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TECHNICAL ADVANCES IN MILLING AND PROCESS METALLURGY IN CANADA DURING 1957.

by

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Introduction

DURING the year the Canadian mining industry was, with its characteristic resilience, girding itself against the adverse effects of falling base-metal prices. This was expressed by the intensified research into improving methods of recovery and processing of metals especially by the larger companies. The trend of paying particular attention to research was exemplified by the new wing that Cominco added to its research and development laboratories at Trail. It was also lucidly emphasized by Inco Vice-President, R. D. Parker[1] in his address to the Sixth Commonwealth Mining and Metallurgical Congress in Sudbury on September 24.

The dynamic nature of the Inco enterprise is shown by the fact that work has continued during the year on the development of the Company's mammoth Manitoba project. The railway spur from Sipiwesk to the Thompson townsite was completed on October 20. The completion of the spur before the winter freeze-up will permit the company to move in the thousands of tons of materials and heavy equipment required for the continuing programme.

In the Maritimes, a new chapter in Canadian milling history was opened up in New Brunswick by Brunswick Mining and Smelting Corporation, and by Heath Steele Mines. To the best knowledge of the writer these two companies are handling ores which, metallurgically, are very complex. However, such is the genius of persistence of the private mining industry that, undismayed by most forbidding aspects of complexities of their ores, both companies went determinedly ahead with their research, and in the case of Heath Steele, reached the production stage.

Crushing

A forum on "Protective Devices for Jaw Crushers"[2] was held by the Metallurgy Division, C.I.M., at the annual meeting of the Institute in Ottawa last April. On the invitation of the forum chairman, D. A. Livingstone, several experts both from Canada and the U.S.A. attended this forum, whose discussions, though not offering any positive solution to the problem, nevertheless showed how alert both the operators and the manufacturers are in their endeavours to alleviate a rather serious situation.

The concluding session of this forum will be held at the Diamond Jubilee Meeting of the C.I.M. in Vancouver in April.

Grinding

Two extremely interesting grinding circuits have been developed at extreme opposite ends of Canada — one in Newfoundland and the other in British Columbia.

At Buchans Mining Company's mill, Buchans, Newfoundland, treating a gold-silver-copper-lead-zinc ore, the grinding circuit is a combination of two and three stages. In the primary grinding two mills are on two-stage grinding and two on single stage. After primary and secondary classification the products of both circuits are pumped under pressure to 12-inch cyclones which are in closed circuit with a cylindrical ball mill. In the two-stage flow the first stage is accomplished in a conical mill containing 3-inch balls and the

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second stage takes place in a similar mill charged with 1¼-inch balls. In the single stage circuit two conical mills are in parallel and are loaded with a rationed charge of 2-inch and 3-inch balls. The final grinding of original ore is done by ¾-inch balls in the cylindrical mill already mentioned.

The initial two-stage grinding gives some saving in grinding costs but the single stage permits more flexibility. As both circuits give the same grind, and from test work, equivalent metallurgy, the present flow sheet was adopted to gain part of the benefits of the two procedures. The cyclones overflow at 23% solids with the following mesh sizes: 3.5% + 200, 9.9% + 325, and 86.6% − 325. Ball consumption is 1.55 lb. per ton of ore.

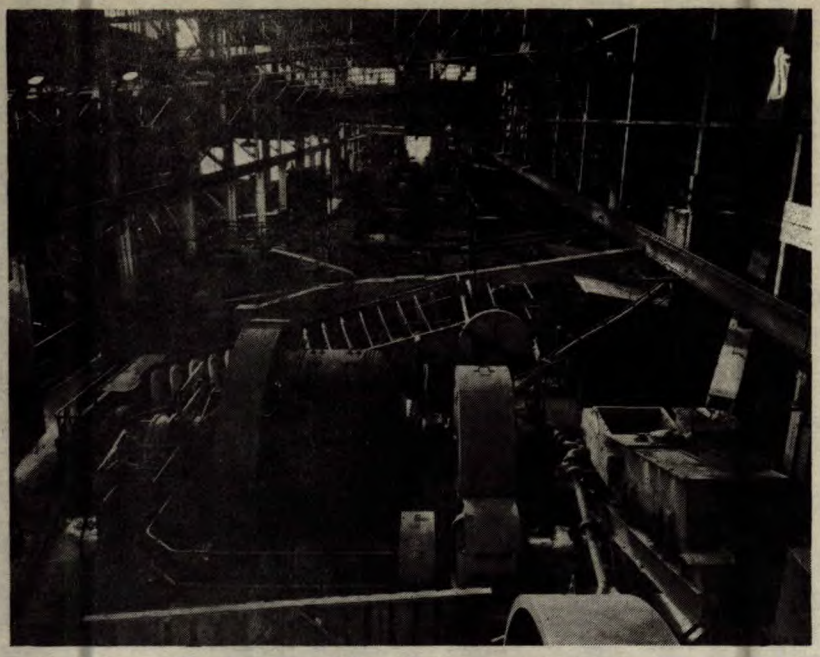
In the Canadian Exploration lead-zinc mill near Salmo, British Columbia, the through-put was increased from 1,700 to 2,000 tons per day by accepting a slightly coarser grind. There are now two regrind units in the mill, one grinding lead rougher concentrate for feed to the lead cleaner circuit, the other grinding zinc rougher concentrate for feed to the zinc cleaner circuit.

These regrind circuits have given a definite increase in concentrate grades with no loss of recovery and have contributed to the increase in milling rate by permitting a coarser initial grind to be accepted.

In the final analysis, the writer ventures to say that the work of both mill operators shows that a successful solution of the flotation problem is tied directly to the successful solution of the grinding problem. In other words, both mill operators treated their grinding circuits as conditioners of feed to flotation.

A paper is being prepared on "Regrind Practice at Canadian Exploration Limited" by H. A. Steane, which will be presented at the C.I.M. meeting in Vancouver next April.

A forum on "Ball Milling"[3] was held in Ottawa at the C.I.M. annual meeting in April. Such is the attraction of "Grinding" that not only was all the seating accommodation taken but in addition fifteen participants remained standing during the whole session. The forum chairman presented data on 47 ball mills operating from Quebec to British Columbia. Many of those present took part in the discussion by asking questions and also commenting from their experience. Another forum on ball milling will be held in Vancouver when advantages and disadvantages of the non-cataracting ball mill will be discussed.



Ball Mill bay at the Sullivan concentrator.

Cominco photo

The writer cannot help but reiterate his statement of last year that the technical sessions held at the annual meetings of the C.I.M. are one of the most important factors in speeding up technical advances in mining and metallurgy.

At the forum on ball milling one of the points discussed in detail was the wear of balls. However, whether this prompted Algoma Steel Corporation to make a new approach to the production of forged steel balls, the writer cannot say. Briefly, this approach is based on an evaluation of hardenabilities resulting from high austenitizing temperatures and an exploration of direct quench heat treatments. The wear of the product is predicated upon extreme hardness coincident with controlled residual stress distribution, thereby resisting abrading and peening forces encountered in wet and dry grinding.

As opposed to grinding with steel balls, a trend to grind ores with screened pieces of ore as pebbles[4] is being slowly introduced into Canadian milling practice. The mill of Bicroft Uranium Mines, which went into production at the end of 1956, is using screened pieces of ore as grinding media. During 1957, both Faraday Uranium Mines and North Rankin Nickel Mines went into production also using screened pieces of ore for grinding instead of steel balls. In addition, grinding with pieces of ore as pebbles was installed at Renabie mines.

At the Renabie mill the grinding circuit was completely revamped. The new installation comprises a 6′ x 8′ rod mill which will grind the minus ⅜″ mill feed to minus 10 mesh. The discharge will be split between a 10′ x 10′ mill and a 9′ x 11′ mill using minus 3-inch plus 1½ inch ore as grinding pebbles. The tonnage will be raised to 600 tons per day from the present 500 tons, the final grind being 70% minus 200 mesh. The main purpose of the change was to reduce the consumption of steel which was running about 4 pounds per ton.

It is interesting to note that some time ago grinding experiments with screened pieces of a copper-lead-zinc ore as pebbles were made in the laboratories of Mines Branch[5]. The ore was a medium soft ore. The experiments indicated that the grinds obtained with screened pieces of ore were similar to those obtained with steel balls, showing that grinding was not affected by the softness of the ore. Nor were the flotation results, as compared to those obtained after grinding with steel, changed in any way.

Hydrocyclones

The trend to replace the rake and spiral classifiers by hydrocyclones has become very marked during the year.

Mention has already been made of the use of hydrocyclones for fine classification at the mill of Buchans Mining Company. In addition, hydrocyclones are used as an aid to thickening there.

At Lake Shore mill all the classi-

New Levack mill under construction.

fiers were replaced by three banks of four hydrocyclones, operating on pressures from 13 to 20 p.s.i. One out of every four hydrocyclones is a standby. The primary bank handles minus 10 mesh material with approximately 22% of minus 325 mesh in it, and in the final stage of grinding the feed to the hydrocyclones contains about 55% minus 325 mesh, the pressures being in the 15 p.s.i. range.

As yet not sufficient data are available for determining the cost or the life expectancy of the body spigot or vortex finder. However, as far as classification efficiency is concerned, the operators of the Lake Shore mill feel that the performance of their hydrocyclones is comparable to the performance of the classifiers. This has been borne out by rather extensive screen and infrasizer analyses over the period of their operation.

At the Dome Mines, sixteen 4-foot gravity cones and two distributing cones were replaced by five 12-inch hydrocyclones and the classifiers in their tertiary grinding circuit by two 18-inch hydrocyclones during the year.

At the Canadian Refractories Limited plant hydrocyclones are being tried for dewatering minus 3/16-inch fines ahead of Hum-mer dewatering screens from which a plus 48-mesh product is binned for later blending with sink product from HMS plant.

Heavy Media Beneficiation

The Department of Mining and Metallurgy of the University of Alberta this past year has completed an extensive research project on Heavy Media and the Driessen Cone. In detail these investigations consisted of:

1. Apparent viscosities of various types of heavy media, viz. galena, magnetite, ferrosilicon, pyrite and barite, were determined in a rotational viscometer. Then, by an indirect method, using the apparent viscosities obtained in the viscometer, the apparent viscosities of the same media were determined in the cone under various cone operating conditions.

2. The effects of change in the apparent viscosities of heavy media in the cone were analysed, with respect to all other operating variables and the mineral separation efficiency of the cone.

It is believed that these investigations have evolved for the first time a method of determining apparent viscosities of heavy media in the cone. Further, it is considered that the data obtained from these investigations makes it possible now to determine more precisely:

1. What operating conditions should exist in different sizes of cones to give comparable metallurgy.

2. The through-put capacities of various sizes of cones when operating under the above conditions.

3. How to determine operating conditions in a particular cone to give optimum metallurgy.

This work has been carried out by Professor E. O. Lilge, Head of the Department, ably assisted by T. E. Fregren, Senior Research Engineer, and a staff of some 10 graduate and undergraduate engineers. The research project is financed by the Atomic Energy Control Board and the funds are administered by Eldorado Mining and Refining Limited.

Flotation

The mill of Buchans Mining Company in Newfoundland treats an ore which is an extremely fine-grained aggregate containing sphalerite, galena, pyrite, chalcopyrite, gold and silver with minor amounts of bornite, tetrahedrite, tennantite and covellite. The gangue is essentially baritic with silicates and calcite.

The special features of the present flotation practice at Buchans mill are:

1. The addition of sulphur dioxide gas prior to copper-lead flotation;

2. Flotation of galena at a pH of 6.2;

3. Five stages of cleaning in copper-lead flotation;

4. Copper lead separation with sulphur dioxide gas and sodium bichromate at a pH of 5.2 to 5.4;

5. Deleading of copper concentrates, which is done only when high lead reports in the copper concentrates.

In the Sudbury district the construction of new Levack mill of the International Nickel Company of Canada was continued. In this mill, using selective flotation, both copper and nickel concentrates will be produced.

Development of Controls in Flotation

A 150 tpd pilot mill was built in the Sullivan Concentrator of Cominco to provide a means of investigating problems in the treatment of ore which are beyond the scope of laboratory investigations. The feature of the pilot mill design is extensive use of instrumental control. Pulp density of the feed, for example, is accurately controlled by a Gammagage, and the Gammagage together with a Parshall flume maintain a constant tonnage to the pilot mill automatically. The recording xan-

thate meter and recording pH meter obtained in 1956 have been installed in the pilot mill. Flowrators continuously indicate the rate of addition of reagents. All instruments together with appropriate controls are located in a central control room. Operation commenced in September.

Some laboratory work on the chemistry of xanthates in flotation of Sullivan ore was completed. It was shown that flotation results in the lead circuit are functions of the product of the concentrations of xanthate and hydrogen ions. Xanthate usefully adsorbed is a function of this product. In addition, a considerable amount of xanthate is uselessly abstracted from solution. The useless abstraction is a function of the product of the square of the xanthate concentration and the first power of the hydrogen ion concentration. A paper on this work is being prepared for the 1958 C.I.M. meeting.

Following laboratory studies, an order was placed for an X-ray spectrograph to record continuously the percentage of zinc in Sullivan Concentrator zinc rougher tailings. Delivery is expected in 1958.

Materials Handling

At the mill of Kerr-Addison Gold Mines, three 10″ x 8″, 125 h.p. primary Dorrclone pumps and three 10″ x 8″, 125 h.p. disposal tailing pumps were transferred to a new pump room. The primary Dorrclone pumps were fitted with outboard bearings to support the large 10-belt pulleys, which had caused several broken shafts. No shafts have broken since. The tailing pumps were fitted with controls to regulate the speed according to the depth of pulp in the pump box and thus avoid pumping air into the tailing lines. The controls consist of bubble tubes and pneumatic controls connected to variable fluid drives. These are working satisfactorily.

Beneficiation of Iron Ores

At Steep Rock Iron Mines construction was started on two gravity concentration plants. These plants will produce a high grade concentrate from lean material which is associated with the regular direct-shipping ore. These plants will consist of three major units, namely, a heavy density separation section, a jig section — using a Remco jig, and a spiral section — using Humphreys spirals. The classification of the three sections depends largely upon the variable size of the material, and a size separation of approximately ½ inch will be made between the heavy media and jig feeds. The spirals will concentrate all fine materials from the rest of the plant, which are recovered from the classification of underflow materials from screens, jigs, heavy media, etc.

Each of these plants will have a capacity of 7000 tons per day of crude ore and the recovery will vary with the iron content of the crude feed. The plant known as the North Concentrator will handle material from the open pit mines during its first year of operation and will, therefore, only work on a summer season programme. The other plant, known as the South Concentrator, will work primarily on feed from the underground mines, and will, therefore, be a year round operation.

Extractive Metallurgy

At the mill of the Macassa Mines due to high grade patches of ore going to the mill, overall recoveries were liable to fluctuate. However, by varying the tonnage of precipitated solution according to the value of mill heads, a steady head was maintained to precipitation presses, which helped to overcome the problem. Thus, by keeping pregnant solution values under control, mill recoveries of around 95% were maintained.

It is also interesting to note that in refining of gold precipitates at the same mine, the replacement of the previous burner by an Anthony burner cut the oil consumption by 50%. The use of an oxidizing flame together with a flux the composition of which is strictly controlled by the gold content of the precipitate resulted in a gold bullion which has been consistently of 950 total fineness or better. This naturally has meant savings in mint charges.

At Copper Cliff, a sulphuric acid plant now under construction by Canadian Industries Limited will utilize rich sulphur dioxide bearing gas generated by the fluid-bed roasters of the Iron Ore Recovery Plant of Inco.

The International Nickel Company of Canada also made an agreement with Texas Gulf Sulphur Company whereby that organization will build and operate a pilot plant at Copper Cliff to investigate processes for the recovery of elemental sulphur, also from gas generated by the fluid-bed roasters of the Iron Ore Recovery Plant.

Developments in Uranium Metallurgy

Although developments in uranium metallurgy are part of extractive metallurgy, due to their increasing national importance the writer has decided to treat them in a separate chapter.

Uranium metallurgy is still very young, hence it is no wonder that many further improvements and new developments have taken place during the year.

PORT RADIUM, N.W.T.
(Eldorado Mining and Refining)

Construction of a solvent extraction section in the leaching plant was nearly completed by the year's end. This unit will replace the present aluminum precipitation section.

BEAVERLODGE, SASKATCHEWAN
(Eldorado Mining and Refining)

The leaching plant capacity was increased from 750 to 2000 tons per day as the enlarged plant commenced operation and reached its rated capacity by mid-year.

The expanded flowsheet was designed to treat ore from the Verna Mine as well as ore from the older Ace Mine. The new features in the process are:

1. Flotation of pyrite and
2. Separate leaching of pyrite concentrate by sulphuric acid, and precipitation with hydrated magnesia; the precipitate is sent to the main carbonate leaching circuit for retreatment.
3. The additional leaching capacity is provided by 24 Pachuca tanks arranged in lines of six.
4. Steam stripping of pregnant solution is included in the flowsheet. This operation will reduce the caustic soda requirements by lowering the amount of sodium bicarbonate prior to precipitation of uranium with sodium hydroxide.

BLIND RIVER AREA

The mill of the Lake Nordic property of Northspan Uranium Mines, which was started in September, uses Pachuca tanks instead of Dorr-type mechanical air agitators in its leaching section. It was found that the Dorr-type agitators did not work too well due to the abrasiveness of Blind River ores. By using Pachuca tanks, preliminary results seem to indicate

that glue is not required, which means a saving of almost 20 cents per ton.

The interesting technical advance in uranium metallurgy is the moving bed ion exchange system, first installed at Consolidated Denison and subsequently at the mills of Can-Met Explorations, of the three Northspan Uranium Mines properties and of Milliken Lake Uranium Mines.

The process differs from the fixed bed ion exchange in that three steps of adsorption, elution and backwashing are done in separate columns rather than all done in the one column in turn. The resin is first saturated with uranium in the adsorption column, then transferred hydraulically to a backwash column where the slimes are removed by an upward flow of solution through the resin. After backwashing is completed, the resin is transferred to an elution column where a nitrate solution strips the uranium from the resin, After this is completed the resin is again transferred to the adsorption column.

This type of system has a number of advantages, the main one being that one can obtain a larger plant capacity for a smaller capital cost. It also has the advantage that the pregnant solution and eluting solutions never enter the same sets of columns and thereby mixing is practically impossible. Also, saturation of the resin is always obtained, as well as higher grades in the eluting solution. The latter points save money from an operating standpoint because more uranium is loaded on a resin, and is eluted more efficiently.

At the mills of Northspan Uranium Mines, in their neutral filtration, in order to save on filter bags, a "Snap-Blow" arrangement has been installed recently. This arrangement works so that the blow-off air to a disc filter is admitted for only fractions of a second, at a high pressure, thereby knocking the cake off the sector and thus rendering the use of scraper blades unnecessary.

In the drum filtration sections of the same mills a scraper, or blow-back type filter, rather than a string discharge filter, is being used with excellent results. The soluble losses at the Algom-Nordic mill are consistently less than 1% and most of the time are running somewhere around ½%. Installed in these filters is also what the Company's metallurgists call a purge system. This purge system allows the filtrate lines to be exhausted with air, thereby clearing all the filtrate out of the filtrate lines; then when the blow-off is applied, no blow-back occurs.

The writer would like to mention here that a Forum on Problems in Uranium Metallurgy will be held at the Diamond Jubilee Meeting of the C.I.M. in Vancouver on April 23, 1958.

Recovery of Metals from Metallurgical Gases at Flin Flon

The Hudson Bay Mining and Smelting Co. are now recovering the values in the gases of their copper reverberatory furnace and converter, which were escaping their Cottrell precipitators. They are using a Dracco Automatic Type SG dust arrester equipped with glass fabric bags and operated at temperatures of about 400°F. The installation consists of 12 units of 10 compartments each, and 154 bags per compartment. Each compartment has 2004 square feet of bag area.

The unit was designed to handle 205,000 CFM of gas measured at 32°F and of the following average analysis: SO_2 - 2.0%; SO_3 - .005%.

An average of 35 tons of dust per day is collected of the following analysis: Zn - 31.7%; Cd - 1.3%; F - 0.08%; Pb - 17.9%; Fe - 1.5%; Cu - 1.7% As - 4.5%.

The gas leaves the Cottrell outlet at an average temperature of 800°F and by use of "U" type cooling tubes and admission of tempering air is cooled to 400°F before entering the dust arrester.

The dust is removed from the bags, either by a periodic gentle shaking of the bag or by reversing the suction on the bag thus allowing it to collapse.

Draft is maintained at the Cottrell outlet by automatic controls on the arrester induced draft fan dampers. The exhaust gases are delivered to the smelter stack. By using glass bags, the temperature of the gas can be maintained above the condensation point of its acid content, thus preventing corrosion of the steel flues and the brick stack.

Metallurgical Progress by Cominco

A. Trail Metallurgical Plants

The complete conversion to continuous casting of zinc and zinc alloys highlighted a continuing trend to increased mechanization.

The large proportion of zinc leaching residues in smelter feed resulted in a low percentage of lead in the charge. Valuable experience was gained in handling this type of charge.

The new high velocity lead clad flue in the sintering plant, and the new conditioning tower, were completed during 1957, and are giving excellent service.

The expansion of indium sales continued, and prospects for further expansion are considered excellent.

B. Pig Iron

Detailed engineering studies are progressing on production of pig iron from by-product iron calcine at Kimberley.

C. Metal Use Research

Application research has resulted in the development of a new ductile zinc extrusion alloy which is suitable for extrusion at moderate pressure. Considerable progress has been made in defining the preferred composition of galvanic zinc anodes. The properties of the zinc rich paints have been thoroughly investigated. A unique laboratory test for evaluating these materials has been developed, and the procedure distributed to paint research laboratories and others interested.

Smelting of Low-Grade Manganese Ores

One of the significant developments in smelting of low-grade manganese ores was the erection of a pilot plant at Niagara Falls, Ontario, for smelting of Woodstock, N.B., manganese ores, presently under development by Stratmat Limited. This company's preliminary estimates place the tonnage of Woodstock deposits at 214 million tons, averaging 13% iron and 7% manganese. Hence, the deposits appear to be of great potential importance to the nation.

The smelting process used at the pilot plant is known as the Udy process which was proved to be metallurgically successful in electric smelting experiments in the laboratories of the Mines Branch. Following these experiments, the pilot plant at Nia-

gara Falls was designed and built with a view to establishing the economic feasibility of the process.

The operation of the plant was recently described by Monture[6] to whose excellent article the reader is referred.

Mines Branch

As in previous years, during 1957 the number of investigations carried out on metallic ores in the laboratories of Mineral Dressing and Process Metallurgy Division reflected the increase in mining developments. Many of the investigations were on base-metal and iron ores and some of them on ores of the less-common metals. Pilot plant runs were made on many hundreds of tons of copper-nickel, lead-zinc, iron, molybdenum and other ores. New research projects were started with a view to solving beneficiation problems encountered in developing low-grade ore deposits, and the research on grinding was resumed. Recently, a description of the above laboratories was given by Banks[7].

Process research and many investigations were carried out by the Radioactivity Division on radioactive ores and products, shipped from most of the uranium mining areas. In this work, the emphasis was on the solvent extraction process for the recovery of uranium from leach and ion exchange liquors when alternative stripping procedures were developed.

Studies were also made by the Radioactivity Division on the recovery of thorium by the solvent extraction process and a method for producing high-purity thorium oxide from thorium-bearing ion-exchange effluent was worked out. Pilot plant runs were made on fatty acid flotation of a uranium ore in cooperation with Professor T. V. Lord's department of Queen's University. Investigation by the division of tracers in following circuit flows at operating mills was carried out. Finally it might be mentioned here that a comprehensive manual of analytical procedures for use in the uranium industry has been prepared and will be issued shortly.

Milling Developments in New Brunswick

At the beginning of this review, a reference was made to the milling developments that have been taking place in New Brunswick. These developments are very welcome in an area which has not in the past shared very largely in Canada's mining history. Since they have not been described so far, a few words devoted to them might be opportune.

Brunswick Mining and Smelting, largely financed by St. Joseph Lead Company of the U.S.A., after having conducted metallurgical research including operation of a 150-ton-per-day flotation pilot plant for 2 years, at the time of the writer's visit in August was planning design of a 2000-ton-per-day concentrator. The ore is a copper-lead-zinc-pyrite ore containing around 0.5% copper, 2.5% lead, 6.0 zinc, 65.70% pyrite, some graphite, and 10 to 15% non-sulphide gangue. The first step in the flowsheet is to float away the graphite. This is followed by flotation of copper, then lead and zinc are floated in succession, when concentrates averaging 35% lead and 50% zinc, respectively, are produced. Provision will also be made in the 2000-ton concentrator for floating of pyrite. Satisfactory recoveries have been obtained in pilot plant work.

Heath Steele Mines, owned by the American Metals Company of the U.S.A. and the International Nickel Company of Canada, went into production in 1957. The mill is designed to treat 1500 tons of ore per day and consists of two separate sections of 750 tons each. Initially, one section of the mill is treating chalcocite ore and the other lead-zinc-copper ore. During the writer's visit last August the mill was not working at capacity, the mill circuit adjustments still being in progress.

The chalcocite ore is mined from an open pit and varies considerably in character and mineral content. The ore averages around 4 per cent copper and 2 per cent zinc; the copper mineral is so intimately associated with zinc mineral that there is no attempt made to separate these two. Thus, chalcocite concentrates, usually containing less than 20 per cent copper, contain 10 per cent or more zinc.

The lead-zinc-copper ore, which comes from underground and an open pit, presently averages about 3 per cent lead, 8 per cent zinc and 0.7 per cent copper. Ore from the pit contains some ferrous salts and copper sulphate. The latter is particularly objectionable in a flotation circuit since it activates the zinc mineral which, once activated, is extremely difficult to de-activate. Research, both on a laboratory and plant basis, continues in an effort to improve the metallurgical results. After floating the copper concentrate, the lead concentrate is floated off. The final stage is flotation of the zinc.

Conclusion

This is the fifth annual review of milling and process metallurgy that the writer has prepared, and so it is little wonder that he feels introspective. Probably each milling or metallurgical development by itself does not represent a great achievement, but the progress of the industry is the sum of all the individual accomplishments such as have been described. Only the professional scientist and engineer know how much thought and care have to be expended to make even a small improvement to an already efficient industry. For example, the following sentence which stands all alone occurs in this review:

"The expansion of indium sales continued, and prospects for further expansion are considered excellent."

This modest statement represents the result of years of thought and research work by scores of scientists and engineers. A few years ago hardly anybody wanted indium; it was an unwanted metal and before it could be marketed uses which meshed with the peculiar properties of indium had to be found. It has been never-ending intensive research which has discovered these uses, a remarkable achievement in the conservation of metals, and a boon, however small, to the Nation.

Acknowledgments

This review would have been impossible without the cooperation of the executives of the mines, mill operators and metallurgists in the field. To all who assisted the writer in the preparation of this review, he wishes to express his grateful appreciation.

References

1. Parker, R. D., *Research and the Nickel Industry;* C.I.M., Trans., Vol. LX, 1957, pp. 357-362.
2. Livingstone, D. A., *Forum on Protective Devices for Jaw Crushers;* C.I.M., Vol. 50, No. 546, Oct., 1957, pp. 629-637.
3. Djingheuzian, L. E., *Forum on*

Ball Milling; C.I.M., Trans., Vol. LX, 1957, pp. 290-304.
4. CROCKER, B. S., *Pebble Grinding Gains Slowly in Canada;* The Northern Miner, Annual Review Number, Nov. 28, 1957, p. 65.
5. DJINGHEUZIAN, L. E., *Development of Ore Dressing Procedures for Canadian Ores at the Mines Branch, Ottawa;* Can. Min. Journ., Vol. 77, No. 10, 1956, and Western Miner and Oil Review, No. 11, 1956.
6. MONTURE, G. C., *Woodstock Manganese Ores;* Can. Min. Journ., Vol. 78, No. 4, 1957, pp. 117-120.
7. BANKS, H. R., *Mineral Dressing and Testing Facilities;* Sixth Commonwealth Mining and Metallurgical Congress, *The Milling of Canadian Ores*, 1957.

(*Reprinted from CANADIAN MINING JOURNAL, February*, 1958)

Printed in Canada