Improving scheelite recovery from gold tailings

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INTRODUCTION

Tungsten occupies a very important place amongst the strategic metals. However, resources available in India are scarce and lean in grade. Various physical methods of beneficiation have been tried to beneficiate such low grade ores, but these have not been generally efficient in terms of high recoveries and concentrate grades. Tungsten minerals, wolframite and scheelite being friable, tend to slime during size reduction stages. Because of this, high loss in slimes occurs during conventional gravity operations. Flotation techniques too have not been very successful though some excellent results have been reported by Mercade (1) on direct flotation of scheelite from low grade ores. Recently special gravity concentration equipment such as Bartles Mozley Separator (BMS) and Cross Belt Concentrator (CBC) have been used in separation of a wide variety of fine heavy minerals including scheelite (2, 3, 4, 5). To obtain a high grade concentrate, a combination of gravity and flotation and/or magnetic separation method is generally employed.

The gold tailings from Kolar Gold Fields contain small amount of scheelite ($CaWO_4$). A 50 tpd plant to recover scheelite has been in operation at KGF of Bharat Gold Mines Limited. The process flow-sheet adopted at the plant involves a multistage operation including desliming, gravity concentration, flotation and magnetic separation. Scheelite recovery in the plant is much lower than the designed plant value. Most of the losses seem to occur during preconcentration stages of the gravity operation. An attempt has been made to relate the efficiency of operation of each stage of gravity beneficiation in terms of feed characteristics and to find causes of sub-optimal separation. Alternate means of improving scheelite recovery are also suggested.

Mineralogy and feed characteristics :

The mineralogical composition of the feed sample is as follows :

Table 1.

Mineral	Wt. %
Quartz and Feldspar	65.0
Amphiboles and Pyroxene	34.2
Calcite, Zircon and other trace transparent minerals	0.2
Scheelite	0.2
Arsenopyrite	0.3
Other opaque minerals	0.1
Total	100.0

Scheelite particles are completely liberated and no composite grains are present even in the coarser sizes. The feed samples used in our experiments showed considerable variations in WO_3 content (0.098–0.16% WO_3). The particle size distribution and WO_3 distribution in various size fractions of the feed are given in Fig. 1. This shows that nearly 50—60% of the WO_3 values are distributed in the –200 mesh fraction in 36 — 40% weight of feed. The percentage of fines and WO_3 distribution in fines is much higher than the design values of the plant.

Spiral tests

Any concentration technique is efficient over a particular range of particle size and this limits the efficiency of the concentrating

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equipment. Separation efficiency is also dependent on a stable feed, constant flow rates and percent solids. Maximum recovery can be obtained at low flow rates and high pulp density(6).

In the BGML Plant practice, preconcentration is done in the spirals. Feed slurry is directly treated on the primary spirals followed by scavenging the tails on secondary spirals. The composite spiral concentrate is further upgraded on wet shaking tables. For spiral tests a feed sample of about 40 kg is repulped to a slurry density of 15—20% solids. The feed slurry is pumped to a Humphrey's 5 turns spiral at a flow rate 40 LPM. Initially the product streams are recirculated till a steady state is reached. There after the two streams are collected separately. The spiral concentrate thus obtined gives an enrichment ratio of 1.7 at about 64% WO_3 recovery.

In view of the large amount of fines present in the feed an attempt is made to find out the effect of desliming the feed and spiral treatment of the sand fraction. The feed sample is deslimed in a hydrocyclone; slimes so obtained consist of particles finer than 37 microns. It has a lower concentration of WO_3 (0.09% WO_3) inspite of the fact that −400 mesh fraction in the feed has higher enrichment of WO_3 values. The WO_3 distribution in slimes fraction is only 7.5% in 11.5% weight. The sand fraction from the cyclone is treated on the spiral under test conditions mentioned above. The spiral concentrate obtained from the deslimed feed gives an enhanced recovery of 76% at comparable enrichment ratio in about 49 % weight. Beneficial effects of treating deslimed gold tails are reflected in improved recoveries in each size fraction (Fig. II). It is important to note that in the case of particles in size range of 50 to 100 microns, the recovery is over 90 %. On the otherhand particles coarser than 100 microns show poor recovery. Still poorer recovery is obtained for particles finer than 50 microns. Thus in a mixed feed of coarse and fine particles, settling characteristics of particles of different sizes and consequently their separation behaviour differ. In order to find out the effect of treating a feed consisting particles of close size range, further tests are carried out on classified feeds.

The feed sample is classified at 100 mesh. The +100 and −100 mesh fractions are treated separately on spiral under test conditions of 40 LPM slurry flow rate at 15—20% solids. Product streams are collected separately for each fraction. Experimental results are given in Table. 2.

This shows that an overall recovery of 56.5 % in 11.8 % weight at an enrichment ratio of about 5 is obtained in the composite spiral concentrate. High tailings assays of 0.05% WO_3 in + 100 mesh fraction and 0.06 % WO_3 in −100 mesh fraction indicate the feasibility of improving scheelite recovery at lower enrichment ratio, by scavenging the spiral tailings.

A comparision of spiral performance on deslimed gold tails and classified tails is shown in Fig. III. It is seen that classification followed by spiral treatment of classified fractions gives an improvement of nearly 10% recovery with a slightly better enrichment ratio over deslimed feed. Further upgrading of spiral concentrates is carried out on wet shaking tables. The maximum recovery obtainable on shaking tables is found to be about 64% at 14% WO_3 grade, evaluated on the basis of data collected on the efficiency of shaking tables on direct tabling as well as tabling of classified products as discussed later. Thus a total loss of 36% of tungsten values seems to be unavoidable if preconcentration by spiralling is carried out. Hence an alternate process for obtaining higher scheelite recovery at comparable grade is attempted by optimizing operation on wet shaking table without preconcentration.

Laboratory tests on wet shaking table :

The performance of any gravity concentration unit is primarily determined by the marked differences in specific gravity between the valuable and gangue minerals. However, factors such as particle size and shape, especially in a feed with wide size distribution like the one under investigation, can be very significant. Extensive tests are carried out on Deister table to study the effect of particle size, desliming and classification on particle behaviour during tabling operation.

Tabling of gold tails :

A feed sample of 25 kg is directly treated on the Deister table and a high weight percent of rougher concentrate collected. No significant improvement is observed by scavenging the table tails. Rougher concentrate on cleaning yields a cleaner concentrate assaying 14% WO_3 at about 71 % recovery in about 0.75 % weight. Some of the results are given in Table-3.

The relationship between particle size and scheelite recovery is shown in Fig. IV. It can be seen that maximum recovery occurs for particles between 52 to 104 microns. High scheelite losses occur in the finer sizes i.e. −400 mesh fraction and to a lesser extent for particles coarser than 104 microns. During tabling a part of the feed is washed off from the deck surface as slimes. At the top of the surface a clean concentrate streak of fine scheelite closely followed by an overlapping wider band of fine and coarse material are observed. The coarse band is adversely affecting the fine scheelite grains which do not get sufficient chance to really reach the deck surface due to incessant shuffling caused by the coarse particles. Also, fine particles which might have settled are pulled away from the supporting plane. They return back to the moving bed and are exposed to cross wash water current. The net result is that these particles are swept off to the tailings end. This interaction between coarse and fine particles can be avoided if closely sized feed is used for tabling. Further tests are carried out on deslimed and classified feeds.

Effect of desliming and classification :

About 25 kg. of feed sample is treated on the Deister table and sand and slimes fractions collected separately. That part of the feed which is swept off across the table deck surface is collected as slimes fraction. It mostly consists of particles smaller than 37 microns, with 0.076% WO_3 and only 7.8% WO_3 distribution in 16 % weight. The sand fraction is classified at 100 mesh. The optimal conditions for tabling of +100 mesh fraction are 9 mm stroke length, 0.5° slope angle and 7 LPM wash water. A high weight percent rougher concentrate is collected followed by cleaning the same to obtain a cleaner concentrate assaying 14.2 % WO_3 in 0.18% weight. The operating parameters for tabling of —100 mesh fraction are 7 mm stroke length 0.4° slope angle and 5 LPM wash water. A clean concentrate band analysing 20.6% in WO_3 in 0.34% weight and middling fraction are separately collected. The later, on cleaning, gives a second concentrate with 6.6% WO_3 in 0.29% weight. Typical results are given in Table-4. This shows that at a comparable grade of about 14% WO_3, the classified material gives an enhanced recovery of 9% over unclassified feed.

Effect of classification is shown in Fig. V. At high weight percent of concentrate collection about 85% of the values are recovered, which is about 15% improvement over direct treatment of unclassified feed. Some data on direct tabling of original feed and classified feed are plotted in grade vs recovery plot in Fig. VI. It shows that a scheelite concentrate assaying 14% WO_3 at 78—80% recovery can be obtained with classified feed.

It can also be seen that desliming results in an enriched −100 mesh sand fraction, with minimal loss of WO_3 values in a higher weight percent of slimes. Bulk of the scheelite present in the sand fraction of −100 mesh is recovered in the concentrate and middling fractions; loss of values in tailings being only 4.4% at 0.016% WO_3 grade.

Tabling performance of −100 mesh and +100 mesh fractions is extensively examined by conducting a series of experiments. The concentrate bands are examined visually under a u.v.

light to collect clean concentrate and middling fractions. Results are given in Table 5.

Experimental data on 100− mesh fraction are plotted in Fig. VII. It clearly shows that scheelite recovery of about 85% at lower enrichment is obtained from the −100 mesh fraction. On the other-hand no improvement in recovery beyond 75% is obtained from the +100 mesh fraction. This loss of 25% values is attributed partly to the tendency of some scheelite particles to roll down the table deck. When particles become more spherical, rolling instead of sliding occurs (7). Faster and lateral drift of coarse spherical grains results in their scattered distribution in the moving particle bed ultimately leading them to the tailings end. Thus recovery from finer sizes is superior than that from the coarser sizes.

The overall recovery is dictated by the scheelite content present in the coarser sizes; higher the distribution in this fraction lower will be the recovery.

Mineralogy of table concentrates :

The constituent minerals in the table concentrates are estimated by petrological analysis and are given in Table 6. Over 50% of the composite table concentrate consists of amphiboles followed by arsenopyrite, scheelite and quartz in decreasing order of abundance.

Flotation and magnetic separation :

In the scheelite recovery plant at K. G. F. the table concentrate is subjected to arsenopyrite flotation followed by magnetic separation of the scheelite rich sink fraction.

Laboratory tests have been carried out on table concentrate obtained from —100 mesh fraction assaying 20—24% WO_3 in a Mineral Master's Flotation cell (1 litre) at 15.20% solids for arsenopyrite flotation. Amyl xanthate and pine oil are used as collector and frother respectively. Wet magnatic separation of the sink fraction yields a high purity scheelite concentrate. Some of the results are given in Table 7.

This shows that under optimal conditions of flotation and magnetic separation a high grade scheelite concentrate assaying 75% WO_3 at about 95% (stage) recovery can be obtained from the table concentrate.

Based on our experiments an integrated process flowsheet to recover scheelite from the KGF gold tails is suggested (Fig. VIII).

Conclusions :

Desliming of gold tails followed by classification of sand and subsequent tabling of each fraction separately yields a concentrate assaying 14% WO_3 at 78−80% recovery. Contrary to general belief higher recovery is obtained from the fine fraction than from the coarse one. Particle shape plays an important role during tabling of the coarse fraction. Thus overall recovery is dependent on the scheelite distribution in the coarser sizes. The table concentrate is amenable to arsenopyrite flotation using a xanthate and pine oil; loss of scheelite values in the float is less than 1%. A high grade scheelite concentrate assaying 75% WO_3 at 95% (stage) recovery is obtained by the magnetic separation of the sink fraction.

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Table — 2 : Results of spiralling of classified gold tails

Fraction	Wt. %	WO_3 %	Dist. %	Enrichment ratio	Stage recovery %
+ 100 mesh	42.0	0.1	37.0		
— 100 mesh	58.0	0.124	63.0		
Feed	100	0.114	100.0		
Conc. (+100 mesh)	6.2	0.39	21.2	3.9	57.0
Tails („)	35.8	0.05	15.7	—	
+ 100 mesh	42.0	0.1	36.9		
Conc. (−100 mesh)	5.6	0.715	35.3	5.8	56.1
Tails („)	52.4	0.06	27.7		
— 100 mesh	58.0	0.124	63.0		
Composite conc.	1.18	0.54	56.5	4.8	

Table — 3 : Results of direct tabling of gold tails

Expt. — 1

Fraction	Wt. %	WO_3 %	Dist. %	Enrichment ratio
1. Cleaner conc.	0·29	23.0	56.6	192.0
2. Cleaner Tails	0.67	0.25	1.4	2.1
3. Tails	99.04	0.05	42.0	
Feed	100.00	0.12	100.0	
1+2	0.96	7.12	58.0	59.4

Expt. — 2

1. Cleaner conc.	0.59	13.8	61.5	106.2
2. Cleaner Tails	1.89	0.37	5.3	2.8
3. Tails	97.52	0.045	33.2	
Feed	100.00	0.13	100.0	
1+2	2.48	3.56	66.8	27·4

Expt. — 3

1. Cleaner conc.	0.75	14.1	70.5	93.0
2. Cleaner Tails	5.69	0.12	4.6	
3. Tails	93.56	0.04	24.9	
Feed	100.00	0.15	100.0	
1+2	6.44	1.8	75.1	12

Table — 4 : Tabling results of desliming and classification

Fraction	Wt. %	WO_3 %	Dist. %	Enrichment ratio
1. + 100 mesh	42.0	0.085	24.8	
2. – 100 mesh	42.4	0.23	67.6	1.6
3. Slimes	15.6	0.07	7.6	
Feed	100.0	0.144	100.0	
2+3	58.0	0.187	75.2	

+ 100 mesh

				Overall Wt.%	Overall Dist. %
1. Cleaner Conc.	0.42	14.2	70.4	0.18	17.5
2. Cleaner tails	5.85	0.07	4.8	2.46	1.2
3. Tails	93.73	0.022	24.8	39.37	6.2
Feed	100.00	0.085	100.0	42.01	24.9
1+2	6.27	1.02	75.2	2.64	18.7

— 100 mesh

4. Concentrate	0.8	20.6	71.7	0.34	48.5
5. Cleaner Conc.	0.68	6.6	19.5	0.29	13.2
6. Cleaner tails	5.0	0.1	2.3	2.12	1.6
7. Tails	93.52	0.016	6.5	39.65	4.4
Feed	100.00	0.23	100.0	42.4	67.7
Conc. 4+5	1.48	14.2	91.2	0.63	61.7
Conc. 4+5+6	6.48	3.3	93.5	2.75	63.3
Conc. 1+4+5	1.9	14.2		0.81	79.2

Table — 5 : Tabling results of — 100 & + 100 mesh fractions (cumulative)

— 100 mesh

Fraction	Expt. 1				Expt. 2				Expt. 3				Expt. 4			
	Wt. %	WO_3 %	Dist.%	ER	Wt%.	WO_3 %	Dist. %	ER	Wt.%	WO_3 %	Dist. %	ER	Wt.%	WO_3 %	Dist. %	ER
Conct. 1	1.0	9.7	80.9	81.0	0.63	14.8	73.8	114.0	1.4	7.7	81.6	59.2	2.73	6.7	82.1	30.5
Conct. 2	5.1	2.0	84.4	17.0	3.23	3.4	87.8	26.2	5.0	2.4	89.2	18.5	4.89	3.9	85.5	17.7
Tails assay		0.02				0.016				0.015				0.034		
Feed assay		0.12				0.13				0.13				0.22		

+ 100 mesh

	Expt. 1				Expt. 2				Expt. 3			
	Wt. %	WO_3 %	Dist.%	ER	Wt.%	WO_3 %	Dist. %	ER	Wt.%	WO_3 %	Dist. %	ER
Conct. 1	0.42	14.8	70.4	160.0	1.16	5.0	72.5	62.5	1.0	5.4	71.05	71
Conct. 2	6.21	1.05	73.6	11.9	7.63	0.8	76.3	10.0	6.2	0.92	75.00	12
Tails assay		0.025				0.02				0.02		
Feed assay		0.088				0.08				0.076		

ER = Enrichment Ratio

Table — 6 : Mineralogical composition of table conc.

No.	Product	Percent Mineral					
		Wt. %	Scheelite	Arseno-Pyrite	Amphibo-les	Quartz	Others
1	Cleaner conc (+ 100 mesh)	0.21	20.1	32.4	46.0	0.9	0.6
2	Conc 1 (— 100 mesh)	0.21	30.7	19.4	46.3	2.4	1.2
3	Conc 2 (— 100 mesh)	0.21	8.3	20.5	69.0	1.4	0.9
	Conc 2+3 (— 100 mesh)	0.42	19.5	20.0	57.6	19.0	0.10
	Conc 1+2+3	0.62	19.6	24.4	53.5	1.6	0.90

Table — 7 : Flotation and magnetic separation of table conc.

Fraction	Wt. %	WO_3 %	Dist. %	Wt. %	WO_3 %	Dist. %	Wt. %	WO_3 %	Dist. %
Nonmag	30.8	75.0	96.30	30.2	76.0	95.6	22.3	75.5	88.0
Mag	26.9	3.07	3.40	30.2	3.3	4.2	28.1	4.9	7.0
Arseno-pyrite Float	42.3	0.12	0.30	39.6	0.14	0.2	49.6	1.2	5.0
Feed (Table conc)	100.00	24.0	100.00	100.0	24.0	100.0	100.0	19.2	100.0

FIG. I. SIZE DISTRIBUTION OF WALKER GOLD TAILS

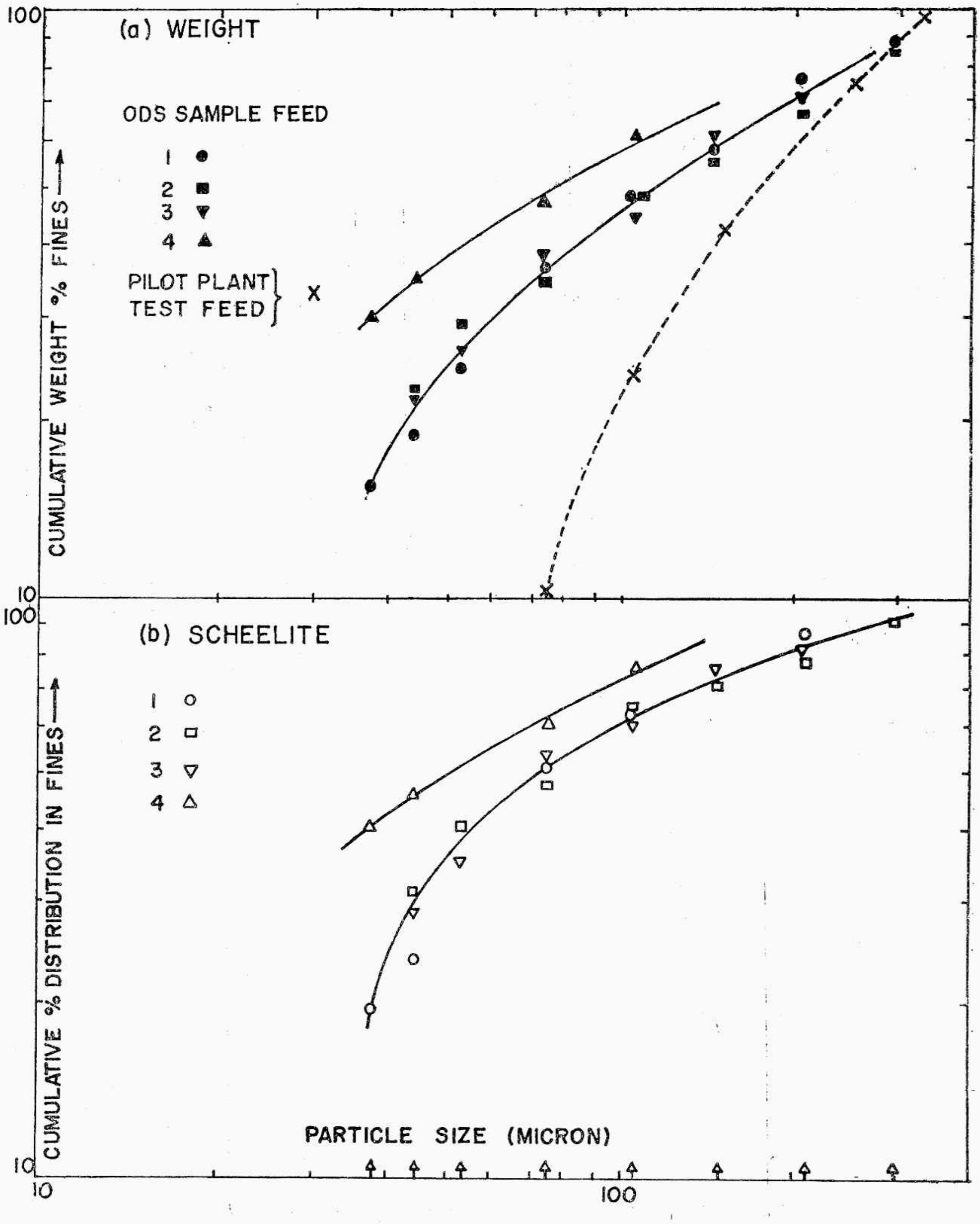


FIG. II COMPARISON OF SPIRALLING EFFICIENCY AS A FN. OF PARTICLE SIZE (PLANT & LAB. TESTS)

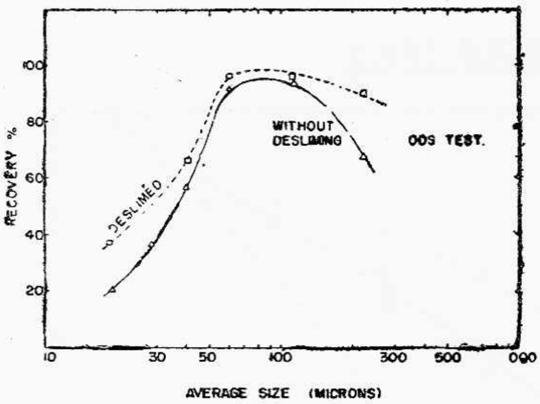


FIG. III. EFFECT OF DESLIMING AND CLASSIFICATION ON SPIRALLING OF WALKER GOLD TAILS

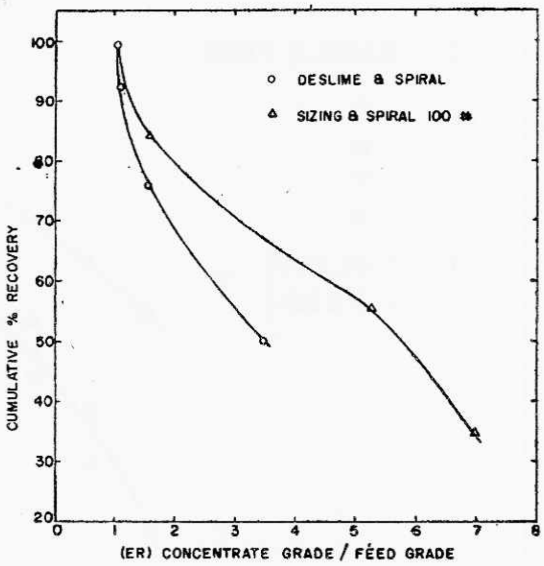


FIG IV RELATION: PARTICLE SIZE Vs RECOVERY IN TABLING (ODS TEST)

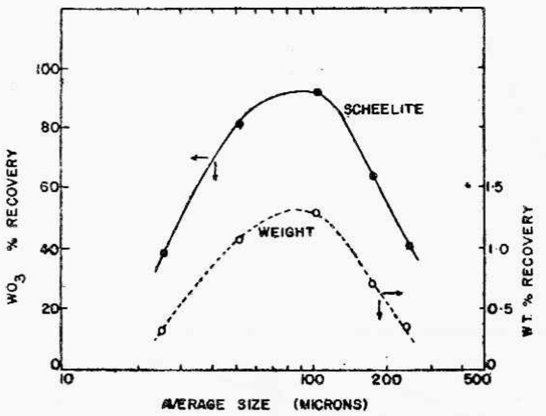


FIG. VII. TABLING OF -100 # FRACTION

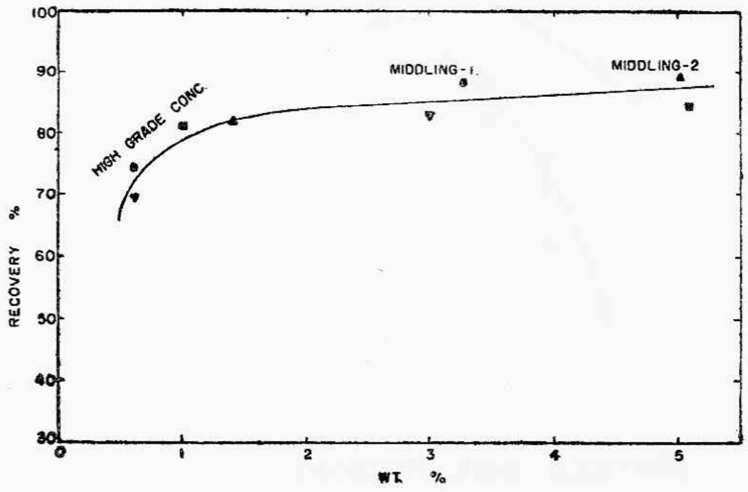


FIG. V. EFFECT OF CLASSIFICATION DURING TABLING
(RECOVERY Vs PERCENT WEIGHT)

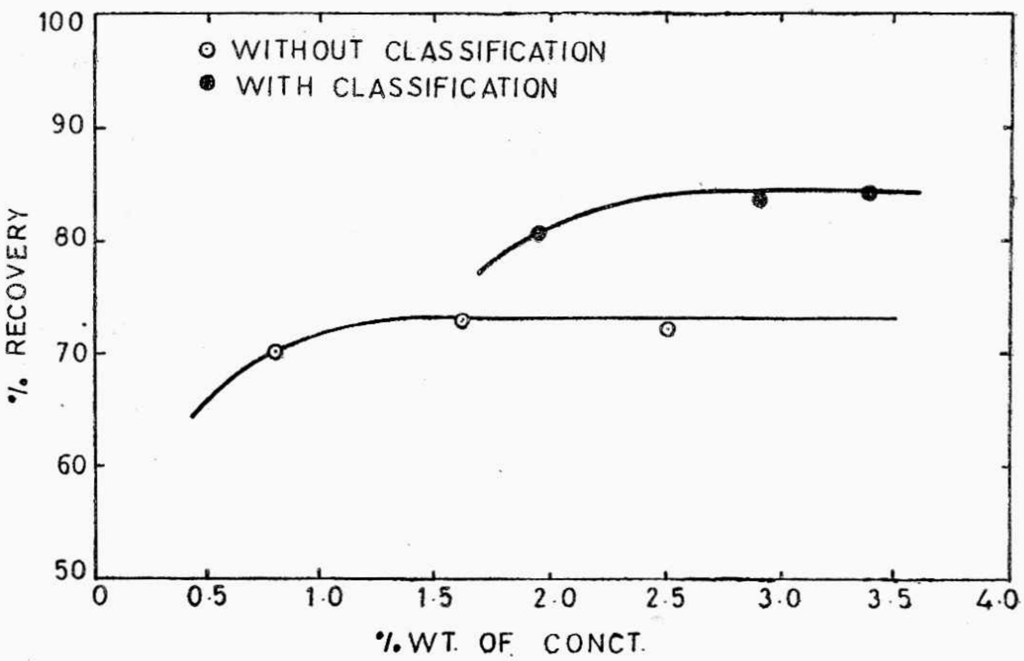


FIG VI EFFECT OF CLASSIFICATION DURING TABLING
(RECOVERY Vs GRADE)

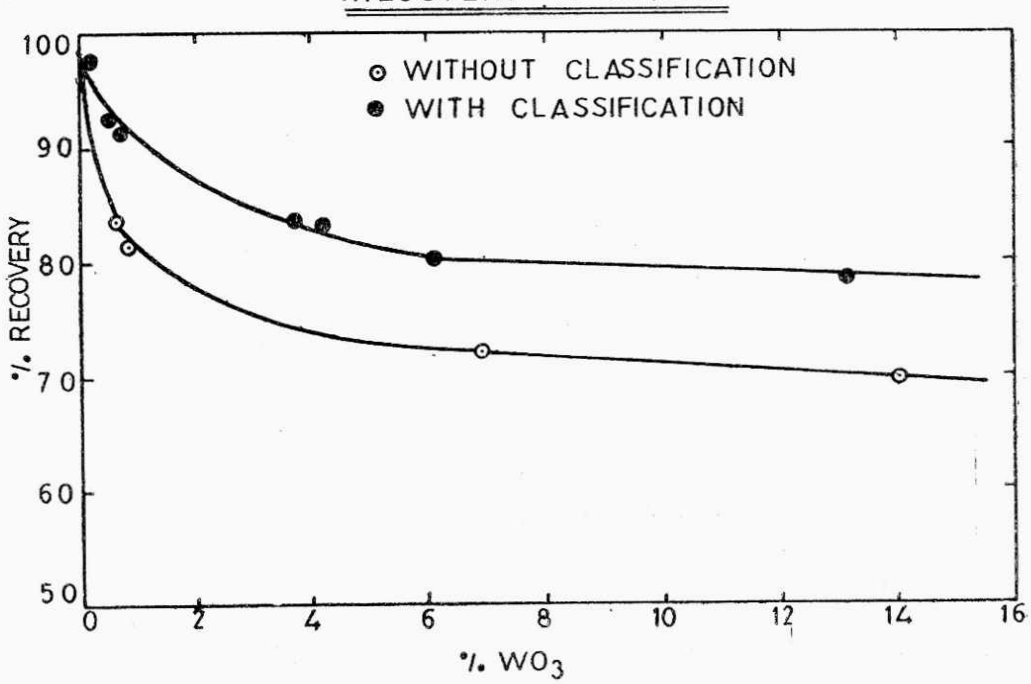
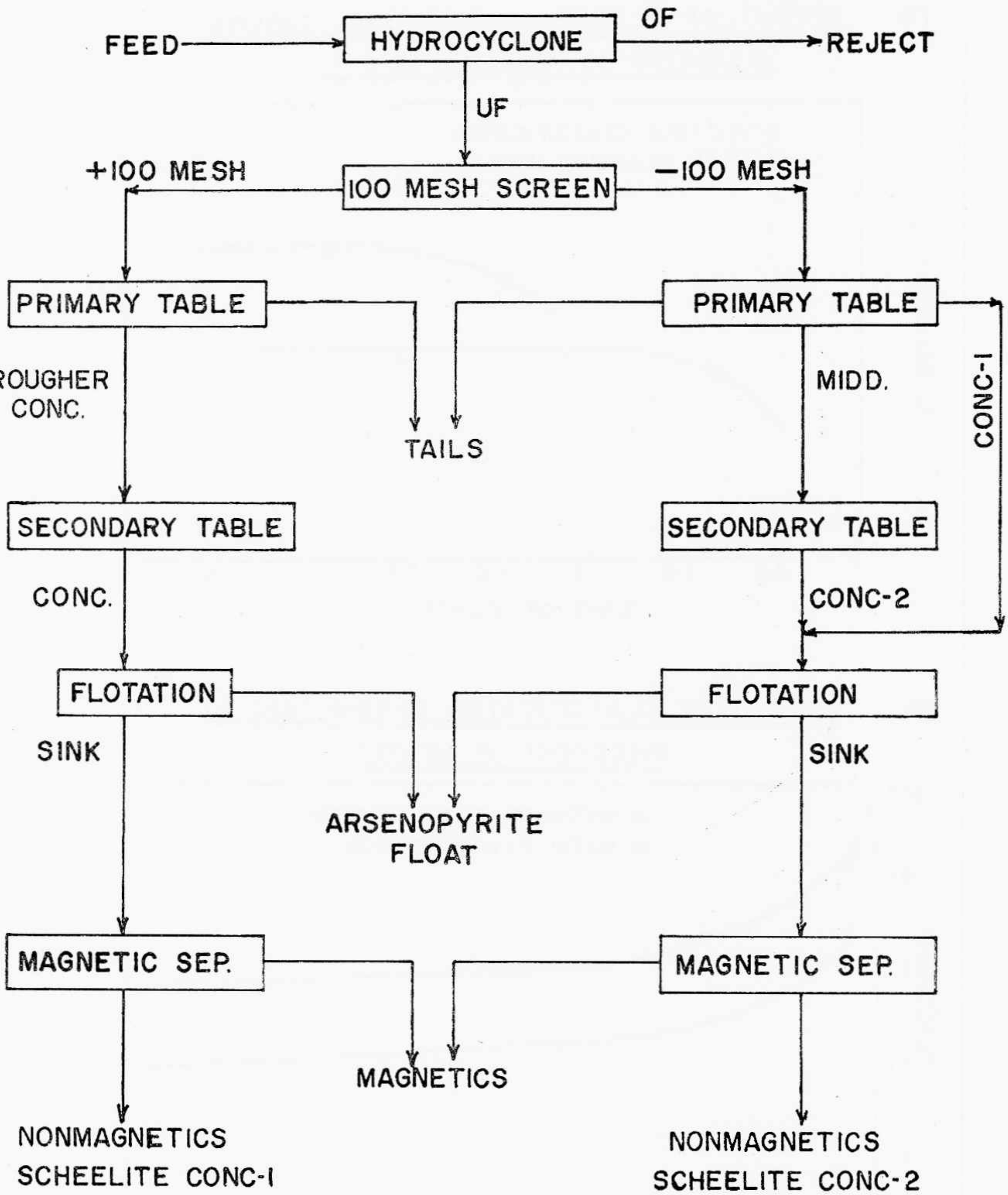


FIG. VIII FLOWSHEET FOR SCHEELITE RECOVERY FROM GOLD TAILS



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DISCUSSION :

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Question 1 : At what size you have deslimed the feed ?

Author : The slimes, as referred to in the text was that part of the feed which was swept-off across the table deck and collected separately. It contained only 7.6% WO_3 distribution in 15.6% Wt, as against nearly 20% WO_3 distribution in over 18% wt of the —400 mesh fraction of the feed. Hence it was assumed that only ultra-fine particles constitute the slimes fraction.

Question 2 : What is the overall recovery of WO_3 ?

Author : An overall recovery of about 70% at +70% WO_3 could be obtained.