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THE CONCENTRATION OF CANADIAN MOLYBDENITE ORES

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Introductory

Articles have appeared from time to time in the technical press descriptive of the methods applied to the concentration of molybdenite ores in various parts of the world. The chief occurrences in Canada, the history of early concentration methods, the uses etc. of the metal molybdenum, are fully described by V. L. Eardley-Wilmot in his monograph "Molybdenum", Bureau of Mines, Department of Mines and Resources, Ottawa, Publication No. 592.

The present article, prepared in memorandum form, will serve as a supplement to the portion dealing with the concentration of the ores, and covers the practical details of the concentration of the different types of Canadian molybdenite ores. It is intended to assist the mill operator in selecting the type of concentration plant best suited for his ore, and to aid the millman in the manipulation of his concentrator so as to attain the best results.

Molybdenite, the sulphide of molybdenum, is the chief mineral of the metal, and is found widely scattered throughout Canada, from Manitoba east to the Atlantic seaboard; and from the Rocky mountains west to the Pacific ocean. During the war quite an industry was developed in Canada; a number of concentration plants were erected, and reduction plants were established at Belleville and Orillia; in 1918 the Canadian production of molybdenite reached a total of 378,029 pounds. The rapid decline in the market price at the close of the war was responsible for the closing down of all Canadian properties. However, the demand is now steadily rising due to its greatly increased use in alloy steel and iron for industrial applications as well as to the progress made in metallurgical research in finding new uses for the metal, so that the future looks promising for the revival of the molybdenum industry in Canada.

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<u>Character and types of molybdenite ores:</u> From the viewpoint of the operator and the millman who are concerned with the concentration of the ores, Canadian ores may be classified into the following types:

1. Ores of the large flake variety in which the molybdenite occurs in flakes above half an inch in diameter, the associated minerals being iron sulphides in a pyroxenite-calcite gangue. As an example of this type may be cited the ores of the Spain mine in Griffith township, Renfrew county, Ontario.

2. Heavy pyritic ores, in which the molybdenite is of the medium flake variety, associated mainly with the iron sulphides, pyrite and pyrrhotite, the gangue being as a rule pyroxenite. In this type of ore the flake is mostly above one eighth of an inch in diameter, and may be present up to two inches in diameter. As examples of this type may be cited the ores of the Bain mine in Masham township, Hull district, Que., and the ores of the Renfrew Molybdenum Mines, Brougham township, Renfrew county, Ont.

3. Ores of the medium-flake variety in which the molybdenite is more or less disseminated throughout the pyroxenite gangue rock and associated with small amounts of iron sulphides. The flake as a general rule is smaller than the No. 2 type, requiring finer grinding to free it. As an example of this type may be cited the ores of the Joiner property on Lots 3 and 4, Concession XX, Cardiff township, Haliburton county, Ont.

4. Ores of the medium-flake variety in which the molybdenite with an appreciable amount of iron sulphides is disseminated throughout a gangue of quartz, feldspar, and fluorite (altered syenite-gneiss). The flake of this type rarely exceeds half an inch in diameter, and is all freed by grinding to from 35 to 48 mesh. As an example of this type may be cited the Moss Mine ores, Onslow township, Pontiac district, Que.

5. Ores of the medium-flake variety; the molybdenite occurring in feldspathic quartz veins with sericite. The molybdenite is generally in the form of rosettes not exceeding half an inch in diameter, and can be freed from the gangue by crushing to 35 to 40 mesh. As an example of this type may be cited the ores on the properties of the Molybdenite Reduction Co. in LaCorne and Malartic townships, Abitibi district, Que.

6. Ores of the fine flake and amorphous variety; the molybdenite occurring along the fractures and disseminated throughout the quartz gangue. Examples of this type are the ores of the Alice Arm district, B. C., and the deposit at Kakabeka Falls, Ont. Very fine grinding (to at least 80 mesh) is required to free the molybdenite from the gangue rock.

<u>Concentration process best suited for Canadian ores:</u> Molybdenite is one of the easier flotative minerals, as it possesses a marked affinity for oils, especially kerosene, to a similar extent to graphite. Due to its flaky nature and its greasy feel, it is readily concentrated by the flotation process. Earlier methods of concentration consisted of

simply floating the dry ground ore on water or by oiling the wet ground ore and bringing it to the surface of the water. By both these methods the molybdenite floated off on the surface of the water and the gangue sank. These methods have been entirely replaced by modern flotation machines whereby higher grade of concentrates and increased recoveries are obtained.

General Flow-Sheet for Canadian molybdenite ores: With slight alterations to meet the requirements for each particular ore, the flow-sheet given on the last page of this report will be found to give the most satisfactory results with respect to the grade of concentrates produced, recovery, simplicity and low cost of operation.

In the case of ores of the first mentioned type, the large flakes can be hand picked, and after crushing the ore is given a preliminary treatment by rolling and screening to obtain as much coarse flake as the operation will warrant. The ore can then be passed to the ball mill and the general flow-sheet followed.

On ores of the second type, a preliminary operation will hardly pay unless a good percentage of the flake is large - above 1 inch in diameter. The general flow-sheet can be followed with few exceptions. More careful manipulation is required to produce a high-grade concentrate on account of the preponderance of iron sulphides present in this type.

For ores of the more or less disseminated type as represented by the third, fourth, fifth, and sixth types described, the flow-sheet can be closely followed with good results. Each particular ore will require certain variations as to grinding, depending at what fineness the flake is entirely freed; to pulp densities of grinding and flotation operations; to the amounts of reagents used; deflocculation devices, and aperture of the screens used in the final operation.

Most molybdenite ores can be hand sorted as the mineral is easily distinguished, thus permitting the barren rock to be discarded. Sorting should, therefore, be done whenever possible, so as to give a fair grade of feed to the concentrating plant. As a general rule, the ores of the larger flake variety can be sorted up to 5 per cent MoS_2 without discarding payable ore, but it would seem that the operation cannot be carried much beyond this point.

Concentration results on the various types of ores: Type No. 1

A considerable tonnage of this type of ore was treated during the war when the Ore Testing Laboratories were receiving ores on a custom basis for concentration purposes. As a great number of small individual shipments were received, the concentration results from each were not kept separate. The general procedure with ores of this type was to pick out any large flake that was free of gangue; the ore was then crushed in a jaw crusher, and after removal of the fines any further clean flake was sorted out by passing over a picking belt. The coarse ore was then fed to rolls, and by screening on a 2 mesh screen an oversize product, containing a high percentage of flake, was obtained which was further rolled and screened until the product was of commercial grade. The throughs from the above operations were fed to the ball mill and the regular flow-sheet followed. As a general rule, in ores of this type considerable waste rock can be discarded by hand-picking.

Type No. 2

These ores do not, as a general rule, lend themselves to hand sorting for the recovery of clean flake. Some flake may be obtained in this manner, but care should be taken not to carry the operation to the unprofitable limit. Barren rock, however, can be discarded and picking operations should be practised to remove waste, so as to give a good feed to flotation. Ores of this type are not as amenable to concentration with the production of high-grade concentrates as the more siliceous types that contain lesser amounts of iron sulphides, due to the tendency of the fine iron sulphides to float and adhere to the molybdenite in the flocculation of the fine flakes. The flake itself in many cases contains fine iron between the laminae, so that concentrates much above 90 per cent MoS_2 cannot be obtained by any mechanical means.

The results of a small scale test and of a tonnage test on a carload shipment of ore from the Indian Lake deposit, Masham township, Hull district, Que., are given below. The ore is of the medium-flake variety in which the molybdenite is associated with a large amount of massive iron pyrite. The gangue is pyroxenite and other lime-silicate minerals. The richer portions of the ore are almost entirely iron sulphides.

Small scale test

Product	Weight, gms	Weight, %	Assay MoS_2 %	Per cent MoS_2 values	Remarks
Conc. +80 mesh	17.7	1.8	89.25	65.1	)
" -80 "	37.2	3.7	17.00	26.0	) Total recovery 88 %
Middling	33.3	3.3	1.94	2.6	)
Tailing	891.8	89.2	0.17	6.3	4-lb/ton kerosene
Feed	980.0	98.0	2.42	100.0	1 " pine oil
					A little lime added

Tonnage scale test

Weight of shipment	61,500 lbs.
Analysis of sample cut by Vezin sampler	0.83 % MoS_2
Average analysis daily sample wet feed to flotation cells	0.92 % "
Analysis of feed by calculation from concentration results	1.00 % "
Content in ore, assuming 1.00% MoS_2 as assay of ore	616.72 lbs.
Weight of concentrates obtained	668.5 "
Average analysis of concentrates	78.5 % MoS_2
Content MoS_2 in concentrates	524.6 lbs.
Clean-up from run (669 lbs. @ 2.98% MoS_2)	19.9 "
Average analysis of tailing samples	0.12 % MoS_2
Content in tailings, MoS_2	72.2 lbs.
Recovery MoS_2 from concentration products	87.9 %
[illegible] formula $R = \frac{100(H-T)C}{H(C-T)}$	88.2 %

Reagents used: Korosene 0.8-lb. per ton; Pine oil 0.3-lb. per ton

Fineness of grinding: 12.5% on 65 mesh; 50% on 100 mesh

Conclusions from results of concentration tests: The above results show that on an ore of this type averaging 1 per cent MoS_2, a concentrate containing 80 per cent MoS_2 can be produced, with a recovery of better than 88 per cent of the molybdenite values in the ore. The ore submitted was taken from near the surface and was somewhat oxidized. This state of the ore did not have any appreciable effect on the recovery, as tailings as low as 0.08 per cent MoS_2 were produced during the run. It may, however, have had some effect on the grade of the concentrate, and it is possible that on fresh ore of this grade a concentrate of 85 per cent MoS_2 could be obtained. The production of a high grade concentrate from this type of molybdenite ore in which the iron sulphides predominate over the siliceous gangue minerals, is more difficult than from the more highly siliceous ores. More careful control of reagents, pulp densities, deflocculation devices, etc. is required. With proper control, the results given above should be obtained, with the possibility of producing higher grade concentrates on freshly mined ore.

Note: For further details of these tests readers are referred to Summary Reports of Investigations of the Mines Branch for 1921 and 1924.

Type No. 3

The dissimilarity of this type as compared with No. 2 is not in the size of the flake but in the absence of large amounts of iron sulphides. The size of the flake generally prohibits hand-picking but waste rock should be discarded to give a good flotation feed. The type of ore is very amenable to concentration with the production of high grade concentrates and good recoveries. The general flow-sheet can be followed very closely. The following results of some small scale tests, and of a tonnage test, are given on the various classes of ore from the deposits on Lots 3 and 4, Concession XX, Cardiff township, Haliburton county, Ont.

Small scale test

Four lots of ore were received, representing four types found on the property. In lot No. 1 the ore was of the medium-flake variety the flake being much larger and containing more iron sulphides than the other lots. In lots Nos. 2 and 3, the flake was much smaller being more evenly disseminated throughout the gangue rock. The ore contained very little iron sulphides. In lot No. 4, the rock contained an appreciable amount of graphite.

Lot No.	1	0.027	% MoO_3	0.68	% MoS_2
"	2	0.027	"	0.32	"
"	3	0.025	"	0.38	"
"	4	0.025	"	0.12	"

Lot No. 4 was too low-grade to be worked commercially and no tests made.

Lot No.	Mesh	Product	Weight gms	%	Assay MoS_2%	Per cent MoS_2 values	Remarks
1	48	Conc.+80m	7	0.7	93.31	81.9	Total recovery 91%
		" -80m	31	3.1	2.20	8.5	
		Middling	57	5.7	0.38	2.8	½-lb/ton kerosene
		Tailing	902	90.5	0.06	6.8	½- " pine oil
2	65	Conc.+80m	3	0.3	80.25	75.6	Total recovery 84%
		" -80m	33	3.2	0.58	5.9	
		Middling	86	8.5	0.18	4.7	½-lb/ton kerosene
		Tailing	891	88.0	0.05	13.8	½- " pine oil
3	65	Conc.+80m	4	0.4	87.25	75.4	Total recovery 83%
		" -80m	39	3.8	0.64	5.4	
		Middling	96	9.5	0.20	4.1	½-lb/ton kerosene
		Tailing	872	86.3	0.08	15.1	½- " pine oil

Tonnage scale test

This test was on a carload shipment of low-grade ore from the deposit first opened up on the property. The molybdenite flake was up to half an inch diameter in a pyroxenite gangue rock.

Weight of shipment	59,026 lbs.
Analysis of ore	0.308 % MoS_2
Analysis of concentrates obtained	89.65 %
Analysis of tailings	0.115 %
Recovery of molybdenite values	62.7 %

Reagents used: ¾-lb per ton kerosene and pine oil

Conclusions from results of above tests: The ore is very amenable to flotation, with the production of a high grade concentrate and good recoveries. A 90 per cent concentrate should readily be made from these ores. The large scale test was made during the earlier test work on molybdenite ores and the best operating conditions were not practiced. Tailings as low as 0.05 per cent MoS_2 should have been produced on this grade of ore, which would give a recovery of 83.8 per cent. The small scale tests which were run later indicate this possible recovery.

Type No. 4

The flake of this variety of ore is usually below one quarter of an inch in diameter and fairly well disseminated throughout the siliceous gangue rock which consists of quartz, feldspar, and fluorite (altered syenite-gneiss). An appreciable amount of iron sulphides is present. The nature of the gangue makes the rock more difficult to crush than the other types but as all the flake is freed at 48 mesh, crushing and grinding costs are reasonably low. The ore is very amenable to concentration so that the general flow-sheet can be followed very closely. Sorting out of waste rock should be practiced to give a good grade of mill feed. Ores of the former types appear to contain much more molybdenite than ores of the same grade of this type, due to the smaller flake and the more disseminated character of the latter. The following tonnage tests were made on two carloads of ore from the Moss mine, Onslow township, Pontiac district, Que.

Tonnage scale tests

Shipment No. 1

One car of ore, net weight	50,600 lbs.
Analysis of sample cut from dry ore by Vezin sampler	2.21 % MoS_2
Average analysis daily sample wet feed to flotation cells	2.45 "
Average analysis of dry and wet samples	2.33 "
Content MoS_2, using average analysis	1178.98 lbs.
Amount of concentrate obtained	1213 "
Analysis of concentrate	92.93% MoS_2
Content of MoS_2 in concentrate	1127.24 lbs.
Calculated analysis of tailing	0.10 % MoS_2
Recovery MoS_2, from average assay and calculated tailing	95.6 %

Shipment No. 2

One car of ore, net weight	84,600 lbs.
Analysis of sample cut from dry ore by Vezin sampler	2.33 % MoS_2
Average analysis daily sample wet feed to flotation cells	2.60 "
Average analysis of dry and wet samples	2.48 "
Content MoS_2, using average analysis	2081.16 lbs.
Amount of concentrate obtained	2135 "
Analysis of concentrate	93.44% MoS_2
Content of MoS_2 in concentrate	1994.94 lbs.
Analysis of tailing, average of daily samples	0.12 % MoS_2
Calculated analysis of tailing	0.12 "
Recovery of MoS_2	95.8 %

Conclusions from results of concentration tests: The ore is very amenable to concentration by flotation. With proper manipulation and under the right conditions, a high grade concentrate, 93 per cent MoS_2 is obtained with recoveries in excess of 95 per cent of the molybdenite content in the ore. Concentrates assaying over 96 per cent MoS_2 were made during the runs under the best conditions. The concentrates are exceptionally free from deleterious substances; are suitable for the manufacture of molybdic acid, molybdic salts, molybdenum metal, ferro-molybdenum, and should command the highest market price.

Note: For further details of these tests readers are referred to Summary Report of Investigations of the Mines Branch, Ore Dressing and Metallurgical Division for 1924.

Type No. 5

In this type of ore the molybdenite occurs in quartz, feldspathic quartz, and feldspar veins, generally in the form of rosettes, rarely exceeding one quarter of an inch in diameter. It is usually associated with sericite. Very little iron sulphides are present. The chief known occurrences of this type are south of Amos, Que. and in Nova Scotia. Barren quartz and feldspar are easily sorted out, and this should be practiced to give a good grade of ore to the mill. The ores are very amenable to concentration, so that the general flow-sheet can be followed closely. Crushing operations do not need to be carried finer than 48 mesh to free and flake. A tonnage test on the ore from the Molybdenite Reduction Company's properties in LaCorne and Malartic townships, Abitibi district, Que., gave the following results:

Tonnage scale test

Weight of ore concentrated	19,757 lbs.
Analysis of ore	2.02 % MoS_2
Content of MoS_2 in ore	399.5 lbs.
Concentrates obtained	365.5 "
Analysis of concentrates	90.80 % MoS_2
Content of MoS_2 in concentrate	323.9 lbs.
Clean-up of ball mill, etc.	1253.5 "
Analysis of clean-up, etc.	4.59 % MoS_2
Content of MoS_2 in clean-up	57.54 lbs.
Tailings, weight	18,147 "
Analysis of tailings	0.10 % MoS_2
Content of MoS_2 in tailings	18.15 lbs.

Conclusions from results of concentration test: With an average mill feed of 2.02 per cent MoS_2, a concentrate averaging 90.8 per cent MoS_2 was obtained with an average tailing of 0.10 per cent MoS_2. This gives a recovery of about 95 per cent of the molybdenite content in the ore. Higher grade concentrates and lower tailings were made at intervals during the run. The ore is very amenable to concentration. Its physical character and the absence of appreciable quantities of other sulphides such as copper and iron, make it an attractive milling ore. It is not difficult to grind, the molybdenite being freed at about 40 mesh. These characteristics permit of an exceptionally high grade concentrate being produced with very high recoveries of the molybdenite values in the ore.

Note: For further details of this test, readers are referred to Summary Report of Investigations of the Mines Branch, Ore Dressing and Metallurgical Division for 1923.

In more recent years, the earlier type of flotation cell was replaced by modern mechanically agitated cells. Apart from this change, the flow-sheet has not been altered nor the reagents.

In July 1938, 23 tons of ore of this type from the Molydor Mines Ltd., were milled. This ore was low-grade, containing 0.48 per cent MoS_2. Grinding to minus 35 mesh, and floating with 0.26 pound kerosene and 0.075 pound pine oil per ton, a 90 per cent recovery of the molybdenite was obtained. The ratio of concentration was 202:1 with an 86.4 per cent MoS_2 concentrate produced. During the run concentrates assaying as high as 90 per cent MoS_2 were obtained.

Type No. 6

Ores representative of this type are more difficult to concentrate with the production of high-grade concentrates and low tailings. Much finer grinding is required. The fine flake and amorphous variety is generally associated with a quartz gangue. The quartz is sometimes discoloured by the presence of extremely fine flake. Grinding should not be carried beyond the profitable limit. The general flow-sheet can be followed with variations as to degree of grinding, pulp densities, amounts of reagents used, and to the screens used for obtaining the finished concentrate. The following concentration results are given from small scale tests made on ores from Kakabeka Falls, Ont., and Alice Arm, B.C.

Ore from Kakabeka Falls: The molybdenite was of the amorphous variety, filling the fractures in the quartz and disseminated throughout the quartz. A small amount of pyrite is present. Analysis showed it to contain: Molybdenite 2.46 per cent; copper none; bismuth none; arsenic none.

Test No.	Mesh	Product	Weight gms	Weight %	Assay MoS_2 %	Per cent of MoS_2 values	Reagents
1	50	Concentrate	33	3.3	60.97	67.6	1½-lb/ton kerosene
		Middling	38	3.8	9.17	11.6	½ " crude
		Tailing	929	92.9	0.68	20.8	turpentine
2	80	Concentrate	41	4.1	52.44	73.1	3-lb/ton kerosene
		Middling	40	4.0	10.19	13.8	1 " crude
		Tailing	919	91.9	0.42	13.1	turpentine
3	80	Concentrate	40	4.0	58.87	76.6	3-lb/ton kerosene
		Middling	97	9.7	4.93	15.5	1 " pine oil
		Tailing	863	86.3	0.28	7.9	

Conclusions from results of concentration tests: The ore requires grinding to at least 80 mesh to give low tailings. The concentrate made from these small tests is below marketable grade but by screening on 100 mesh, a portion of the fine iron and silica adhering to the flakes will be removed. A 70 to 75 per cent MoS_2 concentrate should be obtained from this class of ore. The recovery should be about 80 per cent.

Ore from Alice Arm, B.C.: The molybdenite is of the fine flake and amorphous variety, filling the fractures and disseminated throughout the quartz gangue.

Test No.	Mesh	Product	Weight gms	Weight %	Assay MoS_2 %	Per cent of MoS_2 values	Reagents
1	65	Concentrate	31	3.1	66.51	77.6	1-lb/ton kerosene
		Middling	20	2.0	10.72	8.3	½ " pine oil
		Tailing	949	94.9	0.39	14.1	Little lime added
		Feed	1000		2.63		
2	65	Concentrate	51	5.1	60.45	93.2	1-lb/ton kerosene
		Middling	41	4.1	2.36	2.9	½ " pine oil
		Tailing	908	90.8	0.14	3.9	Little lime added
		Feed	1000		3.28		

Conclusions from results of concentration tests: The ore requires grinding to 65 mesh to obtain low tailings. The concentrates made are below marketable grade but by deflocculation and screening to remove adhering silica and pyrite a 70 to 75 per cent concentrate should be obtained from this class of ore. The recoveries should be between 85 and 90 per cent. The copper content of the ore was about 0.2 per cent, and the concentrates assayed 0.15 per cent copper.

Notes on flotation of molybdenite ores:

1. The ore should be ground to practically all through 35 mesh for flotation. Large thick flakes will be lost in the tailing unless ground to this mesh. The fineness of grinding will depend on the mesh at which the flake is freed and on the character of the flake. A large thin flake will float with more ease than a small thick flake. The degree of grinding should be determined by small scale laboratory tests.

2. The reagents best suited for the flotation of molybdenite ores are pine oil as the frothing oil and kerosene as the collecting oil. The best quality steam-distilled pine oil, such as the General Naval Stores No. 5, and the British American Oil Company's "Lampolene" brand of kerosene, are preferable. The amounts of these oils used need to be determined for each individual ore, and will depend on the character of the ore, its molybdenite content, the nature of the flake, whether thin flat or heavy thick flakes, etc. For an ordinary clean ore of one per cent grade the average amounts of reagents will be: Pine oil about 0.25 pound per ton and kerosene 0.5 to 0.75 pound per ton. If an excess of pine oil is added, the flotation circuit will build up with too much dead oil, giving a voluminous froth with very little carrying property, resulting in the lowering of the grade of the concentrate and increasing the loss in the tailing. The oil should be added to the ball mill, especially the kerosene, a portion of the pine oil can be added to the ball mill and a portion to the head of the flotation cells. The addition of other reagents, such as lime and soda ash, is not necessary on an ordinary clean ore, although they have the effect of raising the grade of the concentrate, this is at the expense of a higher tailing. The use of these reagents increases the amount of kerosene necessary to produce low tailings. In cases where the ore is very badly oxidized and the circuit becomes built up with soluble salts, destroying the effectiveness of the flotation oils, it becomes necessary to use alkaline salts to counteract the acidity of the ore.

3. The proper density of the pulp in the ball mill and in the flotation circuit should be determined for each individual ore. The best results are usually obtained with a pulp density between 60 and 70 per cent solids in the ball mill. The correct oiling effect on the molybdenite to give the best results is not obtained by too thick or too thin a pulp. The proper pulp density can be guaged by the character of the froth on the flotation cells. The froth should consist of lively breaking bubbles,

the molybdenite appearing on the convex faces near their domes, and all coming off in the first foot or so of the cells. If on the other hand the froth is voluminous, heavy, and slow-breaking, and the molybdenite appears in the troughs between the bubbles and is carried down towards the discharge end, the proper conditions do not prevail.

4. In order to produce a high-grade concentrate care should be taken to keep the flake at the coarsest size possible at which it will readily float, and at the same time, free from any attached particles of gangue or other mineral. In order to prevent freed flake from returning with the classifier oversize, the classifier can be equipped with air and water sprays. By permitting the feed to plunge down into the settling area, thus creating a boiling action which tends to bring the flake to the surface; and by using water sprays on the rakes to wash out the flake from the oversize; and by the use of an air spray to blow the flake towards the overflow, it is possible to reduce the amount of flake returning to the mill with the oversize by approximately 50 per cent.

5. In the flotation of molybdenite there should be ample rougher cell capacity to make a clean tailing to go directly to waste, and to provide for any emergencies such as increased grade of the ore, the adjustment of flotation conditions, and the return of large amounts of middling products from the cleaner cells and finishing screens. The cleaner cell operations should be crowded, so as to take off as high grade products as possible. To obtain high grade concentrate it is better to have two cleaners, one following the other, than only one. A much higher grade product will be sent to the finishing screen.

6. In the case of some ores which are exceptionally clean, the finishing screen can be dispensed with, but as most ores contain some pyrite and other minerals, which in a fine state of division will float and become entangled with the molybdenite, the screen is necessary. The mesh of this screen will depend on the fineness of the flake. For ores other than No. 6 type described above, an 80 mesh "Ton-cap" screen is used. For ores of the No. 6 type, 100 mesh screens are necessary. The use of the finishing screen for increasing the grade of the concentrate depends on the coagulating effect of kerosene on fine particles of molybdenite, thus permitting them to form a larger unit and stay on the screen while the fine pyrite and gangue passes through. A series of analyses made of the concentrate before and after passing over the screen showed that the use of the screen raised the grade 5 to 10 per cent in MoS_2 content.

This coagulating effect, or flocculation, of the molybdenite has a tendency to include some fine pyrite and other minerals with it, and has to be broken up to a certain extent before the cleaner concentrate passes onto the screen. This can be done by feeding fresh water with the cleaner concentrate to a centrifugal pump and pumping to a feed-well for distribution onto the screen. The control of the amount of water is important. An excess breaks up the flocculation of the molybdenite permitting too much fine molybdenite to pass through the screen and be returned to the flotation circuit. Too little will not permit the fine pyrite and gangue to become disentangled, thus lowering the grade of the concentrate. The use of the centrifugal pump between the last cleaner cell and the screen is to re-flocculate the molybdenite in a pulp of clean water, so that the fine pyrite and gangue will be delivered onto the screen free from entanglement in the flocculated molybdenite, and so pass through the screen.

Market requirements: The market requirements call for 85 per cent molybdenite in ores and concentrates. During the war a concentrate assaying over 65 per cent MoS_2 was received by the reduction plants, provided that the other minerals contained in this low-grade concentrate were mostly iron sulphides. As a rule this was the case, and permitted straight reduction to ferro-molybdenum without the addition of iron, with the production of the ferro-alloy containing 70 per cent molybdenum, less than 0.4 per cent sulphur. It was on this basis of analysis that the ferro-molybdenum produced in Canada was sold. Molybdenum concentrates should, therefore, contain over 65 per cent MoS_2 for the reduction to ferro-molybdenum to be used for steel purposes. Small amounts of copper and of other metals, below 0.5 per cent, should not be harmful, as the amounts of the metal used for steel purposes is generally under 0.5 per cent molybdenum, so that the amount of copper and other metals taken up by the steel from the ferro-molybdenum will be infinitesimally small.

For the manufacture of calcium molybdate, concentrates with a higher copper content can be used. On the American continent today (1939) the proportion of molybdate to ferro-molybdenum being used as an addition agent is at least 4 to 1. The tendency in England is leaning more to the use of the salt than before.

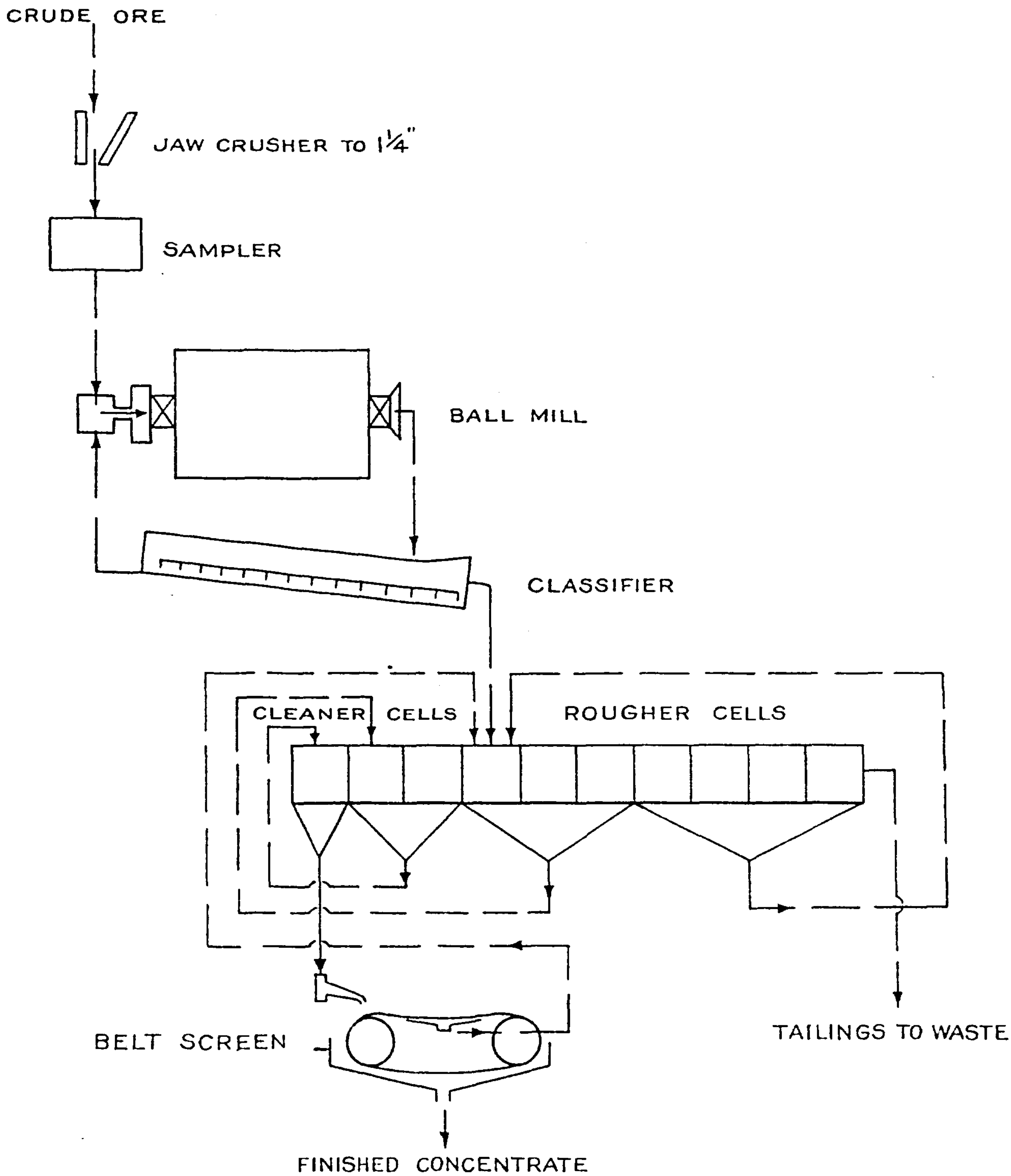
Canadian molybdenite ores as a rule are exceptionally free from harmful impurities and the concentrates produced from them are high-grade. This is especially true of the eastern deposits. The western deposits are more apt to contain copper and other impurities.

Market Quotations

The New York quotations of 90 per cent molybdenite concentrate is nominally 45 cents per pound of contained molybdenum sulphide. Against this price there is a U. S. tariff of 35 cents per pound metallic molybdenum contained therein or 21 cents per pound of molybdenite content, which makes the Canadian market price nominally 23 cents per pound, less transportation charges. The price in England is about 42/- per unit (22½ lbs.) or 46 cents per pound molybdenite contained in an 85 per cent concentrate. Quotations for lower grade concentrates vary from 34 cents for a 65 per cent concentrate upwards, but sales for under 80% material are decidedly limited. Indications are that the price is not likely to drop in the near future.

Present Outlook: With the United States now producing upwards of 15,000 tons of metallic molybdenum a year, imports into that country from Canada, particularly with the adverse tariff, would be very difficult to maintain. On the other hand the demand in England - and elsewhere in Europe - is increasing rapidly and many enquiries have been received recently (1938) from England for Canadian molybdenite concentrates. The buyers prefer a guarantee of regular monthly shipments of a consistent grade of concentrate of not less than 80 per cent molybdenite. However, there is a limited market for the odd small shipments of lower grade material.

As shown from the concentration of the ores given above, the process is simple, the majority of Canadian ores are readily amenable to concentration, grinding in most cases does not have to be carried finer than 48 mesh, so that concentration charges are low. The chief item of cost is mining and development. Owing to the character of the deposits and veins, considerable waste has to be broken and sorted out. Much development has to be done in waste rock, so that mining costs will be as high, if not greater than quartz-lode mining. Capital expenditure for mining plant and equipment will be similar to quartz-lode mining for the same tonnage mined, but the cost of the concentration plant will be lower, as the process as a general rule is simpler.



GENERAL FLOW-SHEET FOR CONCENTRATION OF MOLYBDENITE ORES