October, 1932

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

MILLING METHODS AND COSTS AT A FLAT RIVER, (MO.) MILL

BY

WILL H. COGHILL AND R. G. O'MEARA

I.C.6658,
October, 1932.

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

MILLING METHODS AND COSTS AT A FLAT RIVER (MO.), MILL[1]

By Will H. Coghill[2] and R. G. O'Meara[3]

INTRODUCTION

This paper on milling methods and costs at a flat river (Mo.), mill is one of a series of information circulars on milling methods and costs which is being prepared by the United States Bureau of Mines.

The mill under consideration treats 5,000 tons of lead ore daily by table concentration and flotation. It is 25 years old, and yet it is a new mill. Research has been in continual progress at the plant since its beginning, and accordingly a day never passes without a record of change for advancement. The changes have been so orderly that no evidence of obsolete equipment remains.

The mill is not of the sort to be indorsed by those who stress simplicity in mills; yet the operating cost is phenomenally low. Gravity tailing with a tenor of 0.11 per cent of lead, and flotation tailing with a tenor of 0.15 per cent of lead characterize the metallurgical results.

An unusual policy of the management, reflected by the employees, accounts for the superior accomplishments. "Get the mineral first and afterwards figure the cost of remodeling" is the slogan. Thus the old idea that "the change will cost all the extra mineral is worth" has been rejected.

The mill is very complex. Gravity products have several treatments and some flotation products have many cleanings. But the procedure is so orderly that very little extra expense is incurred.

The mill has 217 motors drawing a load of 4,800 kilowatts. The use of 14 hydraulic classifiers, 116 concentrating tables, and 21 desliming drags is required. Pulp is thickened in two thickeners with an area of 39,000 square feet, and the 8,000 gallons per minute of thickener-water is returned to the mill and circulated through 8 water pumps and 62 sand pumps. Conveying is accomplished by 2,500 feet of conveyor belt and 1,600 feet of elevator belt. The flotation requires a quarter of a mile of pneumatic flotation machines. Consideration of all these things together with the results obtained justifies putting before operators the idea that good milling depends more on good equipment well installed than on mere simplicity.

The United States Bureau of Mines in cooperation with the Missouri School of Mines and Metallurgy, Rolla, Mo., began a study of the milling at Flat River, Mo. (Southeast Missouri lead district), in the early part of 1926.

The major investigation was to compare the already installed distributed-feed system with classification for tabling. Although classification had experienced several unfortunate trials, the first tests justified remodeling one section of a mill for classification. As a

1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6658."

2 - Supervising engineer, ore dressing section, metallurgical division, U. S. Bureau of Mines; and supervising engineer, U. S. Bureau of Mines, Mississippi Valley Experiment Station, Rolla, Mo.

3 - Assistant metallurgist, U. S. Bureau of Mines, Mississippi Vally Experiment Statio, Rolla, Mo.

result of the improved performance a second section was remodeled, and the change was continued section by section in the first mill and others until finally five of the six mills of the district were remodeled for classification. The alterations of the flow sheets were carefully planned for Sundays so that none of the mills lost time.

Formerly, in order to maintain a satisfactory grade of concentrate and tailing, it had been necessary to wet-screen through 10 mesh. The operation was expensive and generally unsatisfactory.

By the new plan the wet screens were replaced by the classifiers; these sent a sized feed to the tables from which as much coarse material as desired could be sent back to the ball mills and again to the classification system. Thus the ball mills were in closed circuit with classifiers and tables, whereas they were formerly in closed circuit with screens. The new circuit was flexible and made a perfectly prepared feed to the ball mills. In a battery of 10 tables the first 5 could return the tailing to the ball mills while only the last 5 made tailing to waste; the dividing point could be changed at will.

On account of the coarse chats which contaminate the table concentrate the mill under discussion has not been able to take full advantage of the screenless sections adopted in some of the other mills; however, the screens have been reduced in number and are of a coarser mesh than those employed before classification was installed.

Although many improvements were in progress and ultimate results depended upon many factors, it may be said that the metallurgical results shown in Table 28 would not have been attained without classification. The table tailings of the first mill that was remodeled had been the most unsatisfactory of all the mills of the district, but after installing the new system the tailings were markedly the best of the district.

ACKNOWLEDGMENTS

The hearty cooperation of all the mill operators is hereby acknowledged. Special acknowledgment is made to T. J. Clifford, one of the operators, who aided in the preparation of the tabulated material in this report.

Of the Missouri School of Mines and Metallurgy, Horace Scruby gave valuable assistance in the district. Later, A. B. Campbell and J. B. Clemmer, both of the U. S. Bureau of Mines, assisted. Acknowledgment is made to Alexander M. Gow for valuable service in the preparation of the report.

LOCATION AND GENERAL LAYOUT

The mill described in this paper is located at Flat River, Mo., 70 miles south of St. Louis. The mill is housed in a steel-and-concrete building adjacent to the hoisting shaft and is divided into three sections: The primary crushing plant, the secondary and roll crushing plant, and the concentrator. The three sections are connected by enclosed conveyors. The concentrate drying plant, shops, and other buildings are nearby.

The mine is a part of the network of mines supplying about 22,000 tons of ore daily to the several mills of the "Lead Belt" district. Most of the mines are connected by an extensive underground haulage system. Mining is by open stoping with pillar support. Timbering is rarely necessary. The stopes are large, and the ore is loaded by mechanical shovels into 2.5-ton cars, trammed to the shaft pockets, and hoisted in skips of 6.3 tons capacity. All the ore is delivered through a 2-compartment shaft to the crude-ore bin. Underground grizzlies are not used, so that the ore is unsized when it reaches the mill.

The building, which is covered with corrugated iron, is well ventilated and lighted by a large number of swinging windows. It is also well illuminated artifically by electric

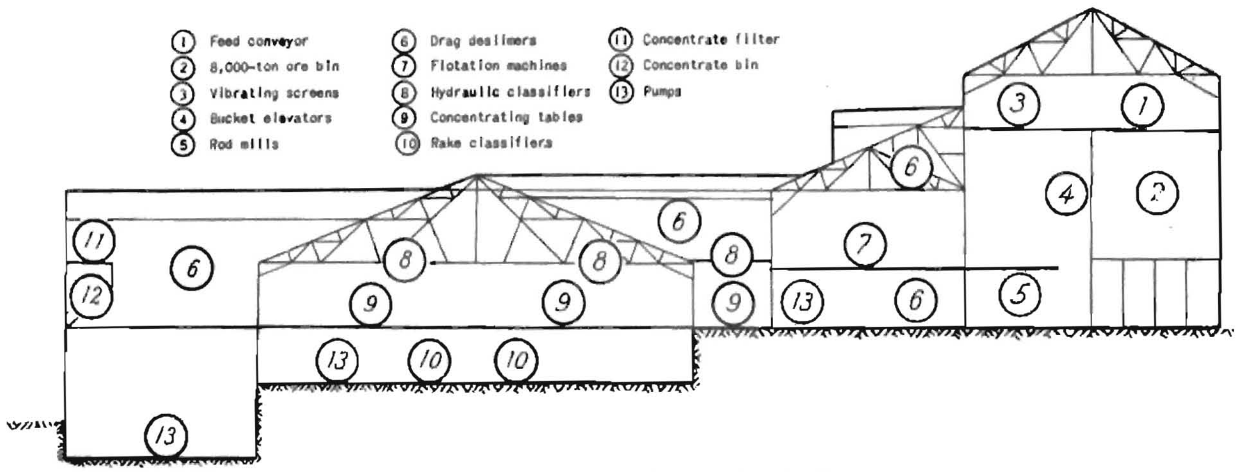


Figure 1.- Diagrammatic section through mill

lights. Although fireproof in construction, the building is protected by an automatic sprinkling system.

The concentrator is built on two terraces and has four principal floors, as indicated in diagrammatic section, Figure 1. On the bottom floor, or first terrace, are belt conveyors and pumps for handling table products and flotation tailings. At a slightly lower elevation are other pumps to raise the secondary slime to the thickeners. On the second floor, which is an extension of the second terrace, are the concentrating tables. Rod mills, drag deslimers, and flotation-product pumps are located on the second terrace. The foundations of the concentrator bin are also on this terrace and the discharge of the bin is only a few feet above. The bin extends to the top of the mill and occupies much of the space above the terrace floor. On the upper floors and intermediate galleries are the flotation machines, screens, drag classifiers, flotation-feed distributors, and hydraulic classifiers.

Although designed for a flow sheet which is now obsolete, the mill was so well planned that it has been adapted to subsequent changes. A notable feature in the present design is the storage facilities. Bins of 180, 900, and 8,000 tons capacity, respectively, are at the heads of the primary breaking unit, the secondary and roll crushing unit, and the concentrator. The large storage bin at the head of the concentrator allows continuous mill operation in spite of short delays in the dry-crushing units.

An abundant water supply is available from the mine, but most of the water is recovered and reused, some within the mill and some through the circulating system.

Power is purchased from the Union Electric Power and Light Co.

ORE TREATED

The only metal of economic importance in the ore is lead; however, minor amounts of iron, copper, zinc, cobalt, nickel, and silver occur. They appear in small amounts in the feed, and are graded up in both the table and flotation middlings.

The lead occurs as galena. The presence of oxidized lead has been suspected but not proved. The iron, copper, and zinc occur as sulphides in mixtures of pyrite, marcasite, chalcopyrite, and sphalerite. Likewise, the cobalt, nickel, and silver probably are present as sulphides.

The gangue is chiefly dolomitic limestone. However, siliceous substances, such as sandstone, and shaly glauconitic and chloritic minerals are present.

The tenor of the ore is about 3.5 per cent of lead, occurring as galena disseminated through the gangue. Jackson[4] writes of the character of the ore as follows:

> In general, it may be said of the district that galena occurs disseminated through dolomitic limestone and shaly beds, in horizontal sheets and along bedding planes, in vugs and cavities, filling or lining walls of joints and crevices and as aggregates of cubes in channels and joints.

A chemical analysis of the ore is given in Table 1.

The dolomitic limestone is a hard, dense variety fairly resistant to crushing. The glauconitic and chloritic material is largely eliminated in the primary slime. The sandstone is present in such small amounts that its resistance to grinding is negligible. Galena breaks readily, but the other sulphides are more difficult to crush.

---

4. Jackson, C. F., Methods of Mining Disseminated Lead Ore at a Mine in the Southeast Missouri District: Information Circular 6170, Bureau of Mines, Sept., 1929, p. 3.

Table 1.- Chemical analysis of the ore

Constituent	Assay, Per cent
Lead	3.5
Silica	3.2
Alumina	1.3
Iron oxide	6.6
Lime	27.4
Magnesia	15.5
Manganese oxide	.7
Sulphur	.8
Copper, nickel, cobalt	.1
Zinc	.2
Carbon dioxide (by difference and undetermined)	40.7
	100.0

Some of the lead is finely disseminated and some is more coarsely crystalline. Formerly, when a 5-mesh feed was sent to the tables the coarsest concentrate was too contaminated with locked gangue to be marketable. Now, a feed through 7 mesh gives a product of acceptable grade. Locking is also noticed in the gravity tailing, the lead content of which is never in a free state.

None of the gangue is entirely free from lead. The specific gravity of particles of crushed ore ranges from less than 2.85 that of galena (7.5), and all specific-gravity increments of any mesh contain lead. The assay per cent of lead in the increments of stated sizes and densities is given in Table 2. The lead assay of each specific gravity increment, excepting the sink in 3.34 specific gravity, decreases as the finer sizes are approached.

Table 2.- Assay of percentage of lead in the specific-gravity increments of the ore

Size, mesh	Assay, lead, per cent				
	Float on 2.85 specific gravity	2.85 to 2.90 specific gravity	2.90 to 2.95 specific gravity	2.95 to 3.34 specific gravity	Sink in 3.34 specific gravity
Plus: 4	0.36	0.35	1.07	7.74	19.10
6	.18	.15	1.07	7.64	45.46
8	.16	.14	.76	6.86	54.93
10	.16	.09	.59	6.74	59.32
14	.09	.09	.36	5.98	60.50
20	.07	.08	.25	5.06	60.84
28	.07	.07	.25	4.90	64.39
35	.06	.06	.14	4.68	64.05
48	.05	.05	.13	4.60	61.52
65	.05	.05	.09	3.30	64.39
100	.05	.05	.08	2.50	65.57

Other sulphides as well as lead are locked. The lightest increment in Table 2, the float on 2.85 specific gravity, contains a higher percentage of lead than the corresponding sizes of the next heavier increment, 2.85 to 2.90 specific gravity. This lightest portion is the most siliceous part of the ore and the locking with lead is more persistent; finer crushing is required to liberate it.

The siliceous character and the locking of lead in the float on 2.85 specific gravity is present in even a lighter increment. The separation between 2.80 and 2.85 specific gravity, showing the same persistent locking, is given in Table 3.

If the mill were making a tailing with a tenor of 0.75 per cent of lead, the locking mentioned would not come up for consideration, but when a tailing of 0.11 per cent of lead is made, as is the practice at this mill, the dissemination is very important.

Table 3.- Persistent locking of lead, and siliceous character of lightest specific-gravity increments

Product	Weight, per cent	Assay, per cent: Lead	Assay, per cent: Insoluble
Float on 2.80 specific gravity	12.30	0.12	30.21
2.80 to 2.85 specific gravity	55.28	.01	5.92
Sink in 2.85 specific gravity	32.42	-	-
Total	100.00	-	-

The entire story of the dissemination of lead is not told by the assays of the increments alone. The weight percentages and distribution of the lead add to the knowledge of the character of the ore. This information is given in Table 4.

The sink in 3.34 specific gravity is not indicative of the grade of concentrates that can be made. The galena itself is high grade; hand-picked coarse galena and fine table concentrates assay as high as 84 per cent of lead. As previously mentioned, considerable free galena is liberated from the coarse sizes. The ultimate freeing of lead, however, requires fine grinding.

Thus far the discussion of locking has related primarily to the galena and nonsulphide gangue. Galena is also locked with other sulphides. This was shown by a microscopic examination of a flotation middling, where it was observed that the iron and copper content was high and the locking of the lead with sulphides was more pronounced than with dolomite.

HISTORY

The mill was built in 1906, about a decade before flotation was introduced into the district; and gravity concentration was predominant in the original flow sheet. The mill was the largest in the district and had a capacity of 2,600 tons daily. A feature was a separate outside crushing plant where the ore was dry crushed to pass 8-millimeter screens. It then passed through a sampling plant to the mill storage bins. This arrangement was a big advance over anything practiced in the district. Three screen sizes above the 2-millimeter size were made and each was treated on Harz jigs while the undersize of the 2-millimeter screen was classified. Some of the spigots were jigged and others were tabled.

Later the Harz jigs were replaced by Hancock jigs. This change simplified the flow sheet and enabled the capacity to be increased from 2,600 to 4,000 tons per day.

Table 4.- Specific-gravity analysis of mill feed, per cent

	Float on 2.85 specific gravity			2.85 to 2.90 specific gravity			2.90 to 2.95 specific gravity			2.95 to 3.34 specific gravity			Sink in 3.34 specific gravity			Total		
Size, mesh	Weight	Assay, lead	Distribution of lead	Weight	Assay, lead	Distribution of lead	Weight	Assay, lead	Distribution of lead	Weight	Assay, lead	Distribution of lead	Weight	Assay, lead	Distribution of lead	Weight	Assay, lead	Distribution of lead
Plus: 4	7.47	0.36	0.57	1.07	0.35	0.08	0.48	1.07	0.11	0.60	7.74	0 86	0.24	19.10	0.95	9.86	1.23	2.57
6	15.31	.18	.58	2.09	15	.07	.90	1.07	.20	1.24	7.64	2.00	.70	45.46	6.80	20.24	2.25	9.65
8	10.79	.16	.37	1.62	.14	.05	.61	.76	10	.71	6.86	1.03	.76	54.93	8.83	14.49	3.38	10.38
10	7.30	.16	.25	2.12	.09	.04	.45	.59	.06	.48	6.74	. 68	.83	59.32	10.49	11.18	4.86	11.52
14	5.51	.09	.10	1.29	.09	.03	.40	.36	.03	.30	5.98	.38	.70	60.50	8.98	8.20	5.48	9.52
20	3.29	.07	.05	1.10	.08	.02	.43	.25	.02	.15	5.06	.16	.46	60.84	5.97	5.43	5.41	6.22
28	2.43	.07	.04	.94	.07	.01	38	.25	.02	.10	4.90	.10	.51	64.39	6.95	4.36	7 71	7.12
35	1 79	.06	02	.86	.06	.01	.26	.14	.01	.06	4.68	06	.43	64.05	5.81	3 40	8.20	5.91
48	1.64	.05	.02	.81	.05	.01	30	.13	.01	05	4.60	.05	.38	61.52	4.88	3.18	7.38	4.97
65	.93	.05	01	.79	05	.01	.23	.09	.00	.03	3.30	.02	.31	64.39	4.28	2.29	8.91	4.32
100	.79	.05	.01	.95	.05	.01	.25	.08	.00	.03	2.50	.02	.35	65.57	4.89	2.37	9.82	4.93
Minus: 100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[1]22.89	15.00	7.20	22.89
Total	57.25	0.17	2.02	13.64	0.11	0.34	4.69	0.57	0 56	3.75	6.92	5.36	5.67	57.21	91.72	100 00	4.72	100.00

1 - All the lead in the minus 100-mesh product is assumed to be free.

The size of the mill feed was increased from 8 to 10 millimeters, and the plus $1\frac{1}{4}$-millimeter part of the feed was treated on the Hancock jigs to give concentrate, tailing, high-grade middling, and low-grade middling. Additional concentrate was recovered from the high-grade middling by screening on 2-millimeter mesh and taking the oversize as concentrate. The undersize was reconcentrated on a jig from which a tailing, a middling, and a concentrate were obtained; the tailing was tabled to remove a small amount of fine lead, and the middling containing zinc, lead, iron, and copper was treated in a magnetic plant along with the table middling. The mixed sulphide middling was roasted and the pyrite and chalcopyrite were removed by a Cleveland-Knowles magnetic machine. The tailing from the magnetic machine -- the zinc concentrate -- was tabled to separate the remaining lead. The magnetic concentrate had 7 per cent of copper and some silver.

The low-grade middling was reconcentrated on jigs. Products similar to those of the "ore" jigs were made. The low-grade middling was reground in rolls and the plus $1\frac{1}{2}$-millimeter part returned to the jigs.

The undersize of the original feed (minus $1\frac{1}{4}$ mm.) and the undersize of the reground jig middling (minus $1\frac{1}{2}$ mm.) were deslimed, classified in hydraulic classifiers, and tabled. The classifiers used were largely of the Richards vortex type, but some were of the Bunker Hill & Sullivan type. A tailing, middling, and concentrate were made on all the tables. The middling was reground in rolls.

The slime was treated in spitzkasten and the spigot products were concentrated on tables and vanners. The table and vanner tailings and slimes were treated in a canvas plant. The concentrate of the canvas plant was cleaned on tables and vanners. A lead concentrate was all that was recovered in the slime treatment.

To recapitulate: Before the advent of flotation the concentration was by jigs, tables, vanners, and a canvas plant; roasting and magnetic separation were applied to the complex sulphide middlings.

During the course of this early milling a large tailing pile accumulated, many parts of which had a tenor in lead as high as 1 per cent.

In 1914 flotation was adopted. This was the turning point in the milling, for slimes could then be treated efficiently. The way was paved for finer grinding and the consequent lower tailing of to-day. Although all-tabling of a minus 2-millimeter feed had been attempted at an earlier date, it had failed because of the inability to recover the lead in the slime.

The first flotation practice consisted in thickening the slime to about 20 per cent of solids and floating the thickened product. Crude wood creosote was used as the frothing agent; acid was not used.

Since 1914 fine grinding, table concentration, and flotation all have advanced. The dry-crushing plant was remodeled in 1926; the primary breakers were replaced by new crushers and placed in a separate plant. This change made finer grinding possible and increased the capacity to 5,000 tons per day. In 1927 the last jig was discarded.

In 1928, as a result of a cooperative investigation with the United States Bureau of Mines and the Missouri School of Mines and Metallurgy, hydraulic classification was substituted for the "distributed" table feed. Earlier attempts to improve results by classifying the table feed had failed. Whereas desliming had always been practiced, it was not until this change was made that the benefit of actual classification was fully realized.

During the last four years, five mills of the district with an aggregate capacity of 19,000 tons per day have been remodeled to adapt them to multiple-spigot hydraulic classification in place of the customary distributed table feed.

In the last few years low-pressure air flotation machines have almost entirely replaced the mechanical and high-pressure air types. Pine oil or cresylic acid and xanthate are now generally used as flotation reagents. Trommels have been replaced by vibrating screens. Rod mills have superseded rolls for regrinding middlings. Table tailings that were formerly dewatered and carried to waste by a long series of belt conveyors are now deslimed, mixed with part of the flotation tailings, and pumped to waste. Table concentrates are filtered before shipment instead of merely being dewatered by drags.

PRESENT MILLING PRACTICE

The descriptions which follow are of the milling practice as in 1931. Concentration is by tabling and flotation. Table concentrates at present constitute about 52 per cent of the output and have a content of 76 per cent of lead. On account of much regrinding about two-thirds of the mill feed is eventually treated by flotation to produce the other 48 per cent of the total concentrates. Flotation concentrates are not as rich as gravity concentrates and average 71 per cent of lead.

CRUSHING AND ROLL GRINDING

Dry crushing, in three steps, reduces the run-of-mine ore to 5-mesh (0.17-inch). The first reduction is by breaking in 9E Telsmith gyratories to less than 3 inches, the second by crushing in 48-inch Symons horizontal disk crushers to less than 1.5 inches, and the third step by grinding in 48 by 24 inch St. Joe rolls to pass 5-mesh screens. This size is considered the practical minimum without sacrificing tonnage. The dry-crushing flow sheet is shown in Figure 2.

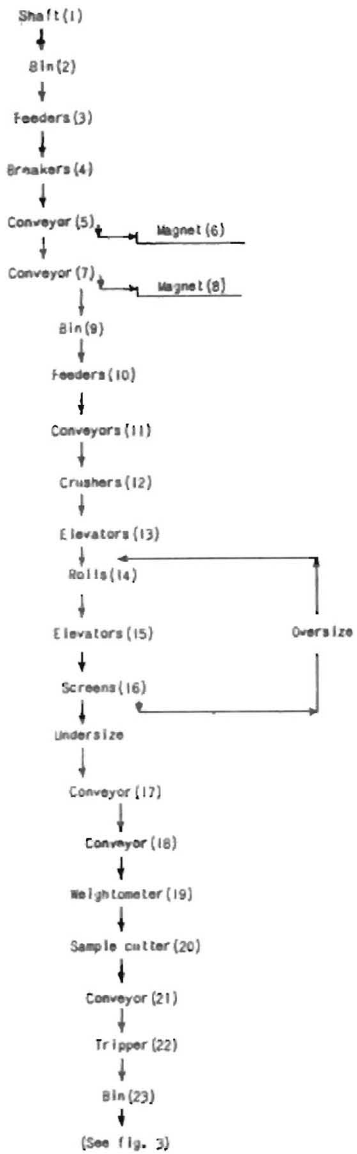
Crude ore is dumped into bins as hoisted. Iron bars hanging in the bin act as buffers and protect the bin wall. Ore is fed to the breakers by apron feeders under hand-operated arc gates and heavy iron fingers. The gates are opened wide and the fingers retard the flow of ore onto the feeders. When the ore hangs up in the bin it is barred down by hand. Grizzlies are not used underground and pieces too large for the breaker are sledged or bulldozed in the primary-crushing plant. A 40-ton crane above the gyratories facilitates repairs and replacements.

The breakers handle in two shifts enough tonnage to employ the disk crushers and rolls for three shifts. The respective capacities in terms of original feed are about 107 tons per hour for each breaker, 56 tons per hour for each disk crusher, and 56 tons per hour for each set of rolls. The 9E Telsmith primary breakers are able to handle a considerably larger tonnage than they do now, for even in their present operation of only two shifts they are not heavily loaded.

Although considered an old type of crushing equipment, the Symons horizontal disks, which have been in use for over 20 years, are retained because they are still able to give the required service. However, it is likely that before many years they will be replaced by newer machinery.

The 48 by 24 inch St. Joe rolls are operated in closed circuit with vibrating screens with 5-mesh openings. This fine roll-grinding necessitates dressing the roll shells about every three months to remove flanges and corrugations. To do this the roll on its shaft is lifted out of the frame and placed in special bearings. It is turned down by rotating at about 2 r.p.m. against a cutting tool that moves automatically across the face. Sometimes a grinding wheel instead of the cutter is mounted on the tool carriage.

The operating details of the primary crushers, the secondary crushers, and the rolls are given in Table 5. The sizing analyses of the products of each step are shown in Table 6.



Metallurgical details

(1) Two 6.3-ton skips

(2) 180-ton crude-ore bin

(3) Three drum feeders, 4 feet 9 inches in diameter by 4 foot 8 inch face, 0.3 to 0.4 r.p.m., No. 4 Reeves and 5-hp. motor on each

(4) Three 9-E Telsmith primary breakers (see Table 5)

(5) 36-inch belt conveyor (see Table 21)

(6) 36-inch Ohio mill-type electromagnet

(7) 36-inch inclined belt conveyor (see Table 21)

(8) 36-inch Cutler-Hammer electromagnet

(9) 900-ton bin

(10) Two Stephens-Adamson 36-inch pan feeders 8 feet long, 10 feet per minute, No. 4 Reeves and 5-hp. motor on each

(11) Two 24-inch inclined belt conveyors (see Table 21)

(12) Four 48-inch Symons horizontal disk crushers (see Table 5)

(13) Two 28-inch bucket elevators (see Table 22)

(14) Four 48 by 24 inch St. Joe rolls (see Table 5)

(15) Four 28-inch bucket elevators (see Table 22)

(16) Twelve Leahy dry screens (see Table 19)

(17) 24-inch belt conveyor (see Table 21)

(18) 24-inch inclined belt conveyor (see Table 21)

(19) Merrick weightometer, model E

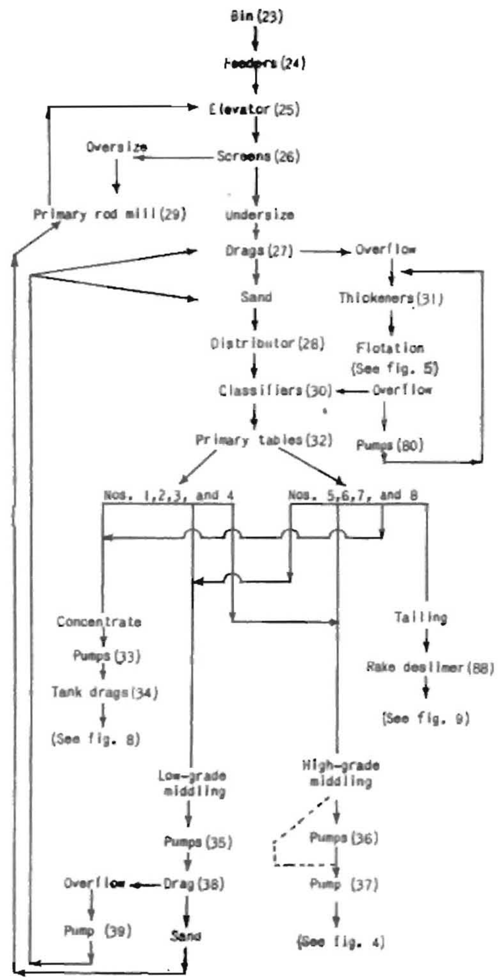
(20) Vezin-type sample cutter, 14.5 r.p.m.

(21) 24-inch belt conveyor (see Table 21)

(22) Jeffrey automatic 2-way tripper

(23) 8,000-ton concentrator bin

Figure 2.- Dry-crushing flow sheet



Mechanical details

(23) 8,000-ton concentrator bin

(24) Three 24-inch belt feeders, 10 feet long; 13 feet per minute; slope, 2.4 inches per foot; fed by hopper with adjustable gate; drive, No. 3 Reeves, DeLaval worm gear, 10-hp., 870-r.p.m. motor. One 24-inch pick-up conveyor, 19 to 38 feet long; 105 feet per minute; drive, bevel gear from feeder

(25) 20-inch bucket elevator (see Table 22)

(26) Two Leahy wet screens (see Table 19)

(27) Two drag deslimers (see Table 20)

(28) 2-way revolving distributor, 15 r.p.m.

(29) 6 1/2 by 12 foot rod mill (see Table 9)

(30) Two hydraulic classifiers (see Table 11)

(31) Two 150-foot Dorr thickeners (see Table 18)

(32) 16 concentrating tables (see Table 13)

(33) 4-inch Morris pumps (see Table 23)

(34) Two tank drags (see Tables 20 and 25)

(35) 4-inch Wilfley pumps (see Table 23)

(36) Morris pumps (see Table 23)

(37) Wilfley pump (see Table 23)

(38) Drag deslimer (see Table 20)

(39) 8-inch Wilfley pump (see Table 27)

(80) 8-inch Wilfley pumps (see Table 23)

(88) Reciprocating rake deslimer (see Table 26 and fig. 9)

Figure 3.- Flow sheet of one section of primary wet grinding and gravity concentration

Table 5.- Details of dry-crushing units

Data	Dry-crushing equipmnt		
	Primary crushers	Secondary crushers	Rolls
Flow-sheet serial	(4)	(12)	(14)
Crushers, in operation	3	4	4
Type	Gyratory	Symons horizontal-disk	Spring type
Manufacture	Smith Engineering Works	Nordberg Engineering Co.	St. Joseph Lead Co.
Size	9 E	48-inch	48 by 24 inch
Opening:			
Top ... inches	19½	-	-
Maximum discharge ... do.	2 to 2¼	7/8	Set close
Minimum ... do. ... do.	1-1/16 to 1¼	½	-
Gyrations per minute	108	-	-
Eccentric throw ... inches	One at 5/8 Two at 3/4	-	-
Speed:			
Countershaft ... r.p.m.	324	-	-
Disk ... do.	-	100	-
Eccentric ... do.	-	250	-
Rolls ... do.	-	-	60.0 to 65.2
Motors ... horsepower	Three at 150	Two at 250[1]	Two at 250[1]; Two at 150
Circuit, open or closed	Open	Open	Closed
Power consumption, each ... horsepower	44 average	40 to 45	161 to 164
Material:			
crushing-surface	Manganese steel	Manganese steel	Chrome steel
Frame	Cast steel	Cast iron	Cast steel
Wearing part, life ... years	-	Disks, 2	Shell, 1
Shifts operated	Two, 8-hour	Three, 8-hour	Three, 8-hour
Oil used per shift per machine ... gallons	4	4	-
Feed:			
Character	Run-of-mine	Primary crusher discharge	Symons discharge and screen over-size
How fed	Drum feeder	Chute	Launder
New, per hour ... tons	107	56	56
New, per hp.-hour ... do.	2.43	1.31	0.34
Total, per hour ... do.	-	-	309.2
Total, per hp.-hour ... do.	-	-	1.9

1 - 250-hp. motor for two Symons and one set of rolls.

Table 6.- Sizing analyses of successive dry-crusher products

Size	Weight, per cent				
	Primary breaker discharge (Symons horizontal disk-crusher feed)	Symons horizontal disk-crusher discharge (new feed to roll)	Composite roll feed (new feed and dry screen oversize)	Roll discharge	Finished roll discharge (screen undersize)
Plus: 3.0 inch	11.7	-	-	-	-
2.1 do.	19.0	-	-	-	-
1.5 do.	17.6	13.3	1.8	-	-
1.05 do.	12.0	32.2	4.3	-	-
.742 do.	8.4	23.4	5.0	1.2	-
.525 do.	6.6	10.9	6.9	7.7	-
.371 do.	5.3	7.3	20.9	15.8	-
3 mesh	4.2	4.0	19.3	19.8	-
4 do.	3.7	2.5	19.2	19.5	-
6 do.	2.2	1.0	11.4	11.9	3.0
8 do.	2.0	1.0	6.5	8.5	14.5
10 do.	1.8	.7	1.9	2.3	18.6
14 do.	.9	.5	.6	2.3	12.9
20 do.	.8	.4	.2	1.2	7.9
28 do.	.6	.3	.2	1.2	8.0
35 do.	.5	.3	.1	.8	5.5
48 do.	.5	.2	.1	.6	3.9
65 do.	.4	.2	.1	.6	3.7
100 do.	.2	.2	.1	.4	2.3
150 do.	.2	.1	.1	.4	2.0
200 do.	.4	.2	.1	.3	2.0
Minus: 200 do.	1.0	1.3	1.2	5.5	15.7
Total...........	100.0	100.0	100.0	100.0	100.0

After passing the 5-mesh screens the ore is conveyed over a Merrick weightometer to the concentrator bin. In case the conveyor belts stop, automatic lights signal the operator in the primary-crushing plant to close the crude-ore bin gates.

WET GRINDING AND GRAVITY CONCENTRATION

For discussion, the wet-grinding and gravity concentration are divided into primary and secondary circuits. In the primary gravity circuit, wet-grinding, hydraulic classification, and table concentration are done in six similar sections of the concentrator. One of these sections, the flow sheet of which is given in Figure 3, will be discussed. It deals with the new feed and the returned low-grade middling. The secondary gravity circuit deals with the high-grade middling from the first operation, and will be discussed later. In all, gravity concentration uses 116 tables and 7 rod mills. Table 28 shows that the grade of the table tailing is 0.11 per cent of lead. Such a low tailing would not be obtainable were not every effort made to keep lubricating oil out of the ore.

Primary Gravity Circuit

The ore for each circuit is drawn from the concentrator bin by three belt feeders, is lifted to the top of the mill in a bucket elevator, and is sized by two 7-mesh vibrating screens. On account of the fineness of the dry feed the screens are lightly loaded. The oversize is ground in a primary rod mill and is returned to the screens by the new-feed elevator. The screen undersize is deslimed in two drag deslimers. The overflow runs to flotation thickeners. The sand discharge is divided by a 2-way mechanical distributor and is sized in two 10-spigot hydraulic classifiers. The overflow of the hydraulic classifiers also goes to the flotation thickeners. The 10 spigot discharges of each classifier are treated on eight concentrating tables. The first six spigots feed one table each, while the seventh and eighth spigots, and the ninth and tenth spigots, are combined to feed the other two tables. A concentrate, a high-grade middling, and a low-grade middling are made on each of the first four tables. The last four tables make similar products and a tailing in addition. Sizing analyses of the table tailings and concentrates of the combined primary and middling circuits are shown in Table 7. The low-grade middlings from all eight primary tables are dewatered in a drag deslimer and reground in the primary rod mill. The sizing analysis of the low-grade table middlings is given in Table 8. The high-grade table middlings constitute the feed for the secondary gravity circuit and will be discussed under that caption later.

Table 7.- Sizing analyses of composite table tailing and composite table concentrate

Size, mesh	Weight, per cent: Table tailing	Weight, per cent: Table concentrate
Plus: 14	-	2.1
20	-	3.5
28	3.5	4.6
35	13.1	8.3
48	28.7	14.3
65	42.3	24.0
100	8.6	12.5
150	3.0	12.8
200	.5	8.1
Minus: 200	.3	9.8
Total...	100.0	100.0

Table 8.- Sizing analyses of primary rod-mill products

	Weight, per cent			
Size, mesh	Screen oversize (1)	Low-grade middling drag discharge (2)	Rod-mill feed (1) and (2)	Rod-mill discharge
Plus: 6	2.8	-	0.5	-
8	28.8	0.3	7.8	-
10	36.6	4.6	16.0	-
14	13.6	9.1	14.2	0.2
20	3.7	10.1	8.8	.3
28	2.9	17.1	19.2	10.7
35	1.3	22.0	16.2	17.7
48	1.2	19.4	7.6	15.5
65	1.1	13.4	3.4	14.5
100	.8	1.9	1.1	5.2
150	.7	.6	.7	4.9
200	.7	.2	.5	3.8
Minus: 200	5.8	.5	4.0	27.2
Total....	100.0	100.0	100.0	100.0

Rod-Mill Grinding

The primary rod mill reduces the wet-screen oversize and the low-grade middlings from the primary tables to 20-mesh. In other words, the rod mills are operated in closed circuit with both screens and tables. The new feed to each of the six sections is 850 tons per 24 hours. Because of the circulating load the tonnage of rod-mill feed is about the same as that of the new feed.

The pulp density in the mills is about 40 per cent of solids by volume, 65 per cent by weight. The sizing analyses of the several products are given in Table 8. The mechanical details of the rod mills are given in Table 9. The driving gears on the rod mills may be reversed to compensate for wear.

Unusually long liner lifer is obtained in the rod mills. After five years of continuous service, the estimate has been made that the life will reach seven years. This may be attributed to the softness of the ore, the fineness of the feed, and the method of installing liners. The liner sections are bolted in place with 1/8-inch shims between the liners and the shell of the mill. Then molten zinc is poured between and under the sections so as to form a continuous and cushioned all-metal lining in the mill. After five years it has been found expedient to reverse the sections and rezinc them, because of the breaking loose and erosion of the zinc. The greatest wear on the liners had taken place toward the discharge end of the mill, but rod wear was uniform throughout the length of the rods.

Table 9.- Rod-mill data

	Primary	Secondary
Flow-sheet serial	(29)	(53)
Mills, in operation	6	1
Manufacture	Allis-Chalmers	Allis-Chalmers
Size ... feet	6½ by 12	5 by 9
Feed:		
Character	Wet screen over-size and table re-turn	Low-grade middlings
Rate per 24 hours ... tons	850	125
Solids by weight ... per cent	66	66
Feeder type	Scoop	Scoop
Discharge type	Overflow	Overflow
Liners:		
Type	Wave	Wave
Weight ... pounds	-	19,660
Composition	Manganese steel	Manganese steel
How held	Bolted and zincked in	Bolted and zincked in
Life ... years	7[1]	6[1]
Zinc used ... pounds	4,800 to 5,600	3,900
Make-up rods:		
Diameter ... inches	2	2
Load ... pounds	55,000	28,000
Consumption ... do.	0.38, per ton of crude ore	2.97, per ton of actual feed
Drive, type	Direct with her-ring-bone gear	Direct with her-ring-bone gear
Mill speed ... r.p.m.	16.9	20.8
Motor:		
Type	Induction	Induction
Power consumption ... horsepower	190	95
Capacity ... do.	200	100

1 - Estimated.

The rods are hot-sawed and machine-straightened. The length is 11 feet 11½ inches maximum, and 11 feet 10½ inches minimum. The chemical specification is as follows:

Constituent	Per cent
C	0.60 to 0.75
Cr	0.30 to 0.50
Mn	0.50 to 0.70
Si	0.15 to 0.25
S (max.)	0.04
P (max.)	0.04

The rod charge in the primary rod mills is given in Table 10. The original charge to the primary mills was 55,000 pounds with a maximum size of 4 inches. This maximum has been reduced to 2 inches, and the tendency is toward a further decrease. This is prompted, at least in part, by the thought that the large rods break the small ones prematurely.

Table 10.-Primary rod-mill charge

Rods, inches diameter	After about four years operation			As returned to mill		
	Rods, number	Weight, pounds	Weight, per cent	Rods, number	Weight, pounds	Weight, per cent
2-1/2	-	-	-	80	15,912	28.1
2	47	5,983	11.8	38	4,837	8.5
1-7/8	88	9,847	19.5	92	10,295	18.1
1-3/4	135	13,163	26.0	117	11,408	20.1
1-5/8	93	7,812	15.4	75	6,300	11.1
1-1/2	67	4,797	9.5	54	3,866	6.8
1-3/8	84	5,057	10.0	69	4,154	7.3
1-1/4	41	2,038	4.0	-	-	-
1	(1)	1,910	3.8	-	-	-
Total..	555	50,607	100.0	525	56,772	100.0

1 - Broken rods, 2 to 7 feet long.

Hydraulic Classification

Two 10-spigot hydraulic classifiers of the constriction-plate type are used in each of the six primary sections. Two others are in the middling sections. Each is fed about 430 tons per 24 hours by a drag deslimer. The mechanical details of the classifiers are given in Table 11 and some data on the products of one are shown in Table 12. The results of an efficiency test on a similar classifier, giving more complete data, are presented in a recent publication.[5]

Several kinds of spigot liners including rubber and case-hardened steel types, have been tried, but porcelain has been adopted finally. The present liners are porcelain cylindrical tubes about 1-1/8 inches outside diameter and 1 inch long. The holes are 3/4, 5/8, 1/2, or 7/16 inch in diameter, the larger holes being at the feed ends of the classifiers.

5 - Coghill, Will H., Classification and Tabling of Difficult Ores, with Particular Attention to Fluorspar: Paper 455, Bureau of Mines, 1929, p. 38.

Table 11.-Details of hydraulic classifiers

Flow-sheet serial	(30)	(41)	(47)
Classifiers in operation	12	1	1
Cells:			
Number		10	
Size ... inches		10 by 10	
Dividers, height ... do.		12	
Overflow type		Side and end	
Overflow height ... inches		20	
Material		Cypress	
Hole spacing in plates		Corner of 2-inch squares	
Hole diameters ... inches		4 cells, 1/4; 4 cells, 3/16; 2 cells, 1/8	
Discharge type		Continuous spigots	
Spigot diameters ... inches	Two, 3/4 four, 5/8 four, 7/16	Two, 3/4 four, 5/8 two, 1/2 two, 7/16	Two, 5/8 six, 1/2 two, 7/16
Feed:			
Rate per 24 hours ... tons		430	
Pulp density ... per cent		38.5	
Hydraulic water per minute ... gallons		275	
Ratio ... water : solids		3.8 : 1	

Table 12.-Sizing analyses and tonnages of hydraulic-classifier products

Size, mesh	Weight, per cent									
	Feed	Spigot No. 1	Spigot No. 2	Spigot No. 3	Spigot No. 4	Spigot No. 5	Spigot No. 6	Spigots No. 7 and No. 8	Spigots No. 9 and No. 10	Overflow
Plus: 8	0.2	1.6	0.4	0.1	-	-	-	-	-	-
10	3.7	17.8	9.8	2.7	0.3	0.1	-	-	-	-
14	8.0	28.0	19.7	9.3	2.3	1.5	-	-	-	-
20	6.6	17.9	16.4	11.6	4.9	4.1	0.4	0.3	0.2	-
28	11.1	16.0	18.5	20.2	13.1	11.5	3.5	2.6	2.2	-
35	13.2	9.6	15.1	22.0	22.3	16.9	8.8	7.4	6.6	-
48	14.3	4.4	9.5	16.2	24.5	19.8	21.4	18.0	16.1	-
65	20.3	3.2	7.0	12.2	22.9	34.1	41.7	45.0	38.0	-
100	7.4	.8	1.9	3.1	5.0	6.7	13.1	14.8	21.4	1.2
150	5.1	.4	.9	1.4	2.5	3.0	7.0	8.0	12.3	14.3
200	2.3	.1	.4	.5	.9	.3	.4	1.2	1.1	17.1
Minus: 200	7.8	.2	.4	.7	1.3	2.0	3.7	2.7	2.1	67.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean mesh, millimeters	0.305	0.828	0.623	0.451	0.323	0.287	0.215	0.207	0.195	-
Tons per 24 hours	[1]418.4	52.1	78.4	41.4	48.8	49.4	47.6	52.3	48.4	-

1 - This tonnage does not include the slime in the overflow.

Table Concentration

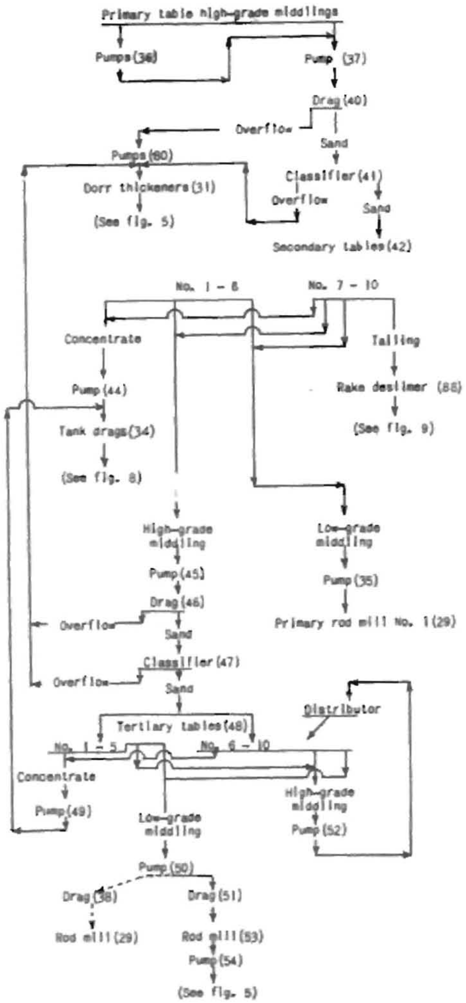
The 10 spigot products of each primary classifier are treated on 8 tables. The amount of feed ranges from 50 to 75 tons per table per 24 hours. The table feeds are about 25 per cent solids. From 4 to 15 gallons of wash water per minute are used on each table. The mechanical and operating details of the concentrating tables are given in Table 13.

Linoleum and quick-setting cement were used formerly for deck-surfacing material, but both have been replaced by live-rubber covers. Rubber as thick as 1/4 inch has been tried but a thinner cover, 1/8 or 3/16 inch thick, is now used. At first rubber cement and tacks were used to hold the rubber cover in place, but now the practice is to tack the cover at one end, stretch it well by a weight applied to the other end, and finally tack the rest of the cover in place.

Table 13.-Data on concentrating tables

Flow-sheet serial	(32) (42) and (48)			
Table, make	Wilfley	Butchart	Deister-Plato	St. Joe
In use, each	76	19	2	19
Strokes per minute	270	255	270	240
In use, total	116			
Stroke length ... inches	7/8 to 1-3/8			
Drive, type	Belt-and-pulley			
Power, total ... horsepower	192			
Connected per table ... do.	1.65			
Deck:				
Size ... feet	5 by 15			
Slope, longitudinal ... degrees	0 to 1/2			
Slope, lateral ... do.	3 to 5-1/2			
Surfacing material	1/8 to 3/16 inch rubber			
Riffles, type	Straight, parallel to motion			
Material	Rubber, or wood and rubber			
Height ... inches	1/16 to 3/8			
Spacing ... do.	2			
Feed:				
Character	Spigot discharge			
Rate per 24 hours ... tons	50 to 75			
Pulp density ... per cent	25			
Wash water per minute ... gallons	4 to 15			

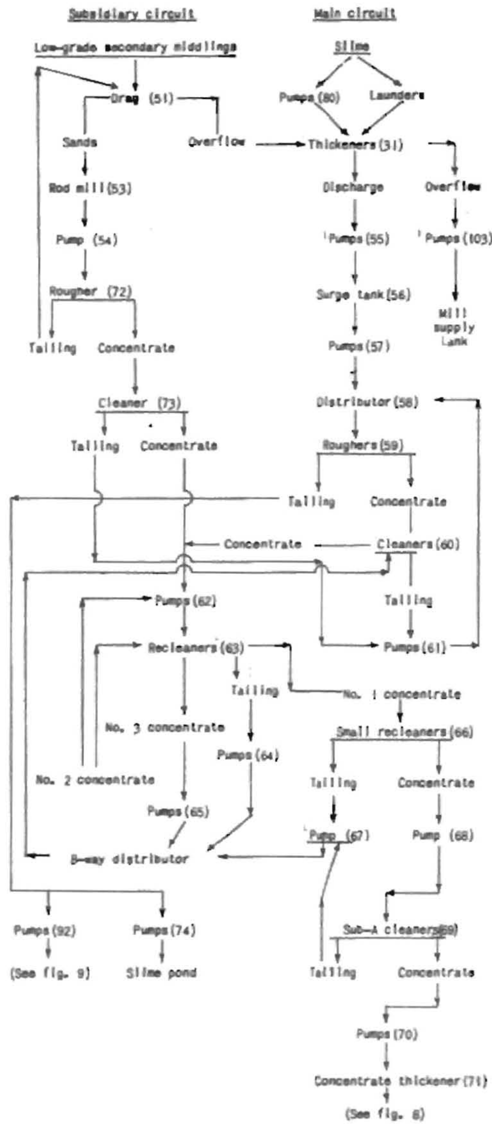
Rubber has proved more resistant to wear than linoleum and does not become uneven, as was the case with the cement deck. The porosity of the cement gradually allowed water to seep through to the boards underneath, causing them to warp and distort the surface. Cement is objectionable also because of its weight. The life of the rubber covers has not yet been determined but it is over two years. Some buckling occurs after long service but if properly laid the covers are quite satisfactory. One operator has determined that the life depends on the amount of absorbed water. After long service the tops contain from 2 to 14 per cent of moisture. The high moisture content is found in rubber with a low zinc oxide content. Tops containing 39 per cent of zinc oxide are good, while those with only 2 to 3 per cent are not so satisfactory.



Mechanical details

(29) 6 1/2 by 12 foot rod mill (see Table 9)
(31) Dorr thickeners (see Table 18)
(34) Tank drags (see Table 20)
(35) Low-grade middling pump of sec. 1 (see Table 23)
(36) Morris pumps (see Table 23)
(37) 4-inch Wilfley pump (see Table 23)
(38) Drag deslimer (see Table 20)
(40) Drag deslimer (see Table 20)
(41) Hydraulic classifier (see Table 11)
(42) Ten concentrating tables (see Table 13)
(44) 4-inch Morris pump (see Table 23)
(45) 4-inch Wilfley pump (see Table 23)
(46) Drag deslimer (see Table 20)
(47) Hydraulic classifier (see Table 11)
(48) Ten concentrating tables (see Table 13)
(49) 4-inch Morris pump (see Table 23)
(50) 4-inch Wilfley pumps (see Table 23)
(51) Drag deslimer (see Table 20)
(52) 4-inch Morris pump (see Table 23)
(53) 5 by 9 foot rod mill (see Table 9)
(54) 4-inch Wilfley pump (see Table 23)
(80) Three 8-inch Wilfley pumps (see Table 23)
(88) Reciprocating rake deslimer (see Table 26)

Figure 4.- Flow sheet of table middling section



Mechanical details

(31) Two 150-foot Dorr thickeners (see Table 18)
(51) Drag deslimer (see Table 20)
(53) 5 by 9 foot rod mill (see Table 9)
(54) 4-inch Wilfley pump (see Table 23)
(55) 5-inch Morris pumps (see Table 23)
(56) Cylindrical concrete tank, 24 feet in diameter by 8 feet deep
(57) 5-inch Morris pumps (see Table 23)
(58) 24-outlet distributor (see fig. 6)
(59) Twenty-three 36-foot St. Joe flotation machines (see Table 17)
(60) Twenty-three 12-foot St. Joe flotation machines (see Table 17)
(61) Four 5-inch Morris pumps (see Table 23)
(62) 4-inch Wilfley pumps (see Table 23)
(63) Two 42-foot St. Joe flotation machines (see Table 17)
(64) Two 4-inch Morris pumps (see Table 23)
(65) Two 4-inch Morris pumps (see Table 23)
(66) Two 12-foot St. Joe flotation machines (see Table 17)
(67) 4-inch Morris pump (see Table 23)
(68) 4-inch Wilfley pump (see Table 23)
(69) Two 2-cell Denver Sub-A flotation machines (see Table 17)
(70) 4-inch Morris pumps (see Table 23)
(71) 50-foot Dorr thickener (see Table 18)
(72) 36-foot St. Joe flotation machine (see Table 17)
(73) 12-foot St. Joe flotation machine (see Table 17)
(74) 5-inch Morris pumps (see Table 23)
(80) Three 8-inch Wilfley pumps (see Table 23)
(92) 5-inch Morris pumps (see Table 23)
(103) Water pumps (see Table 27)

Figure 5.- Flotation flow sheet

Straight riffles, laid parallel to the axis of motion, are used. They are of live rubber on the recent installations, but riffles of wood faced with rubber strips are found on the older tables. The riffles are held in place by copper tacks.

Secondary or Table Middling Circuit

The treatment of the high-grade primary table middlings is shown in the flow sheet, Figure 4. The middlings are gathered from all six primary sections and sent to a middling section with ten tables where they are classified and concentrated without preliminary grinding. A concentrate, high-grade middling, and low-grade middling are made on each table, and, in addition, a tailing is made on the last four.

The low-grade middling is reground in one of the primary rod mills and thus returns to the primary circuit. The high-grade middling is treated in a circuit of another group of 10 tables similar to the one described above for high-grade primary table middlings. In this circuit no tailing is made. It yields only concentrate, high-grade middling, and low-grade middling. The high-grade middling is circulated in the section by being distributed to the last five tables. The low-grade middling is dewatered in a drag deslimer and ground to flotation size in a 5 by 9 foot secondary rod mill. The sizing analyses of the feed and discharge of this mill are given in Table 14.

The rod-mill discharge is treated directly by flotation on a St. Joe rougher in the subsidiary flotation circuit, and the tailing is returned to the drag in closed circuit with the rod mill. This drag overflow, together with the overflow of the other two drags and hydraulic classifiers, is joined with the flotation feed that is pumped to the large Dorr thickeners. The drag sand returns to the rod mill. This part of the flow sheet is novel in that the rod-mill discharge goes to flotation and the flotation tailings return to the rod mill.

Table 14.-Sizing analyses of feed and discharge of secondary rod mill

Size, mesh	Weight, per cent Feed	Weight, per cent Discharge
Plus: 10	2.6	-
14	5.4	-
20	8.4	-
28	9.3	-
35	10.4	-
48	8.5	-
65	15.6	1.4
100	11.8	2.6
150	10.5	5.9
200	6.3	8.4
325	7.9	31.7
Minus: 325	3.3	50.0
Total......	100.0	100.0

FLOTATION

Flotation is in a main circuit and in a subsidiary circuit. The main circuit has 23 rougher-and-cleaner units and six recleaners; the subsidiary circuit has one rougher-and-cleaner unit. With the exception of the final recleaners, the machines are a modification of the Forrester or Welsch pneumatic type and are called St. Joe low-pressure flotation machines. A rougher-and-cleaner unit consists of a 36-foot rougher in tandem with a 12-foot cleaner, both of which receive air from one long, horizontal header pipe at the end of which is a centrifugal blower; the unit is about 55 feet long. Each of two 42-foot recleaners has its own blower, but only one blower is required for two small 12-foot recleaners set in close parallel. The final recleaners are two 2-cell, 24-inch Denver Sub-A mechanical-type machines. All the pneumatic flotation machines are set parallel on one floor with the blowers in line at one end.

The subsidiary circuit receives reground low-grade table middlings from the gravity plant, and its products join the corresponding products in the main circuit. The main circuit feed is primary and secondary slimes, thickened in the two 150-foot Dorr thickeners. Rougher concentrates are cleaned four times to make final concentrates. The flotation flow sheet is given in Figure 5.

The primary feed is a pulp of about 20 per cent solids by weight, and it is distributed to the roughers by a 23-outlet distributor, shown in Figure 6. The cleaners are fed a pulp of lower density. Sizing analyses of feed, concentrate, and tailing are given in Table 15.

Flotation reagents are potassium xanthate, sodium cyanide, and cresylic acid or pine oil, or a mixture of the two. The device for feeding pine oil is sketched in Figure 7. Other reagents are fed in solution by pulley and scraper feeders. The flotation circuit is slightly alkaline, having a pH value of about 8.3.

Table 15.-Sizing analyses of flotation feed, tailing, and concentrate

Size, mesh	Weight, per cent		
	Feed	Tailing	Concentrate
Plus: 65	0.8	1.0	-
100	3.4	3.1	0.3
150	9.6	9.4	1.0
200	10.2	13.5	2.5
325	21.8	22.7	15.5
Minus: 325	54.2	50.4	80.7
Total....	100.0	100.0	100.0

In the main circuit xanthate and cresylic acid or pine oil are fed to the intake pipe of the pump that elevates the feed from the surge tanks to the distributor. Sodium cyanide is added to the sump of the pumps that elevate the cleaner concentrates to the first recleaners. Thus the conditioning periods are very short.

In the subsidiary circuit, xanthate and cyanide are added to the rod mill, and cresylic acid or pine oil to the sump of the pump that elevates the mill discharge to the flotation machine.

The amount of reagents per ton of flotation feed is given in Table 16.

Mechanical details of the St. Joe pneumatic and the Denver Sub-A mechanical flotation machines are given in Table 17. Data on the Dorr thickeners for dewatering flotation feed and flotation concentrates are in Table 18.

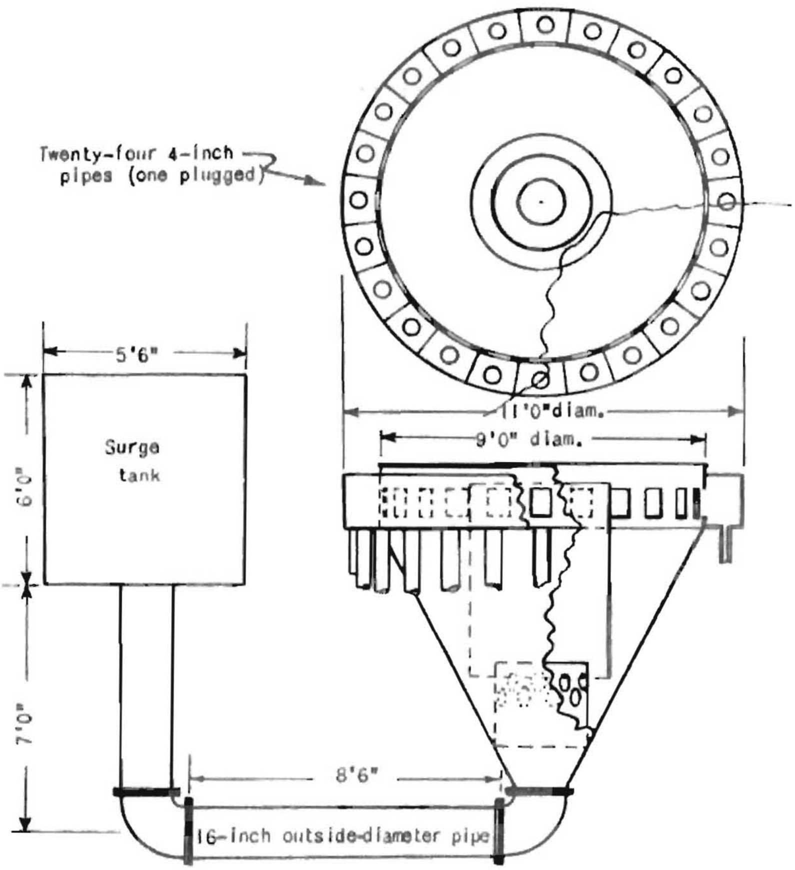


Figure 6.- Flotation feed distributor (58)

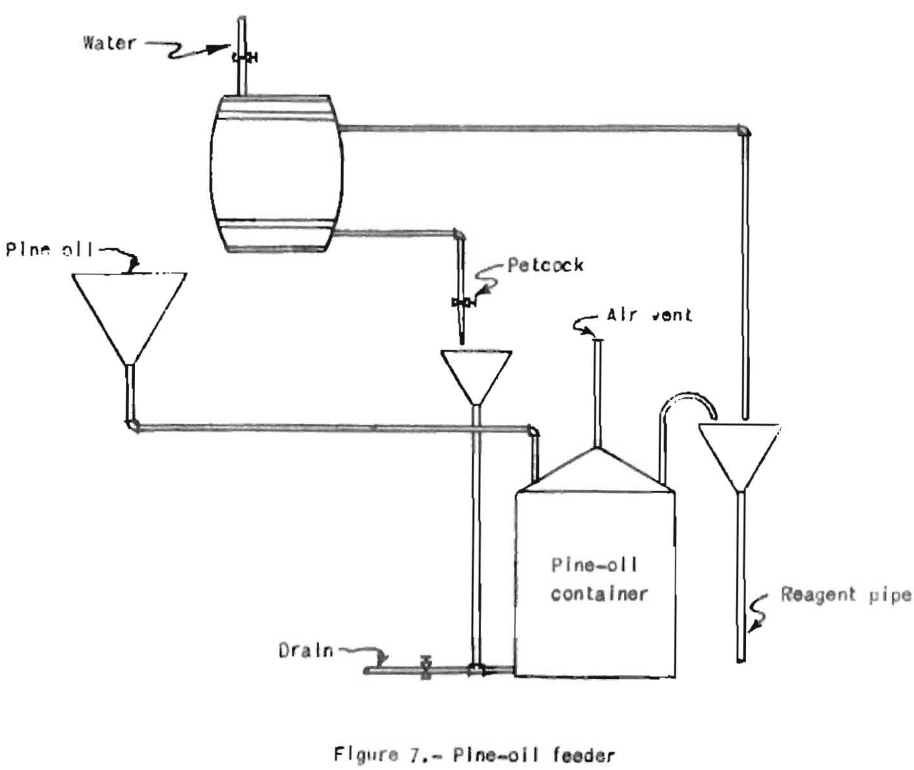


Figure 7.- Pine-oil feeder

Table 16.-Amount of flotation reagents per ton of flotation feed

Using cresylic acid		Using pine oil	
Reagent	Per ton of flotation feed, pounds	Reagent	Per ton of flotation feed, pounds
Cresylic acid	0.20	Pine oil	0.06
Potassium xanthate	.083	Potassium xanthate	.083
Sodium cyanide	.04	Sodium cyanide	.04

Table 17.-Flotation machine data

Flow-sheet serial	(59) (72)	(60) (73)	(63)	(66)	(69)
Machines, in use	24	24	2	2	Two, 2-cell
Type	Low-pressure pneumatic				Mechanical
Size	37 inches wide by 38-1/2 inches deep				44 by 59 inches
Manufacture	St. Joe	St. Joe	St. Joe	St. Joe	Denver Sub-A
Service	Rougher	Cleaner	Recleaner	Small recleaner	Final recleaner
Length, feet	36	12	42	12	
Impellers, diameter, inches	-	-	-	-	24
Overflow height:					
Tailing, do.	18	18	21	19	-
Froth, do.	27	24	32	39	21
Air header, diameter, do.	16	16	16	16	-
Air pipes:					
Size, inches	Diameter, 3; opening, 1/4 by 3-1/2				-
Number	48	12	60	18	-
Length	To within 5 inches of bottom of trough				-
Blower type	G. E. type F S 353, 3,500 r.p.m.				-
Air, per minute, cubic feet	4,000 per unit		4,000 each	1,700	-
Pressure, ounces	12		12	16	-
Motor capacity, horsepower	18		18	12	Two, 5 each
Drive	Direct		Direct	Direct	4-belt texrope

Table 18.-Data on Dorr thickeners

Flow-sheet serial	(31)	(71) (75)
Thickeners, in use	2	2
Type	Traction	Central-shaft
Feed	Flotation feed	Flotation concentrate
Diameter ... feet	150	50
Depth ... inches	15	--
Speed ... r.p.m.	0.29	0.15
Solids:		
Per 24 hours, dry ... tons	1,454, each	--
In feed ... per cent	4.42	--
In discharge ... do.	48 to 55	--
In overflow ... do.	Trace	--
Area per ton per 24 hours ... square feet	11	--
Motor capacity ... horsepower	10	5
Drive, type	Direct-connected, gear reducer and spur gear	Motor, gear reducer, chain-and-sprocket

Screening and Mechanical Classification

Vibrating Screens

Screens are used at two places in the flow sheet. Dry screening is done in closed circuit with the roll grinding, and wet screening is carried on in closed circuit with the primary rod-mill grinding. Vibrating screens of the Leahy type are used throughout. Some of the screens have ball-bearing head motions but most of them are of the babbitted-bearing type. Woven wire with square openings is used for both wet and dry screening. The details of operation are given in Table 19.

Drag Deslimers

Desliming is by 21 drag deslimers and 2 tank drags. They are of the Esperanza chain type, and are driven by belt and spur gear. Some of them remove slime and divert it to the Dorr thickeners, and others serve only as dewaterers. No spray water is used, but water is added to the bowl of the drags treating the wet-screen undersize. The operating data on drags are given in Table 20. (The reciprocating rake drags used for tailing disposal will be treated in another section).

Table 20-a shows data from an efficiency test of a drag deslimer.

Mechanical Handling

The mechanical handling of the ore is by belt conveyors, bucket elevators, sand and slime pumps, and launders.

Table 19.-Screen data

Flow-sheet serial	(16)	(26)
Screens, in use	12	12
Width, effective ... inches	45	28
Length, effective ... do.	48	[1]55
Slope per foot ... do.	8-1/4	7-3/8
Tension application	Side	Side
Opening ... inches	0.17	0.12
Wire size, and diameter ... do.	No. 14, 0.08	No. 14, 0.08
Life ... days	[2]16	[2]16
Vibrator pulley speed ... r.p.m.	189 to 203	197 to 239
Vibrations:		
Per revolution	8	8
Per minute	1,512 to 1,624	1,576 to 1,912
Amplitude ... inches	1/8	1/8
Feed:		
Character	Roll discharge	Primary rod-mill discharge and section feed (wet)
Per hour per screen ... dry tons	107	35.4
Per square foot ... do.	7.1	3.3

1 - At each end 1½ inches and 3½ inches are doubled back; screen sheets are 60 by 34 inches.

2 - Working days of 24 hours each.

Belt Conveyors

The belt conveyors use 2,421 feet of belting over a total transporting length of about 1,200 feet. The connected power is 205 hp. The discharge of the primary crushers is transported by belts to the secondary storage bin. The discharge of this bin is conveyed from the feeders to the horizontal disk crushers, and the finished roll product is conveyed to and distributed over the concentrator storage bin. The deslimed table tailing is conveyed by belt to the pump box preparatory to mixing with part of the flotation tailings to be pumped to the tailing pond. The mechanical and operating details of the conveyors are given in Table 21. Specifications for conveyor belting call for 32-ounce duck, a friction of 25 to 30 pounds and a tensile strength of 3,500 to 4,000 pounds.

A belt conveyor transports the flotation concentrate from the dryer to the box-car loader, and two belts carry the gravity concentrates from the bin to the box-car loader; these are, however, small installations and are not described in Table 21.

Table 20.-Drag-deslimer data

Flow-sheet serial	(27)	(38)	(40) (46)	(51)	(34)
Drag deslimers, in use	12	6	2	1	2
Type	Esperanza	Esperanza	Esperanza	Esperanza	Tank drags[1]
Incline, length ... feet	15	14½	12	12	([2])
Slope per foot ... inches	5¼	8½	4¼	5½	7¾
Width ... do.	52	56½	55	68	22
Speed ... r.p.m.	30.7	33.9	37.0	33.0	31.8
Chain spacing ... inches	29	48	24	42	Single chain
Flights:					
Number	52	37	32	34	41
Spacing ... inches	8	12	12	12	16
Size ... do.	41x3x3/8	46x8x3/8	46x3x3/8	54x3x3/8	16x3x3/8
Feed:					
Character	Wet screen undersize	Low-grade primary table middlings	Middlings in retreatment circuits	Low-grade middlings from second middling section	Table concentrate
Per 24 hours ... dry tons	625	300	-	-	(Table 25)
Rake product ... do.	430	300	-	-	-
Overflow ... do.	195	-	-	-	-
Motor capacity ... horsepower	10, for 4 drags	5	5	5	5

1 - Cylindrical tank, diameter 9 feet, height 8½ feet.
2 - Flight length 57.6 feet.

Table 20-a.-Efficiency of a drag deslimer

Size, mesh	Weight, per cent		
	Feed	Discharge	Overflow
Plus: 6	0.4	0.7	-
8	6.5	9.4	-
10	9.4	14.4	-
14	7.1	11.0	-
20	4.3	6.6	-
28	6.0	8.9	-
35	7.2	8.7	0.1
48	8.0	11.0	.5
65	12.8	14.0	7.4
100	4.6	3.3	8.2
150	4.5	2.3	9.3
200	4.4	1.7	9.9
Minus: 200	24.8	8.0	64.6
Total	100.0	100.0	100.0

Table 20-a.-Efficiency of a drag deslimer (Continued)

Product	Tons per 24 hours: Feed	Discharge	Overflow	Removed in overflow, per cent
Solids	1,474	972	502	-
Water	[1]1,222	192	1,030	[2]84
Through 200 mesh	[3]380	[3]73	[3]307	[2]81
150 to 200 do.	66	16	50	[2]76
100 to 150 do.	68	21	46	[2]68
65 to 100 do.	70	31	39	56
48 to 65 do.	180	141	39	22

1 - Including fresh water.
2 - 78.5 per cent efficiency through 100 mesh.
3 - Correct numbers. Those not marked check very closely.
Note: Type of deslimer, Esperanza; Width, 46½ inches; slope, 8½ inches per foot. Flights, length 46½ inches; depth 3⅜ inches; thickness, ⅜ inch; spaced 12 inches center to center; number, 38. Speed, 44.8 feet per minute. Fresh water, 132 gallons per minute.

Table 21.-Belt-conveyor data

Product conveyed	Flow-sheet serial	Belt details: Length, feet	Width, inches	Ply	Duck belting, ounces	Rubber cover thickness, inches: Top	Bottom	Kind of drive	Slope per foot, inches	Speed of belt, f.p.m.	Motor horsepower	Average tonnage per hour
Discharge of three 9 E Telsmith primary breakers	(5)	95	36	5	32	3/16	1/32	Direct with reducer	Horizontal	394.3	5	329
Discharge of above conveyor	(7)	286	36	6	32	3/16	1/16	Belt and spur-gear	3-7/8	483.3	50	329
Feed to Symons horizontal disk crushers, west	(11)	178	24	5	32	1/4	1/16	do.	3-3/4	375.6	20	112
Feed to Symons horizontal disk crushers, east	(11)	178	24	5	32	1/4	1/16	do.	3-3/4	402.3	20	112
Undersize of dry screens	(17)	250	24	5	32	1/8	1/16	do.	Horizontal	320.0	20	224
Discharge of above incline to concentrator	(18)	450	24	5	28	3/32	3/32	do.	3-3/4	472.5	50	224
Mill feed, tripper conveyor	(21)	510	24	5	32	3/32	1/8	do	Horizontal	387.6	20	224
Table tails, east	(89)	124	22	(1)	32	3/32	1/8	Direct with reducer	1	265.4	5	42
Table tails, west	(89)	170	22	(1)	32	3/32	1/8	do.	1	272.0	5	42
Table tails, composite	(90)	180	22	(1)	32	3/32	1/8	Belt and spur-gear	1	374.4	10	84

1 - These belts are all of step construction, 3, 4, and 5 ply.

Bucket Elevators

Both dry and wet bucket elevators are used. Fourteen elevators require 1,585 feet of belting. The discharge of the Symons horizontal disk crusher is elevated to rolls, and the discharge of the rolls is elevated to the screens which are in closed circuit with the rolls. In the sampling plant the rejects of the cutters are returned to the mill feed by an elevator. The concentrator feed is united with the primary rod-mill discharge and elevated to the wet screens. In the flotation concentrate drying plant the discharge of the thickeners is raised to the filter by an elevator. Table 22 gives the mechanical and operating details of these installations.

The elevator belts are covered all around with cider cloth. A tensile strength of 3,500 to 4,000 and a friction of 20 to 24 pounds per square inch on the dry elevators and of 25 to 30 pounds on the wet elevators are specified. The life of both wet and dry elevator belts is three years or more.

Table 22.-Bucket-elevator data

Flow-sheet serial	(13)	(15)	(25)	(96)	(78)
Elevators, in use	2	4	6	1	1
Belting:					
Kind	Rubber	Rubber	Rubber	Rubber	Rubber
Duck, weight ... ounces	36	36	36	34	34
Ply	9	9	8	8	7
Cover thickness:					
Bucket side ... inches	3/16	3/16	1/8	1/8	1/16
Pulley side ... do.	1/8	1/8	1/8	1/8	1/8
Length ... feet	95	116	125	125	56
Width ... inches	28	28	20	16	16
Speed ... f.p.m.	344 to 410	415 to 450	340 to 352	269	460
Buckets:					
Number	67	81	83	62	37
Size ... inches	24 x 8 x 8 1/2	24 x 8 x 8 1/2	18 x 8 x 8 1/2	14 x 8 x 7 1/2	14 x 8 x 7 1/2
Spacing ... do.	17	17	18	24	18
How attached	Bolted with two rows of 3/8-inch bolts; strip of belting used to hold bottom of cups out			One row of bolts	
Pulley:					
Head, diameter and face ... inches	48, 30	48, 30	42, 22	36, 18	36, 18
Shaft, diameter ... do.	4 15/16	4 15/16	[1]4 15/16	3 7/16	3 7/16
Boot, diameter and face ... do.	30, 30	30, 30	30, 22	24, 18	24, 18
Elevator inclination	Vertical	Vertical	Vertical	Vertical	Vertical
Feed:					
Character	Symons discharge	Roll discharge	Wet screen feed	Mill feed, sample reject	Thickened flotation concentrates
Pulp per hour ... tons	112	322	111	3.5	8.5
Solids ... per cent	(2)	(2)	64.1	(2)	69.2
Motor capacity, horsepower	50	50	[3]20	[4]50	5
Drive	Belt and spur gear				Direct with speed reducer

1 - The bore of the pulley is 4 15/16 inches, but the bearings are 4 7/16.

2 - Run-of-mine ore contains 2.75 to 3.0 per cent of moisture.

3 - A 20-hp. motor on each wet elevator also drives two Leahy screens

4 - The 50-hp. motor also drives inclined conveyor from secondary plan

Table 23. - Operating details of sand slime pumps

Product	Primary table concentration				First middling treatment		Second middling treatment			
	Low-grade middling	High-grade middling		Concentrate	High-grade middling	Concentrate	High-grade middling	Concentrate	Low-grade middling	
Flow-sheet serial	(35)	(36)	(37)	(33)	(45)	(44)	(52)	(49)	(50)	(54)
Pumping:										
Source	Basement	Basement	Basement	Basement	Basement	Basement	Basement	Basement	Basement	Rod-mill floor
Disposal	Dewatering drags	Pump (37)	1st middling section drag	Tank drags	2nd middling section, drag	Tank drags	Tables of slime section	Tank drags	Middling rod mill feed drag	Flotation machine
Pumps, in use	12	5	1	6	1	1	1	1	1 in use 1 spare	1
Manufacture	Wilfley	Morris	Wilfley	Morris	Wilfley	Morris	Morris	Morris	Wilfley	Wilfley
Size . . . . . inches . . .	4	(Four, 3 (One, 4	4	4	4	4	4	4	4	4
Motor . . . horsepower	20	10	35	10	20	10	10	10	20	10
Speed . . . r.p.m.	860	860	865	900 or 860	900	870	870	870	865	870
Intake piping:										
Head . . . . . feet . . .	2 1/2	1/2	1 1/2	1/2	2 1/2	1/2	1/2	1/2	3	1/2
Diameter . . . inches . .	6	Four, 4 One, 3	6	4	6	4	4	4	6	[illegible]
Length . . . . feet . . .	1/3 to 1	1/3 to 1	1	1/3 to 1/2	3/4	1/3	3/4	2/3	1	1/2
Fittings	None	None	None	None	None	None	None	Valve	Valve	None
Discharge piping:										
Vertical lift . . . feet	20	4 1/2 to 7 1/2	23	28	33 1/2	26	20 1/2	28	23 1/2	23
Diameter . . . . inches .	Some 4, most 6	Two 3, three 4	4	Three 3, three 4	4, and 6	4	4	4	4	4
Length . . . . feet . .	90 to 157	61 to 19[illegible]	93	53 to 116	107 of 4-inch, 50 of 6-inch	158	76	137	135	80
Fittings	90°, 45°, and hose	90°, 45°, and hose	90°, 45° and hose	90°, 45°, tees, and hose	90°, 45°, and hose	90°, 45° and hose	90°, tees and hose	90°, tees, and 45°	90°, 45° and hose	Valve, and 90°
Feed:										
Rate per 24 hours . tons	225	50	300	17	150	10	10	6	122	122
Solids .. per cent	12	24.7	24.7	5.3	24.7	5.3	24.7	5.3	24.7	20 -25

Product	Flotation										Tailing disposal	
	Dorr thickener feed	Dorr thickeners discharge	Surge tank discharge	Cleaner tailing	Cleaner concentrate and recleaner No. 2 concentrate	Recleaner tailing No. 3	Recleaner concentrate No. 3	Small St. Joe and Sub-A tailing	Small St. Joe concentrate	Sub-A concentrate	Flotation tailing	Combined flotation and gravity concentrate.
Flow-sheet serial	(80)	(55)	(57)	(61)	(62)	(64)	(65)	(67)	(68)	(70)	(74)	(92) (93)
Pumping:												
Source	Basement sump	Dorr thickeners	Surge tank	Rod-mill floor	Rod-mill floor	Rod-mill floor	Rod-mill floor	Rod-mill floor	Rod-mill floor	Rod-mill floor	Basement	Basement
Disposal	Two 150-foot Dorr thickeners	Surge tank	Distributor	Distributor	Recleaner	Cleaners distributor	Cleaners distributor	Cleaners distributor	Sub-A machines	Filtering and drying plant	Slime pond	Slime pond
Pumps, in use	3	2 in use, 1 spare	1 in use, 1 spare	4	2 in use, 2 spares	2	2	1	1	1 in use 1 spare	2 in use, 1 spare	2 in series
Manufacture	Wilfley	Morris	Morris	Morris	Morris	Morris	Morris	Morris	Wilfley	Morris	Morris	Morris
Size . . . . . inches . . .	8	5	5	5	4	4	4	4	4	4	5	5
Motor . . . horsepower	100	40	40	50	10	10	10	20	10	20	40	75
Speed . . . r.p.m.	860	870	870	850	870	870	860	865	850	1130	870	1160
Intake piping:												
Head . . . . . feet . . .	[illegible]	19	4	3	3	3	3	3	3	3	8	3
Diameter . . . inches . .	8	6 and 10	8	5	6 and 4	4	4	4	6	6	8	6
Length . . . . feet . . .	4 1/2	3 1/2 of 6-inch 87 of 10-inch	21	1 1/2	1/2 of 6-inch, 1/3 of 4-inch	1	1	1	2/3	1/2	38	1/2
Fittings	Valve and 45°	Valves, Y, and increasers	90°, and valves	Valve	Reducer, and valve	Valve	Valve	Valve	Valve	Valve, and reducer	90°, tees, and valves	None
Discharge piping:												
Vertical lift . . . feet	41	27	43	41	35	32	32	32	17	7	---	---
Diameter . . . . inches .	8,10,12	---	---	---	---	---	---	---	4	4	One 12, one 8	8
Length . . . . feet . .	6 of 8-inch 16 of 10-inch, 406 of 12-inch	210	94	73 to 151	96 to 81	106 to 122	118 to 122	122 1/2	42	513	3,500	2,700
Fittings	Increasers 90°, 45°	90°, discharge 1 1/2-inch diam.	90°	45°, 90°, and tees	45°, 90°, and hose	45°, 90°, and hose	Hose, 45°, 90°, and valve	45°, 90° and hose	90°, and hose	90°, 45° and hose	90°, and tees	90°, and tees
Feed:												
Rate per 24 hours . tons	667	1,600	3,200	600	----	----	----	----	----	----	----	----
Solids .. per cent	4.5	45-50	20	10	12	----	----	----	----	----	22	35-38

Malleable iron buckets of the "AA" type, having a reinforced front edge and corners, are used. The life of the wet elevator buckets is about 11 months. Formerly the dry elevator buckets wore away at the front corners, but now the lip is reinforced by welding on an edge of Hascrome or Stoody rod.

Solid boot pulleys are used instead of the rimless pulleys employed in some of the other mills of the district. The operation of the solid pulley has been satisfactory, and the wear not excessive. Both wooden and oil-packed steel bearings are used in the boots.

Sand and Slime Pumps

Pumps are used for the dispostion of sands and slimes. (The water pumps will be discussed elsewhere). They are all of the centrifugal type, 3, 4, and 5 inch Morris pumps, and 4 and 8 inch Wilfleys, and are direct driven by induction motors. No water is used on the Wilfleys, but clear water is used on the stuffing boxes of the Morris pumps. The details of sand and slime pump operation are given in Table 23.

The two makes of pumps are used more or less interchangeably. However, certain features in the designs have been recognized as more adaptive to one service than another. The positive suction at the intake of the Morris pump enables it to lift fine flotation products from a lower level. On the other hand, the gravity intake of the Wilfley has led to its use on coarser and heavier products that can not be lifted by suction. The absence of suction by the Wilfley pumps prevents the air locking that causes surging in other pumps. It is claimed that the cost of upkeep of the Wilfley pumps is considerably less, and there is a tendency to use them for coarser, heavier, or more abrasive solids.

Launders

Launders of the box-conduit, hose, and pipe type are used. The box-conduit launders are used for large tonnages and for smaller tonnages if more convenient than the other types. The principal uses of this type of launder are for transporting the desliming-drag discharges to the 2-way revolving distributors feeding the hydraulic classifiers, and for carrying the spigot discharges of the classifiers to the concentrating tables. These launders are lined with cast iron or rubber; a flat piece is laid in the bottom and a triangular piece of wood moulding is used to line the corners. Rubber hoses are used for uniting small tonnages in a common launder or pump sump. The pipe type is used only for slime. The data on the box-conduit launders are given in Table 24. Other launders are used for the disposition of the table products; they are not included.

Table 24.-Box-conduit launders to hydraulic classifiers and concentrating tables

Product	Desliming drag, rake discharge	Flow-sheet serial	Hydraulic-classifier spigot products								Flow-sheet serial
Transportation:											
From	Drag deslimer	(27)	Hydraulic classifier								(30)
To	2-way distributor	(28)	8 primary tables of each half section								(32)
Launders, in use	6		96								
Width ... inches	12		4 3/4								
Depth ... do.	9		3								
			Table number								
			1	2	3	4	5	6	7	8	
Slope per foot, minimum ... do.	2		3 15/16	6 1/2	7	4 3/8	2 1/4	2 1/2	2 1/8	2 1/4	
Feed:											
Solids ... per cent	22.4		34.8	34.0	33.6	20.0	37.3	38.0	39.3	28.8	
Rate per 24 hours ... tons	850		(See Table 10)								

DEWATERING THE CONCENTRATES

Table and flotation concentrates are dewatered separately. Figure 8 is the flow sheet of the dewatering of these products.

Gravity Concentrates

The table concentrates are first dewatered in two tanks equipped with drag mechanisms. The tanks give a longer periphery for overflow and more depth than is customary on other drags. The water overflows and joins the flotation concentrates, the dewatering of which is discussed later. The drag discharge is further dewatered in a Dorrco filter. The filtered concentrates drop into two bins from which they are conveyed to a Stephens-Adamson box-car loader and loaded for shipment. The details of the operation of the tank drags are given in Tables 20 and 25.

Table 25.-Operation of tank drags for table concentrates

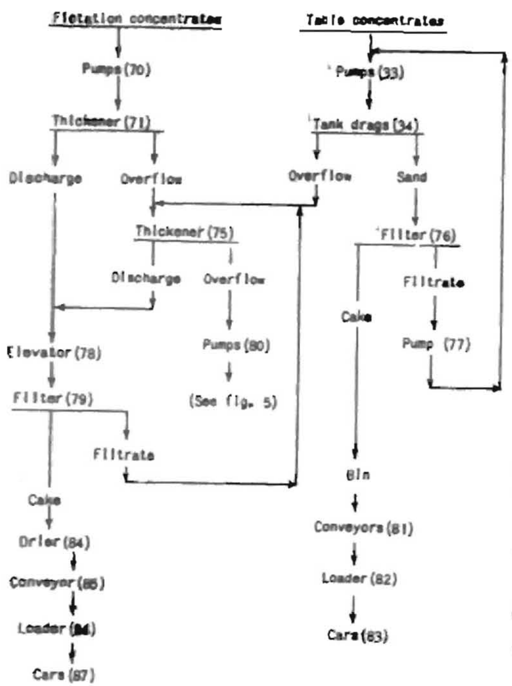
(See also Table 20)

Flow-sheet serial	(34)
Feed:	
Rate per 24 hours, wet ..... tons	2,796
Rate per 24 hours, dry ..... do.	148
Water in ..... do.	2,648
Solids ..... per cent	5.3
Rake discharge (filter feed):	
Rate per 24 hours ..... tons	165
Water in ..... do.	17
Water rejected ..... do.	2,631
Solids ..... per cent	90
Overflow:	
Rate per minute ..... gallons	439
Solids per gallon ..... grams	2
Solids per 24 hours ..... tons	1.4
Assay, lead in solids ..... per cent	60.7

The Dorrco filter feed of about 145 tons per 24 hours contains 10.2 per cent of moisture and is reduced to 134 tons with 2.8 per cent moisture; this product is the finished gravity concentrate. The water rejected, 11 tons per 24 hours, is 74.6 per cent of the water in the filter feed; 25.4 per cent of the water, or 3.75 tons is still contained in the finished product.

The Dorrco filter is 10 feet in diameter by 2 feet long and is operated at 1 r.p.m. The filter cloth consists of burlap supporting Victor twill, which is discussed later in the operation of the Oliver filter. The cloth is held in place by ropes. The filter is driven by a 5-hp. induction motor, 1,140 r.p.m., through a Philadelphia Gear Works speed reducer, ratio 12.75:1, connected with the filter by a chain-and-sprocket drive.

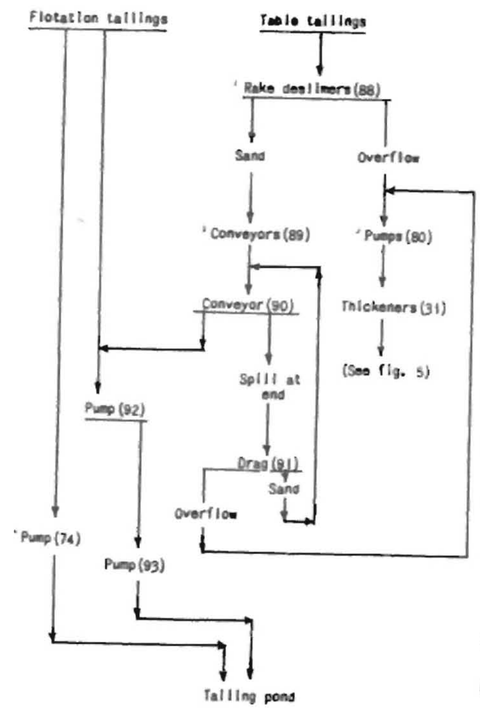
The vacuum pump used in connection with the filter is an Ingersoll-Rand with a 14 by 5 inch vacuum cylinder. It is operated by a 15-hp. induction motor with Texrope drive. From 12 to 16 inches of vacuum is maintained.



Mechanical details

(33) 4-inch Morris pumps (see Table 23)
(34) Two tank drags (see Tables 20 and 25)
(70) 4-inch Morris pumps (see Table 23)
(71) 50-foot Dorr thickener (see Table 18)
(75) 50-foot Dorr thickener (see Table 18)
(76) Dorrco filter, 10-foot diameter by 2 feet long, 1 r.p.m., 5-hp. motor
(77) 2-inch Gould pump, 1,720 r.p.m., 5-hp. motor
(78) 16-inch bucket elevator (see Table 22)
(79) Oliver filter, 11 feet 6 inches in diameter by 12 feet long, 0.12 r.p.m., 5-hp. motor
(80) Three 8-inch Wilfley pumps (see Table 23)
(81) Two 24-inch belt conveyors, 9 feet long; 3-hp. motor; Reeves No. 0 for both
(82) Stephens-Adamson box-car loader
(83) Box cars, 40 to 50 tons capacity
(84) Lowden drier, 12 by 28 feet long, 11-inch stroke, 2.4 s.p.m., 5-hp. motor; gas-fired
(85) 24-inch belt conveyor, 24 feet long; 40 feet per minute chain drive at tail pulley from drier
(86) Stephens-Adamson box-car loader
(87) Box cars, 40 to 50 tons capacity

Figure 8.- Flow sheet of concentrate dewatering



Mechanical details

(31) Two 150-foot Dorr thickeners (see Table 18)
(74) 5-inch Morris pumps (see Table 23)
(80) Three 8-inch Wilfley pumps (see Table 23)
(88) Four rake classifiers (see Table 26)
(89) Two 22-inch belt conveyors (see Table 21)
(90) One 22-inch belt conveyor (see Table 21)
(91) 23-inch single-chain drag deslimer; 16 feet long, slope 5.9 inches; 48 flights, 19 by 2 by 1/4 inch; spacing 8 inches; 16.2 feet per minute; 3-hp. motor
(92) 5-inch Morris pump (see Table 23)
(93) 5-inch Morris pump (see Table 23)

Figure 9.- Flow sheet of tailing disposal

A Connersville blower, size 20 B, supplies the pressure for removing the cake. It is operated by a 3-hp. motor, 1,140 r.p.m., direct-connected. A pressure of 2 to 4 pounds, depending on the condition of the filter cloth, is maintained.

A small Goulds pump, direct-connected to a 5-hp. motor, running at 1,720 r.p.m., removes the filtrate to a pump that feeds the tank drag.

Flotation Concentrates

The flotation concentrates, together with the overflow of the tank drags, are dewatered in a 50-foot Dorr thickener and the overflow is settled in another thickener of the same size. The overflow of the second concentrate thickener is returned to the pumps that elevate the slime to the big flotation-feed Dorr thickeners. The thickened concentrates from both concentrate thickeners are elevated to an Oliver filter. The filtrate is returned to the second concentrate thickener, and the cake is dried on a Lowden dryer. The dried concentrate is conveyed to the box cars and loaded by a Stephens-Adamson box-car loader.

Two 8-hour shifts with four hours intervening are necessary for dewatering and drying the flotation concentrates. The operating time is adequate to handle the 3-shift production of the flotation plant.

Flotation produces 3.9 dry tons of concentrate per hour. This is pumped to the first 50-foot Dorr thickener in a pulp of 13.3 per cent of solids, so that the gross weight is 29.3 tons per hour. Thus, 25.4 tons of water per hour goes to the first Dorr thickener.

The time of operation of the filter is 16 hours per day, and the amount treated by the drying plant is 5.9 dry tons per hour of operation.

The concentrate thickeners discharge 8.5 tons of pulp of 69 per cent solids per hour for a period of 16 hours, and for the remaining two 4-hour periods nothing is drawn from the tank. Hence, of the 25.4 tons of water per hour sent to the Dorr thickener, 359 tons for 16 hours and 210 tons for 8 hours, or a total of 569 tons for the 24-hour shift, is rejected; 41 tons remain with the feed of the Oliver filter.

The Oliver filter feed of 8.5 tons per hour in a pulp of 69 per cent solids is reduced to 6.7 tons per hour in a product with 12.1 per cent of moisture. The water rejected in the filtering is 1.8 tons per hour.

The Lowden dryer reduces the moisture of the cake from 12.1 to 7.3 per cent. The dried concentrate is 6.4 tons per hour, and the water rejected by the dryer is 0.3 tons per hour. The amount of water rejected in the successive steps is as follows:

Source	Tons per 24 hours	Weight, per cent
In Dorr tank	569	93.3
In Oliver filter	28	4.6
In Lowden dryer	5	.8
Remaining in concentrate	8	1.3
	610	100.0

The Oliver filter is 11 feet 6 inches in diameter and 12 feet long, and is driven through a worm gear at a speed of 0.12 r.p.m. Two covers are used; they consist of a burlap cover and a 14 by 37.5 foot Victor twill, No. 223. The wire for holding the covers is a No. 12 hard-drawn, galvanized steel wire would spirally with a pitch of 3/4 inch. The life of the filter cloth is 11 months. The long life is probably due to its being given every 7 or 8 weeks an acid wash in which 114 pounds of commercial hydrochloric acid is used. The bowl of the filter is of the shallow semi-cylindrical type. To keep the concentrates in suspension in the bowl a reciprocating paddle is used.

The two vacuum pumps, one of which is a spare, are the Oliver make, Type M O, 14 by 8 inch cylinder, 300 r.p.m. Each has 400 cubic feet displacement and is operated by a 25-hp. motor. The vacuum is maintained at 15 to 16 inches.

From 1 to 3 pounds air pressure is used to displace the cake. The pressure depends on the condition of the canvas; very little is required for a new canvas. The cake is drier with an old canvas than when a new one is used; with a new canvas the moisture in the cake may run as high as 20 per cent, but the cake is generally thicker.

The Lowden dryer is 12 feet wide and 28 feet long and is driven by a 5-hp. motor. The rake mechanism makes a forward stroke of 11.5 inches at the rate of 2.4 r.p.m. and has a lift of 3 inches. Natural gas is used for heating.

A flat arch over the fire box of the Lowden dryer is employed. Formerly the ordinary arch construction was used and considerable trouble was encountered from failure. The flat arch has eliminated this fault. The method of construction is as follows:

There are three horizontal I-beams over the fire box, perpendicular to the long axis of the dryer. Six smaller I-beams are bolted to the underside of these and perpendicular to them. On the smaller I-beams are hung six rows of 24 fire bricks. Each brick is 10.5 inches wide, 5 inches long, and 12 inches high and is made with a center groove to fit the I-beams so that the top of the brick is flush with the upper horizontal part of the beam. All of the bricks are fitted closely together.

DEWATERING AND DISPOSAL OF TAILINGS

Only the table tailings are dewatered prior to disposal. They are then mixed with a portion of the flotation tailings and pumped to the slime ponds. The rest of the flotation tailings are pumped separately to waste. The flow sheet of the dewatering and disposal of tailings is given in Figure 9. The table tailings are dewatered in four Dorr rake deslimers. The details of the rake deslimer operation are given in Tables 26 and 26-a.

Since the adoption of the method of pumping the combined tailings to waste, the classifiers serve principally as deslimers, whereas with the old system of conveying the tailings to waste, their principal use was for dewatering. The rake overflow is joined with the flotation feed and the sands are collected, repulped, and pumped to waste. A second pump in series is used to keep up the velocity and prevent settling of the sands in the pump line leading to the tailing pond.

Table 26.-Reciprocating rake-deslimer data

Flow-sheet serial	(88)
Classifier:	
Type	Duplex reciprocating rake
Size ... feet	8 1/3 by 30
Slope per foot ... inches	4
Lift ... do.	4
Stroke ... do.	11
Speed per minute ... strokes	17.6
Motor ... horsepower	10
Feed:	
Rate per 24 hours, wet ... tons	1,700
Rate per 24 hours, dry ... do.	381
Solids ... per cent	22.4
Rake discharge:	
Rate per 24 hours, wet ... tons	498
Rate per 24 hours, dry ... do.	374
Solids ... per cent	75.2
Overflow:	
Rate per 24 hours, wet ... tons	1,202
Rate per 24 hours, dry ... do.	7
Solids ... per cent	0.57
Water removed ... do.	90.6

Table 26-a.-Sizing analyses of rake-deslimer products

	Weight, per cent		
Size, mesh	Feed	Rake discharge	Overflow
Plus: 28	5.1	5.2	-
35	13.1	13.0	-
48	25.0	27.1	0.6
65	35.9	39.2	2.3
100	10.2	8.2	9.6
150	6.5	4.6	17.2
200	2.6	1.9	18.3
Minus: 200	1.6	.8	52.0
Total	100.0	100.0	100.0

The tailing-pond dam consists of current table tailings, and it is raised from time to time to keep pace with the filling of the pond. To build the dam, or to raise it, clear water, in place of flotation tailings, is pulped with the table tailings; the sand deposits more rapidly on the top of the embankment when pulped in this manner. The flotation tailings are deposited simultaneously on the inner side to seal the bank. The dam requires attention about once a year.

The pond overflow is recovered by a vertical concrete tower, 5.5 feet square, located within the impounded area. The lower portion is concrete on four sides and the upper part has only two opposite sides extended. These sides are built with notches at both ends, and timbers are filled in to raise the weir as often as necessary to obtain a clean overflow. The tower is bottomed by a horizontal tunnel extending through the dam. Through this tunnel the intake lines of the pumps for returning the clear water to the mill are laid; pipes are connected with the bottom of the vertical tower which forms a sump (see fig. 11).

SAMPLING

The mill feed sample is taken as the ore drops to the tripper conveyor over the mill bin. The further treatment is shown in the flow sheet of the sampling plant, Figure 10. over a period of five months the assay determined by sampling the mill feed checked the lead as determined by assay and weight of concentrates and tailings with an error of only one in 200; that is, with an error of 0.02 per cent of lead when the mill feed was 4 per cent of lead.

Two shift samples, table tailings and flotation tailings, are taken by mechanically operated cutters. Fifteen other shift samples — new flotation feed, rougher feed, cleaner concentrate, cleaner tailing, recleaner concentrate No. 1, recleaner concentrate No. 2, recleaner concentrate No. 3 and recleaner tailing, finished concentrate (Denver Sub-A concentrate), Denver Sub-A tailing, reground table middlings (subsidiary flotation circuit feed), subsidiary flotation circuit tailing, table concentrates, A-middling-section concentrate, and B-middling-section concentrate -- are sampled by hand. For the hand samples at least six cuts per shift are taken. The mechanical samplers cut the flotation and table tailings every 18 minutes.

Concentrates are sampled in the cars and also in the mill. In the loading, the table concentrates are leveled in the cars to a depth of 22 inches and flotation concentrates to a depth of 30 inches; the space in front of the car doors is left clear. Three rows of four vertical holes are sampled on either side of the door. The samples are taken by a conical cutter 1 inch in diameter at the bottom and 2 inches in diameter at the top. The entire amount of concentrate held in the cutter is taken as the sample and is cut down in the sample room. Two separate rooms are used for preparing mill samples for assay. The "concentrate room" is used for table and flotation concentrates, and the "ore room" for ore, middlings, and tailings.

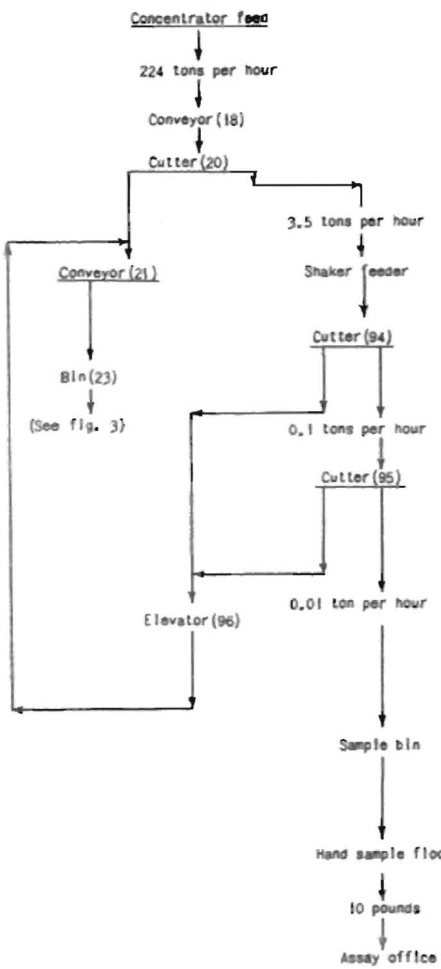
MILL WATER

The mill water is obtained from four sources, the mine, the large Dorr thickeners, the tailing pond, and the table low-grade middling drags. The circulation of the water is shown in Figure 11.

For 11 hours each day the make-up water is pumped from the mine at the rate of 2,000 g.p.m. The total water in circulation is about 10,000 g.p.m., which on the basis of 5,000 tons of ore per 24 hours is a water-to-ore ratio of 12 to 1 by weight.

The thickener overflow is piped to a sump and is pumped to the mill supply tank. The mine water, when pumped, is delivered to the same sump and the overflow is diverted to the tailing pond. The tailing-pond water is returned to the mill when the supply of mine water is insufficient or when the mine pump is not in operation.

The overflow of the drags that dewater low-grade primary table middlings is reused in the mill to dilute the wet elevator feed, to further dilute the same product as it is fed to the drag deslimers, and to dilute the rake discharge of the drags so that it can be laundered to the hydraulic classifiers. The operating data of the pumps for circulating mill water are given in Table 27.



Mechanical details

(18) Belt conveyor (see Table 21)

(20) Vezin-type sample cutter, 1-wing, 4-inch opening, 14.5 r.p.m.

(21) Belt conveyor (see Table 21)

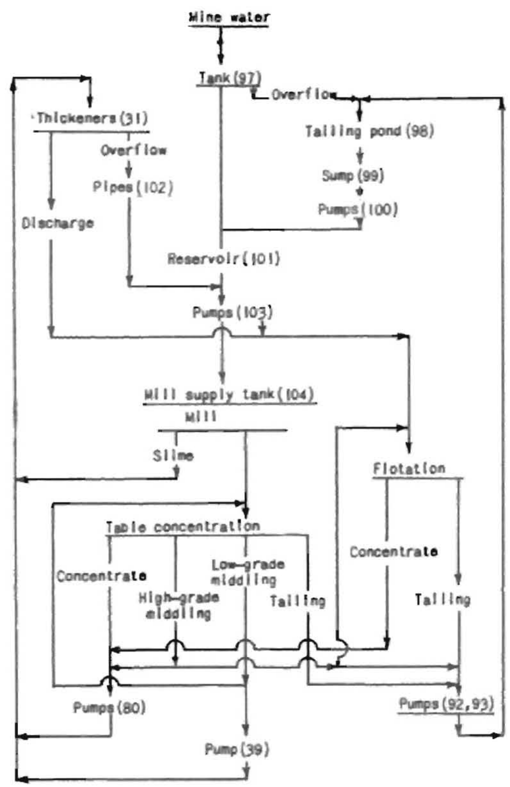
(23) 8,000-ton concentrator bin

(94) Vezin-type cutter, 2-wing, 3-inch opening, 15.6 r.p.m.

(95) Vezin-type cutter, 4-wing, 3-inch opening, 13.6 r.p.m.

(96) 16-inch bucket elevator (see Table 22)

Figure 10.- Flow sheet of sampling plant



Mechanical details

(31) Two 150-foot Dorr thickeners (see Table 18)

(39) 8-inch Wilfley pump (see Table 27)

(80) Three 8-inch Wilfley pumps (see Table 23)

(92) Pump (see Table 23)

(93) Pump (see Table 23)

(97) 500,000-gallon tank, 50 feet in diameter by 33 feet high

(98) Tailings pond

(99) Overflow tower and sump, 5 feet square

(100) Two 10-inch Allis-Chalmers pumps (see Table 27)

(101) Reservoir

(102) 18-inch tile pipes from thickeners, 27-inch pipe to sump

(103) Two 16-inch Alberger pumps (see Table 27)

(104) 108,000-gallon tank, 24 by 24 by 12 feet

Figure 11.- Flow sheet of water circulation

Table 27.-Pumps for mill water

Flow-sheet serial	(103)	(103)	(103)	(100)	(39)	(103)
Pumps, in use	1	1	1	2 (1 spare)	1	2
Manufacture	Dayton-Dowd	Dayton-Dowd	Jeanesville	Allis-Chalmers	Wilfley	Alberger turbine
Size ... inches	16	6	12	10 x 10	8	16
Capacity per minute ... gallons	8,000	8,000	-	2,000	-	5,000, each
Serving	Mill supply tank	Flotation and stuffing boxes on 5-inch pumps	Spare to mill tank	Slime pond to reservoir	-	Spares to mill tank
Motor:						
Type	Synchronous	Induction	Synchronous	Induction	Synchronous	Synchronous
Capacity ... horsepower	250	75	150	50	100	250
Speed ... r.p.m.	1,200	1,755	600	1,740	900	600
Intake piping:						
Head ... feet	4	4	4	-	-	-
Diameter ... inches	20	8	12	-	-	-
Length ... feet	4	4	1	-	-	-
Fittings	90°, and valve	90°, and valve	90°, and valve	-	-	-
Discharge piping:						
Vertical lift ... feet	76, from water surface to discharge	-	76	-	-	76
Diameter ... inches	20	6	12	-	-	-
Length ... feet	76	76	76	-	-	76
Fittings	90°, and valves	90°, and valves	90°, and valves	90°, and valves	90°, valves, and tees	90°, and valves

POWER

The electric power is 3-phase, 60-cycle current transmitted to the mill at a potential of 7,200 volts. It is stepped down to 440 volts for all motors and to 110 for lighting circuits. With the exception of five synchronous motors used on mill water the motors are all of the induction type. A 125-volt d.c. generator, 400 amperes, 50-kilowatt compound wound, driven by a 75-hp. induction motor at 1,150 r.p.m., supplies the direct current for excitation of the synchronous motors and for the two electromagnets in the primary-crushing plant.

Mechanical transmission of power is by many methods. Belt-and-pulley drives, either direct or by means of a line shaft, are used on the primary breakers, secondary crushers, rolls, screens, and concentrating tables. Belt drives with Reeves speed reducers are used on some feeders. Belt and spur gears are used on belt conveyors, drag deslimers, and bucket elevators. The rod mills are driven by herringbone gear and pinion direct-connected by a flexible coupling to the motors. Direct-connected motors are used on the flotation blowers. Direct-connected gear reduction units are used at various places on feeders, thickeners, etc. Bevel gears are used on some conveyor belts in connection with the concentrator feeders. Chain-and-sprocket drive with gear reducers is used on the 50-foot Dorr thickener.

RECOVERY AND LEAD LOSSES

The recovery of lead is between 96 and 97 per cent. The average assays of the feed, tailing, and concentrate for 1926 to 1930, respectively, and for the first five months of 1931 are given in Table 28. During the 6-year period the loss in the tailings was reduced to about one-third of what it was originally. This emphasizes the benefits of research, one of the results of which was the introduction of classification.

A complete analysis of a table concentrate and a flotation concentrate is given in Table 29. The representative lead assays of the shift samples of other products in the mill are shown in Table 30. The metallurgical data of the overall operation are given in Table 31. The screen analyses of table and flotation tailings are given in Table 32.

Table 28.-Average assay, lead in mill feed, tailings, and concentrates, per cent

Product	Assay, lead, percent					
	1926	1927	1928	1929	1930	1931[1]
Feed	3.91	3.92	3.72	3.51	3.55	3.43
Tailing:						
Table	.40	.23	.16	.12	.11	.11
Flotation	.19	.20	.16	.16	.15	.12
Combined	.33	.22	.16	.15	.14	.12
Concentrate:						
Table	72.53	74.38	75.38	74.53	76.52	76.04
Flotation	62.14	71.99	70.89	71.80	71.36	69.42
Combined	69.09	73.54	73.69	73.47	74.30	72.84

1 - First five months.

Table 29.-Complete analyses of table and flotation concentrates

Product	Assay, per cent										Ounces per ton,
	Pb	Cu	Insol.	Fe	CaO	MgO	S	Zn	CO_2	Ni-Co	Ag
Table concentrate	75.89	0.14	0.3	4.5	0.8	0.5	17.0	0.5	1.1	0.12	1.2
Flotation concentrate	73.03	1.11	1.6	3.0	.8	.5	15.9	2.4	1.2	.15	1.9

Table 30.-Representative lead assays of shift samples

Product	Assay, lead, per cent
Gravity concentrates of A-middling section	57.3
Gravity concentrates of B-middling section	71.1
New flotation feed	2.21
Feed to roughers	2.35
Denver Sub-A concentrates (finished flotation concentrate)	73.2
Denver Sub-A tailings	27.2
Cleaner concentrate	45.1
Cleaner tailing	6.21
No. 1 recleaner concentrate	56.9
No. 2 recleaner concentrate	49.6
Recleaner tailings (No. 3 recleaner concentrate and tailing)	4.01
Reground low-grade table middling:	
Rougher feed	6.36
Rougher tailing	0.39
Rougher concentrate	69.6
Cleaner tailing	4.42

Table 31.-Metallurgical data

	1926	1927	1928	1929	1930	1931[1]
Ore treated, total ... tons	1,551,776	1,642,945	1,523,218	1,577,351	1,473,801	492,302
Per 24 hours, average ... do.	5,022	5,301	4,929	5,177	5,047	5,076
Production per man-shift ... do.	35.34	39.31	42.05	45.87	50.38	69.93
Mill shifts operated	927	930	927	914	876	291
Time per day ... hours	24	24	24	24	24	24
Period ... do.	8	8	8	8	8	8
Concentrate, total ... tons	77,713	79,840	70,905	69,942	65,609	21,790
Rate per 24 hours, average ... do.	251.50	257.55	229.46	229.56	224.70	224.61
Table, total ... do.	52,518	51,811	44,170	42,823	37,434	11,448
Rate per 24 hours, average ... do.	169.96	167.13	142.94	140.55	128.19	118.02
Flotation, total ... do.	25,195	28,029	26,735	27,118	28,174	10,342
Rate per 24 hours, average ... do.	81.54	90.42	86.52	89.01	96.51	106.59
Recovery:						
Total lead ... per cent	91.70	94.53	95.77	95.91	96.24	96.64
By tables ... do.	67.6	64.9	62.3	61.2	57.0	52.5
By flotation ... do.	32.4	35.1	37.7	38.8	43.0	47.5
Water consumption:						
Gross ... ratio	-	-	-	12 to 1	12 to 1	12 to 1
Net ... do.	-	-	-	1 to 1	1 to 1	1 to 1

1 - First five months.

Table 32.-Screen analyses of table and flotation tailings, per cent

Size, mesh	Table tailing			Flotation tailing		
	Weight	Assay, lead	Distribution of lead	Weight	Assay, lead	Distribution of lead
Plus: 28	3.5	0.15	4.9	-	-	-
35	13.1	.13	15.9	-	-	-
48	28.7	.10	26.8	-	-	-
65	42.3	.09	35.4	3.6	0.13	3.9
100	8.6	.10	8.0	8.0	.09	6.0
150	3.0	.10	2.8	12.1	.06	6.1
200	.5	.29	1.4	10.6	.06	5.3
325				24.3	.07	13.3
Minus: 325	.3	1.70	4.8	41.4	.19	65.4
Total	100.0	0.11	100.0	100.0	0.12	100.0

LABOR

The workmen are all American-born and in most cases are natives of the district. The labor turnover is low.

A total of 69 men are employed. A superintendent and assistant superintendent are directly in charge of the plant. There are six shift bosses, one per shift in the secondary crushing plant, and one per shift in the concentrator. Sixty-one men are employed in operation and maintenance.

Including the shift bosses, three 8-hour shifts of 11 men per shift are employed in the concentrator, and three shifts of four men in the secondary and roll crushing plants. Two shifts of one man are operated in the primary crushing, and in the flotation concentrate filtering and drying plant. In the case of the 2-shift operation the shifts are separated by four hours. Three men are employed on sampling. The maintenance is handled by a crew of 15 men. The wage scale for the principal classes of labor for 1931 is given in Table 33.

COSTS

The milling costs in units of tons per man per 8-hour shift, kilowatt hours per ton run-of-mine ore, and pounds of reagents per ton of flotation feed are given in Table 34.

Table 33.-Labor costs in 1931[1]

Type of labor	Wage per 8-hour shift
Shift bosses	$4.70
Crusher feeders	3.50
Roll-floor men	3.70
Screenmen	3.25
Rod-mill men	3.70
Rod-mill helpers	3.10
Tablemen	3.70
Table helpers	3.25
Flotation men	3.90
Flotation helpers	3.10
Filter and dryer men	3.90
Concentrate loaders	3.50
Motor attendant	3.55
Maintenance:	
Foreman	4.90
Machinists	3.30 to 4.50
Machinists' helper	3.15
Mill repairmen	4.10 to 4.30

1 - First five months.

Table 34.-Summary of costs in units of labor, power, and flotation reagents

		Per man per 8-hour shift[1], tons		
Labor	Dry crushing	340		
	Wet grinding	567		
	Table concentration	567		
	Flotation	850		
	Sampling	1,700		
	Concentrate filtering, drying, and loading	1,700		
	Superintendence	1,020		
	Maintenance	283		
	Overall	70		

		Per ton of run-of-mine ore, kilowatt-hours		Distribution of power	
		1930	1931[1]	1930	1931[1]
Power	Dry crushing	3.4	3.4	18.9	20.4
	Wet grinding	4.2	4.0	23.3	24.0
	Table concentration	1.6	1.7	8.9	10.2
	Flotation	4.6	4.6	25.6	27.5
	Slime disposal	.4	.4	2.2	2.3
	Concentrate loading	.2	.1	1.1	.6
	Water supply	2.7	2.0	15.0	12.0
	Tailing disposal	.9	.5	5.0	3.0
	Total	18.0	16.7	100.0	100.0

		Per ton of flotation feed, pounds	
		1930	1931[1]
Reagents	Cresylic acid	0.185	0.20
	or		
	Pine oil	.053	.06
	Potassium xanthate	.079	.083
	and		
	Sodium cyanide	.036	.04

1 - First five months, 1931.