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Construction of a concentrating plant in the Waco area of the Tri-State District

William Henry Backer

CONSTRUCTION OF A CONCENTRATING PLANT IN

THE WACO AREA OF THE TRI-STATE DISTRICT

BY

WILLIAM HENRY BACKER

A

THESIS

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Professor of Mining Engineering

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Company: St. Louis Smelting and Refining Company

Personnel: Mr. H. H. Utley, District Superintendent

Mr. W. H. Backer, Metallurgist in Charge of Construction

Mr. E. C. Long, in Charge of Waco Properties and Assistant in Charge of Construction

Mr. B. H. Rucker, Jr., Draftsman

The fee is some five hundred acres of mining land is owned by the company, and an additional two hundred acres is held under a mining lease. Drilling had proved the ore to occur in a dolomitic horizon and to contain from 3 to 12 per cent zinc and small quantities of lead. Early in 1930, some thought was given by the officials of the company to the erection of a concentrator to mill the ore from this acreage. During the ensuing months a basic flow sheet and type of structure were tentatively approved, but no further action was taken for years because of the low prices offered for zinc concentrates.

In the latter part of 1936, interest was revived in these properties, and a detailed estimate of the amount and cost of materials required for the proposed concentrating plant was prepared by the writer. Other estimates were made by the mining department for the opening and equipping of abandoned shafts. Funds for the work were appropriated by the company and were placed in the hands of local officials in September, 1937.

A suitable location for a mill-site was the first consideration. It was decided to erect the structure on land in which the fee was owned by the company to forestall any future litigation relative to the damage to crops or the disposal of tailing. The second consideration in this selection was a site nearest the largest tonnage to be mined so that the least expenditure would be made in hauling the ore to the concentrator. Another problem to consider was topographical features necessary for provision of a large mill pond and a suitable area for disposal of tailing, which might have future sales value. A location adjoining the Kansas City Southern Railroad tracks, and meeting all of the above requirements, was finally decided upon.

Although, as mentioned before, basic line drawings had been made for flow sheet and estimating purposes, it was necessary to make detailed drawings to definitely locate machinery, establish the necessary fall for launders, and obtain an intelligent list of lumber and building material. These drawings were made by the company engineers named in a minimum length of time, and the building foundations were surveyed and staked on the selected location.

On October 4, 1937, excavation was started for the foundations of the main mill building. Four large concrete corner piers and other adequate footings, extending well into the hard-pan,support the main mill structure. A crew of local workmen poured these concrete footings, using a standard brand of cement and locally-procured aggregate, in close succession to excavation. Sand, coarse tailing or chat, and boulders were very plentiful on adjoining properties, and these materials (mixed in varying proportions as the requirements demanded) were used as aggregates for all concrete work. Fresh, soft water was procured from a nearby pond.

The building was to be of wood construction throughout. As a mill structure is subject to severe shocks and stresses, caused by moving heavy machinery and by drives delivering large amounts of power, very rigid construction was necessary. All posts, columns, and caps were of 8-inch by 8-inch pine, knee-braced with 4-inch by 8-inch and 6-inch by 8-inch timbers, as required. The trusses,which were of the Fink type, had 6-inch by 8-inch timbers for the upper chords, and 6-inch by 6-inch spreaders with 1-inch rods for the members in tension. The floor was laid with 2-inch by 12-inch oak plank on 2-inch by 10-inch joists spaced 16 inches apart. The upper truss members support 4-inch by 6-inch purlins, 2-inch by 6-inch rafters, and 2-inch by 4-inch sheathing. This entire building and all accessory buildings were covered with 2-ounce, spot-test, "Seal of Quality" galvanized corrugated steel.

All of the pine lumber was furnished by a local lumber yard. Of this material, the timbers were cut in Arkansas and hauled to the job by truck; dimension lumber (both white and yellow pine) was shipped in from the west. Oak lumber was furnished by owners of small saw-mills in the vicinity at a price of $17.50 per thousand board feet.

A carpenter crew was employed shortly after the excavation started, and by the time the footings were completed, practically all the trusses had been framed and erection of the building was well under way. By the end of October, the same month construction was started, the building was more than half completed, and by the 17th of the following month, it was completely erected, covered, and glazed as far as possible until certain large machines were installed. Meanwhile, the concrete crew had poured practically all the large foundations, all of which were reinforced with either old 8-pound tee rails, salvaged from operating mines of the company, or standard deformed reinforcing bars, the latter being used in the ball mill, crusher, and all roll foundations where severe shocks are encountered.

Typical concrete yardage required for machine foundations used in the mill are as follows:

Table piers	17 cu. yd. each
Ball mill foundation	48 cu. yd. each
Rougher jig foundation	60 cu. yd. each
Cleaner jig foundation	54 cu. yd. each
42-inch by 16-inch sand rolls	24 cu. yd. each
54-inch by 24-inch coarse rolls	52 cu. yd. each
Elevator boots	10 cu. yd. each
Hopper foundation	19 cu. yd. each

A total of 902 cubic yards of concrete was required in the mill and accessory buildings. Careful records of labor, material, and forming were kept, which showed a cost of $6.00 per cubic yard, including cost of excavation.

Since lands owned in fee by the company and lands held under lease were to be mined concurrently, it was necessary to weigh and obtain a correct sample to assay from each batch of ore from each property. These requirements were necessary primarily to ascertain a fair division of the royalty due properties held under lease, and secondarily to obtain for economic purposes a true result of the recovery obtained in the concentrator. It was decided early in the construction period that the primary crushing department would be a separate unit from the mill, but whether to do the final crushing to mill size wet or dry was a subject of long discussion. It was finally decided to crush to minus one inch dry, then weigh and sample; the ore would likely contain some soapstone and very wet material not amenable to dry screening. This also would eliminate a very dusty condition in the final stage of crushing and thus avoid the possibility of the workmen acquiring silicosis. By this time, it was also decided that it would be more economical to haul the ore to the concentrator by trailer-truck units than by surface railroad trains.

Accordingly, a crushing plant was designed embodying all the above features. The construction was carried on in much the same manner as that of the concentrator, and the type of structure was the same on a smaller scale. Although only very small crews of carpenters and laborers were employed during February and March, the mill was completed and ready for operation by April 1, 1938, less than six months after construction was started.

Although the machinery was installed when convenient and desirable, as construction progressed, it will probably be better in this paper to follow the flow sheet when listing and describing the equipment. All machines were powered by electricity.

Two steel receiving hoppers of fifty tons' capacity each were erected ahead of the crushing plant. Each hopper discharges upon a separate pan feeder which in turn discharges upon a 36-inch belt conveyor centered between the two hoppers. A unique drive on the two pan feeders is so arranged that only one can operate at a time, although they have a common drive. Duplication of the steel hoppers was necessary so that delays in hauling from the different properties could be avoided. The pan feeders were regulated to deliver fifty tons of ore per hour to the conveyor.

The 36-inch conveyor discharges into a 30-inch by 18-inch jaw crusher manufactured by the Webb City-Carterville Foundry and Machine Works. The discharge of this crusher falls upon a 24-inch conveyor belt, which discharges into a set of 54-inch diameter by 24-inch width geared rolls. These rolls operate at 45 revolutions per minute; the back or flanged shell is gear driven, and the front or plain shell is belt driven. This machine is also made by the Webb City-Carterville Foundry and Machine Works and will crush the ore to minus one inch. A 24-inch conveyor carries the discharge from these rolls over a Merrick Weightometer, which records the weight accurately within two-tenths of one per cent. The conveyor discharges into a 4-foot Vezin sampler, the reject of which goes to a 24-inch vertical elevator discharging into the mill storage hopper.

A flow sheet of the sample taken by the original 4-foot Vezin follows: The original sample, 10 per cent of the crushing plant product, flows by gravity to a set of 36-inch-diameter, 14-inch-face, belted rolls, which crush the sample to minus one-half inch. A 12-inch conveyor takes the sample to a small elevator to gain sufficient elevation that the sample will flow by gravity through the remaining samplers. This elevator discharges into a 28-inch Vezin sampler, which takes another 10-per-cent sample. This sample passes through a mixing barrel to a set of 12-inch-diameter, 10-inch-face rolls, which reduce the material to minus one-eighth inch. The sample passes through two more 20-inch Vezin samplers with a mixing barrel between them, each sampler taking a 5-per-cent sample of the feed to it. All of these samplers are powered with gear-head motors and cut the stream at the rate of 30 times per minute. The rejects from all the samplers flow by gravity into the elevator feeding the mill storage hopper, and the final sample discharges into a milk can housed inside a cabinet so that any accidental spill cannot salt the sample.

The mill storage hopper is of wood construction designed to hold an 8-hour run for the concentrator, or between four and five hundred tons. Feed to the mill is drawn from this hopper with a 24-inch conveyor belt which discharges into the mill feed elevator. Sufficient height is gained through this elevator for the feed to pass over a 5-foot by 10-foot Robins Gyrex screen, the oversize flowing by gravity to a set of 54-inch-diameter, 24-inch-face rolls, and thence return to the elevator. These rolls revolve at 50 revolutions per minute and are similar to those in the crushing plant, but are belted instead of geared. Both sets of the latter-mentioned rolls are equipped with manganese steel shells and draw-type cores.

The Robins screen is equipped with a woven wire jacket having $\frac{1}{2}$-inch-square openings. The undersize from this screen flows into a belt drag classifier which deslimes the feed to the rougher jigs.

At this point, a classifier which is known as "the live-feed drag," will be referred to. This drag is located near the center of the mill and at sufficient elevation to overflow by gravity into the Dorr thickener. Overflow from all classifiers throughout the mill discharge into this drag and the overflow from it in turn makes up the sole feed to the flotation department. The drag was designed by the company engineers and consists of a large steel tank which permits an overflow on three sides. Sand and coarse material is dragged from the tank up the inclined fourth side by means of blades bolted on a 30-inch belt at 1-foot intervals.

To return to the drag classifier after the Robins screen, the overflow goes to the live-feed drag and the deslimed material is split to two 6-cell rougher jigs. These jigs are of wood construction, and each contains approximately 12,000 board feet of lumber and seven kegs of 20d nails. The cells are each 42 inches in width and 48 inches in length and have a fall of $3\frac{1}{4}$ inches from cell to cell. Plungers operate at 120 strokes per minute, the stroke varying from 7/8 inch on the head cells to 5/8 inch on the tail cells. Rougher jigs are so laundered that the hutch product and the material drawn from the beds of the first four cells go to the cleaner jig elevator. The material from the last two cells of each jig goes to the live-feed drag. A De-Mier cone classifier at the end of each jig completely deslimes the tailings which then flow by gravity to the tailing elevator.

The cleaner jig elevator discharges into a belt drag classifier located ahead of the cleaner jig. The purpose of this classifier is to dewater the feed to the jig. The cleaner jig is also composed of six cells, each 42 inches in length and 36 inches in width. Material required for the building of this jig is approximately the same as for each rougher jig. It operates at 180 strokes per minute, the length of stroke being between 1/2 inch to 5/8 inch for all plungers.

To those unfamiliar with Tri-State milling practice, it is timely to describe in brief the functions of the three jigs. Rougher jigs are used to separate the values from the barren material or gangue, which becomes tailing. The cleaner jig is used to take this enriched product and separate the galena from the sphalerite, and the sphalerite from the barren material and from the material containing some values still locked with the gangue. In other words, a clean lead concentrate assaying up to 84 per cent lead, and a clean zinc concentrate assaying 59 per cent to 61 per cent zinc are made on the cleaner jig. Because galena is the heaviest material, it is cleaned on the first cell. The product of the second cell contains some lead and is returned to the head of the jig through the cleaner jig elevator. Sphalerite is cleaned on the third, fourth, and fifth cells. The product of the sixth cell is a combination of sphalerite and sand and is returned to the head of the jig by means of the elevator. Reject or tailing from this jig flows to the live feed drag.

Nine tables of the latest design manufactured by the Butchart Manufacturing Company, a local concern, comprise the table department. The feed to seven of these tables is furnished by the product of the live-feed drag, which discharges into the sand elevator. This elevator in turn furnsihes the feed to two 4-foot by 5-foot Leahy screens equipped with 2-mm. punched-plate jackets. The oversize from each screen flows by gravity through individual sets of 42-inch-diameter, 14-inch-face, high-speed sand rolls in closed circuit with the sand elevator. Both sets of rolls are equipped with cast iron shells, shingled to their cores.

The undersize from the 2-mm. screens flows into a belt drag classifier discharging into a 3-foot hydraulic classifying cone. The underflow of this cone furnishes the feed to four tables, the overflow going to a 4-foot hydraulic classifying cone. This second cone furnishes the feed to three tables and the overflow returns to the live-feed drag.

Five products are made by each of the first-mentioned seven tables: a zinc-lead middling, a clean zinc concentrate, a zinc sand middling, a middling composed of mineral particles interlocked with gangue, and a tailing. The zinc-lead middling is sent to the ball mill elevator and the zinc concentrate is recovered in a box provided for that purpose. The zinc-sand middling flows to a Wilfley pump and is sent to one table so riffled as to make a desirable separation and a clean zinc concentrate. The interlocked middling flows to the ball mill elevator for further treatment, and the tailing flows to the tailing elevator. No tailings are cut from the zinc-sand middling table, but the reject from this unit is also sent to the ball mill elevator.

The ball mill elevator discharges into a dewatering drag, the coarse product of which drops into the ball mill dipper box and furnishes the feed for the ball mill.

A Marcy ball mill 6 feet in diameter and $4\frac{1}{2}$ feet in length was owned by the company and had been used at another property recently depleted. Although this mill was slightly large for the purpose needed in the Waco area, it had been decided to use it, operating with a minimum grate opening in the discharge end, thereby eliminating excessive liner wear but accomplishing the desired grinding. This mill was so situated and given enough elevation that the discharge flows by gravity into the live-feed drag.

As stated before, the overflow of the live-feed drag comprises the sole feed to the flotation department, the first unit of which is a 60-foot-diameter, Dorr-type thickener. Overflow from the thickener returns to the mill pond and the pulp is pumped from the thickener with a 4-inch diaphragm pump. Other equipment in the flotation department consists of four 3-cell units of Denver sub-areation flotation machines, two Wilfley sand pumps, one Butchart sand pump, one filter feed pump, and one 3-leaf American filter with accessory equipment. Accessories with the filter are a vacuum pump, Roots blower, filtrate pump, and moisture and vacuum traps. Each cell of the flotation machines is 38 inches by 44 inches in area, and the impellers are made of hard rubber. Reagent feeders are provided to add frothers, collectors, and activators.

The diaphragm pump that lifts the pulp from the thickener discharges into a Wilfley pump sump box at which point the reagents necessary to float the lead are added. The Wilfley pump discharge line is piped with a large bleeder returning to the sump box, which acts as an excellent conditioner for the pulp. Only three cells of the flotation machines are allotted to the treatment of lead because of the low lead content of the feed. Froth from the first cell is pumped to a Butchart table for recleaning, and the froth from the second and third cells is returned to the head of the circuit. As all twelve cells are set in line, the cells will be referred to by number for the remainder of the flow. The tails from cell No. 3 (lead tails) are dropped into a second Wilfley pump sump box for conditioning, and reagents to activate the sphalerite and an additional collector are added. This pulp is pumped into cell No. 5. The froth from cells Nos. 5, 6 and 7 goes to cell No. 4 for recleaning, and a clean zinc concentrate is made at this point. This concentrate is pumped to the filter. The tails from cell No. 4 flow into the head of the zinc circuit, i.e., cell No. 5. The froth from cells Nos. 8, 9, and 10 return to No. 5, and the froth from cells Nos. 11 and 12 return to No. 8. The tailings from cell No. 12 flow to the tailing elevator.

Jig, table, and flotation tails were all laundered to one elevator known as the tailing elevator. It was built 60 feet in height from the center of the tail pulley to the center of the head pulley. An additional height of eight feet is required for the head house. Seven 16-foot sections of flume, supported by light timber bents at each section and having a fall of two inches to the foot, discharge the tailings at a suitable distance from the mill.

During the time of construction of the mill, a mill pond was built with teams and scrapers. The dam has two 12-foot spillways to take care of excess water in case of a cloudburst. Both dam and spillways were so constructed that an additional 2-foot depth of water could be held if necessary. A pump house of sufficient size to enclose the mill pump a large fire pump, and the pump sump was built upon completion of the dam. The sump was dug to a depth of 12 feet to prevent swirling, and was lined with concrete.

Water for milling purposes is supplied by a Peerless turbine-type pump capable of delivering 3000 gallons per minute to a height of 40 feet. In order to eliminate friction, a 16-inch discharge line was provided between this pump and the concentrator, a distance of about 500 feet, at which point the diameter was reduced to 12 inches. A 12-inch header was carried just under the mill floor the full length of the mill, and water lines to the various machines were welded into this header. High-pressure water for sprays and water lines in the top of the mill is furnished by a 6-inch Goulds booster pump with its suction welded into the main header.

Individual drives were provided wherever practical for all machines throughout the entire plant. In some cases, where a group of machines had to run as one unit, a line shaft was provided to serve this group.

In the crushing plant where failure of the source of power to any of the machinery would cause dangerous and costly choke-ups to occur, an electrical interlocking device was provided to automatically shut down all machines ahead of the source of trouble. For instance, should the drive to the elevator feeding the mill storage hopper fail, the coarse rolls, crusher, pan feeders under the receiving hoppers, and all intervening conveyors would automatically stop, which would eliminate any serious choke-ups.

A list of the main drives and the horse power required for each follows:

Crusher: Fifty-horse-power, slip-ring motor equipped with a V belt drive.

Coarse rolls: Fifty-horse-power, squirrel-cage motor equipped with a V belt drive to a 15/16-inch shaft, and flat belts to the pulleys on the rolls.

Mill storage hopper elevator: Fifteen-horse-power motor with a flat belt drive.

Regrind or finishing rolls: Fifty-horse-power motor equipped with a V belt drive to a 3 15/16-inch shaft and flat belts to the roll pulleys.

Robins Gyrex screen: Five-horse-power motor equipped with V belt drive.

Mill feed elevator, rougher fig drag, rougher jigs, cleaner jig elevator, cleaner jig drag, and cleaner jig: Seventy-five-horse-power motor equipped with a V belt drive to a 3 7/16-inch shaft and flat belts to the machine pulleys.

Two sets sand rolls, sand elevator, sand drag, ball mill elevator, ball-mill drag, and live-feed drag: Sixty-horse-power motor equipped with a V belt drive to a 3 7/16-inch line shaft and flat belts to the machine pulleys.

Ball mill: One-hundred-horse-power motor equipped with a V-flat drive to the pinion shaft. Power is transmitted from the pinion shaft to the ball mill by means of a Hill friction clutch.

Tables: Individual $1\frac{1}{2}$-horse-power motors with V belt drives.

Flotation machines: Each group of three cells is driven by a 10-horse-power motor and V belts.

All other flotation equipment: Forty-horse-power motor with flat belts to line shafts and machines.

Tailing elevator: Fifteen-horse-power motor equipped with a V belt drive.

Booster pump: Twenty-five-horse-power motor direct-connected.

Peerless mill supply pump: Forty-horse-power motor direct-connected.

Conveyors and pan feeders: Small motors direct-connected to speed reducers with a chain drive to the head pulley of conveyor or feeder.

A very important piece of electrical equipment which should be mentioned at this time is a Dings suspended magnet which hangs over the conveyor between the crusher and coarse rolls to remove all tramp iron in the mill feed.

A total of 681 horse power was connected to operate all of the machinery.

When selecting bearings for the various pieces of equipment, three types were decided upon. For all slow-speed shafts, babbited bearings designed for grease lubrication were used. On higher speed shafts, such as elevator and drag counter, ring-oiling babbited bearings were employed. All main-line shafts transmitting large amounts of power were equipped with either ball or roller pillow blocks of a standard make.

The mill is many miles from any town having available fire-fighting equipment. In order to obtain a reasonable insurance rate, it was decided to install equipment for fire protection at the property that would meet underwriters' specifications. Accordingly, a 3-stage Goulds fire pump, designed to deliver 500 gallons per minute at 100 pounds per square inch pressure, was purchased and installed in the mill pump house. Three fire hydrants with regulation 2½-inch fire hose connections were so located in the mill yard that the mill building, crushing plant, office, shop, and compressor plant could be reached in case of fire. Ample hose was purchased and distributed according to the insurance inspector's recommendations. The source of power for the fire pump and the mill supply pump is on an independent circuit from the mill power. By means of a "pole top," air break switch, all power may be cut off from the transformer house, crushing plant, and concentrator without interruption of service at the pumps.

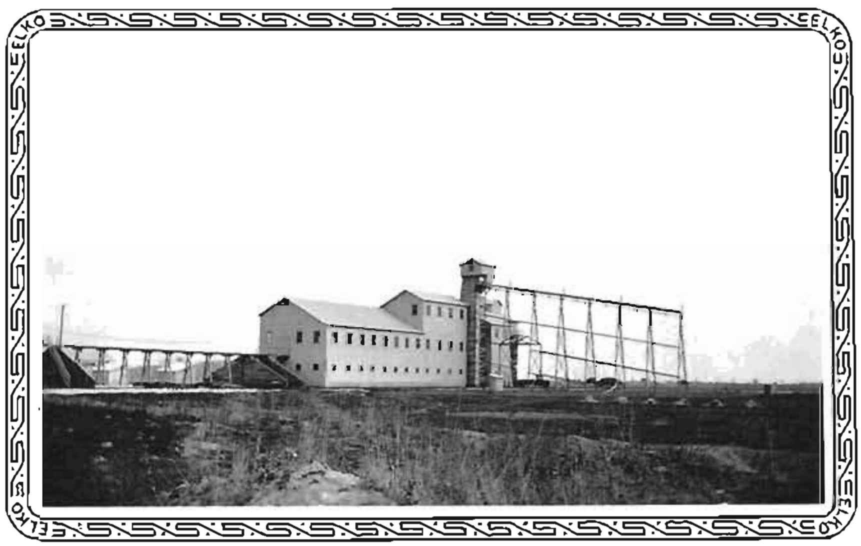
The last accessory equipment necessary to complete the plant was a concentrate storage bin. For this purpose, a reinforced concrete slab 50 feet wide and 100 feet long was poured, outside and adjacent to the mill. An oak trestle was constructed longitudinally down the center of this slab to carry the concentrate cars as wheeled from the mill floor. Oak partitions segregate the different concentrates.

In conclusion, it is worthy of note that, although construction is recognized as one of the most hazardous occupations by all insurance companies, only one lost-time accident was experienced during the construction of this plant. In this instance, a carpenter who had been working in a confined place and in an unnatural position complained of a sore back which caused him to lose ten days' work.

RECIEVING HOPPERS

CRUSHING PLANT AND CONCENTRATOR FROM EAST

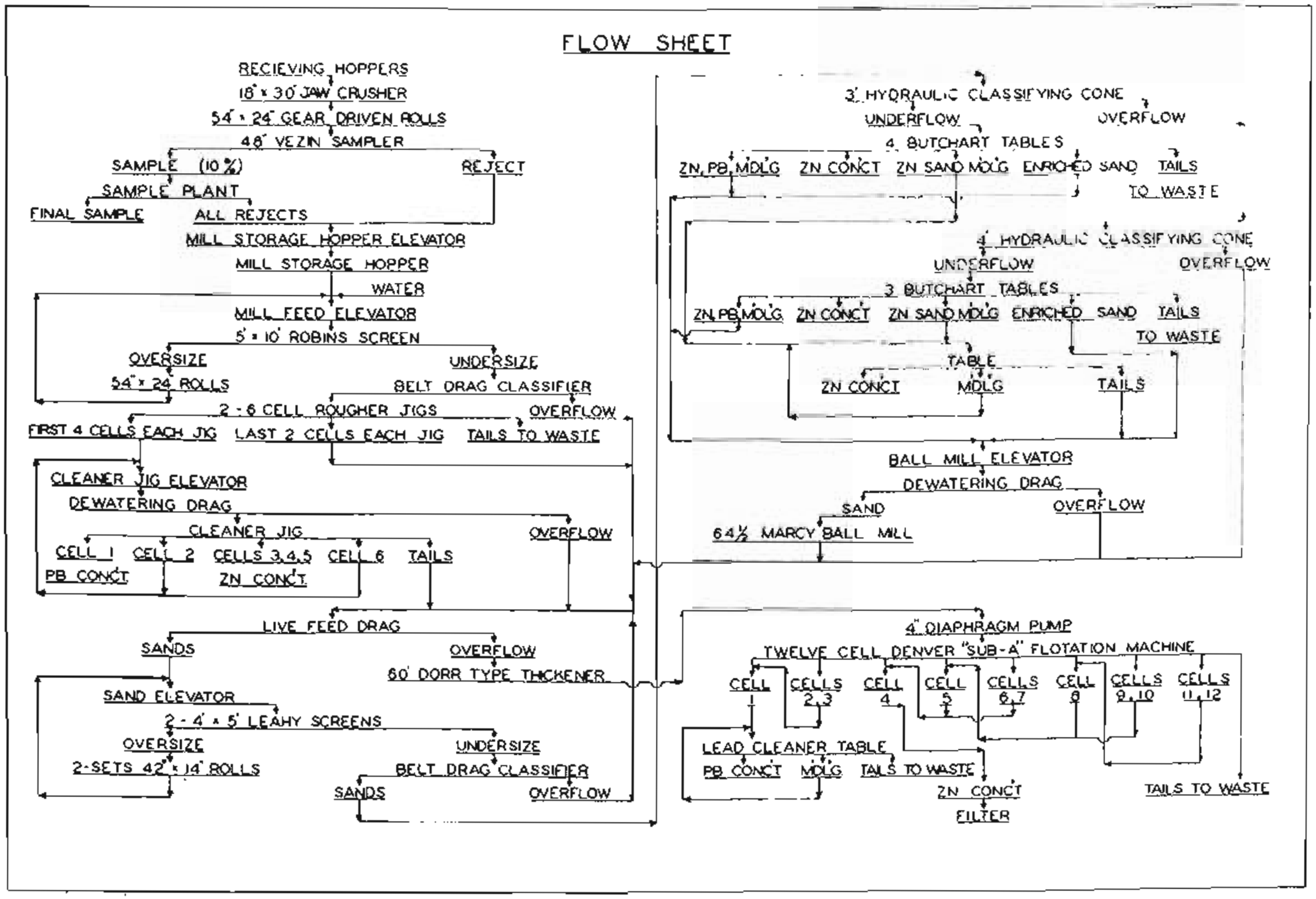
CONCENTRATOR FROM N. W. SHOWING THICKENER AND CONCENTRATE BINS



CONCENTRATOR FROM S. W.

PUMP HOUSE

COMPRESSOR PLANT, SHOP, HEAD FRAME AND HOPPER


FLOW SHEET
RECIEVING HOPPERS
18" x 30" JAW CRUSHER
54" x 24" GEAR DRIVEN ROLLS
48" VEZIN SAMPLER
SAMPLE (10%)
REJECT
SAMPLE PLANT
FINAL SAMPLE
ALL REJECTS
MILL STORAGE HOPPER ELEVATOR
MILL STORAGE HOPPER
WATER
MILL FEED ELEVATOR
5' x 10' ROBINS SCREEN
OVERSIZE
UNDERSIZE
54" x 24" ROLLS
BELT DRAG CLASSIFIER
2 - 6 CELL ROUGHER JIGS
OVERFLOW
FIRST 4 CELLS EACH JIG
LAST 2 CELLS EACH JIG
TAILS TO WASTE
CLEANER JIG ELEVATOR
DEWATERING DRAG
CLEANER JIG
OVERFLOW
CELL 1
CELL 2
CELLS 3,4,5
CELL 6
TAILS
PB CONCT
ZN CONCT
LIVE FEED DRAG
SANDS
OVERFLOW
60' DORR TYPE THICKENER
SAND ELEVATOR
2 - 4' x 5' LEAHY SCREENS
OVERSIZE
UNDERSIZE
2-SETS 42" x 14" ROLLS
BELT DRAG CLASSIFIER
SANDS
OVERFLOW
3' HYDRAULIC CLASSIFYING CONE
UNDERFLOW
OVERFLOW
4 BUTCHART TABLES
ZN, PB, MDLG
ZN CONCT
ZN SAND MDLG
ENRICHED SAND
TAILS
TO WASTE
4' HYDRAULIC CLASSIFYING CONE
UNDERFLOW
OVERFLOW
3 BUTCHART TABLES
ZN, PB, MDLG
ZN CONCT
ZN SAND MDLG
ENRICHED SAND
TAILS
TO WASTE
TABLE
ZN CONCT
MDLG
TAILS
BALL MILL ELEVATOR
DEWATERING DRAG
SAND
OVERFLOW
64½ MARCY BALL MILL
4" DIAPHRAGM PUMP
TWELVE CELL DENVER "SUB-A" FLOTATION MACHINE
CELL 1
CELLS 2,3
CELL 4
CELL 5
CELLS 6,7
CELL 8
CELLS 9,10
CELLS 11,12
LEAD CLEANER TABLE
PB CONCT
MDLG
TAILS TO WASTE
ZN CONCT
FILTER
TAILS TO WASTE