Report on 23 G(150)

GRINDING AND CONCENTRATION TESTS

on

JULIAN IRON ORE

submitted by

CANADIAN JAVELIN LIMITED 1-118

LAKEFIELD RESEARCH OF CANADA LIMITED

- LAKEFIELD, ONTARIO, CANADA -

Report on

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Progress Report No.1

Project No.: L.R. 845

NOTE:

This report refers to the samples as received.

LAKEFIELD RESEARCH OF CANADA LIMITED
Lakefield, Ontario
March 6, 1961

INTRODUCTION

Approximately 34 long tons of Julian ore were received at Lakefield in December, 1960. Authorization was given by Mr. W.H. Roxburgh to proceed with a testing program with this ore, involving grinding in a Hardinge 'Cascade' mill and concentration by means of Humphreys spirals. The purposes of the investigation were:

1. To produce about 11 long tons of high grade iron concentrate.
2. To produce about 4 tons of ground ore as a reserve for further concentration tests.
3. To produce one or two tons of spiral tailings for possible testing.
4. To obtain data for preliminary concentrating plant layout and cost estimates.

The grinding and concentration tests were commenced on January 6th and completed on January 11th, 1961. Those present during part or all of this period included:

Mr. W.H. Roxburgh, Vice-President, Canadian Javelin Company,

Mr. B.S. Crocker, Vice-President, Kilborn Engineering Limited,

Messrs. H. Snedden and D. Ennis of Humphreys Engineering Company

Mr. W.J. Mix of the Hardinge Company, Incorporated.

The helpful advice and assistance given by these gentlemen is gratefully acknowledged. Particular credit is due to Messrs. Snedden and Ennis, who assisted in setting up the spirals and supervised their operation.

SUMMARY

Five pilot plant runs were made according to the flow sheet shown as Figure 1 on page 4. A final run was made with the 'Cascade' mill to produce ground ore only. Detailed results are given as Tables 1 to 10 on pages 10 to 22.

The ore grinds readily in the 'Cascade' mill yielding a product which is about 80% plus 200 mesh. Calculated net power requirement is 2.2 kw. hr. per long ton of ore. Capacity of each rougher spiral is about 1.4 long tons of new feed per hour and one cleaner spiral is required for every two rougher spirals.

Summary (cont'd)

In one pair of tests 76.6% of the iron was recovered in a concentrate which assayed 64.5% iron (acid soluble). Recovery was 79.6% in the other pair of tests but the grade of concentrate was only 63.5% iron. These results could undoubtedly be improved to some extent in practice, but no marked increase in recovery can be expected.

LAKEFIELD RESEARCH OF CANADA LIMITED

John W. Britton

John W. Britton, P. Eng.
Vice-President and General Manager

REGISTERED PROFESSIONAL ENGINEER
CHEMICAL
JOHN W. BRITTON
METALLURGICAL
PROVINCE OF ONTARIO

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FLOW SHEET

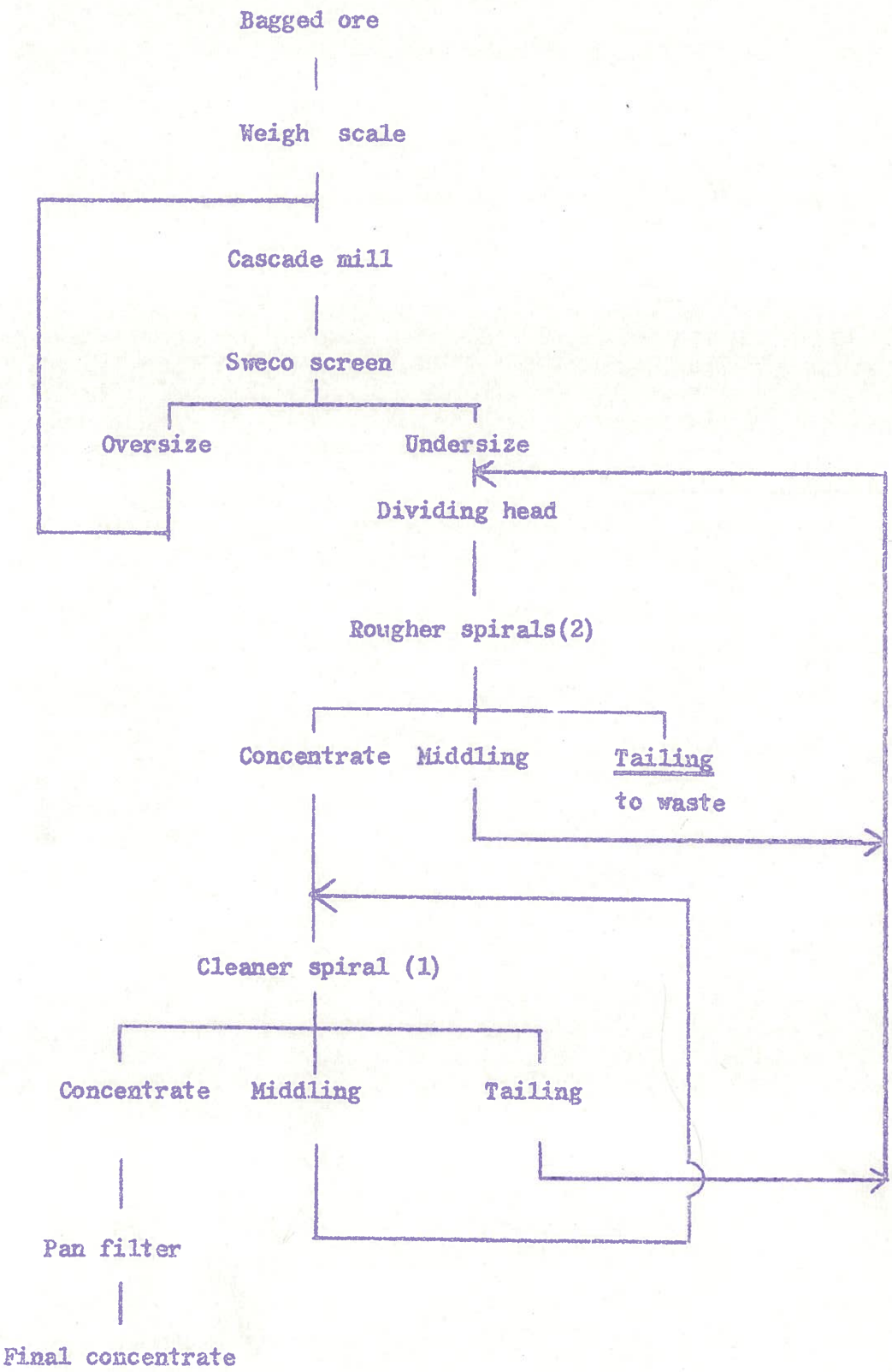


Figure 1 - Simplified flow sheet of pilot plant circuit

DESCRIPTION OF EQUIPMENT

(a) Grinding Circuit

Ore is fed to the 6' x 2' Hardinge 'Cascade' mill by means of a belt conveyor. The mill is equipped with grates which are mounted on top of filler plate castings on the discharge head of the mill in such a way that the product passing through the grates is scooped upwards and then discharges by gravity through the trunnion. There are two rows of grate liners, and each row has five 3/4" slots arranged circumferentially.

The mill drive consists of a 25 H.P. English Electric motor, three C-section V-belts and two vari-pitch sheaves, a Winsmith speed reducer and a single chain drive to the mill. Power consumed by the mill drive motor is measured with a Sangamo power-demand kilowatt-hour meter which includes a ratemeter as well as a cumulative meter. The ratemeter is useful in regulating the feed to the mill while the cumulative meter readings are taken to determine the total power consumption for each test.

Product discharges from the mill by gravity to a 30" diameter double deck Sweco screen. For these tests a 1/4" scalping screen was used on the top deck. The lower, or finishing screen was a 20 mesh screen for the first run and a 16 mesh screen with a square opening of 0.0445" for the remaining runs. (Tyler standard 14 mesh opening is 0.046"). Oversize from both screens was combined and returned by conveyor to the feed belt. Undersize from the finishing screen was discharged to the rougher spirals feed pump.

(b) Spiral Circuit

Three rubber-lined 5 turn Humphreys spirals were used as concentrators. Two of these were set up in parallel as roughers while the third was used as a cleaner. Spirals were mounted on a 4' wooden platform and all spiral products were handled with pumps. A 2 x 2 SRL pump was used for the rougher feed. For the remainder of the spiral circuit 3/4" and 1" Denver vertical sand pumps were employed. Tailings were removed with a 1 1/2" vertical sand pump.

Feed to the rougher spirals was split with a dividing head. This consisted essentially of a 4" pipe cross; pulp was introduced from underneath through a 1 1/2" line and discharged from the cross through two 1 1/2" horizontal sections of pipe. The pulp stream on each side was directed downwards into the spiral feed box through a tee and a length of rubber hose. The upper side of this tee was open to the atmosphere to prevent siphoning into the feed box. On the upper side of the dividing cross a 4' section of 3" pipe was installed to dampen out surges from the feed pump.

Water lines were connected to the wash water inlets and to the feed boxes on the spirals. A portable hose was directed into the cleaner feed pump to increase the velocity in the feed line and to provide additional water at the feed box. Additional water was provided at the feed cone and gland of the SRL pump.

Concentrate was partially dewatered on a 3' x 3' pan filter and stored in 25 gallon steel drums.

PROCEDURE

A simplified flow sheet of the pilot plant circuit is shown as Figure 1 on page 4.

The bagged ore was weighed in batches and fed to the mill continuously over predetermined intervals. To ensure mixing of the ore and also to maintain the correct proportion of ore from the various pits the batches were fed as follows:

1. Ten batches of 5 bags, each batch including 1 bag from each of the 5 pits.

2. One batch of 3 bags, including one bag from each of pits 2, 3 and 4.

This sequence was maintained throughout the tests, excepting for a sixth run, when ore from Pits 1 and 5 was depleted about 1/2 hour before the end of the run.

Sufficient water was added to the 'Cascade' mill to ensure a very fluid discharge and to reduce the overgrinding in the mill to a minimum.

Some surging occurred in the spiral circuit due to difficulty in maintaining a steady flow rate from the rougher feed pump. Any sudden change in the circuit resulted in several minutes of unsteady operation until the SRL pump was readjusted.

For the first runs the dividing head over the rougher spirals did not split the feed evenly. This was improved considerably after the third run by replacing the original 4' length of vertical feed line with a 6' length and by levelling the cross carefully. Some changes were made at the same time in the water distribution lines to increase the amount of water available at the cleaner spiral.

During the first run an attempt was made to filter the concentrate on a Dorrco filter but difficulty was encountered due to cake failing to adhere to the cloth. Whether this was due to the inherent nature of the material itself or to some fault in the filter was never established due to the limited amount of ore available for initial experimentation. A pan filter was substituted although it did not have sufficient capacity to yield a dry cake.

The first run was a 2 hour preliminary test. Ore was fed to the mill at a rate of 3.6 long tons per hour for the first hour and 2.8 long tons per hour for the second hour. During this run the load level in the mill built up to 17% only of the mill volume (18" below centre line) and it appeared that there would be no difficulty in maintaining a grinding rate of at least 3 tons per hour. Adjustments were made to the spirals during this run. The concentrate from the first part of the run was pumped to tailings. The balance was reserved and was run through the spirals a second time. Several mechanical improvements were made following this run, and the finishing screen was changed from a 20 mesh to a 16 mesh screen.

Runs 2 and 3 were made to obtain concentrate and obtain operating information The 'Cascade' mill was fed at the rate of 3.0 long tons per hour for the both runs and the operation was continuous excepting for a brief shut-down a few minutes after starting up. The total operating time of 3.95 hours was split evenly into the two runs for sampling purposes only.

PROCEDURE (cont'd)

The fourth and fifth runs were made under similar conditions to the two previous runs excepting that the grinding rate was reduced to 2.7 long tons per hour and some minor changes were made in the spiral circuit. Both runs were terminated by mechanica trouble with the tailing pump after 1.77 hours and 2.25 hours for runs 4 and 5 respectively

The sixth run was made to produce ground ore only. No change was madein the feed rate. The production rate was too high to handle the product with the pan filter so the pulp was run into drums and allowed to settle for about 1/2 hour. The water which was relatively clear, was decanted from each drum and the solids were transferred into fewer drums. Additional water was drained off by placing the closed drums on their sides. Rougher tailing was collected during Runs 2 to 5 inclusive in the same manner. In each case a small loss of slime occurred.

Several interruptions resulted from air locking of the SRL pump during the sixth run. For this reason, and since the run was very short, the power consumption is not reported.

Power calculations were made according to methods used by the Hardinge Company. Total power consumption is that registered by the Sangamo kilowatt-hour meter. Gross mill input is the calculated power imparted to the mill, which is equal to the total power multiplied by the efficiency of the motor and drive. (This includes the drive motor, sheaves, reducer and chain drive. The chain drive efficiency is assumed to be 90%). Net no-load power was determined by making a 3 hour run with no load on November 16th, 1960.

The calculated weight of ore milled for each run was based on the feed to the mill plus or minus the change in load in the mill during the run. Volumes of the mill load at various levels were taken from a graph prepared by Mr. W.J. Mix and the bulk density of the load was taken as 156 lb./cu.ft. This figure was determined by weighing the load in the mill after the final run. Excluding the first run, the mill load varied from 18" below centreline (8 cu. ft. or 17% of the mill volume) to 14" below centreline (11 cu. ft. or 24% of mill volume). Total mill volume is 46 cu. ft.

SAMPLING AND SCREEN ANALYSES

Regular sampling commenced with the second run.

The following samples were taken from the grinding circuit:

Mill discharge - Exactly one litre taken @ 1 hr. intervals for density determination.
Screen oversize (recycle) - 30 second cut taken @ 30 minutes for tonnage rate. Returned to circuit after weighing.
Screen oversize (recycle) - 5 second cut taken @ 30 minutes. Composited for each run for screen analysis.
Screen undersize (see below).

In the spiral circuit all samples were taken for 10 seconds from the whole stream in each case. Samples from the two rougher spirals were combined. The following were sampled at 20 minute intervals on each run.

SAMPLING AND SCREEN ANALYSES (cont'd)

Head sample (screen undersize)
Rougher concentrate
Rougher tailing
Cleaner concentrate
Cleaner tailing

The following were sampled at hourly intervals:

Rougher feed
Rougher middling
Cleaner feed
Cleaner middling

Spiral samples were composited for each run and the volume of pulp, weight of pulp and weight of dry solids were determined (see table 11).

Each dry sample was broken up, mixed and riffled to obtain one sample of approximately 500 grams and one sample of 400 grams. The remainder of each was bagged and retained.

Each 500 gram sample was riffled into two portions (A and B). Each portion was wet screened on a 325 mesh screen and the oversize was screened on the following sieves 20, 35, 48, 65, 100, 150, 200, 270 and 325 mesh. (The +150 was combined with the +200 and the +270 with the +325). All screen fractions were weighed and retained.

The 400 gram samples were each split by riffling once. One half was retained while the second half was ground in a Braun pulverizer, mixed and sampled for assay. One half of the pulverized material was also retained.

DISCUSSION

Results are shown in Tables 1 to 11B on pages 10 to 22 .

The ore grinds readily in the 'Cascade' mill yielding a product which is about 80% plus 200 mesh. Calculated net power requirement is 2.2 kw. hr. per long ton of ore. Capacity of each rougher spiral is about 1.4 long tons of new feed per hour. One cleaner spiral is required for every two rougher spirals.

Iron recovery was 76.6% in a concentrate assaying 64.5% acid soluble iron. (Average of runs 4 and 5). Improved recovery of 79.6% was achieved but the grade of concentrate was reduced to 63.5% iron (average of runs 2 and 3).

Undoubtedly these results could be improved to some extent. Little time was available during the pilot runs to determine the optimum conditions of operation due to the limited amount of ore available. Some operating problems were experienced, such as surging, insufficient washwater, and unequal splitting to the rougher spirals. These no doubt had an unfavourable effect on the efficiency of the separation.

DISCUSSION (cont'd)

Due to the desliming effect of the spirals the tailing losses are chiefly in the fines. Referring to Table 6, one analysis shows that 54.9% of the iron in the tailing is in the -325 mesh fraction, with an additional 13.3% in the -200 +325 mesh portion. Any significant improvement in recovery could only come about by reducing the amount of fines produced in the 'Cascade' mill. Some improvement might result if the mill were operated at a lower density, say 50% solids, to effect quicker removal of the fines from the mill.

Calculated circuit tonnages, flow rates and densities are given in Tables 3A and 3B. Calculated rougher and cleaner feeds are shown for comparison with the directly sampled feeds. Pulp tonnages and flow rates of combined products do not necessarily add up to the directly sampled products since water was added to the rougher and cleaner feed pumps. Calculated grades of rougher and cleaner feed are shown in Tables 9 and 10. Comparison between calculated and actual new feed to the spirals is shown in Table 2.

In general the figures relating to the calculated products agree reasonably well with those of the directly sampled products. One exception resulted from what appeared to be an excessively large rougher concentrate sample for run No. 2 which contributed to the high calculated cleaner feed tonnages (Table 3A). The order of samples for runs 2 to 4 was: cleaner concentrate and rougher tailing; cleaner tailings, middlings and feed; rougher middlings, concentrate and feed; and new feed (Sweco screen undersize). Some disruption was caused in the rougher circuit when the cleaner tailing was sampled and this could account for some abnormal figures. On the final run the cleaner tailing was sampled after sampling of the rougher circuit was completed.

Investigation by: I.C. Edwards, P. Eng.

LAKEFIELD RESEARCH OF CANADA LIMITED
Lakefield, Ontario.
PAW/March 6, 1961

DATA AND RESULTS

TABLE 1 - HARDINGE MILL GRINDING DATA

	Run No. 1	Run No. 2 + 3	Run No. 4 + 5	Run No. 6
Product screen, mesh	20	16*	16	16
Duration of run, hr.	1.98	3.95	4.02	1.58
Feed to mill, lb.	13,494	26,599	24,444	9,454
Mill load level, in. below C.L., start	Empty	18	14	16
" " " " " " finish	18	14	16	16
Change in mill load, lb.	+1250	+468	-234	-
Calc. weight of material ground, lb.	12,244	26,131	24,678	9,454
Calc. milling rate, long tons/hr.	2.76	2.97	2.74	2.67
Circulating load, long tons/hr.	-	1.86	1.78	-
" " %	-	63	65	-
Calc. pulp density, % solids **	-	71	71	est. 70
Total power consumed, kw.hr.	-	54.0	53.0	-
" " " H.P.	-	18.3	17.7	-
Motor and drive efficiency, %	-	72.5	72.5	-
Gross mill power input, H.P.	-	13.3	12.8	-
Net no load power, H.P.	-	4.6	4.6	-
Net power input, H.P.	-	8.7	8.2	-
" " " H.P. - hr./long ton	-	2.93	2.99	-
" " " kw. hr./long ton	-	2.19	2.23	-

For all runs full grate discharge was used. Mill speed 23.0 r.p.m. = 71.5% of critical speed.

* Equivalent to Tyler standard 14 mesh opening.

** Calculated density of mill discharge, excluding recycle portion.

TABLE 2 - METALLURGICAL RESULTS

Run No.	Product	Tonnage Long tons/hr	Weight %	Assay % Sol. Fe	Recovery %
2	Cleaner concentrate	1.30	47.8	63.55	78.5
	Rougher tailing	1.42	52.2	15.82	21.5
	Head (calc.)	2.72	100.0	36.68	100.0
	Head Sweco U.S.)	2.54		39.64	
	Calc. milling rate *	2.97			
3	Cleaner concentrate	1.49	51.7	63.46	80.6
	Rougher tailing	1.39	48.3	16.36	19.4
	Head (calc.)	2.88	100.0	40.73	100.0
	Head (Sweco U.S.)	2.70		39.10	
	Calc. milling rate *	2.97			
4	Cleaner concentrate	1.42	48.5	64.55	77.5
	Rougher tailing	1.51	51.5	17.64	22.5
	Head (calc.)	2.93	100.0	40.37	100.0
	Head (Sweco U.S.)	2.68		39.28	
	Calc. milling rate *	2.74			
5	Cleaner concentrate	1.16	44.4	64.55	75.7
	Rougher tailing	1.45	55.6	16.55	24.3
	Head (calc.)	2.61	100.0	37.88	100.0
	Head (Sweco U.S.)	2.71		39.20	
	Calc. milling rate *	2.74			

* From corrected feed rate to Hardinge mill; runs 2 and 3 combined and runs 4 and 5 combined.

TABLE 3A - SPIRAL CIRCUIT TONNAGES, FLOW RATES AND DENSITIES - RUNS 2 AND 3

Product		Dry Solids Long tons / hr.		Pulp Long tons/hr.		Pulp Flow Rate Imp. gals / min.		Pulp Density % Solids	
		Run 2	Run 3	Run 2	Run 3	Run 2	Run 3	Run 2	Run 3
New feed (Screen U.S.)	(1)	2.54	2.70	4.95	4.58	11.33	9.95	51.3	59.0
Cleaner concentrate	(2)	1.30	1.49	2.04	2.34	3.86	4.37	63.9	63.8
Rougher tailing	(3)	1.42	1.39	11.35	12.43	44.02	43.88	12.5	11.2
Rougher feed	(4)	3.33	3.56	14.34	13.26	43.50	40.05	23.2	26.9
Rougher middling	(5)	0.17	0.25	0.37	0.49	0.93	1.20	46.0	49.6
Rougher concentrate	(6)	2.65	1.47	3.92	2.44	7.19	4.97	67.6	60.3
Cleaner feed	(7)	1.62	1.61	3.74	3.74	8.97	9.33	43.2	43.3
Cleaner middling	(8)	0.08	0.12	0.11	0.19	0.21	0.33	65.7	67.1
Cleaner tails	(9)	0.28	0.33	4.92	5.71	18.78	20.72	5.7	5.8
Calculated new feed	(2 + 3)	2.72	2.88						
Calculated rougher feed	(1 + 5 + 9)	2.99	3.28	10.24	10.78	31.04	31.87	29.2	30.5
Calculated cleaner feed	(6 + 8)	2.73	1.59	4.03	2.63	7.40	5.30	67.6	60.5

NOTE : Figures shown are for two rougher spirals combined and one cleaner spiral.

TABLE 3B - SPIRAL CIRCUIT TONNAGES, FLOW RATES AND DENSITIES - RUNS 4 AND 5

Product		Dry Solids Long tons/hr.		Pulp Long tons/hr.		Pulp Flow Rate Imp. gals/min.		Pulp Density % Solids	
		Run 4	Run 5	Run 4	Run 5	Run 4	Run 5	Run 4	Run 5
New feed (Screen U.S.)	(1)	2.68	2.71	5.33	4.60	11.50	9.64	50.3	59.0
Cleaner concentrate	(2)	1.42	1.16	2.13	1.98	4.14	3.67	66.6	58.5
Rougher tailing	(3)	1.51	1.45	13.16	12.67	46.44	44.27	11.5	11.4
Rougher feed	(4)	3.54	3.36	14.26	14.06	43.41	44.49	24.8	23.9
Rougher middling	(5)	0.26	0.17	0.46	0.30	1.02	0.66	56.4	58.1
Rougher concentrate	(6)	1.59	1.56	2.59	2.52	5.87	5.35	61.2	61.8
Cleaner feed	(7)	1.80	1.37	6.27	3.50	19.32	9.78	28.7	39.1
Cleaner middling	(8)	0.07	0.08	0.10	0.13	0.15	0.24	75.0	62.6
Cleaner tails	(9)	0.35	0.32	6.87	6.59	24.80	23.44	5.0	4.9
Calculated new feed	(2 + 3)	2.93	2.61						
Calculated rougher feed	(1 + 5 + 9)	3.29	3.20	12.66	11.49	37.32	33.74	26.0	27.9
Calculated cleaner feed	(6 + 8)	1.66	1.64	2.69	2.65	6.02	5.59	61.7	61.9

NOTE : Figures shown are for two rougher spirals combined and one cleaner spiral.

TABLE 4 - FEED AND PRODUCT ASSAYS

	Run No. 2		Run No. 3		Run No. 4		Run No. 5		Run No. 6	
	Sol. Fe %	Insol. %	Sol. Fe %	Insol. %	Sol. Fe %	Insol. %	Sol. Fe %	Insol. %	Sol. Fe %	Insol. %
Head (Sweco U/S)	39.64	44.04	39.10	43.42	39.28	42.48	39.20	43.22	38.86	42.70
Cleaner concentrate	63.55	9.22	63.46	9.04	64.55	6.94	64.55	7.36		
Rougher tailing	15.82	77.88	16.36	75.38	17.64	74.78	16.55	74.90		
Rougher feed	36.00	47.02	37.32	48.82	38.00	44.92	40.13	42.08		
Rougher middling	23.37	66.84	25.82	62.68	35.37	48.88	36.91	46.68		
Rougher concentrate	56.10	19.16	57.55	17.52	58.19	16.86	57.94	17.38		
Cleaner feed	59.10	21.38	55.90	20.00	58.45	16.10	58.79	15.84		
Cleaner middling	50.82	28.42	45.28	33.84	61.35	11.94	61.18	13.88		
Cleaner tailing	24.18	64.74	25.99	61.54	30.16	56.20	29.14	58.44		

Additional Assays (mostly grab samples)

	Product	Sol. Fe %
Cleaner concentrate	3 p.m. Run 3	63.83
Rougher tailing	Run 3	14.70
Cleaner concentrate	Run 3	61.49
Rougher tailing	4:05 p.m. Run 3	13.82
Cleaner concentrate	Run 3	64.74
Cleaner (?) tailing	Run 3	14.86

TABLE 5 - SCREEN ANALYSES OF FEED, CONCENTRATE AND TAILING

Size Mesh	Weight % Retained Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
(a) Feed (Sweco Screen U/S)						
+ 20		0.4	0.4	0.5	0.5	0.4
35	10.6	10.9	10.3	11.4	11.2	10.7
48	14.6	14.2	13.5	14.7	14.2	14.0
65	17.4	18.7	18.2	18.7	18.3	18.2
100	19.9	18.4	18.6	18.2	18.3	18.1
200	18.0	18.4	19.2	18.0	18.4	18.4
325	7.5	8.6	8.9	8.1	8.6	8.8
- 325	12.0	10.4	10.9	10.4	10.5	11.4
(b) Cleaner Concentrate						
+ 20		0.6	0.5	0.6	0.4	
35		17.7	17.4	19.1	17.6	
48		17.0	17.2	18.7	17.8	
65		18.6	19.0	19.7	19.3	
100		21.6	21.9	20.8	21.4	
200		19.5	19.1	17.3	19.1	
325		4.3	4.1	3.3	3.8	
- 325		0.7	0.8	0.5	0.6	
(c) Rougher Tailing						
+ 20		0.2	0.3	0.2	0.3	
35	5.1	7.1	6.2	6.1	6.4	
48	12.3	12.7	11.3	11.5	11.3	
65	17.5	18.6	17.6	18.2	17.9	
100	17.0	15.4	15.1	16.1	16.0	
200	16.1	16.6	17.3	17.3	17.8	
325	9.6	10.7	12.0	11.4	11.6	
- 325	22.4	18.7	20.2	19.2	18.7	

Note: Where two screen analyses were made the results are shown above only for the first ("A") analysis. Complete analyses shown as Tables 7A to 7E.

TABLE 6 - DISTRIBUTION OF IRON IN SCREEN FRACTIONS OF ROUGHER TAILING - RUN NO. 1

Size, Tyler Mesh	Wt.% Retained	Assay % Sol. Fe	Fe Distribution %
+ 35	5.1	12.90	4.6
48	12.3	8.08	6.9
65	17.5	5.31	6.4
100	17.0	4.41	5.2
200	16.1	7.84	8.7
325	9.6	20.09	13.3
- 325	22.4	35.44	54.9
Total	100.0	14.46	100.0

Direct assay of tailing 14.54%

TABLE 7A SCREEN ANALYSES OF SPIRAL PRODUCTS RUN NO. 2

Size, Tyler mesh	HEAD (SCREEN U/S) (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	CLEANER CONCENTRATE (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER TAILING (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER FEED (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER MIDDLINGS (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%
+20	1.1	0.4	1.1	0.4	1.6	0.6	1.7	0.6	0.5	0.2	0.5	0.2	2.3	0.9	1.9	0.8	4.7	1.7	5.5	2.0
35	28.7	10.9	28.3	11.1	47.1	17.7	47.7	17.7	17.8	7.1	17.6	7.0	26.8	10.5	26.3	10.5	32.5	11.8	32.3	11.6
48	37.2	14.2	36.6	14.3	45.2	17.0	45.7	17.0	31.8	12.7	31.4	12.4	33.6	13.2	33.0	13.2	31.1	11.3	31.4	11.3
65	48.9	18.7	47.1	18.4	49.5	18.6	50.4	18.7	46.4	18.6	46.6	18.4	46.6	18.3	46.7	18.7	58.5	21.2	60.2	21.7
100	48.3	18.4	47.1	18.4	57.1	21.6	57.5	21.4	38.6	15.4	38.8	15.3	49.5	19.3	48.2	19.3	68.7	24.9	68.6	24.7
200	48.4	18.4	47.0	18.4	51.7	19.5	52.4	19.5	41.4	16.6	42.4	16.8	50.2	19.6	49.2	19.7	53.7	19.5	53.7	19.3
325	22.6	8.6	21.7	8.5	11.5	4.3	11.9	4.4	26.8	10.7	28.0	11.1	23.9	9.4	23.4	9.4	16.5	6.0	16.2	5.9
-325	25.6	10.4	25.2	10.5	1.8	0.7	1.9	0.7	44.1	18.7	45.2	18.8	20.2	8.8	19.6	8.4	8.4	3.6	8.4	3.5
Total	260.8	100.0	254.1	100.0	265.5	100.0	269.2	100.0	247.4	100.0	250.5	100.0	253.1	100.0	248.3	100.0	274.1	100.0	276.3	100.0
Orig. wt.	262.5		255.8		265.5		269.3		249.9		252.8		255.3		249.7		275.6		277.7	

Size, Tyler mesh	ROUGHER CONCENTRATE Wt.gm.	Wt.%	Wt.gm.	Wt.%	CLEANER FEED Wt.gm.	Wt.%	Wt.gm.	Wt.%	CLEANER MIDDLINGS Wt.gm.	Wt.%		CLEANER TAILINGS Wt.gm.	Wt.%	Wt.gm.	Wt.%
+20	1.6	0.6	1.7	0.7	2.2	0.8	2.3	0.9	3.3	1.5	*	3.3	1.3	3.6	1.4
35	42.9	16.3	41.9	16.3	40.0	14.8	40.1	15.3	19.0	8.5		17.4	7.0	17.2	6.9
48	44.2	16.7	42.6	16.6	37.6	14.0	37.2	14.2	10.5	4.7		19.2	7.7	19.3	7.7
65	51.7	19.6	49.7	19.4	47.4	17.6	46.0	17.6	16.9	7.5		40.9	16.4	40.2	16.0
100	57.4	21.7	56.4	21.9	59.9	22.3	57.7	22.1	41.4	18.5		51.1	20.5	51.8	20.7
200	48.4	18.3	46.6	18.2	58.5	21.7	55.2	21.1	79.1	35.3		57.1	23.0	57.6	23.0
325	12.3	4.7	11.9	4.6	17.9	6.6	16.7	6.4	45.0	20.1		36.4	14.6	37.3	14.9
-325	4.9	2.1	4.9	2.3	6.0	2.2	5.6	2.4	8.4	3.9		22.4	9.5	21.8	9.4
Total	263.4	100.0	255.7	100.0	269.5	100.0	260.8	100.0	223.6	100.0		247.8	100.0	248.8	100.0
Orig. Wt.	264.0		256.7		269.5		261.4		223.9			249.1		250.5	

* Insufficient sample available.

TABLE 7B SCREEN ANALYSES OF SPIRAL PRODUCTS RUN NO. 3

Size, Tyler mesh	HEAD (SCREEN U/S) (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	CLEANER CONCENTRATE (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER TAILING (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER FEED (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER MIDDLINGS (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%
+20	1.2	0.4	1.2	0.4	1.4	0.5	1.4	0.6	0.7	0.3	0.6	0.2	1.7	0.7	1.6	0.7	6.6	2.5	6.8	2.4
35	28.7	10.3	27.6	10.3	44.3	17.4	43.8	17.7	15.7	6.2	16.7	6.1	26.0	10.4	25.3	10.3	37.1	13.7	39.2	13.8
48	37.4	13.5	35.9	13.4	43.8	17.2	42.8	17.3	29.0	11.3	31.4	11.5	33.0	13.2	32.3	13.1	31.6	11.8	33.5	11.8
65	50.6	18.2	48.4	18.1	48.5	19.0	47.1	19.1	45.3	17.6	48.0	17.6	46.0	18.4	45.0	18.3	57.3	21.3	61.5	21.6
100	51.6	18.6	50.3	18.8	55.5	21.9	53.5	21.6	39.0	15.1	41.2	15.1	48.0	19.2	47.4	19.3	59.4	22.1	62.0	21.7
200	53.0	19.2	51.2	19.3	48.5	19.1	46.3	18.8	44.6	17.3	47.2	17.1	49.0	19.6	48.4	19.6	45.9	17.2	48.8	17.1
325	24.7	8.9	24.3	9.1	10.5	4.1	10.0	4.1	30.9	12.0	32.5	12.1	23.3	9.3	22.8	9.3	19.4	7.2	20.9	7.3
-325	28.3	10.9	26.9	10.6	1.9	0.8	1.9	0.8	49.9	20.2	53.7	20.3	21.5	9.2	21.2	9.4	10.2	4.2	11.1	4.3
Total	275.5	100.0	265.8	100.0	254.4	100.0	246.8	100.0	255.1	100.0	271.3	100.0	248.5	100.0	244.0	100.0	267.5	100.0	283.8	100.0
Orig. Wt.	277.3		267.3		254.6		246.9		257.4		273.2		250.0		246.0		268.6		285.1	

Size, Tyler mesh	ROUGHER CONCENTRATE Wt.gm.	Wt.%	Wt.gm.	Wt.%	CLEANER FEED Wt.gm.	Wt.%	Wt.gm.	Wt.%	CLEANER MIDDLINGS Wt.gm.	Wt.%		CLEANER TAILINGS Wt.gm.	Wt.%	Wt.gm.	Wt.%
+ 20	1.5	0.6	1.4	0.6	2.3	0.8	2.3	0.8	2.7	1.0	*	4.9	1.9	4.7	1.9
35	39.5	15.7	37.8	15.1	45.4	16.6	45.1	16.2	37.5	14.5		25.2	9.6	23.7	9.5
48	39.8	15.8	38.5	15.4	40.7	14.9	41.4	14.8	22.5	8.8		22.3	8.5	21.0	8.4
65	46.4	18.4	45.3	18.1	49.8	18.2	50.4	18.1	34.9	13.5		43.7	16.7	41.0	16.4
100	55.0	21.8	54.9	22.0	59.1	21.6	60.8	21.8	60.4	23.4		51.1	19.5	49.0	19.5
200	49.4	19.6	50.6	20.3	53.9	19.7	56.1	20.1	64.7	25.1		56.2	21.6	54.3	21.6
325	14.3	5.7	14.9	6.0	16.8	6.1	17.4	6.2	29.3	11.4		35.7	13.6	34.5	13.8
-325	5.7	2.4	5.8	2.5	5.5	2.1	5.6	2.0	6.0	2.3		21.3	8.6	21.0	8.9
Total	251.6	100.0	249.2	100.0	273.5	100.0	279.1	100.0	258.0	100.0		260.4	100.0	249.2	100.0
Orig. Wt.	251.9		249.6		273.7		279.2		258.0			261.6		250.6	

* Insufficeint sample available

TABLE 7C SCREEN ANALYSES OF SPIRAL PRODUCTS RUN NO. 4

Size, Tyler mesh	HEAD (SCREEN U/S) (A) Wt.gm.	(A) Wt.%	HEAD (SCREEN U/S) (B) Wt.gm.	(B) Wt.%	CLEANER CONCENTRATE (A) Wt.gm.	(A) Wt.%	CLEANER CONCENTRATE (B) Wt.gm.	(B) Wt.%	ROUGHER TAILING (A) Wt.gm.	(A) Wt.%	ROUGHER TAILING (B) Wt.gm.	(B) Wt.%	ROUGHER FEED (A) Wt.gm.	(A) Wt.%	ROUGHER FEED (B) Wt.gm.	(B) Wt.%	ROUGHER MIDDLINGS (A) Wt.gm.	(A) Wt.%	ROUGHER MIDDLINGS (B) Wt.gm.	(B) Wt.%
+20	1.3	0.5	1.3	0.5	1.6	0.6	1.7	0.7	0.6	0.2	0.5	0.2	1.8	0.7	1.8	0.7	6.5	2.5	6.2	2.3
35	28.8	11.4	28.8	11.4	48.6	19.1	47.6	19.3	16.0	6.1	14.1	5.7	30.2	11.6	29.2	11.4	27.5	10.6	28.6	10.7
48	37.0	14.7	36.9	14.6	47.7	18.7	46.8	19.0	29.9	11.5	27.2	11.0	37.1	14.2	35.7	14.0	20.5	8.0	21.0	7.9
65	47.3	18.7	47.0	18.5	50.2	19.7	48.4	19.6	47.3	18.2	44.0	17.7	48.9	18.8	47.1	18.4	41.2	15.9	42.6	16.0
100	45.9	18.2	45.9	18.2	52.7	20.8	50.6	20.4	41.8	16.1	40.1	16.1	49.3	19.0	48.5	19.0	54.9	21.2	55.6	20.9
200	45.4	18.0	45.4	18.0	44.1	17.3	42.6	17.3	45.2	17.3	44.4	17.8	48.8	18.7	48.3	18.9	55.9	21.6	57.8	21.7
325	20.5	8.1	20.6	8.2	8.4	3.3	8.0	3.2	29.7	11.4	29.8	12.0	23.0	8.8	22.9	9.0	36.7	14.2	38.1	14.3
-325	24.9	10.4	25.1	10.6	1.2	0.5	1.2	0.5	47.3	19.2	45.7	19.5	19.5	8.2	20.0	8.6	14.5	6.0	15.2	6.2
Total	251.1	100.0	251.0	100.0	254.5	100.0	246.9	100.0	257.8	100.0	245.8	100.0	258.6	100.0	253.5	100.0	257.7	100.0	265.1	100.0
Orig. Wt.	252.5		252.7		254.5		246.9		260.5		248.7		260.5		255.4		258.7		266.3	

Size, Tyler mesh	ROUGHER CONCENTRATE Wt.gm.	Wt.%	Wt.gm.	Wt.%	CLEANER FEED Wt.gm.	Wt.%	Wt.gm.	Wt.%	CLEANER MIDDLINGS Wt.gm.	Wt.%		CLEANER TAILINGS Wt.gm.	Wt.%	Wt.gm.	Wt.%
+20	1.7	0.7	1.6	0.6	2.1	0.8	2.1	0.8	2.1	1.0	*	3.7	1.4	3.5	1.4
35	38.2	15.2	37.7	15.0	41.0	15.8	41.1	16.0	12.3	6.0		19.9	7.5	19.2	7.5
48	38.9	15.4	38.1	15.2	39.8	15.3	39.6	15.4	7.0	3.5		18.3	6.9	17.8	7.0
65	45.7	18.1	45.5	18.2	46.6	18.0	45.9	17.8	9.6	4.7		39.4	14.9	37.7	14.7
100	55.2	21.9	54.9	22.0	55.7	21.5	55.5	21.6	28.2	13.7		55.3	20.9	52.6	20.6
200	51.7	20.5	51.7	20.6	53.6	20.7	53.0	20.6	90.7	44.2		66.3	25.0	64.1	25.1
325	15.2	6.0	15.3	6.1	15.3	5.9	15.0	5.8	47.4	23.1		41.5	15.6	40.7	15.9
-325	5.1	2.2	5.2	2.3	5.1	2.0	5.1	2.0	7.9	3.8		19.2	7.8	18.4	7.8
Total	251.7	100.0	250.0	100.0	259.2	100.0	257.3	100.0	205.2	100.0		263.6	100.0	254.0	100.0
Orig. Wt.	252.1		250.5		259.3		257.3		205.3			265.2		255.6	

* Insufficient sample available

TABLE 7D SCREEN ANALYSES OF SPIRAL PRODUCTS RUN NO. 5

Size, Tyler mesh	HEAD (SCREEN U/S) (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	CLEANER CONCENTRATE (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER TAILING (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER FEED (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%	ROUGHER MIDDLINGS (A) Wt.gm.	(A) Wt.%	(B) Wt.gm.	(B) Wt.%
+20	1.2	0.5	1.2	0.5	1.2	0.4	1.1	0.4	0.7	0.3	0.7	0.3	2.0	0.7	2.0	0.8	4.5	1.6	4.7	1.7
35	28.9	11.2	28.5	11.1	47.9	17.6	46.3	16.9	16.3	6.4	16.5	6.5	32.6	12.0	31.8	12.0	25.3	8.9	25.5	9.0
48	36.8	14.2	36.3	14.1	48.5	17.8	48.1	17.6	28.5	11.3	28.9	11.3	38.7	14.3	37.6	14.2	21.4	7.6	21.7	7.7
65	47.3	18.3	47.0	18.4	52.6	19.3	53.4	19.5	45.2	17.9	45.8	17.9	50.4	18.6	49.4	18.7	39.6	14.0	39.7	14.0
100	47.4	18.3	46.9	18.3	58.0	21.4	59.4	21.6	40.3	16.0	40.9	16.0	50.3	18.6	48.8	18.6	54.3	19.2	54.7	19.3
200	47.9	18.4	47.6	18.6	51.8	19.1	53.4	19.5	45.0	17.8	45.7	17.9	50.1	18.5	49.1	18.6	67.2	23.7	67.1	23.7
325	22.4	8.6	22.2	8.6	10.4	3.8	10.7	3.9	29.2	11.6	29.9	11.7	22.8	8.4	22.3	8.4	48.7	17.2	47.5	16.8
-325	25.7	10.5	25.5	10.4	1.5	0.6	1.6	0.6	44.3	18.7	44.7	18.4	22.4	8.9	21.5	8.7	21.1	7.8	20.8	7.8
Total	257.6	100.0	255.2	100.0	271.9	100.0	274.0	100.0	249.5	100.0	253.1	100.0	269.3	100.0	262.5	100.0	282.1	100.0	281.7	100.0
Orig. Wt.	259.1		256.8		271.9		274.0		252.5		255.2		271.0		264.1		283.3		282.9	

Size, Tyler mesh	ROUGHER CONCENTRATE Wt.gm.	Wt.%			CLEANER FEED Wt.gm.	Wt.%			CLEANER MIDDLINGS Wt.gm.	Wt.%		CLEANER TAILINGS Wt.gm.	Wt.%		
+20	1.3	0.5	1.3	0.5	2.3	0.9	2.2	0.8	3.5	1.6	*	4.4	1.7	3.7	1.4
35	37.9	14.7	36.9	14.6	45.5	16.9	44.0	16.8	17.4	7.8		20.3	7.6	19.8	7.7
48	39.8	15.4	38.6	15.3	42.1	15.6	41.1	15.7	5.6	2.5		20.2	7.6	19.3	7.5
65	47.7	18.4	46.8	18.5	48.3	17.9	46.4	17.7	9.0	4.0		43.8	16.5	40.6	15.8
100	57.2	22.1	56.0	22.2	55.7	20.7	54.9	20.8	25.6	11.4		55.4	20.8	54.2	21.1
200	53.1	20.5	52.0	20.6	53.5	19.9	52.7	20.1	85.6	38.2		62.8	23.6	61.5	24.0
325	15.5	6.0	15.3	6.1	16.8	6.2	16.4	6.3	66.6	29.8		39.1	14.7	38.0	14.8
-325	5.4	2.4	5.3	2.2	4.9	1.9	4.5	1.8	10.3	4.7		18.8	7.5	18.4	7.7
Total	257.9	100.0	252.2	100.0	269.1	100.0	262.2	100.0	223.6	100.0		264.8	100.0	255.5	100.0
Orig. Wt.	258.6		252.4		269.3		262.4		223.9			265.9		256.8	

* Insufficient sample available

TABLE 7E SCREEN ANALYSES OF SWECO SCREEN UNDERSIZE - RUN NO. 6

Size, Tyler mesh	(A) Wt. gm.	(A) Wt.%	(B) Wt. gm.	(B) Wt. %
+ 20	1.0	0.4	1.1	0.4
35	27.7	10.7	28.1	10.6
48	36.1	14.0	36.9	13.9
65	47.1	18.2	48.9	18.4
100	46.7	18.1	48.3	18.2
200	47.4	18.4	49.1	18.5
325	22.8	8.8	23.4	8.8
- 325	27.3	11.4	28.4	11.2
Total	256.1	100.0	264.2	100.0
Original weight	258.2		265.6	

TABLE 8 SCREEN ANALYSES OF SWECO SCREEN OVERSIZE (Recycle)

Size, Inches or Mesh	Weight % Retained Runs 2, 3	Runs 4, 5
+ 1"	3.0	10.5
3/4"	23.5	28.2
1/2"	29.1	25.7
1/4"	21.6	18.7
6	7.8	6.9
10	4.6	3.3
20	3.8	2.6
- 20	6.6	4.1

TABLE 9 COMPARISON BETWEEN ACTUAL AND CALCULATED ROUGHER FEED

Product	Run No. 2			Run No. 3			Run No. 4			Run No. 5		
	Long tons per hr.	Wt. %	Assay % Fe	Long tons per hr.	Wt.%	Assay % Fe	Long tons per hr.	Wt.%	Assay % Fe	Long tons per hr.	Wt.%	Assay % Fe.
Screen U/S	2.54	84.95	39.64	2.70	82.32	39.10	2.68	81.46	39.28	2.71	84.69	39.20
Ro. middlings	0.17	5.68	23.37	0.25	7.62	25.82	0.26	7.90	35.37	0.17	5.31	36.91
Cl. tailings	0.28	9.37	24.18	0.33	10.06	25.99	0.35	10.64	30.16	0.32	10.00	29.14
Ro. feed (calc.)	2.99	100.00	37.27	3.28	100.00	36.77	3.29	100.00	38.00	3.20	100.00	38.07
Ro.feed(sampled)	3.33		36.00	3.56		37.32	3.54		38.00	3.36		40.13

TABLE 10 COMPARISON BETWEEN ACTUAL AND CALCULATED CLEANER FEED

Product	Run No.2			Run No. 3			Run No. 4			Run No. 5		
	Long tons per hr.	Wt.%	Assay % Fe	Long tons per hr.	Wt.%	Assay % Fe	Long tons per hr.	Wt.%	Assay % Fe	Long tons per hr.	Wt.%	Assay % Fe
Ro.concentrate	2.65	97.07	56.10	1.47	92.45	57.55	1.59	95.78	58.19	1.56	95.12	57.94
Cl.middlings	0.08	2.93	50.82	0.12	7.55	45.28	0.07	4.22	61.35	0.08	4.88	61.18
Cl.feed(calc.)	2.73	100.00	55.95	1.59	100.00	56.62	1.66	100.00	58.32	1.64	100.00	58.10
Cl.feed(sampled)	1.62		59.10	1.61		55.90	1.80		58.45	1.37		58.79

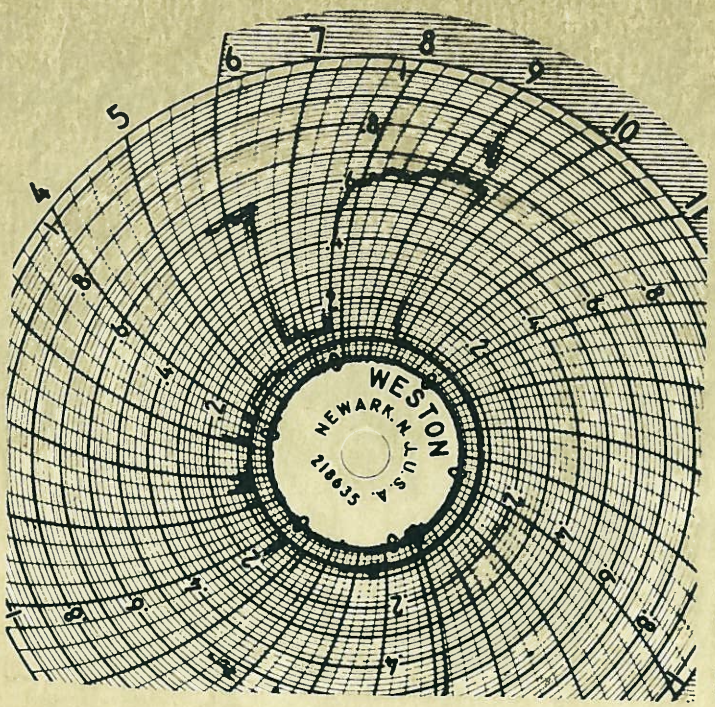
TABLE 11 SAMPLING DATA RUNS 2, 3, 4 AND 5

Sample	Barrel Data Diam. Ins.	Barrel Data Area sq.ins.	Barrel Data Tare wt.lbs	Barrel Data Depth Ins.	Pulp Sample Weight lbs.net	Pulp Sample Volume Cu.ins.	Pulp Sample Volume Imp.Gals.	Solids Dry wt. lbs.	No.of samples	Secs. per sample	Total secs. flow
Run No.2											
Head (Screen U/S)	*	*	24.5	*	154.0	2,610	9.44	79.0	5	10	50
Cleaner conc.			24.5		63.5	891	3.22	40.6	5	10	50
Rougher tailing			39.5		353.0	10,140	36.68	44.1	5	10	50
Rougher feed			22.5		178.5	4,010	14.50	41.4	2	10	20
Rougher middling			-		4.61	-	0.31	2.12	2	10	20
Rougher conc.			24.0		122.0	1,655	5.99	82.5	5	10	50
Cleaner feed			24.0		46.5	827	2.99	20.1	2	10	20
Cleaner middling			-		1.43	-	0.07	0.94	2	10	20
Cleaner tailing			25.5		153.0	4,330	15.65	8.75	5	10	50
Run No. 3											
Head (Screen U/S)	*	*	22.5	*	142.5	2,290	8.28	84.0	5	10	50
Cleaner conc.			26.5		87.5	1,210	4.37	55.8	6	10	60
Rougher tailing			43.0		464.0	12,130	43.88	52.0	6	10	60
Rougher feed			25.0		165.0	3,690	13.35	44.4	2	10	20
Rougher middling			-		6.15	-	0.40	3.05	2	10	20
Rougher concentrate			24.0		76.0	1,146	4.14	45.8	5	10	50
Cleaner feed			24.0		46.5	861	3.11	20.1	2	10	20
Cleaner middling			-		2.31	-	0.11	1.55	2	10	20
Cleaner tailing			25.0		213.0	5,730	20.72	12.45	6	10	60
Run No.4											
Head (Screen U/S)	18.0	254.	20.5	6.25	99.5	1,590	5.75	50.0	3	10	30
Cleaner conc.	18.0	254.	25.0	3.0	53.0	762	2.76	35.3	4	10	40
Rougher tailing	22.5	398.	43.0	21.5	327.5	8,560	30.96	37.5	4	10	40
Rougher feed	18.0	254.	24.5	15.75	177.5	4,000	14.47	44.0	2	10	20
Rougher middling	-		-	-	5.75	-	0.34	3.24	2	10	20
Rougher concentrate	18.0	254.	35.0	4.25	64.5	1,080	3.91	39.5	4	10	40
Cleaner feed	18.0	254.	23.0	7.0	78.0	1,780	6.44	22.4	2	10	20
Cleaner middling	-		-	-	1.24	-	0.05	0.93	2	10	20
Cleaner tailing	18.0	254.	22.0	18.0	171.0	4,570	16.53	8.62	4	10	40
Run No.5											
Head (Screen U/S)	18.0	254.	32.0	8.75	143.0	2,220	8.03	84.3	5	10	50
Cleaner conc.	18.0	254.	31.0	4.0	74.0	1,015	3.67	43.3	6	10	60
Rougher tailing	22.5	398.	40.0	30.75	473.0	12,240	44.27	54.0	6	10	60
Rougher feed	18.5	269.	23.0	15.25	175.0	4,100	14.83	41.8	2	10	20
Rougher middling	-		-	-	3.72	-	0.22	2.16	2	10	20
Rougher concentrate	18.5	269.	23.5	5.5	94.0	1,480	5.35	58.1	6	10	60
Cleaner feed	18.5	269.	23.0	3.35	43.5	901	3.26	17.0	2	10	20
Cleaner middling	-	-	-	-	1.63	-	0.08	1.02	2	10	20
Cleaner tailing	18.0	254.	22.0	21.25	205.0	5,400	19.53	9.98	5	10	50

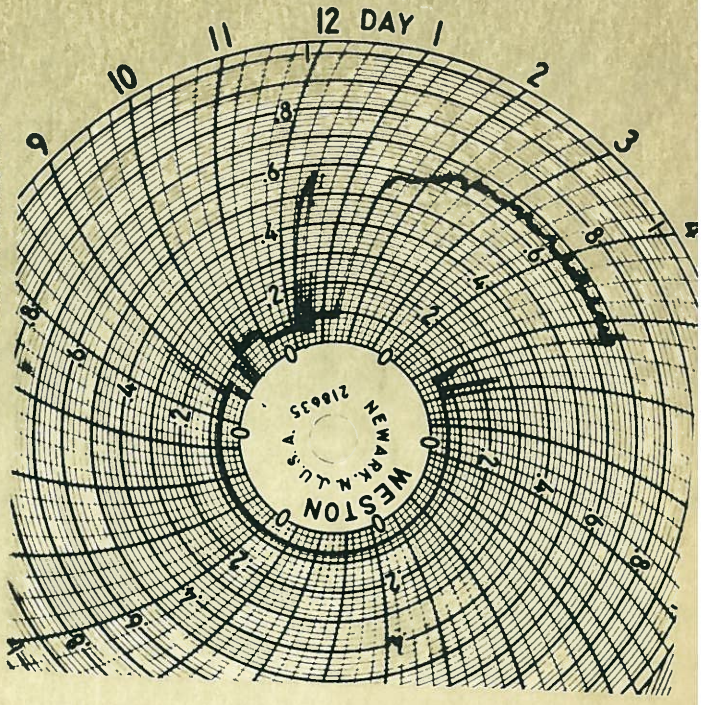
* Information not retained

Note: Middling samples filtered and filtrate weight plus wet cake weight added to get pulp weight.

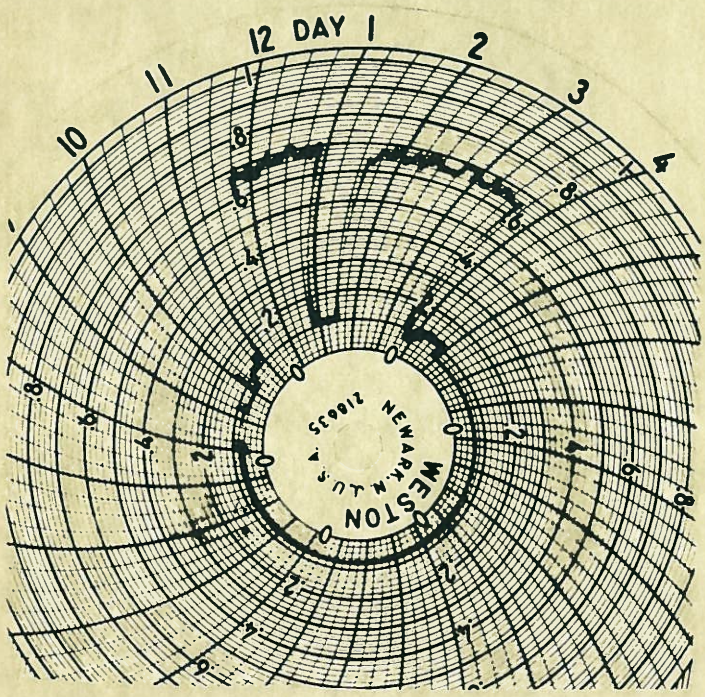
Run No. 6 - Dry weight of sample = 19.3 lbs (6 cuts taken)



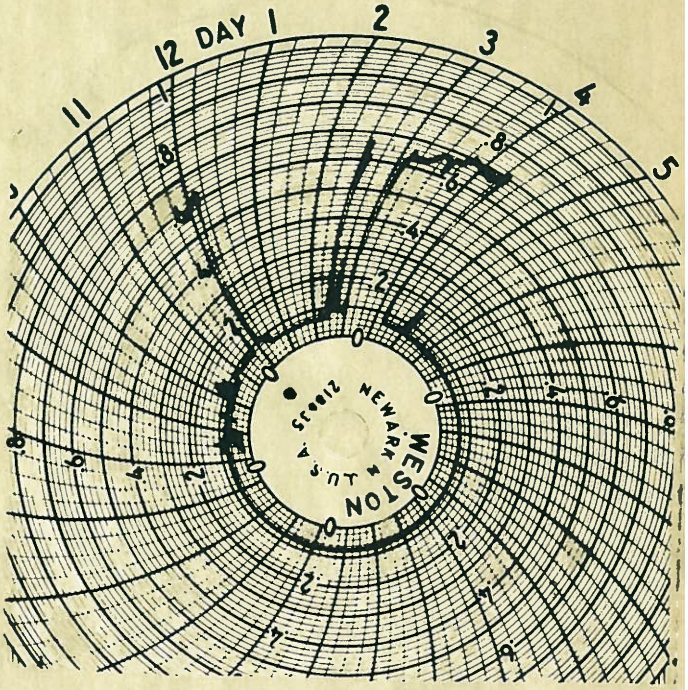
RUN NO. 1



RUN NO. 2 AND 3



RUN NO. 4 AND 5



RUN NO. 6

Figure 2 - Electric car charts