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METHODS OF GOLD ORE DRESSING

at

HEDLEY, B. C.

Report submitted in partial fulfilment of
the course in Applied Science, Third Year,
at the University of British Columbia

Jack Bysterbosch

University of British Columbia

November 15, 1948.

Fort Camp

Vancouver, Canada

November 15, 1948

Dean J. N. Finlayson

Faculty of Applied Science

University of British Columbia

Vancouver, Canada

Dear Sir:

I have the honour to submit a report METHODS OF GOLD ORE DRESSING AT HEDLEY, B. C. as called for by Regulations governing the Course in Applied Science, Third Year, according to Calendar Regulations of the University of British Columbia, 1948.

Yours respectfully,

J. Bysterbosch

J. Bysterbosch

PREFACE

This report is a comparison between the milling processes used by the Kelowna Exploration Company and the Hedley Mascot Gold Mines at Hedley, British Columbia. During the Summer months of 1947 I worked as an operator at the Kelowna mill, while during the summer months of 1948 I worked as an operator at the Mascot mill. Having had some experience at both mills, I hereby endeavour to describe and compare the two processes from information which was compiled by personal inquiries and observations. In doing so I would like to acknowledge the assistance received from the Kelowna mill superintendent, Mr. E.W. Johnson, and the Mascot mill superintendent, Mr. J. Black.

November 15, 1948. J. Bysterbosch

"I"s are too numerous

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at

HEDLEY, B.C.

LOCATION AND HISTORY OF HEDLEY MINES

The gold mining town of Hedley is situated in the Similkameen Valley of southern British Columbia. Hedley is the center of two operating gold mines, the Hedley Mascot and the Nickle Plate. Both these mines are situated on the slopes of Nickle Plate Mountain, which rises about 4,350 feet above the town. The portal of the Hedley Mascot Mine lies on the westerly slope at an elevation of 4,800 feet above sea level, and the Nickle Plate portal lies on the easterly side at an elevation of approximately 5,400 feet above sea level. The mills for both mines are situated near the town on the valley floor.

The oldest of these two mines, the Nickle Plate, was discovered between 1893 and 1902. A mill was constructed and mining operations began in 1904 under the direction of the Daly Reduction Company. In 1909 this company sold the property to the newly-formed Hedley Gold Mining Company which supervised the mine's operation for 21 years. By 1930 the ore deposits were believed to be exhausted and the company was compelled to close down the mine. In 1932 the property was purchased by the Kelowna Exploration Company and extensive development work was done for the next two years. As a result of this development work, mining operations started again in 1934 and have continued successfully up to the present time.

The other of the two producing mines is owned and operated by Hedley Mascot Gold Mines, Limited. This company was formed in 1934 to exploit the long-known mineral deposits in the Mascot fraction of the Nickle Plate claim group. After development work and mill construction were completed, the Mascot production began in April, 1936. Except for a short period of time during the war, this mine has been in continual operation up to the present time.

MINERALOGY OF HEDLEY ORES

Since both mines are exploiting different sections of the same ore bodies of Nickle Plate Mountain, the characteristics of their ores are essentially the same. Consequently, both companies are confronted with the same problems in the treatment of their ores.

The ore, which is common to both mines, is essentially a complex, arsenical gold ore. The metallic sulphides contained in this ore are chiefly arsenopyrite, pyrrhotite, chalcopyrite and sphalerite. The gold, which is extremely fine grained, is associated mostly with arsenopyrite and, to a lesser extent, with pyrrhotite. The gangue consists essentially of greenish-grey chloritic rock, calcite, pyroxene and dipyrite.

The ore taken from the main ore body of Nickle Plate Mountain is extremely hard and brittle. However, the ore taken from an ore body in the lower levels of both mines is comparatively soft due to the presence of chloropal.

The important factors to be considered in the metallurgical treatment of the Hedley ores is that the gold occurs as extremely fine particles within arsenopyrite and that the ore may be either extremely hard or comparatively soft, ~~in nature~~.

GENERAL DESCRIPTION OF THE HEDLEY MILLS

In spite of the similarity in the ores treated, there is a wide difference in milling processes used by the two companies. A few facts must be considered before comparisons can be made as to the specific milling methods that are used.

The Kelowna mill has a capacity of approximately

350 tons of ore in 24 hours. The main steps in the milling procedure of this plant consist of crushing by jaw and cone crushers, grinding by stamps, ball and pebble mills, and the treatment of pulp by cyanidation followed by flotation.

The Mascot mill has a capacity of approximately 160 tons of ore in 24 hours. The main steps of the plant procedure consist of crushing by jaw and gyratory crushers, grinding by ball mills, and the pulp treatment by flotation followed by cyanidation.

Although the Kelowna mill has only about twine the milling capacity of the Mascot mill, it has approximately three times as much floor space. Since the Kelowna mill was constructed about 45 years ago, a considerable amount of floor space has become useless with later installations of newer types of machinery which occupy less space. Since the Mascot plant was constructed only 12 years ago, the machinery is more compactly installed and of a newer design than that of the Kelowna mill, where some of the original machinery is still being used.

COMPARISONS BETWEEN THE MILLING PROCESSES

CRUSHING AND SCREENING

The crushing operations of both mills are similar in many respects. For primary crushing, both Mascot and Kelowna mills use 24-in. by 36-in. Traylor jaw crushers. At the Mascot the jaw crusher is fed from the ore bin by means of a Jeffrey Pan Conveyor, which controls the rate of feeding.

At the Kelowna mill the jaw crusher is fed by a chute directly from the coarse ore bin, the rate of feed being manually controlled. For finer crushing, the Mascot uses a 3.7-ft. gyratory crusher while the Kelowna uses a 4-ft. Symons cone crusher. (see Fig. 1 & 2).

The use of a Jeffrey Pan Conveyor at the Mascot is a definite advantage over the Kelowna's method of feeding, since the jaw crusher can be fed without the constant attention of an operator. However, when the ore is in the form of "gouge", it will adhere to the bottom of the pan conveyor and cause considerable difficulty in the feeding process.

The two mills have different arrangements for the screening of crushed ore. The Mascot uses a 2-ft. by 5-ft. Niagara Screen for removing the fine particles from the jaw crusher product. This is done so that the fine particles may by-pass the gyratory crusher. For this same reason the Kelowna mill uses a 4-ft. by 8-ft. Tyrock Screen. Here, however, this screen is also used as a picking table for the hand-sorting of the ore as it passes over the screen. Suitably sized lumps of suitable ore are picked ~~off~~ from the screen and transferred to the grinding floor where they are used as grinding media for the pebble mills. At the Mascot mill the product from the gyratory crusher is passed over a 6-ft by 7-ft. Niagara vibrator screen which allows only particles of specified size to enter the fine-ore bin. Any oversize is returned to the gyratory for re-crushing. (Fig.2). At the Kelowna mill a 3.5-Ft. by 9-ft. Denver Dillon Screen removes

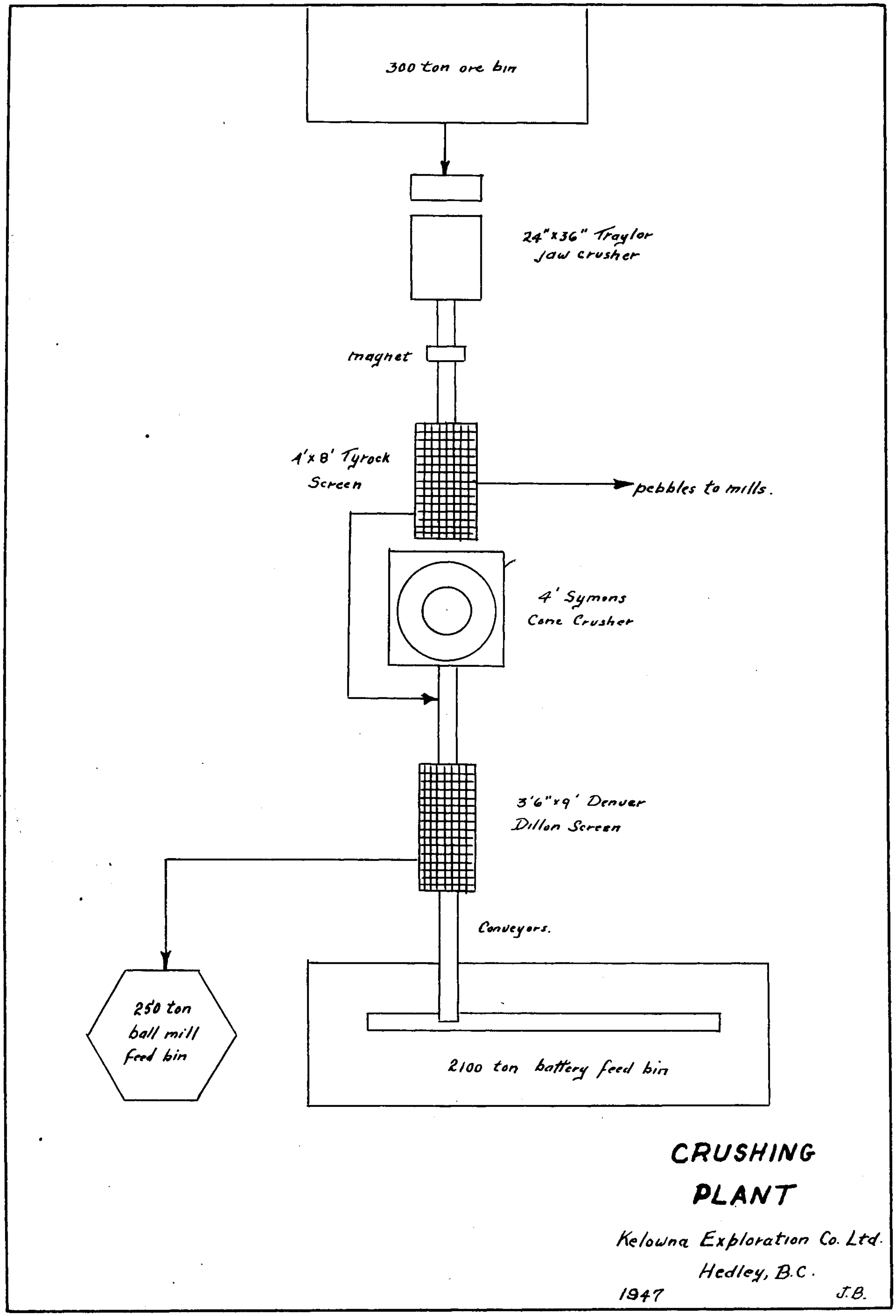

300 ton ore bin
24"x36" Traylor jaw crusher
magnet
4'x8' Tyrock Screen
pebbles to mills.
4' Symons Cone Crusher
3'6"x9' Denver Dillon Screen
Conveyors.
250 ton ball mill feed bin
2100 ton battery feed bin
CRUSHING PLANT
Kelowna Exploration Co. Ltd.
Hedley, B.C.
1947
J.B.

Fig. 1

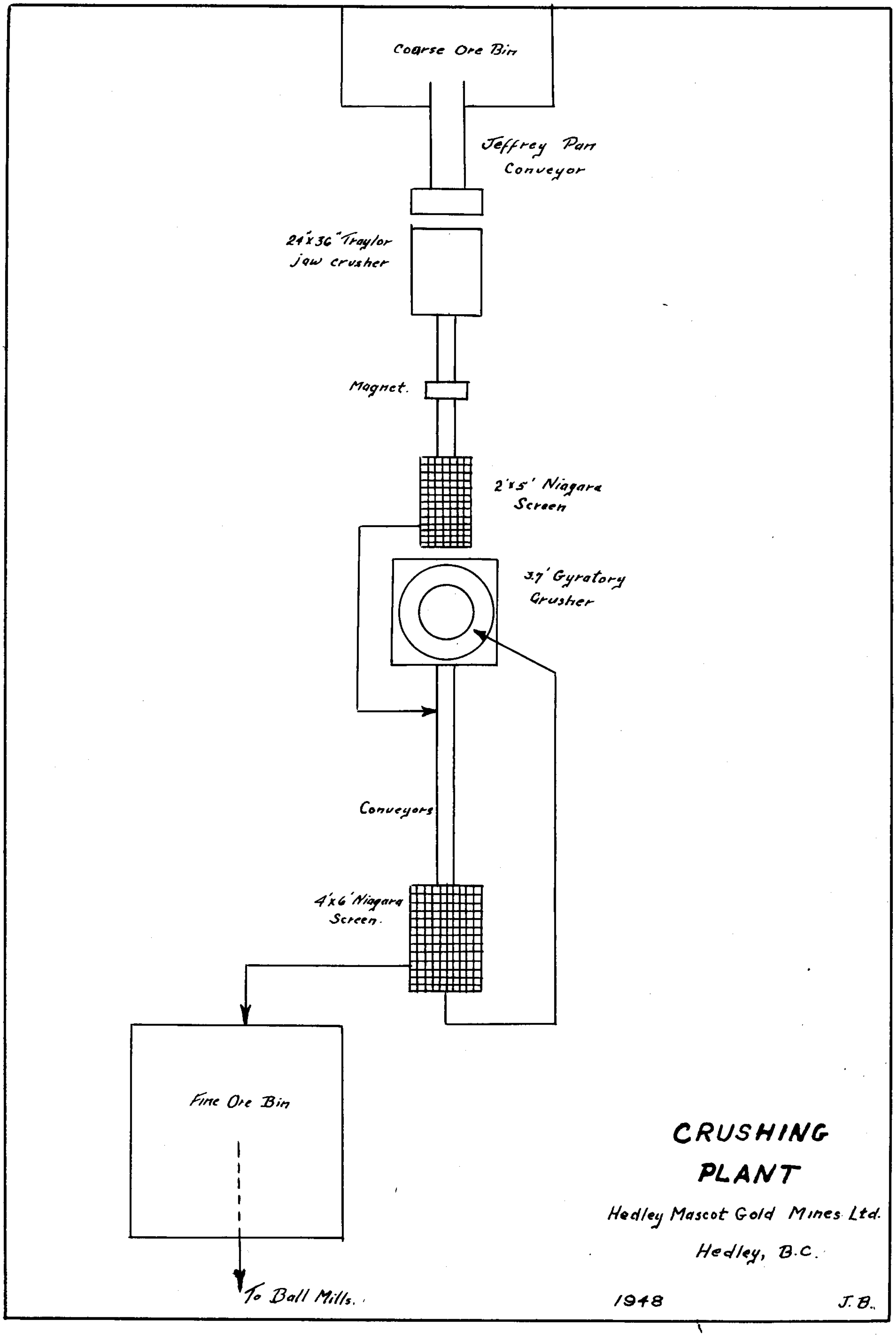

Coarse Ore Bin
Jeffrey Pan Conveyor
24"x36" Traylor jaw crusher
Magnet.
2'x5' Niagara Screen
3.7' Gyratory Crusher
Conveyors
4'x6' Niagara Screen.
Fine Ore Bin
To Ball Mills.
CRUSHING PLANT
Hedley Mascot Gold Mines Ltd.
Hedley, B.C.
1948
J.B.

Fig. 2

the fine particles from the cone crusher product. These "fines" or "slime" particles are dumped into a separate bin so that the fines can be ground separately from the coarser materials. (Fig.1).

GRINDING AND CLASSIFICATION

The grinding unit of the Mascot consists of a 7-ft. by 5-ft. Traylor ball mill and two 6-ft. by 8-ft Dominion ball mills. These ball mills are installed to provide three grinding circuits, known as the primary, secondary and tertiary circuits. The fine ore is fed by a conveyor system to the primary mill and then passes in series through the secondary and tertiary mills before the grinding operation is completed. Flotation cells are placed in between the primary and secondary circuits in order to float off the rougher mineral particles which require no further grinding. (Fig. 3).

For pulp classification, the Mascot mill uses three Dorr classifiers. One of these classifiers is in an open circuit with the primary ball mill. The other two classifiers are in closed circuits with the secondary and tertiary mills respectively. (Fig.3).

At the Kelowna mill, the two crusher plant products, the fines and the coarse materials, are ground separately. The coarse product, which consists of about three quarters of the mill capacity, is crushed to a fine size by forty 1,050-pound stamp mills. The resulting product is ground to the required mesh size by four 5-ft. by 22-ft. Allis-Chalmers pebble mills. The crusher plant fines are ground by means of a 6-ft. by 6-ft. ball mill in series with a 5-ft. by 22-ft. pebble mill. (Fig.4).

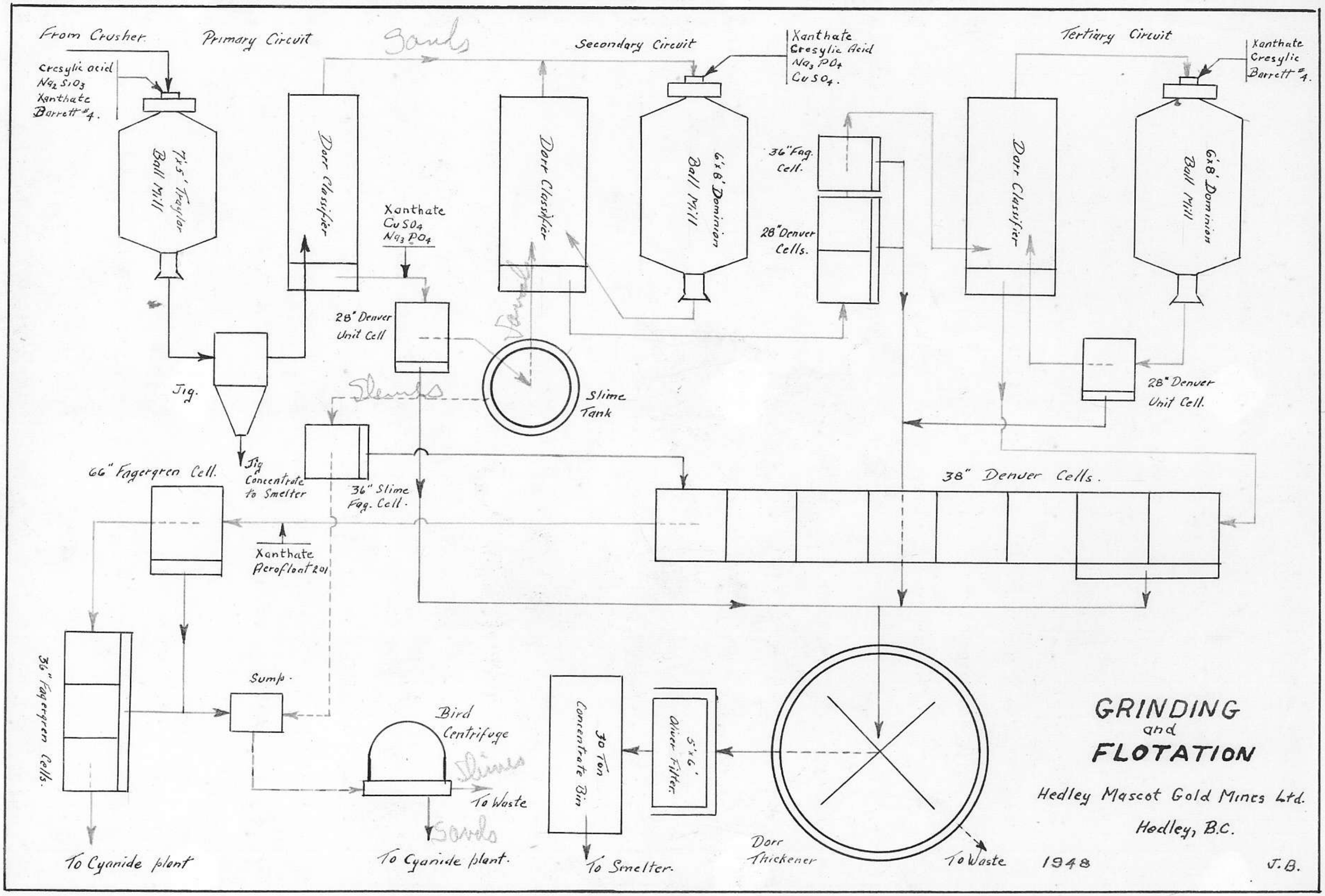
The essential purpose of the classifiers at the Kelowna mill is to cause a separation of the "slimes" from the "sands" so that the two products can be separately treated in the cyanide plant. Three 4.5-ft. by 22-ft. Dorr classifiers are used to classify the pulp products discharged from the 40 stamp mills. Each of these classifiers operates in conjunction with a pebble mill so that the "sands" may be ground by the mill while the overflow "slimes" may be taken directly to the cyanide plant. The discharges from the three mills enter an 8-ft. by 30-ft. by 10-ft. Dorr bowl classifier which is in a closed circuit with a 5-ft. by 22-ft. pebble mill. The purpose of this mill is to regrind the pulp so it is sufficiently fine to overflow from the bowl classifier before entering the cyanide plant.

The ball mill used for grinding the crusher fines is operated in an open circuit with a 4-ft. by 21-ft. Dorr classifier. The sand product from the classifier enters a 5-ft. by 22-ft. pebble mill which is in a closed circuit with a 45-in. Akins classifier. The overflow from the ball-mill classifier is taken directly to the cyanide plant while the Akins classifier overflow enters the bowl classifier. (Fig.4).

JIGGING

The finely divided gold particles in the Hedley ore are mostly associated with dense arsenopyrite. Since arsenopyrite is relatively high in specific gravity it is possible to separate it from the gangue by means of jigging. Mascot

Fig. 3


From Crusher
Primary Circuit
Sands
Secondary Circuit
Tertiary Circuit
Cresylic acid
Na_2SiO_3
Xanthate
Barrett #4.
7'x5' Traylor Ball Mill
Dorr Classifier
Dorr Classifier
Xanthate
Cresylic Acid
Na_3PO_4
$CuSO_4$.
6'x8' Dominion Ball Mill
36" Fag. Cell.
28" Denver Cells.
Dorr Classifier
Xanthate
Cresylic
Barrett #4.
6'x8' Dominion Ball Mill
Xanthate
$CuSO_4$
Na_3PO_4
28" Denver Unit Cell
Slime Tank
Jig.
Slimes
28" Denver Unit Cell.
Jig Concentrate to Smelter
36" Slime Fag. Cell.
66" Fagergren Cell.
38" Denver Cells.
Xanthate
Aerofloat 201
36" Fagergren Cells.
Sump.
Bird Centrifuge
Slimes
To Waste
Sands
30 Ton Concentrate Bin
5'x6' Oliver Filter.
To Cyanide plant
To Cyanide plant.
To Smelter.
Dorr Thickener
To Waste
GRINDING and FLOTATION
Hedley Mascot Gold Mines Ltd.
Hedley, B.C.
1948
J.B.

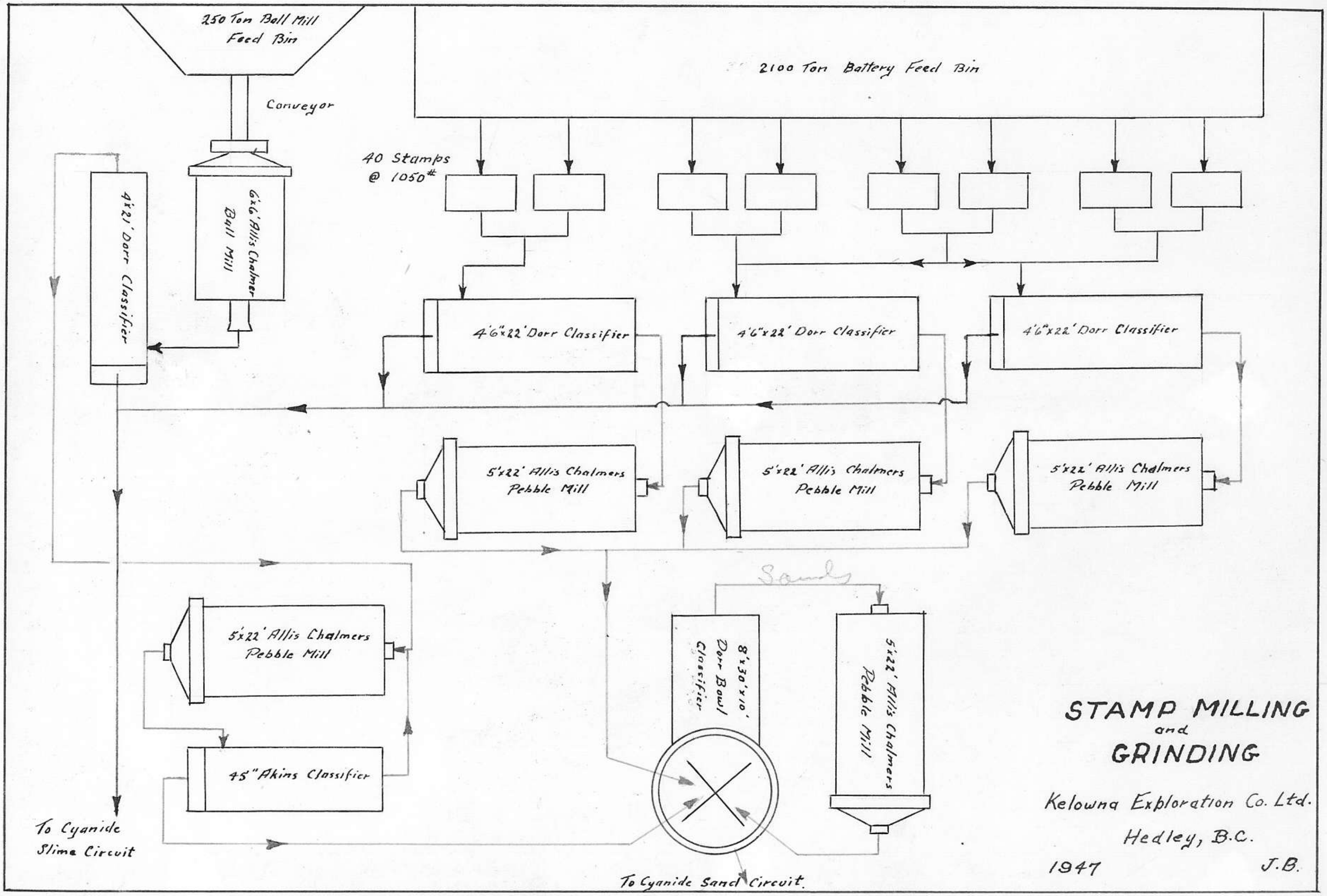

250 Ton Ball Mill Feed Bin
Conveyor
2100 Ton Battery Feed Bin
40 Stamps @ 1050#
6'x6' Allis Chalmer Ball Mill
4'x21' Dorr Classifier
4'6"x22' Dorr Classifier
4'6"x22' Dorr Classifier
4'6"x22' Dorr Classifier
5'x22' Allis Chalmers Pebble Mill
5'x22' Allis Chalmers Pebble Mill
5'x22' Allis Chalmers Pebble Mill
5'x22' Allis Chalmers Pebble Mill
45" Akins Classifier
Sands
8'x30'x10' Dorr Bowl Classifier
5'x22' Allis Chalmers Pebble Mill
To Cyanide Slime Circuit
To Cyanide Sand Circuit.
STAMP MILLING and GRINDING
Kelowna Exploration Co. Ltd.
Hedley, B.C.
1947
J.B.

Fig. 4

has found it advantageous to use a diaphragm jig for the separation of the coarse particles of arsenopyrite and other heavy minerals from the pulp discharge of the primary ball mill (Fig.3). The pulp is rapidly fed over the jig screens and the concentrates are collected in the hutches, which are periodically cleaned out. The jig concentrates are shipped te the smelter for further treatment.

The Kelowna mill does not use a jigging process since the ore is subjected directly to cyanidation.

FLOTATION

The flotation methods of the two mills are different in many respects. Although both mills use flotation as well as cyanidation in their processes, their sequence in mill operation is exactly opposite. At the Mascot mill, the ore is first subjected to flotation so that most of the gold is recovered as a concentrate, and then cyanidation is used to recover any gold which may be left in the flotation tailings. At the Kelowna mill, flotation is used last as a means to recover any gold which may ~~still~~ be left in the cyanide tailings.

At the Mascot mill, flotation is used at several different stages of the grinding process so that concentrates can be removed according to mineral particle size. A 28-in. Denver unit cell received the overflow from the primary classifier. This cell removes comparatively little concentrates since the particles are, at this stage, still too large and probably "slime" coated. To counteract the effect of "sliming", the tailings from this unit cell enter a slime settling tank (Fig.3). The slime particles are floated off the top while the heavier particles sink and are emptied into the secondary classifier. The slimes are run through a 36-in. Fagergren cell which recovers a small amount of concentrates and ejects a tailing which is retreated in the Cyanide plant. A large amount of the heavy sulphide minerals of the ore is removed from the overflow of the secondary classifier. This is accomplished by a string of two 28-in. Denver cells and a 36-in. Fagergren cell, the tailings of which go to the classifier of the tertiary grinding circuit., A 28-in. Denver unit cell is included in the tertiary closed circuit so that any suitably treated mineral particles can be floated off at this point without re-entering the classifier. The overflow of the tertiary classifier is treated by a string of eight 36-in. Denver cells. The first two of these cells remove concentrates which go directly to the concentrate thickener, while the remaining cells of the series are used to return any middling products. The tailings from this cell string are again subjected to flotation by passing through a 66-in. Fagergren cell and a string of three 36-in. Fagergren cells. The middling products removed by these cells are pumped into a Bird centrifuge for slime separation before entering the Cyanide plant. (Fig.3).

Flotation at the Kelowna mill is used as a final means of recovering any valuable mineral products which may be locked in the gangue of the cyanide tailings. By referring to the Kelowna-flotation flowsheet (Fig.5), it is seen that the flotation circuit consists of a four-cell series of 66-in. Fagergren cells, two six-cell series of 36-in. Fagergren cells

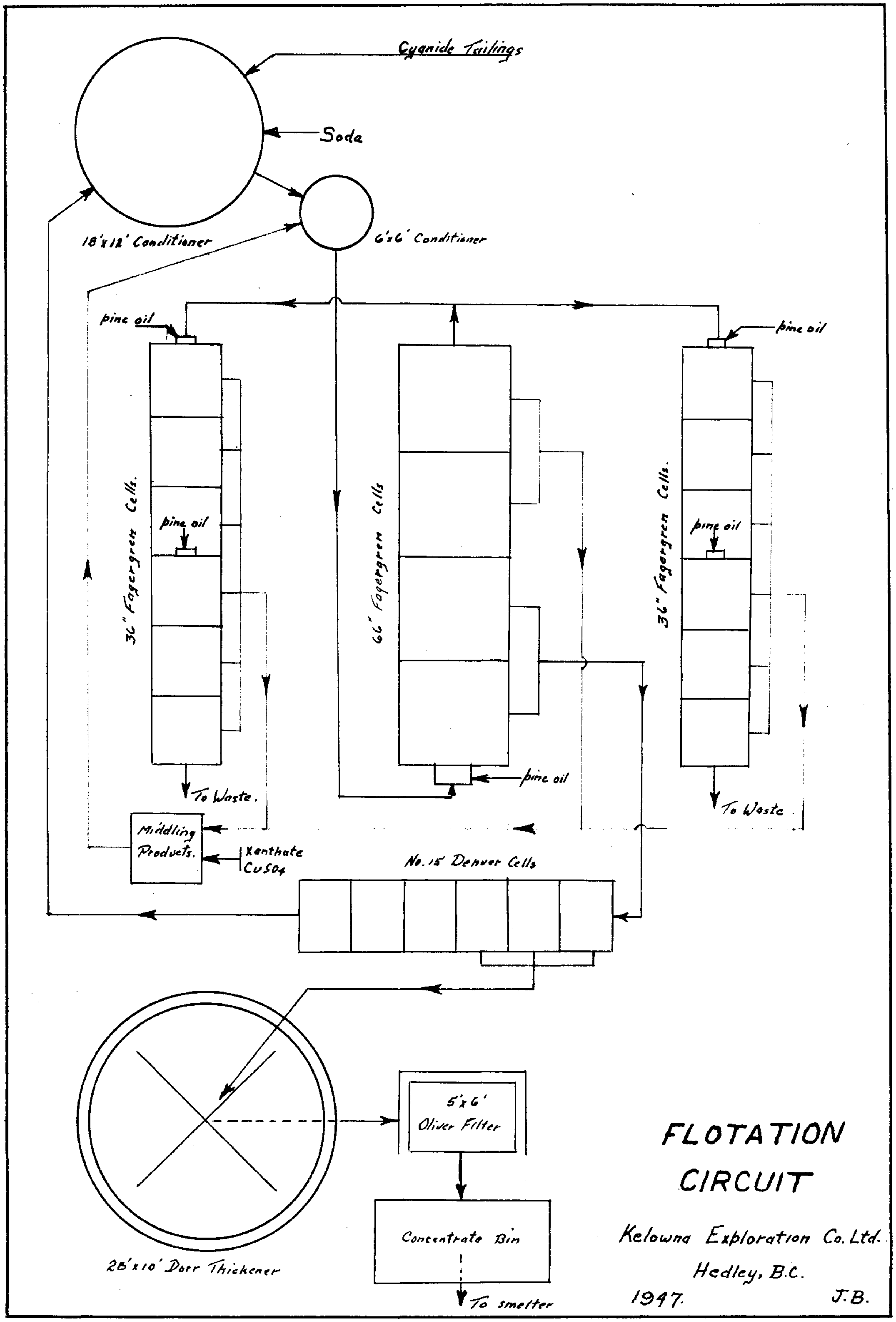

Cyanide Tailings
Soda
18'x12' Conditioner
6'x6' Conditioner
pine oil
pine oil
36" Fagergren Cells.
66" Fagergren Cells
36" Fagergren Cells.
pine oil
pine oil
pine oil
To Waste.
To Waste.
Middling Products.
Xanthate
CuSO4
No. 15 Denver Cells
5'x6' Oliver Filter
FLOTATION CIRCUIT
Concentrate Bin
Kelowna Exploration Co. Ltd.
Hedley, B.C.
28'x10' Dorr Thickener
To smelter
1947.
J.B.

Fig. 5

and a six-cell series of Denver cells. The cyanide tailings are thoroughly treated with soda by means of two conditioning agitators so that any depressive reaction due to lime may be neutralized. The first two cells in the circuit remove the concentrates while the remaining two large cells and the two small-cell strings remove the middling products. These middling products are circulated back through the circuit. The Denver-cell string is used as a cleaner circuit for expelling slimes from the concentrates before they enter the concentrate thickener. The concentrates are pumped from the thickener to a 5-ft. by 6-ft. Oliver filter, which removes the moisture and dumps the semi-dry product into a storage bin.

CYANIDATION

Both the Mascot and Kelowna mills use conventional cyanidation processes. The main differences between the two cyanide plants are their capacities and their flow-sheet sequences. The Kelowna cyanide plant receives the pulp directly from the grinding stage, whereas the Mascot cyanide plant receives the pulp which has already been subjected to flotation. Consequently, the cyanide "heads" and the cyanide recovery of the Kelowna mill will be much higher in value than that of the Mascot mill.

The cyanide plant of the Kelowna mill consists of two different circuits. Before entering the cyanide plant the pulp is separated by the classifiers into "slimes" and " sands". Both slime and sand pulps receive almost identical cyanide treatment but because of metallurgical complications they are kept in separate circuits. The sand circuit consists of (in flow-sheet sequence), a 48-ft. by 12-ft. Dorr Torq primary thickener, four 30-ft. by 16-ft. Devereax agitators, three 16-ft. by 14-ft. Dorr agitators and a 48-ft. by 12-ft. Dorr secondary thickener. (Fig.6). Overflow from the primary thickener is discarded as waste. The overflow of pregnant or gold-bearing solution from the secondary thickener is collected in a storage tank. The secondary thickener solids are filtered by a 14-ft. by 14-ft. Oliver filter and a 14-ft. by 14-ft. N.F. filter. The resulting filtrate is added to the pregnant solution, while the solids are repulped and discharged as a tailing which is retreated by flotation. The "slime" circuit consists of a 35-ft. by 12-ft. Dorr primary thickener, three 18-ft. by 16-ft. Dorr agitators and two 30-ft by 12-ft. Dorr secondary thickeners. The secondary thickener solids are filtered through a 11½-ft. by 12-ft. F.E. Inc. string filter and the filtrate produced is added to the pregnant solution. The solids are repulped and treated by flotation. (Fig.7).

The pregnant and filtrate solutions are pumped through a clarifier to remove any traces of insoluble materials. Precipitation of the pregnant solution is accomplished by two Merrill presses. Some of the barren solution from the presses is used for filter wash and pulp dilution, while the remainder is discarded.

The purpose of the cyanide plant at the Mascot mill is to retreat both middling products and tailings which are

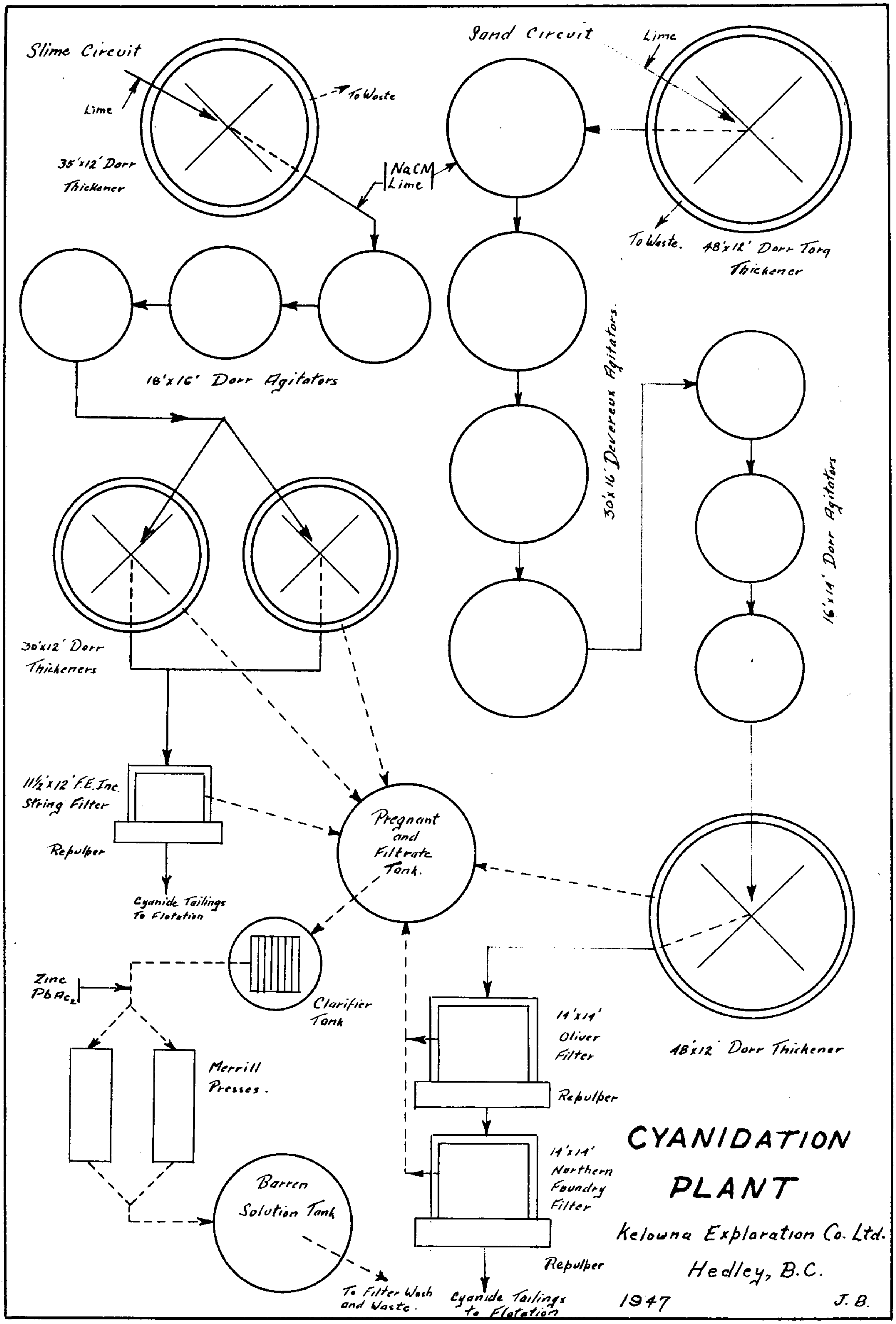

Slime Circuit
Lime
To Waste
35'x12' Dorr Thickener
NaCN
Lime
Sand Circuit
Lime
To Waste.
48'x12' Dorr Torq Thickener
18'x16' Dorr Agitators
30'x16' Devereux Agitators.
16'x14' Dorr Agitators
30'x12' Dorr Thickeners
11½'x12' F.E. Inc. String Filter
Repulper
Cyanide Tailings To Flotation
Pregnant and Filtrate Tank.
Zinc
PbAc₂
Clarifier Tank
Merrill Presses.
48'x12' Dorr Thickener
14'x14' Oliver Filter
Repulper
14'x14' Northern Foundry Filter
Repulper
Barren Solution Tank
To Filter Wash and Waste.
Cyanide Tailings to Flotation
CYANIDATION PLANT
Kelowna Exploration Co. Ltd.
Hedley, B.C.
1947
J. B.

Fig. 6

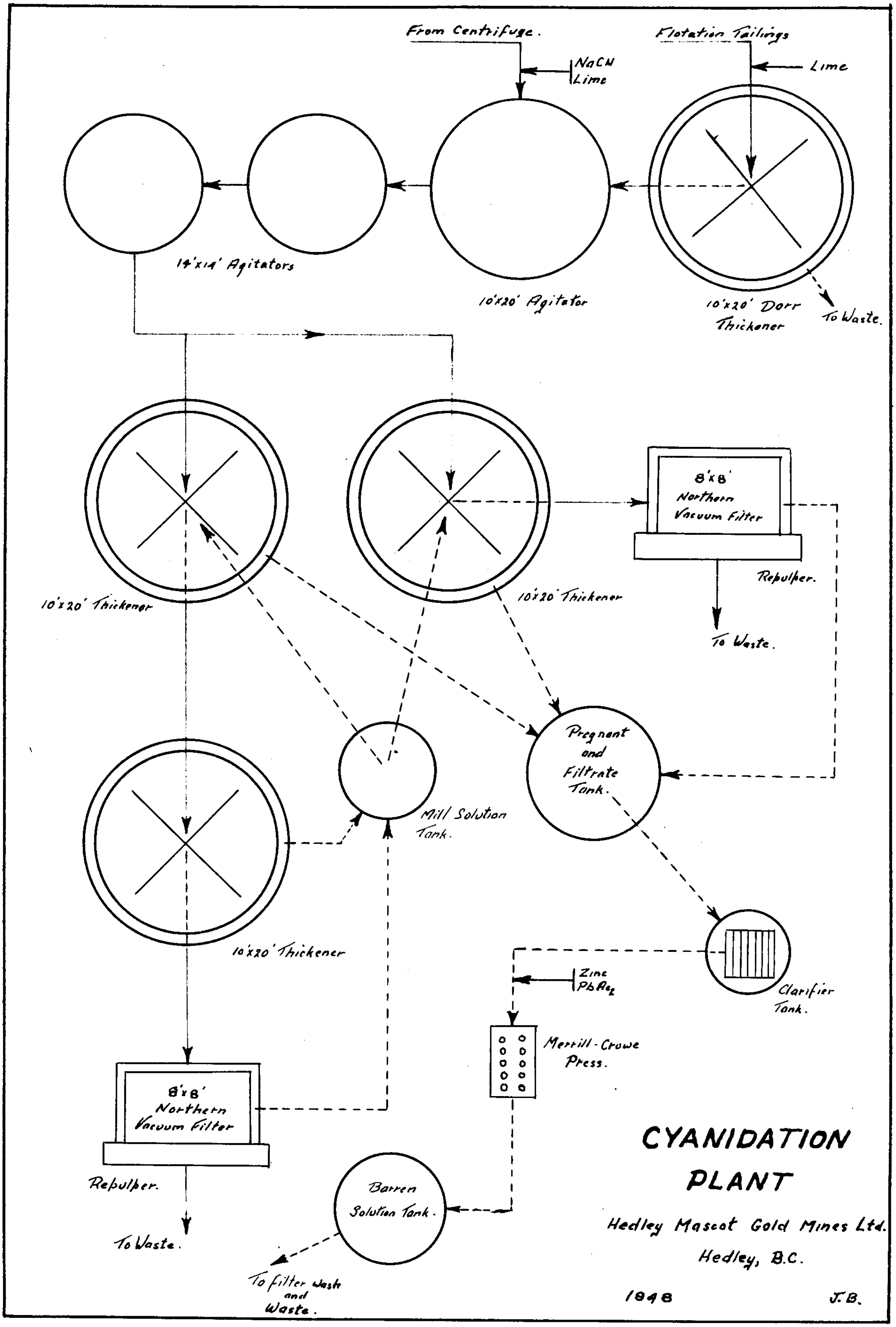

From Centrifuge.
Flotation Tailings
NaCN
Lime
Lime
14'x14' Agitators
10'x20' Agitator
10'x20' Dorr Thickener
To Waste.
10'x20' Thickener
10'x20' Thickener
8'x8' Northern Vacuum Filter
Repulper.
To Waste.
Mill Solution Tank.
Pregnant and Filtrate Tank.
10'x20' Thickener
Zinc
$PbAc_2$
Clarifier Tank.
Merrill-Crowe Press.
8'x8' Northern Vacuum Filter
Repulper.
To Waste.
Barren Solution Tank.
To filter wash and Waste.
CYANIDATION PLANT
Hedley Mascot Gold Mines Ltd.
Hedley, B.C.
1948
J.B.

Fig. 7

discharged from the flotation process. These products are treated together in the same agitation circuit. This circuit consists of a 10-ft by 20-ft Dorr primary thickener, a 10-ft. by 20-ft. agitator, two 14-ft. by 14-ft. agitators and three 10-ft. by 20-ft. secondary thickeners. Before entering the agitation process, the middling products are centrifuged for slime extraction and the flotation tailings are entered into the Dorr primary thickener so that excess solution may be discarded. The thickener solids and centrifuged pulp are then pumped into the agitators (Fig. 7). The agitated pulp is treated by the three secondary thickeners. Pregnant solution is removed from the first two thickeners and collected in a storage tank. The overflow from the third thickener is known as "mill solution" and is circulated back to the first two thickeners for washing purposes. The thickener solids are filtered by two 8-ft. by 8-ft. Northern vacuum filters. The filtrate produced from one of the filters is added to the pregnant solution while the filtrate produced from the other filter is retained as " mill solution". The filter solids are repulped and discarded as a tailing. (Fig. 2)

The pregnant solution is pumped through a clarifier for removing traces of gangue. Precipitation is accomplished by a Merrill-Crowe process. Part of the barren solution is used for a filter wash while the remainder is discarded as waste.

ADVANTAGES AND DISADVANTAGES OF THE PROCESSES

COMMINUTION

At the Kelowna mill the crushed ore is separated into the relatively soft fines and the extremely hard coarse materials. It is of great advantage to the Kelowna to treat these products separately in the grinding process, since each product requires its own special grinding method to gain the maximum efficiency. The Kelowna mill operators maintain that the hard ores can be more economically reduced in size by the crushing impact of stamps than by the abrasive grinding of ball mills. A ball mill is used for grinding the softer materials for which stamp-milling is not particularly adaptable.

The advantages of ball mills are that they are easier to operate, require less operating personnel, and occupy less floor space than the stamps and pebble mills of the Kelowna mill. However, the operation of stamps requires less power than the operation of ball mills. While the total power consumption for the operation of ball mills at the Mascot mill amounts to approximately 2.35 H.P. per ton, the power consumption of the stamps, pebble mills and ball mill of the Kelowna grinding system amounts to approximately 1.85 H.P. per ton. Due to the necessity of repairs, the maintenance cost of stamp-mill operation is higher than the operation of ball mills. This economical advantage of ball mills, however, is somewhat offset by the necessity of using iron balls as a grinding medium. At the Kelowna mill, advantage is taken of the hard ore by using it as a grinding medium for the pebble mills.

With the exception of the crushing plants, both mills are operated 24 hours a day. For the crushing and grinding processes of the mills, Mascot requires only a crusher operator and a ball mill operator while the Kelowna process requires a crusher operator, a pebble picker, a stamp-mill operator and a pebble-mill feeder.

FLOTATION AND CYANIDATION

Both mills have their individual problems regarding the sequence of cyanidation and flotation in their respective flow-sheets. As a result of cyanidation before flotation the Kelowna mill recovers most of the gold in a precipitate. By using floation before cyanidation the Mascot mill recovers most of the gold in a concentrate. Because of its greater bulk, the shipment of a concentrate is considerably more expensive than the shipment of a precipitate.

One of the major problems of both mills is in dealing with the softer ores, which introduce primary slimes. These slimes are very troublesome in a cyanidation process because of settling and filtering difficulties. At the Kelowna mill, this problem is partially solved by treating the slimes and sands in separate cyanide circuits. By using flotation first the Mascot can, to some extent, reduce the amount of slime products entering the cyanide plant.

The Mascot's method of using flotation at different stages of the grinding process is exceptionally favourable for the concentration of the sulphide minerals of the Hedley ore. The disadvantage of the method is that a relatively large variety of reagents are required to gain the maximum flotation recovery. Consequently the flotation circuit becomes involved with a large number of variables which require careful control.

The Kelowna flotation method uses comparatively few reagents and therefore the circuit is more easily controlled.

CONCLUSIONS

From the foregoing discussion it is evident that the metallurgical treatment of the Hedley ores is not a simple matter. Because of the complexity of the ores many problems had to be solved in order to gain a profitable recovery from these ores. Both companies have carried out innumerable tests in an endeavour to increase the efficiency of their respective milling methods.

In the comparison of the two mills it is of interest to note how widely they differ in the treatment of an ore which is common to both mines.

Taking all the known facts into consideration it is the opinion of the writer that the milling process of the Kelowna Exploration Company is a more profitable method than that of the Hedley Mascot. However, it must be remembered that a true determination of the better milling method is impossible without a detailed comparison of operating costs and assay values. If these figures were obtainable, it would greatly increase the interest of this report.

BIBLIOGRAPHY

E. W. Johnson "A Slime Problem at Kelowna Exploration Mill". Western Miner, Volume 17, October, 1944 pp 48-53

Investigations in Ore Dressing and Metallurgy Dept. of Mines, (July - December, 1934)

"Canadian Mill Flow Sheets" Canadian Mining Journal, 1946.