry 900 cubic metre/hour.

* Total HP used to pump slurry to the Tailing Pond - 540 HP.

* Total HP used to pump back the water to the plant for processing - 600 HP.

* Water recovery from the tailings is around 55 to 65%.

6.8 Slurry Transportation at Hutti Gold Mines Co. Ltd

Slurry transportation at Hutti Plant is of two types. The first one is coarse sand transportation to underground bin from the Mill plant and the second type is tailings transportation from milling plant to tailing bund.

SAND TRANSPORTATION TO U/G BIN

The 1000 tonnes of mine ore crushed and ground every day to about 75 μ size to liberate gold are subjected to leaching to extract the gold and tailings are then subjected to classification to separate the fines from the coarse. Particle coarser than 40 μ are sent to U/G for filling the voids in mines, while the particles finer than 40 μ are discharged to tailings bund. The U/G bins are situated at a distance of 150 metres from the classifying unit. Amount of sand transported is about 250 tons per day. It is mixed with sufficient water to maintain a consistency of about 40% solids to facilitate easy flow of material. Hence, the total slurry transportated per day are 300 m³. The pipe used is 3". As the bins are situated above ground total height the sand is transported is about 20 metres. The pump used are Salavasa 284-100 pumps driven by 30 kw motors. After the sand is collected in the bins, excess water is taken to the classifier plant by gravity. The cost of pumping sand is about Rs 8/- per tonne including power, labour and machinery spares.

TAILINGS TRANSPORTATION FROM MILLING PLANT TO TAILING BUND

The second slurry transportation is slime transportation to the tailings bund. The tailing bunds are situated at a distance of about 600 meters from the mill. Total quantity of slime transported varies from 800 tons to 1000 tons per day. The consistancy is 50% solids. Hence the total quantity transported is about 1070 m³/day i.e., 40 to 50 m³/hour in normal course while the sand stowing is done, or else it will be about 50 to 55 m³/day if sand classification is not carried out. Pumps used for this purpose are again 284-100 Salavasa pumps with 4 vane impellers. Total head the pump has to overcome is around 35 metres. Slurry goes through 5" pump with 3 bends. Pumping costs is about Rs 5/- per tonne including power, labour and spare parts.

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6.9 Slurry/Tailings Transportation at Kotambi Iron Ore Beneficiation Plant of M/s D. B. Bandodkar & Sons Ltd, Goa

At Kotambi Iron Ore Beneficiation Plant, the source of water circulation system is river (Mandovi). From the river, water is lifted by two pumps (60 HP each) and is stocked in water tank of capacity 300 m³. From this tank, water is lifted by another pump (60 HP) for screening. Here the Iron Ore gets washed through vibrating screen and classifier. Slurry or Tailings from Classifier is passed through a pipe of 250 mm dia and is connected to a slurry pump (60 HP). To the other end of the slurry pump, one more pipe is connected (outlet) which is having 200 mm dia. This outlet pipe is connected to Tailing pond (200000 m³). The distance between the plant and Tailing pond is about 200 m.

1. Approximate cost for circulation of water system & establishment of slurry transport - Pumps + Tailing line is Rs 6 lakhs.

2. Running/Operating cost per cubic metre of material transport is Rs 2/m³.

6.10 Slurry Transportation at National Aluminium Company's Alumina Refinery at Damanjodi

National Aluminium Company Limited (NALCO), an integrated Bauxite-Alumina-Aluminium complex under the Ministry of Mines was set up in 1981 based on the bauxite resources of the Panchpatmali Bauxite Deposit located in the Koraput district of Orissa. The salient features of the major plants of the company are as under:

* A fully mechanised opencast bauxite mine of 2.4 million tonnes per annum capacity located in the Koraput district of Orissa. The Mine is currently under expansion with capacity increase to 4.8 million tonnes per annum.

* An Alumina Refinery of 0.8 million tonnes per annum capacity located at Damanjodi in the Koraput district of Orissa. The Alumina refinery is currently under expansion with capacity increase upto 1.575 million tonnes per annum.

The slurry transportation in the Alumina Refinery is carried out for the tailings generated out of the processing of Bauxite known as the Red Mud and the Ash generated from the steam generation plant. The mode of generation and disposal of the Red Mud and the Ash is given below.

RED MUD SLURRY TRANSPORTATION

In the Alumina Refinery, bauxite is being processed using the Bayer's atmospheric digestion technology to extract Alumina from the bauxite. During the process of digestion of the bauxite in caustic soda and extraction of Alumina, iron oxides and free silica in bauxite remains undigested. The undigested iron oxides are termed as Red Mud which needs to be disposed off as tailings. For the transportation of the red mud, there are three sets of centrifugal pumps, each consisting of two identical pumps in series to overcome a head of 70 m (liquid column). The pumps take suction from an agitated rank. Each set of pump is having a capacity of 250 m³/hour and provided with it's dedicated suction and discharge pipeline. The first pump in the series is provided with variable speed drive. Normally, two sets of pumps are working and one set of pump is stand by.

Inside the plant, discharge pipeline are laid on the pipe rack having a slope of 3%. However, outside the plant boundary limit, the pipe lines are laid on portals on slope of the lines and specially which it climbs the dam, it is as high as 10-15%. Since the pipelines between the plant and the disposal site runs across hilly terrain, formation of low point is

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unavoidable. Hence, all the pipelines are provided with water flushing arrangement at the suction. Whenever pumps are stopped, lines are thoroughly flushed with water to avoid settling of solids in the pipelines. Additionally, all the pipelines are provided with water back flushing arrangement from disposal end and break off flanges at an interval of 20 m to clear any chocking.

For water recirculation, there are three pumps located on a rail mounted trolley. Trolley position can be adjusted with the help of a winch. For three pumps, there is one discharge pipeline of 350 mm dia running upto the plant. Except for the originating point, water pipeline follows exactly the same route as the slurry pipeline.

Considering the solid consistency of about 350 gpl, solid to water ratio works out to about 1:2.5. The estimated order of magnitude of the cost of the system (excluding cost of recirculation system and red mud disposal pond) is about Rs 5.0 crores.

ASH SLURRY DISPOSAL SYSTEM

In the processing of the bauxite, steam is induced into the process to heat the slurry to a desired temperature. Steam is produced by 3 nos of coal fired boilers of 200 tph capacity each. The boilers use the coal which contains about 40% of ash. About 20% of the ash is collected at the furnace bottom. The remaining fine ash is conveyed out of the furnace by the flue gas and get collected separately. The fly ash as well as the bottom ash are collected and slurry is formed by injecting water. The slurry is then pumped to Ash pond.

For ash slurry transportation also, there are three sets of centrifugal pumps, each consisting of three identical pumps in series to overcome a head of 132 m (Liquid column). The pumps take suction from ash slurry sump pits level of which is maintained by adding water, recirculated from the disposal pond.

Each set of pump is provided with it's dedicated suction. There are two discharge pipelines common for all three sets of pumps and having a capacity of 635 m^3/hr. One set of pump and one pipe line is normally working while two sets of pumps and one pipeline is stand by. To enhance the life of ash slurry pipelines, pipes are rotated by 90 degrees every 1-2 years which ensures uniform erosion on the inner pipe surface.

Considering solid consistency of about 90 GPL, solid to water ratio works out to 1:10. Estimated order of magnitude of cost of the system is about Rs 4.0 crores. Estimated running and operating cost per m^3 of ash slurry is about Rs 2.00.

FUTURE PLANS FOR RED MUD DISPOSAL

NALCO is proposing to adopt the latest technology in tailings disposal i.e. Thickened Tailings Disposal (TTD) in their expansion plan. The mud will be thickened to a value as high as 58% by weight with the application of suitable flocculent. This Red Mud will come to a stop even on a gentle slope. The run of water will flow down and will get collected in a pool, from where it can be recycled to the plant. A fresh layer of thickened mud will be replenished on the surface deposit earlier. The following are the advantages of using the TTD system.

1. Enhanced life of the existing pond by about 8 years for expanded capacity.

2. Reduced soda loss due to recovery of the soda presently locked up in the pond.

3. Easier reclamation of the filled area.

4. Improved water balance.

5. Reduced pond water recycling saving in pumping cost.

6.11 Proposed Transport System for Movement of Beneficiated Iron Ore Concentrate - Kirandul to Visakhapatnam - Nmdc & Essar

National Mineral Development Corporation (NMDC) is a public sector undertaking involved in Mining of Iron Ore in the Bailadila range of hills, Bastar Region of Madhya Pradesh. The Bailadila sector Iron Ore Mines are considered to be the best and very rich in Fe content ranging from 64 to 67%. NMDC is exploiting Iron Ore from number of deposits in Bacheli - Kirandul section of Bailadila range to cater the export commitments to Japan, China and Korea through MMTC and indigenous needs of Visakhapatnam Steel Plant and other Sponge Iron producers.

During the process of mining operations, large quantity of Iron Ore fines/Blue dust is generated and piled up in around the Bailadila Mines. Besides this, fresh generation of fines is also taking place due to increased crushing operations and exploitation of new mines by NMDC in the vicinity.

Even though NMDC have been able to establish market for use of these fines in the Steel industry due to technological developments, still the quantity is accumulated upto 15 Million Metric Tonnes. The continued generation and accumulation of these fines in such mammoth quantity is causing land pollution, water pollution to surface/sub-terranian waters apart from dust and air pollution.

In this background, Essar Steel has proposed Pellet - Benefication complex for converting these waste fines into value added Pellets. In this direction, the Ist phase Pellet Plant is established in Visakhapatnam with plans to double Pelletizing capacity. The Pellet capacity addition will depend on a Beneficiation plant at Bailadila and transport of beneficiated iron ore concentrate through a long distance cross-country slurry pipeline.

6.11.1 Salient Features of the Project

Take off point of the Pipeline

Kirandul Village	North Latitude 18°39'
	East Longitude 81°15'

Altitude - 610m above MSL

Terminal point of the Pipeline

Visakhapatnam	North Latitude 17°33'
	East Longitude 83°2'

Altitude - 2 M above MSL

The distance covered is 268 km in a route passing through 3 states; Madhya Pradesh - 63 km, Orissa - 75 km and Andhra Pradesh - 130 km.

The concentrate will be pelletized in Pellet Plant at Visakhapatnam. End user of the concentrate is the Pellet Complex, Essar Steel, Visakhapatnam. All the pre-construction activities are completed and pipeline construction is to be started. The Pipeline will be commissioned within 18 months from the date of commencement of pipeline construction. The project is likely to take off at any time.

Specific gravity of solids	:	5.0
Specific gravity of the slurry	:	2.20, at 66%, solids by weight
Flow rate	:	740 m³/hr.
Corrosion allowance 0-30 km		- 0.10 mm per year
		30-268 km - 0.075 mm per year.
Main pump station at Zero point, Bailadila Madhya Pradesh.	:	4 Nos. of 1200 kW pumps

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Booster pump station near Chitrakonda, Orissa at Chainage 125 km : 4 Nos. of 1200 kW pumps

Cost of total Slurry Pipeline system : Rs 360 crores

Operating cot (Approx.) : Rs 100/-per tonne

Annual Throughput : 8.0 million tonne of concentrate 66% solids

Some more additional technical details are as follows.

(i)   The materials, design, construction, testing and performance of the mechanical and electrical equipment will comply with US/applicable Indian Standards.

(ii)   The system design life is 25 years, this has been designed for 300 days per year for the ultimate output of 8.0 million tonnes/year. The pipeline will operate to match the concentrate and production rate of 1112 tonnes/hour.

(iii)   The overall philosophy followed in designing this pipeline system is to maximise the reliability of the system while maintaining a simple control system. The degree of instrumentation and control is limited to that which is essential for local as well as remote operation and control of the pipeline. All important installations such as control rooms, pump stations, booster pumping stations, valve stations and the terminal facilities will be round the clock.

(iv)   A corrosion control system is planned to monitor the internal corrosion in the pipeline.

(v)   The slurry pH will be maintained at 10 using hydrated lime solution. A corrosion inhibitor will be added to the flush water.

(vi)   The pipeline will be of 406 mm OD with a flow rate capacity of 740 m^3/hr. with 62 to 68% solids (by weight). The minimum operating velocity for the pipeline will be 1.4 m/sec.

(vii)   Two pumping station have been provided : (one at Bailadila takeoff point and the other Booster station at a distance of 125 Km from Bailadila). The pumps have been sized to deliver 15% more than the design flow rate. The maximum design discharge pressure will be 160 kg/sq.cm.

(viii)   Buffer storage tank for holding Concentrate of the pipeline is provided both at Bailadila (takeoff), and at the Pellet Plant Visakhapatnam. These storages will provide pipeline design flow upto 8 hours.

(ix)   To protect the pipeline against surge pressure in the event of valve closure or pump shut down, pressure relief valves have been provided at the suction of Booster stations, valve stations and at Visakhapatnam terminal, which will protect up-stream pipe section.

(x)   The pipeline will be externally coated over its length with a heat shrinkable polymeric tape coating. The field welds will be coated with heat shrinkable sleeves. The pipeline will be provided with cathodic protection system.

(xi)   To facilitate regular pipeline inspection and maintenance, market posts will be installed at suitable intervals and at bends. A subway of 20 m width would be sufficient for normal construction activities. Minimum soil cover over the pipeline will be 0.9 m. Pipe wall thickness at river crossings will be more at the preceding and succeeding sections, and river crossing will be concrete coated to overcome buoyant forces. For crossing narrow, and deep ravines, aerial spans will be provided, at sufficient height above water mark.

(xii)   In rocky soils, explosives will be used to prepare right of way and for excavating trenches for Pipeline. In such section, pipeline will be padded and shaded by fine granular material.

(xiii)   The entire pipeline shall be hydrostatically tested to a test pressure of not less then 1.1 times the internal design pressure.

(xiv)   All welds will be radiographically inspected.

(xv)   Pipeline operations will be controlled by a Supervisory Control and Data Acquisition (SCADA)

system. Fiber optic cable will be used for communication between the main control room in Bailadila, all pumping stations, valve stations and the Visakhapatnam terminal.

Apart from above, this system is used at many more mines, and is extensively being used for transport of river sand for sand stowing in number of coal mines all over India. It is also being used in levigation of clay where clay is transported in the form of slurry in open channels at suitable gradient.

FUTURE OUTLOOK

India has got a good prospect for iron ore movement by slurry pipeline because -

i) Large volumes of iron ore and concentrate are being transported every year for a long distance between the mines and place of consumption/ports for export. As slurry transport system is cheaper and environment friendly mode of transport, there is a wide scope for its adoption.

ii) The mines are in remote areas, not served by existing rail/road infrastructure. This will also add to possibility of adopting slurry transport system.

iii) High volume of slurry pipeline may eventually be required to avoid over loading rail lines or to overcome the non availability/shortage of rail wagons for transport. Once transport by this system is adopted, it will ensure constant regular supply of raw material.

(iv) It is believed that apart from scarcity of rail-wagons and poorly developed road network the handling losses are as high as 7-8% whereas pipeline transportation performs much better with no handling losses in the form of spillage and this adds to chances of its adoptability.

v) After installation, a slurry pipeline is not affected severely by escalation of direct cost. This is because, this mode of transportation is capital intensive. About 70% cost is capital related, about 15% is power related and 15% is related to labour and maintenance.

vi) Keeping pace with the modern trend of having pollution free environment, mine wastes, beneficiation plants tailings, etc are also required to be transported to a considerable distance for storage/disposal/recycling of used water. In these cases also, transportation by pipelines comes very handy.

vii) M/s.ESSAR STEEL Ltd., Bombay has proposed to build a pipeline starting from their Ore Beneficiation Plant proposed to be installed at Kirandul, Distt. Dantewara (MP) and ending at Vizag in their Pelletisation Plant. Beneficiated ore (concentrate) is proposed to be pumped by them through a 268 KM slurry pipeline. This project, once started successfully will give a way to adopt slurry transport system in number of projects.

viii) There is a possibility to strengthen the pipeline transportation of ores/minerals particularly in hilly terrain where giving infrastructure facility is a biggest economic task. India is a densly populated country with a land availability as low as 2.6 percent of the global land mass area against its share of 16% of global population. About 280 Indian share the each sq.km. of its available land mass area with a meagre forest cover of 11% and most of the mines located in forest areas, puts us under further constraints to develop roads/railways for the purpose of transportation. The disturbances created by the construction

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of the road in a forest area in comparision to lay down a transportation pipe line and its operation directly reflects to the selection of slurry transport through pipe as environment friendly proposition.

In addition to the above, some of the leading consultants/contractors involved in construction, pipeline designing and maintenance of slurry transportation in Indian Mines are stated as below indicating the assignments that had on their credit.

Consultant/construction firms	Worked for	Assignment undertaken
1) M/s Dosal Provate Ltd., Mafatlal House, Backbay Reclamation Mumbai - 400020	Kudremukh Iron Ore Co.Ltd., Kudremukh - 577142. Dist. Chikmaglur Karnataka.	67 km long slurry transportation system from Kudremukh to Mangalore port.
2. M/s Bechtel Overseas Bechtel Corporation San Francisco, California, USA.	Kudremukh Iron Ore Co.Ltd., Kudremukh Dist.Chikmaglur Karnataka	Pipeline designed for Kudremukh transport project.
3. M/s Essar Steel Ltd., Near Flyover, Scindia Road, Visakhapatnam 530 004.	Bailadila Iron Ore Mine of M/s National Mineral Development Corporation Ltd., in Bastar region of M.P.	268 km long transport system for movement of beneficiated ore conc-erate from Kirandul in Bastar region of M.P. to Visakhapatnam in Andhra Pradesh.

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