Ulrich machines, designed by the manager, were installed and used. About eight years ago an experimental plant, using Mechernich machines, was installed at the Central Mine, where, with additions, it has been working until very recently. The great drawback of these magnetic processes, apart from any economical considerations, is the amount of fine dust set free into the atmosphere, despite precautions made to keep the mills free from it, the result being an unusual amount of sickness due to lead poisoning among the employees.

The Mechernich machine is composed essentially of two-bar electro-magnets. The properly crushed and dried material is fed from a shoot into the strong magnetic field between the adjacent north and south poles, the upper one (north) revolving. The intensity of the field gradually decreases after passing the adjacent surfaces. The ore is brought in contact with the poles at its strongest field. The para-magnetic particles adhere to the upper or revolving poles, while the dia-

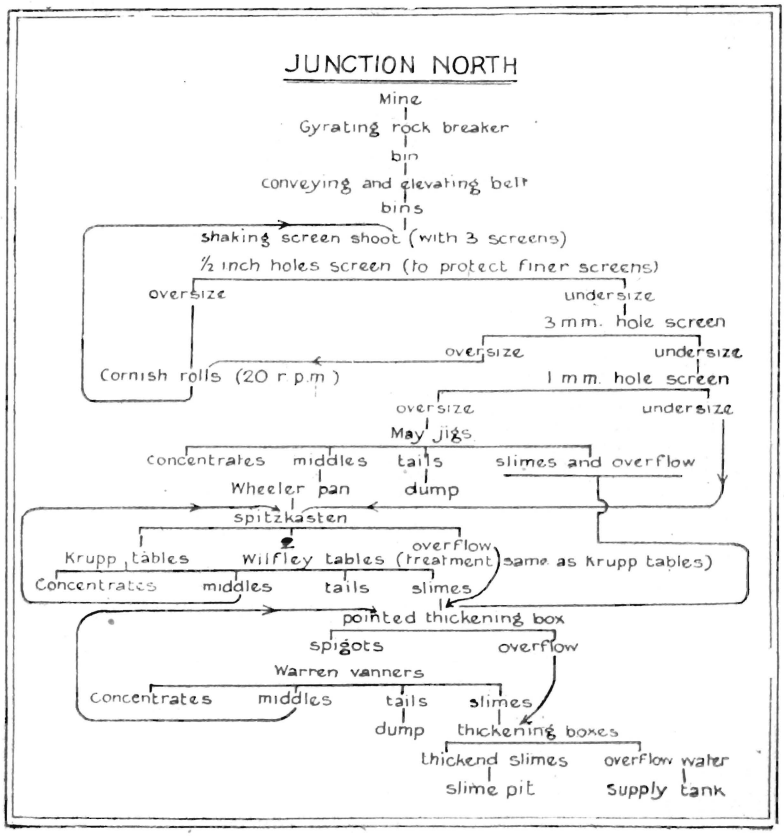

FIG. 3.

magnetic particles fall off, and are collected in bin 1. The para-magnetic particles are carried round by adhering to the pole into a constantly diminishing intensity of field, until they are dislodged by gravitation or some mechanical means. Each of the shoots 2 and 3 may be adjusted to suit the required conditions at the various zones of release.

It has been found that, under the influence of a powerful magnetic field, garnet and rhodonite are much more susceptible than blende, and the latter more so than galena and quartz, which are practically non-magnetic. With suitable machines three products may be made—

1. Garnet rhodonite product to waste.
2. Blende product, which may be further cleansed on another machine.
3. Galena blende quartz products, which are readily separated on wet concentrating tables and vanners into lead concentrates and a small amount of zinc concentrates and quartz to dump.

The scheme of reduction shown in figure 4 outlines the process used at the Central Mine.

Flotation Processes.

Potter Process.—In 1901 C. V. Potter, of Melbourne, took out a patent for the recovery of sulphides from their ores —viz., the addition of very dilute acidulated solutions to finely pulverised ores causes certain sulphides to rise to the surface.* Sulphuric acid is for economical reasons used of a strength

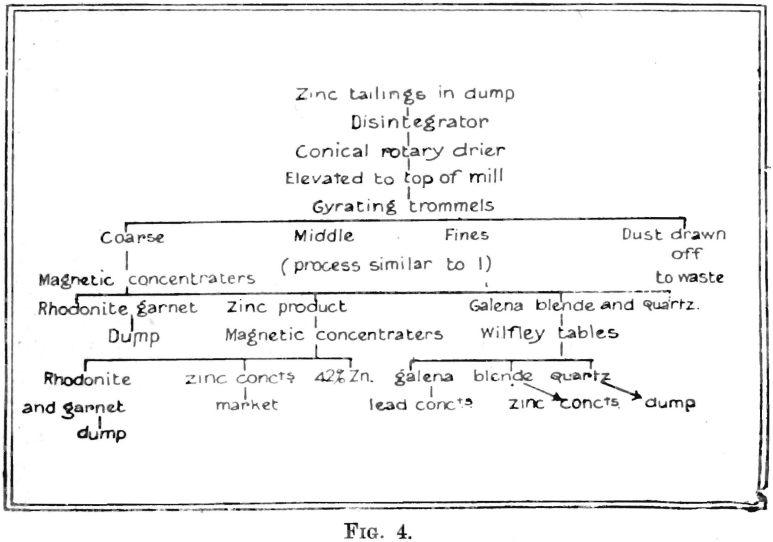

Fig. 4.

*See *Aust. Mining Standard*, 21st August, 1902.

from 1 to 10 per cent. Dilute sulphuric acid will not attack galena or blende to any extent. During the early days of the process the following was supposed to be the action that took place—viz., that acid attacked the sulphide of iron (FeS), which was always present in small quantities, liberating sulphuretted hydrogen (H_2S).

$$H_2SO_4 + FeS = H_2S + FeSO_4.$$

The liberated bubbles attached themselves to the sulphide particles, and when large enough lifted them to the surface. By heating the solution less acid is consumed on account of the expanded bubbles having a greater buoying-up power. When the bubbles break, the particles fall again. Various appliances have been devised to remove the floating particles from the bath before the bubbles break. This process has not been a financial success in its original form, but has suggested other acid flotation processes, some of which are working with a high degree of success.

Delprat or Salt Cake Process.—In 1902 G. D. Delprat, the General Manager of the Broken Hill Proprietary Company, Limited, took out a patent for the salt cake process. In this process salt cake or crude acid sulphate of soda $NaHSO_4$ is dissolved in water until its specific gravity is increased—*e.g.*, to 1·3. Sulphuric acid is added to the solution, heat is applied, and the solution and fine ore particles are treated in vats as hereafter described. Reactions similar to those in the Potter process take place, but it was very soon discovered that the real chemical reactions were different from those previously assumed to take place. It was at once observed that the process was free from the distinctive odour of sulphuretted hydrogen. On examination, the gas given off was found to be CO_2, with a trace of H_2S. The CO_2 was given off from the small amount of calcite and siderite always present. The liberated CO_2 attaches itself to the clean particles of sulphides, but not to earthy or oxidised surfaces. If concentrates which have been produced by an acid flotation process are retreated by themselves, the reactions are feeble, and but a small amount is recovered unless calcite or a similar carbonate is added to the flotation vats. The material treated in the Broken Hill Proprietary Company's zinc plant is derived as follows from the lead concentrating mills:—The tailings of both coarse and fine jigs are passed over shaking screens, to separate the coarse siliceous particles from the finer material containing a fair percentage of both zinc and lead. The former is sent to the dump, and the latter mixed with the tailings from the Wilfley table, and the Luhrig vanners are passed through a spitzkasten to remove slime. The coarser

product is sent to the zinc plant, and the slime product to the slime settling pits. A comparison of the sizing analysis and of the feed already given clearly shows that the former is fine, but contains a very small amount of slime.

One of the special features of this process is the use of the Delprat patent vat. This vat is a steeply-inclined inverted wooden pyramid lined with sheet lead. The vat has two pockets, one with and the other without an outlet. The blind pocket allows the ore particles to overflow steadily into the outlet pocket and at the same time to collect lumps, &c., which might obstruct the outlet. The outlet is regulated by a stopper on the end of a rod, which passes down through the solution. The solution is made up in a vat and heated by a steam coil to about 180 deg. Fahr. The solution passes, by means of a pipe, to near the bottom of the flotation vat, into which the fine ore is fed automatically above the fluid pocket. The gas generated attaches itself to the galena and blende particles, floating them to the surface and overflowing with the excess solution into a settling vat common to several flotation units; while the gangue—principally quartz, rhodonite, and garnet—escapes through the outlet in the pocket on to an endless belt, where it drains sufficiently to allow it to be sent away, to be used for refilling stopes in the mine. The concentrates settle in the tank till it is full, when the stream is diverted to a similar tank, while the former is drained and the solution returned by air-jet to the solution tank. The concentrates are then given a water-wash to remove any chemical solution, and then drained. The vat concentrates may be retreated to increase the percentage of zinc, and at the same time to recover some of the galena as a lead concentrate. This may be done on Wilfley or similar tables and vanners, or, for preference, by magnetic concentrators, as the latter give richer concentrates. Some magnetic concentrators are adapted to treat wet material. The zinc and lead concentrates are then sent away for metallurgical treatment elsewhere.

The following is an analysis of the feed concentrates and tailings of this process:—

		Feed.	Concentrates.	Tailinge.
Insoluble, per cent.	... ...	49·0	8·0	65·0
FeO ,,	... ...	7·3	10·0	4·4
CaO ,,	... ...	3·9	2·7	4·1
Pb ,,	... ...	3·6	5·8	2·7
Zn ,,	... ...	16·4	14·1	5·1
Ag. oz. per ton	... ...	15·3	37·9	2·9

SIZING ANALYSIS.

Sieve.				Feed. Per cent.	Concentrates. Per cent.	Tailings. Per cent.
Caught on	20	...	...	0·7	0·0	1·9
,,	40	...	...	6·1	4·0	8·4
,,	60	...	...	10·7	15·5	14 3
,,	80	...	...	17·8	16·5	16·1
,,	100	...	...	23·8	20·2	23·3
,,	120	...	...	12·9	12·7	11·3
,,	150	...	...	11·2	11·3	13·2
Through	150	...	...	16·8	20·0	11·9

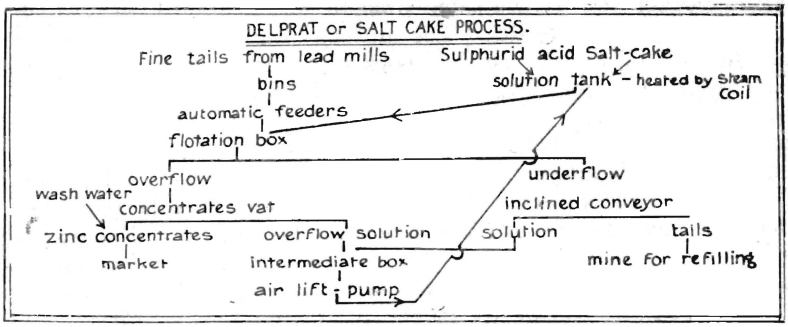

FIG 5.

DE BAVAY PROCESS.—This process makes use of the selective actions of CO_2 in attaching itself to sulphides but not to earthy particles. The CO_2 is generated externally.

BALLOT OR GRANULATION PROCESS.—This was formerly known as the Cattermole process. This is an acid-oil flotation process. The H_2SO_4 is added for the purpose of cleaning the surfaces of the particles of oxidised ore, as oil does not adhere to oxidised or earthy surfaces. With freshly broken sulphide the process is said to work well without acid, but the additional acid assures cleaner surfaces, and hence a better separation. The feed, usually tailings, is ground fine in ball mills or grinding pans, the pans giving best results. This ground pulp is then fed continuously without sizing to the agitation vat, where up to 3 per cent. H_2SO_4 is added as a thin stream, and about ·05 per cent. of oleic oil is added. A large range of oils can be used.

After passing through the agitators the pulp passes through three spitzkasten separating boxes in series. The ore particles are floated over the lips, while gangue passes into the next for retreatment, and from the third is discharged into settling tanks, where the solution is decanted, and the drained tailings are sent to dump. The action is as follows:—The acid cleans the surface of the metallic sulphides; the oil attaches itself to the clean sulphide surfaces, the agitation causing numerous small air-bubbles to be carried down and held in suspension

in the pulp, until they attach themselves to the greasy surfaces. The pulp then coagulates into little lumps, hence it is termed the granulation process. The concentrates assay, on the average—

Zinc	...	...	...	...	43 per cent.
Lead	...	...	...	...	11 ,,
Silver	...	...	...	...	17 oz.

The percentage of zinc is moderate, and that of lead is so high that it might be advantageous, for both metallurgical and economical reasons, to put the granulation process concentrates through magnetic separators to remove a portion of the lead as a separate lead concentrate, as is found advisable in the Delprat process.

This process has the great advantage of giving good results in the presence of slimes. This process has been installed on a large scale at the Central Mine, Broken Hill, for the continuous treatment of tailings of the concentrating tables and vanners of the recently-erected mill. The flow-sheet of this mill deserves sepcial attention, as the process is continuous, giving lead concentrates, zinc concentrates, and worthless tails.

Vacuum Oil Process.—This process has recently been introduced at the Zinc Corporation Works at Broken Hill. The trials gave very good results, and a large working plant has now been erected. The process is described by Mr. George Elmore in the *Mining Journal* (London), of 11th May, 1907. It may be briefly summarised as follows:—

The process is based—Firstly, upon the fact that in flowing pulp of crushed oil and water, oil has a selective action for the mineral particles as distinct from the rocky particles or gangue. (Thus far it follows the original Elmore process.) The selective action is materially increased in some cases by the presence of acid (a modification made since the introduction of the Potter process). Secondly, upon the fact that the air or gases dissolved in milling water are liberated, partially or entirely, upon subjecting the same to a pressure less than the surrounding atmosphere. These liberated gases may be augmented by the generation of gases in the pulp (as in the Potter process or the Delprat process), or by introduction from an external source (as in the De Bavay process). These liberated gases attach themslves to the greased mineral particles (as in the Cattermole process), and, being largely increased in volume as a result of the vacuum or partial vacuum applied thereto, cause the greased particles with their attendant bubbles of air or gas to float to the surface of the liquid from which they are automatically discharged in the form of a rich concentrate leaving clean tailings in the bottom of the vessel in which the operation has been conducted. The application of a vacuum to increase the floating power of the adhering

gas in distinctly novel to this class of process, and takes the place of the simple expedient of heating the solution as in Potter, Delprat, Cattermole, &c., processes.

The crushed pulp from a wet crushing mill is mixed with oil and acid in an agitator. It is thence under the influence of a partial vacuum drawn up into a vacuum separating pan. The metalliferous scum overflows from the top of the separating pan, and is drawn down a long length of water sealed pipe

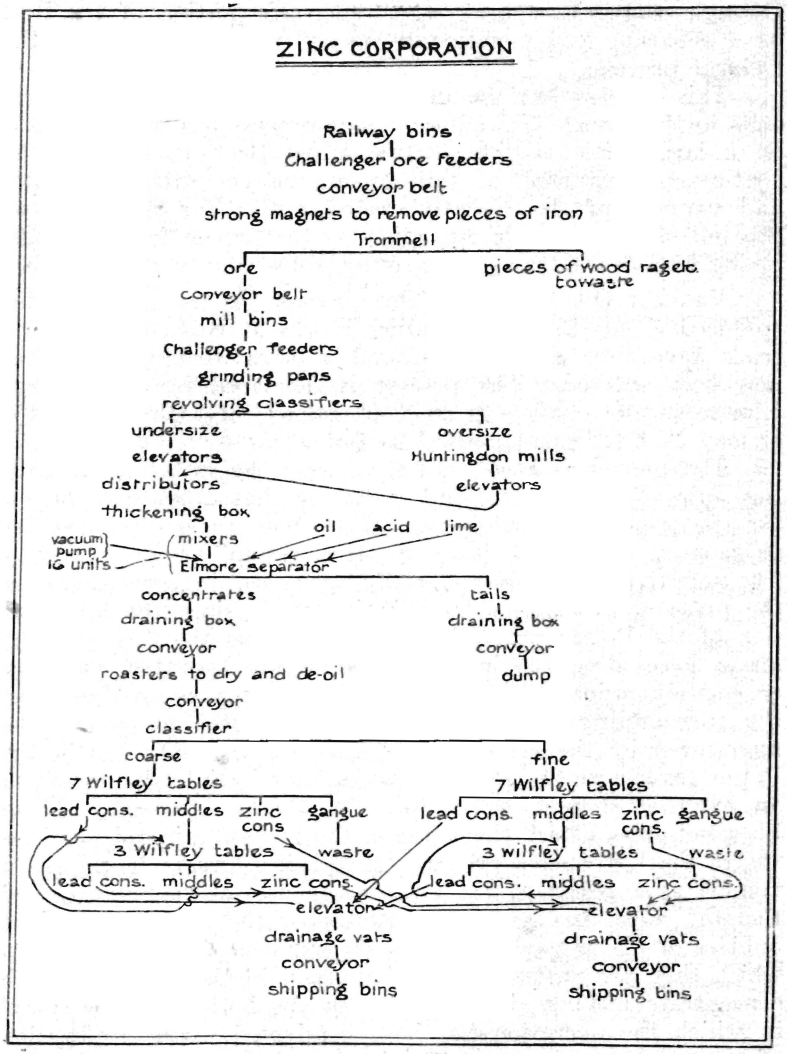

FIG. 6.

into a tank. The tails are likewise, by suitable machinery, raked to the outer edge of the vacuum pans and discharged into a tank in a similar manner to the concentrates.

It is claimed that this process, like the Cattermole process, successfully deals with slimes mixed in the pulp.

Treatment of Old Tailings for Zinc, &c.

The Zinc Corporation is a company that was formed to buy large quantities of tailings and treat them for their zinc, lead, and silver contents. A plant has been erected on the South Block's Hill, and its scheme of operations is as follows*:—The tailings are trucked by rail direct from the original dumps, and tipped into an underground bin alongside the railway line, whence they are hoisted by belt conveyers to the feed bins at the head of the mill. From there they are gravitated to the grinding pans, after treatment by which, the tailings are screened, and the rejects sent to the Huntingdon fine-grinding mills on the floor below.

Only a small proportion of the ore requires regrinding after passing through the grinding pans. From the grinding section the material passes to the Elmore flotation plant, consisting of 16 units, and having a combined estimated capacity of about 500 tons of tailings per day. The proved capacity is 760 tons per day. A separation of the metals from the gangue is here effected, and while the residues are carried out to the tailings dump by belt conveyers, the product, in the shape of a zinc concentrate, is put through the ore roasters, to free it from the oil, and then put over Wilfley tables, which will separate it into two marketable products—a lead and a zinc concentrate. By this means it is intended to increase the percentage of zinc in the original zinc concentrate, besides forming a separate and payable lead concentrate of good grade.

Sampling and Assaying.

It is very desirable in operating ore-dressing mills to sample and assay not only the crude ore entering, and the products leaving, the mill, but also to know the assay value of the various intermediate products at successive stages. It enables the mill superintendent to daily analyse the work under his control, and also to localise the blame on any shift or individual for indifferent results—*e.g.*, one man on each of the three shifts looks after the same, say three jigs. Samples of concentrates and tails for these jigs go to form one average sample of concentrate, also of tails, for each shift. Each sample should be separately assayed, and the result posted in the mill. Blame may then be localised on individual operators, the moral effect

**Aust. Mining Standard*, 26th Feb., 1908,

of which is very great. In all cases the tonnage is determined by weighing each truck or ore before it is tipped to the breakers.

There are two general methods in vogue, each with strong advocates, of determining the average assay value of the crude ore. In the first and more rational method the ore fed to each set of rolls is sampled, say a scoopful of the total stream—*i.e.*, coarse and fine is taken at intervals, say, of half to one hour, the total quantity going to form the average sample of the mill for the eight-hour shift or the 24-hour day. The average assay value of crude ore is fairly uniform and not patchy. The average assay value taken in conjunction with the weighed tonnage gives a firm basis to calculate the total metal contents of the crude ore, and hence, later on after the metal contents of the product have also been ascertained, to determine the actual and percentage recovery of lead, zinc, and silver. The other method in use is to weigh or estimate the weight, sample and assay the products, and thence by back calculation to determine the average assay value of the crude ore. This method is defective, in that it is difficult to sample and weigh the slime slurry going to temporary waste, except by the round-about and uncertain difference in the total weight in balancing the total of the other products against that of the crude ore. The final products have high percentage of moisture when sampled. There is thus a large amount of balancing and calculation to ascertain the value of the crude feed which can be more readily and directly ascertained. It should not be overlooked that the mines using the back calculation of values usually show on paper better percentages of recovery than those directly sampling the crude feed. The intermediate products, such as the concentrates and tailings of jigs, tables, and vanners, are sampled by diverting the whole stream from the launder into a drum, a short length of launder or sheet metal being used for the purpose. The product is allowed to settle, the excess water poured off, and the sample placed with its own co-samples to form the average sample for the shift. The shipping value of concentrates is ascertained by sampling with an augur each truck if shipped loose, or each bag if bagged. The samplings are placed in a drum provided with a close-fitting lid to prevent evaporation of moisture until the bulk sample is quartered down and the moisture per cent. ascertained. Bulk samples are quartered down in the same way.

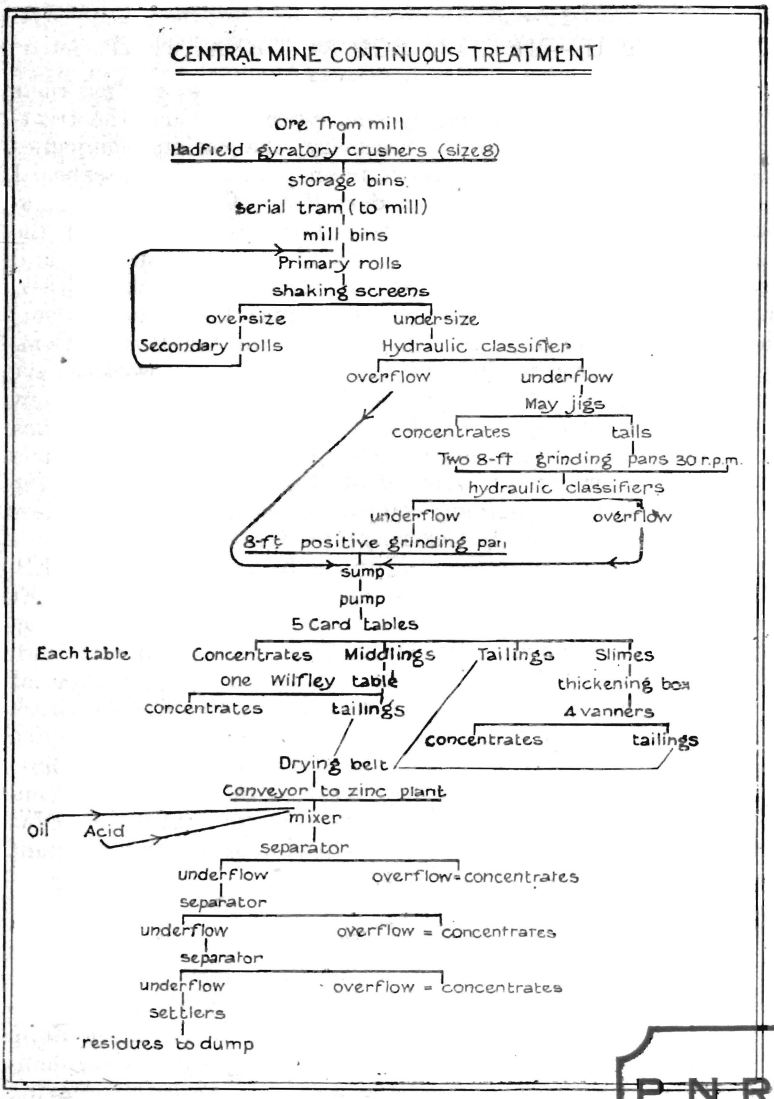

FIG. 7.