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Application of column flotation technology for reduction of silica in zinc concentrate at Rajpura-Dariba mines, India

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ABSTRACT

A 3000 t/d lead-zinc ore beneficiation plant was commissioned in 1983 to produce lead and zinc concentrates suitable for Hindustan zinc Limited's smelters. The problems encountered in individual concentrates are mainly high graphite and lower lead grade in lead concentrate and comparatively high silica in zinc concentrate. Due to inherent nature of ore quality (graphite mica schist) the incidence of high graphite, lower grade of lead concentrate can be explained and taken care by use of effective graphite depressant or gravity techniques.

It is observed during extensive laboratory scale tests by in-house R&D of HZL and by National laboratories in India and plant operations for decade, that type of ore quality (i.e. calc-silicate or graphite mica-schist) does not affect zinc flotation and invariably the silica in zinc concentrate is reported between 5 to 8%, where as the requirement of HZL's smelters is 2.5% max.

In this paper an account of extensive testing done at Central Research and Development laboratory of HZL (India), with operating plant at Rajpura-Dariba Mines is elaborated. It is observed that due to interlocking of gangue with sphalerite up to 2 micron size, fine grinding requirement for liberation of sphalerite and flotation of some gangue due to smearing of graphite on gangue during communition in ball mill, it is very difficult to effectively use graphite/gangue depressant for controlling silica to a level of 2.5 % from 5-6%, without sacrifice of zinc recovery.

After careful and detailed study of zinc concentrate mineralogy and metallurgical results, the route of column flotation for zinc cleaning in place of conventional mechanical cells was tried. Preliminary experiments were conducted on 3" diameter Diester make Flotaire

column set-up at CRDL. The study indicated that flotation by use of column is effective in controlling free silica in concentrate by froth washing.

The study was supplemented with detailed experimentation aimed at generating basic design data for pilot column for Rajpura Dariba concentrator. The data obtained was simulated on simulator developed by M/s Engineers India Limited and reconciled data was processed using computer software developed by EIL. The exercise indicated that by column flotation used in cleaning operations, the silica in zinc concentrate is reduced to a level of 4 %,the recoveries in cleaning operation remained nearly same.

***Key words** : Graphite mica-schist, Calc silicate, Column flotation*

BACKGROUND

Rajpura-Dariba mines is located 80 Km from Udaipur and located in Rajsamand District of state of Rajasthan, India. About 26 million tones ore reserves are proven. The host rock mineralization is in Calc silicate (CS) and graphite mica-schist (GMS) zones. As far back in 1974 it was realized that ore from CS zone would be simpler for beneficiation as lead and zinc liberation is comparatively of coarser size than in GMS zone. Production of fairly clean lead and zinc concentrates from the CS ore is relatively simpler, processing of GMS ore is complicated due to high pyrite content coupled with interlocking at finer sizes with galena and sphalerite and incidence of graphite carbon.

A 3000 t/d beneficiation plant was planned and commissioned in the year 1983 for producing 50 % Pb in lead concentrate and 52 % zinc in zinc concentrate with low levels of impurities i.e. graphite and silica in lead and zinc concentrates (1.5 and 2.5%, respectively).

The expected results could not be obtained in plant. One of the reasons has been varying characteristics of ore treated. Efforts were made towards improvement in quality of lead concentrate by use of effective graphite depressants and lead cleaning on Multi gravity separator, which has indicated good results.

The paper deals with efforts made towards reduction of silica in zinc concentrate from 5-6 % to a level of 2.5 % as operational problems as described below gives lower smelter efficiencies. These are :

i) Agglomeration & development of back pressure resulting in low throughput in roaster.

ii) Slow settling during leaching and

iii) Difficult filtration due to silicate gel formation.

Silica Reduction in Zinc Concentrate

Given below in Table 1 are results obtained during 7 years of plant operation.

Table 1 : 7 years of plant operation results

Year	Ore type CS: GMS	Zn %	Ins%	SiO_2
1987-88	86:14	49.11	7.64	4.62
1988-89	79:21	48.88	7.99	4.69
1989-90	80:20	48.74	7.76	5.18
1990-91	80:20	48.47	8.13	5.20
1991-92	75:25	48.43	9.20	5.77

It is seen that silica content is on increasing trend.

Laboratory Scale Testing

Given below in Table 2 are the brief of results obtained on various routes to control silica in zinc concentrate :

Table 2 : Results obtained on various routes to control silica in zinc concentrate

S.No	Reagent	Ore type CS:GMS	Zn conc. Zn	SiO_2	Zinc rec. %
1	Sod.silicate 300 gpt	90:10	48-54	3.5-5.2	82-85
2	Citric acid 100-250 gpt	80:20	47	8-10	85
3	Lactic acid 250 gpt	90:10	35	10	65
4	Starch	90:10	43	4.60	71
5	Pneumatic vibrator in Zn cleaning	80:20	52-54	5-7	85-87

EFFECT OF REGRINDING

Extensive metallurgical testing indicated that zinc scavenger concentrate and cleaner tails size fractions in range of 53-150 micron, contain locked grains of pyrite & gangue, which could be liberated with regrinding.

- During Oct-Dec 1984 middling regrinding improved Zinc grade by 1.6-2.2% and silica was reduced by 0.6-2.27%.
- Plant trials during Jan-April 1985, when Zinc rougher concentrate was reground, resulted in reduction of silica by 0.18-1.35 %; while during period May-July 1985 it was by 0.4-0.5% only.
- In the month of August 1985, silica reduction was in range of 0.3-0.5 %. During this period plant operations were consistent.

Effect of Gangue Depressants

Carboxy methyl cellulose (CMC) :

CMC and DIG-depress D100 were tried in plant for silica reduction. It was observed that though silica content was in the range of 2-5%, zinc recoveries were quite low.

Guar gum derivatives :

Guargum derivatives (GGD) are known for their usages as gangue depressants. These were tested in plant during Nov 1990-Jan 1991.The plant data indicated that expected reduction of silica has not been achieved. The trials were repeated during period April - June 1991. This time it was observed that GGD aids flotation of pyrite thus lowering the grade of zinc in concentrate and increasing silica.

REMARKS

Thus, extensive investigations over 5 years covering use of gangue depressants, regrinding middling and rougher concentrate for liberation of gangue and application of surface chemistry principles did not result in achieving in plant, production of zinc concentrates less than 2.5 % silica.

TEST WORK ON COLUMN FLOTATION

Laboratory Test Work

Zinc concentrates from RD Mines were studied under microscope for liberation of sphalerite, pyrite and association of gangue. It was observed that approximately 15-20 % of gangue as reported in concentrate is in liberated form and rest

is locked with pyrite+sphalerite at very fine (below 40 microns) or in coarser size (+150 microns). Although the liberation of sphalerite in concentrate if fairly good i.e. 85-90%.

It is therefore thought to try column flotation technique which incorporates froth washing, for removal of liberated gangue reporting to zinc concentrate.

The experiments were carried out on zinc rougher concentrate taken from plant stream. 3" dia. and 11' height DIESTER FLOTAIRE column was used in experiments. Column has two numbers peristaltic roller pumps with variable speed drive and on/off type float level controller which was coupled with tailing pump. There were arrangements to measure air and water flows in bubble generators through flow-meter.

In set of experiments, two schemes as under were tested :

i) Zinc rougher concentrate from plant was subjected to cleaning in column to produce concentrate.

ii) Deleaded tailings from plant was brought to 2 tpd pilot plant .Zinc rougher was produced in pilot plant and subjected to cleaning in column. Tailings from column circuit were recirculated to lead tailings in 2 tpd conventional cells.

Scheme at i) above is open circuit column cell and batch testing. Results are given in Table 3

Table 3 : Results of open circuit column tests, zinc cleaning of rougher concentrate

S.No.	Sample	Assay, %			Rec., %
		Zn	ISM	SiO_2	Zn
1.	Zn conc.	47.0	5.00	2.32	62.2
	Col.Tail	24.0	26.0	17.80	37.0
2.	Zn. conc.	52.9	2.70	1.62	55.7
	Col Tail	24.0	26.8	17.8	44.3
3.	Zn conc.	53.8	1.91	1.50	56.0
	Col Tail	23.6	26.5	15.4	44.0
4.	Zn conc.	54.8	1.70	1.25	56.8
	Col Tail	23.2	27.3	18.7	43.2
5.	Zn conc.	54.4	8.31	2.60	64.8
	Col Tail	20.6	31.3	21.2	35.2
	Zinc rougher	34.5	16.10	9.70	100.0

Scheme at ii) above is conventional agitation cells for rougher and column cell for cleaning in close loop with conventional cells. The results obtained in the scheme are given in Table 5 & scheme is given in Fig.1.

Size analysis of typical column circuit samples is given in Table 4

Table 4 : Sieve analysis of column circuit samples

Size in microns	Zinc rougher Conc.			Zinc conc			Col Tails		
	Wt. %	Assay, %		Wt, %	Assay, %		Wt. %	Assay, %	
		Zn	SiO_2		Zn	SiO_2		Zn	SiO_2
+75	4.40	31.9	31.4	2.80	41.3	2.5	5.70	26.5	30.3
-75+45	15.1	41.0	9.60	18.9	57.5	1.6	11.8	35.0	14.8
-45	80.5	37.0	7.20	78.3	46.3	2.2	82.5	25.5	12.5

Table No 5 : Column in close circuit with conventional cells

Product	Assay, %			Rec. %
	Zn	ISM	SiO_2	Zn
Lead tailings	6.28	64.83	43.34	100
Zn rougher conc.	37.8	17.12	12.00	
Zn scavenger conc.	2.50	62.74	44.00	
Zn tailings	1.00	67.82	48.70	
Zn conc (column)	51.00	4.25	2.70	85
Cl.tails (column)	15.00	49.24	34.50	

OBSERVATIONS

i) It can be seen from Table No 3 , that zinc rougher concentrate of grade 34.5 % Zn and 9.70% SiO_2 was subjected to open circuit cleaning in column cell, has produced zinc concentrate of grade 47-57.8% Zn with SiO_2 content of 1.3-2.6%. Zinc recoveries were in the range of 46.5-64.8%.

ii) The metallurgical results as given in Table No 5 indicates that zinc concentrate of grade 51% Zn and 2.7% SiO_2 was produced from zinc rougher of grade 37.5% Zn and 12 % SiO_2,by recirculation of column tails with fresh feed. Over all zinc recovery from lead tails was 85%.

This indicates that whether in open circuit or close circuit, cleaning of zinc in column lowers silica in zinc concentrate of Rajpura Dariba mines.

Table 6 : Effect of variation in feed grade

S.No	Feed	Concentrate		Recovery %	
	Zn	SiO_2	Zn	SiO_2	Zn
1.	37.0	11.70	54.00	2.60	64.80
2.	41.0	9.70	59.00	1.40	60.00
3.	28.0	22.40	48.50	6.00	35.00
4.	34.5	16.80	54.00	2.50	50.00
5.	30.0	20.00	47.00	5.50	45.50
6.	24.5	26.20	47.00	8.00	40.00
7.	35.0	18.80	52.00	4.50	60.00
8.	30.0	19.90	56.00	2.00	40.00

Tests with Variation in Feed Grade

Due to change in ore ratio i.e. CS: GMS in mill feed there is variation in grade of zinc rougher concentrate obtained in plant. Tests were done on variety of samples obtained from plant. The results are given in Table 6.

Discussions

It is seen from above table and Fig. 2, that as Zn grade in concentrate improves with improvement in feed grade. There is corresponding reduction of silica in concentrate.

Basic Design Parameters for Column

a) The experiments conducted as above confirm amenability of column flotation technology for zinc cleaning on Rajpura Dariba ore, for reduction of silica in zinc concentrate. Recoveries obtained in column circuit were better than obtained in conventional cleaning bank in plant.

Hence experiments were designed to generate critical parameters like carrying capacity, air holdup, flotation rate constant. The reagent addition levels were determined on experience in plant operations. It is seen that copper sulphate, frother and small quantity of collector are required to be added in column operations.

b) With a view to size column and to predict metallurgical performance, a carefully planned test program was conducted on two samples, one assaying 28 % Zn and other 34 % Zn. Column sizing is done based on in-house scale up model developed by Engineers India Ltd (EIL).

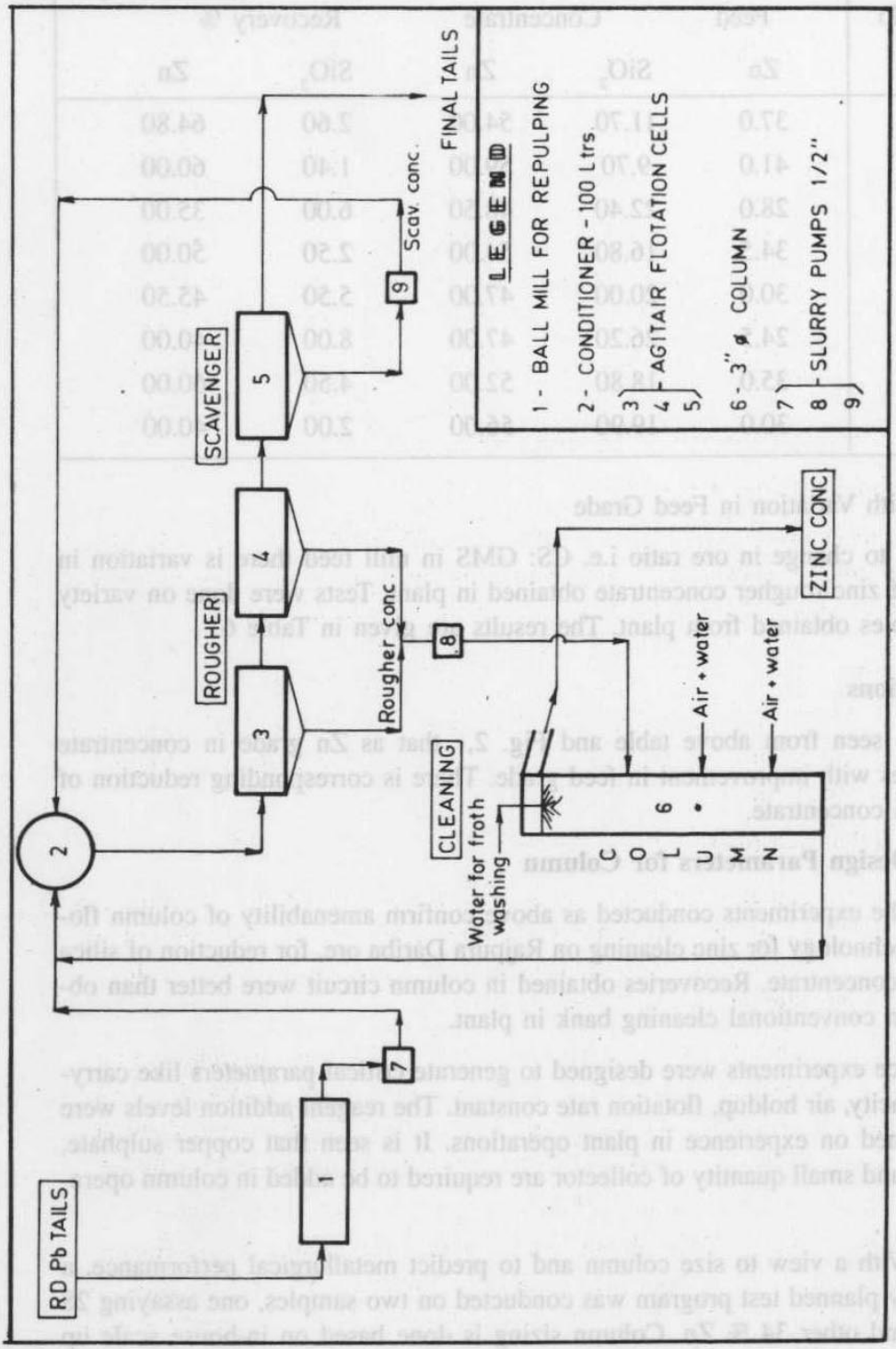

Fig. 1 : Flow scheme adopted for continuous testing of RD lead tailings combining conventional pilot plant cells with flotation column

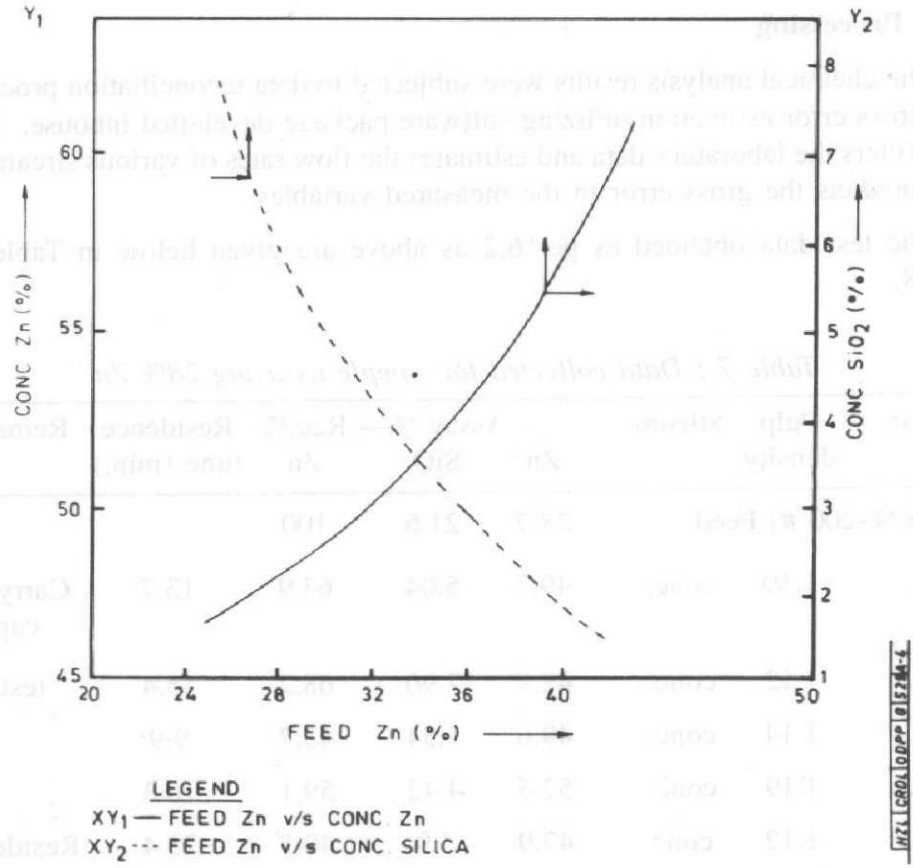

Fig. 2 : Binary plot of Zn grade v/s conc. grade b silica

c) The simulator requires experimentally determined parameters of :

i) Flotation rate constant, and

ii) Carrying capacity

For determining i) at above the particle collection process in column is considered to follow first order kinetics. The objective therefore is to determine fist order rate constant for each mineral species. The experimental procedures consist of a series of column runs at various nominal liquid residence times. The feed used in all tests is of same characteristics, % solids and mineral composition etc. Also wash water, air flow rate and froth interface level were kept constant.

For carrying capacity determination a series of column flotation run at constant residence time with increasing pulp density until a maximum production rate of solids to the concentrate is obtained. In the pilot column experiments pulp density was varied between 1.10-1.40 Kg/ltr.

Data Processing

The chemical analysis results were subjected to data reconciliation procedure and gross error estimation utilizing software package developed inhouse. It not only filters the laboratory data and estimates the flow rates of various streams but also predicts the gross error in the measured variables.

The test data obtained as per 6.2 as above are given below in Table No. 7 & 8.

Table 7 : Data collected for sample assaying 28% Zn

Test	Pulp density	Stream	— Assay %— Zn	SiO_2	Rec.% Zn	Residence time (min.)	Remarks
(70.6 %-200 #)		Feed	28.7	21.6	100		
1.	1.10	conc.	49.7	5.04	63.9	13.7	Carrying cap.
2.	1.12	conc.	42.9	7.90	68.2	15.4	tests.
3.	1.14	conc.	49.6	5.54	43.7	9.9	
4.	1.19	conc.	52.5	4.42	59.1	10.3	
5.	1.12	conc	47.9	5.9	40.5	23.4	Residence
6.	1.12	conc	47.5	5.5	51.8	16.1	time
7.	1.12	conc	50.0	4.8	48.7	13.8	variation
8.	1.12	conc	48.8	4.5	35.3	10.6	

Flotation Rate Constant

For modeling purpose the column is considered to consists of two zones, viz., collection zone which is responsible for recovery and cleaning zone, a packed bubble bed generated by downward flowing wash water. The model equations used for the simulation are based on the first principles of bubble particle hydrodynamics. For this reason the simulator can address the complex inter-relationships between the various parameters and predpict the column response with out extensive experimental data. Analysis of recovery v/s time yielded estimates of desired flotation rate constants Recovery/grade data generated on pilot column experiments were then simulated utilizing in-house computer program for arriving at actual value of rate constants.

Table 8 : Data collected for sample assaying 34 % Zn

Test	Variable	Stream	Assay %		Rec %	Residence	Remarks
			Zn	SiO_2	Zn	Time (min.)	
	(68.3%-200#)	Feed	33.9	18.9	100		
	Pulp density						
1.	1.10	conc	55.0	3.55	59.0	23	
2.	1.12	conc	55.2	4.14	75.0	23	Carrying
3.	1.14	conc	55.0	3.53	76.2	23	capacity
4.	1.19	conc	55.1	4.28	73.4	2	tests
5.	1.14	conc	57.2	2.67	78.3	16	Residence
6.	1.14	conc	55.8	3.02	76.4	14	time
7.	1.14	conc	54.1	3.60	74.1	11	variation
8.	1.14	conc	52.0	4.14	71.8	10	
	cc/min						
9.	64	conc	57.4	2.95	66.1		Air rate variation
10.	78	conc	55.0	3.53	76.2		tests
11.	94	conc	50.1	6.80	69.2		
Froth bed height (cms)							
12.	15	conc	54.8	4.11	82.3		
13.	25	conc	55.0	3.53	76.2		
Wash water variation (cc/min)							
14.	200	conc	50.5	8.80	85.1		
15.	250	conc	55.0	3.5	76.2		

Design Approach

Principle assumptions made during the design are related to carrying capacity (Ref.Fig 2) and tailing specific gravity as a function of percentage flotation.

CONCLUSION

1. Rajpura Dariba zinc rougher concentrate is amenable to column flotation for reduction of silica in concentrate.
2. Based on the design parameters the zinc cleaner consists of two columns arranged in series each of diameter 1.75 meters and height 10 meters. The d80 is assumed to be 110 micron. The column design parameters and basic

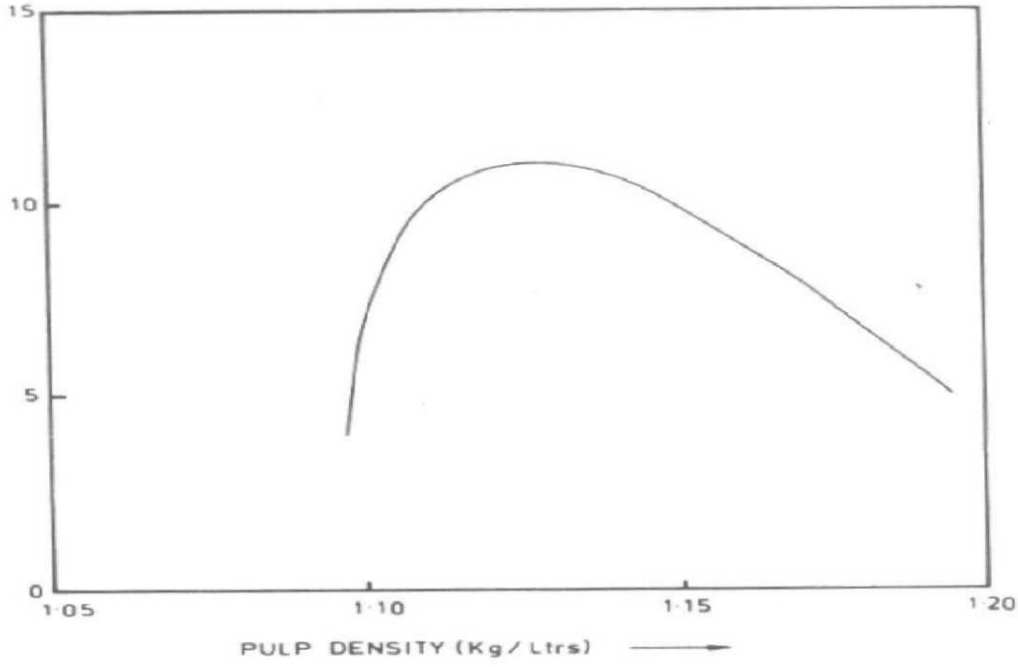

Fig. 3 : Carrying capacity curve

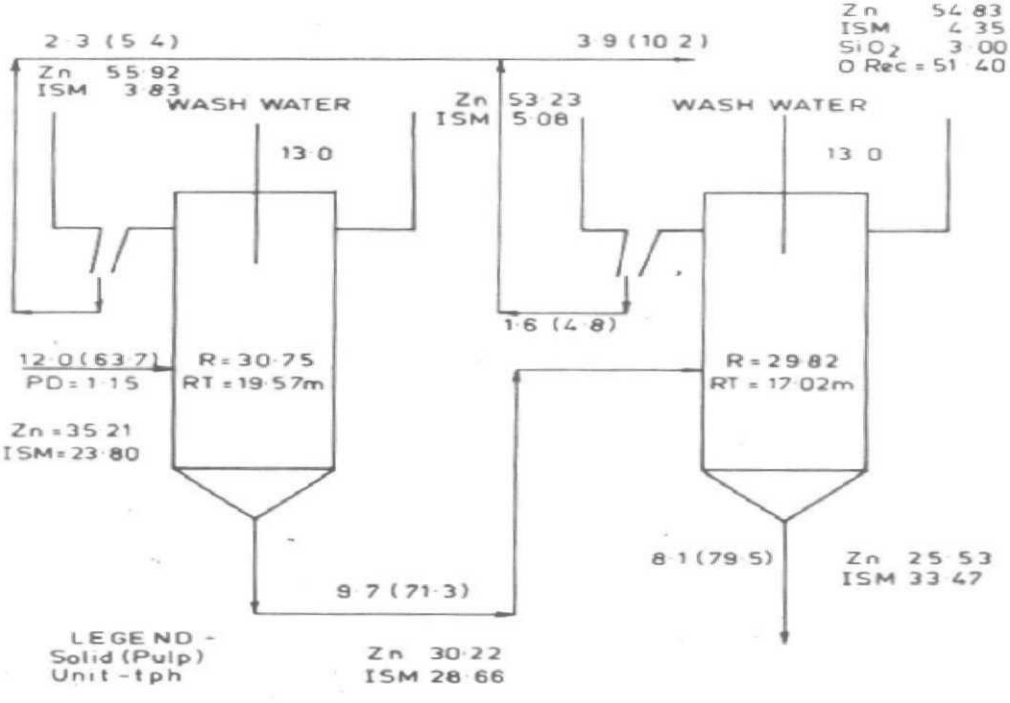

Fig. 4 : Column design
dia = 1.75 mtrs., Ht. = 10 mtrs. ϕ 80-110 mic

engineering was vetted by an expert agency "Control International S.A.", France.

The column flotation package developed under the S&T project will be useful for future design of column cells indigenously. After successful trials in one of the 900 tpd circuit it is being extended to the remaining two streams.

The other process conditions are as under:

Zn rougher Zn 30-35%, SiO_2 23.6%, P.D1.15

Gas hold up 18%, Feed rate 12 tph,

Feed% Solids 20,Carrying capacity 1.78 gm/min/cm^2

Sp. gravity Feed 3.25, Tails 2.9, Conc 3.8-3.9

Through-put 12 tons /hour.

Expected metallurgical results : -

Concentrate Zn 54%, SiO_2 2.72%, ISM 3.78%.

Recovery 55% in column and 85% overall circuit.

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