Discussion.

Mr. ALFRED GILES, President, was sure that if members would consider the time and skill that had been expended upon the Paper and the diagrams, they would not for one moment hesitate to give a cordial vote of thanks to the Author. The Institution had before it a very elaborate description of the different processes of separating minerals from the earth in which they were found. When it was remembered that last month something like £450,000 of gold was received from Africa, and that ore with 5 dwts. to the ton could be made to pay, it would be seen how necessary it was that the best appliances should be employed for separating the ore from the enclosing rock. The Author having directed attention to these facts was therefore deserving of most cordial thanks. Mr. Giles.

Mr. SIDNEY H. FARRAR said, with regard to South African gold ores with which he now had to deal, concentration was undoubtedly a vital question. This was felt so strongly that the Johannesburg Chamber of Mines had offered a prize of, he believed, one thousand pounds for the best concentrator. Trials of concentrators would be made at an exhibition to be held shortly at Johannesburg. At present they had been using very largely the Frue vanner. Some 500 of these machines were in use. He had noticed very carefully what the Author said as to the Frue vanner, and agreed with a good deal of it; but their experience in Johannesburg did not accord with that of the Author as to the efficiency of the motion. No doubt it was the best machine they had, but yet they were never able to extract more than about 30 per cent. of the concentrates carried by the ore. As a rule the tailings carried about 2½ per cent. of the concentrates, and out of that 2½ per cent. the Frue vanner was never found to extract more than about one-third. The Author stated that complete concentration could be effected without any previous classification, and although the particles were more or less uneven in size. He (Mr. Farrar) could not agree with that statement. It could only, he thought, be correct if a number of machines were employed. He had employed another form of shaking table—the Scoular table. The difference between that and the one described by the Author was that the Scoular table discharged the concentrates at the side and the waste tailings over the end. In certain cases it had given very good results, and the cost was less than half that of a Frue vanner. Mr. Farrar.

Mr. Farrar. He had just received some tests recently made with a belt concentrator, which might be of interest as showing what was being done. This concentrator was, he believed, a German invention. Those interested in gold-mining in South Africa had tried hard to get a good concentrator, and the latest machine sent there had proved successful, as the following results of tests showed:—

No.	Raw Ore. Gold per Ton.			Concentrates. Gold per Ton.			Waste Tailings. Gold per Ton.		
	oz.	dwts.	grs.	ozs.	dwts.	grs.	ozs.	dwts.	grs.
1	0	17	9	16	9	0	0	1	10
2	1	3	15	22	7	20	0	1	23
3	0	10	3	10	18	44	0	0	19
4	0	6	11	6	15	20	0	0	11
5	0	8	9	9	5	9	0	0	17
6	0	2	11	0	16	1	trace		
7	0	3	9	1	1	20	trace		

Experience in South African gold ores had shown that with moderately large plants, concentration could be carried out at a cost not exceeding 9*d.* per ton of tailings passed over the concentrators. The after-process of chlorination could be completed at a cost of about 1*s.* 9*d.* per ton of tailings. The total cost of concentration and chlorination would thus be about 2*s.* 6*d.* per ton of tailings. The latter process yielded over ninety per cent. of the gold contained in the ore, and if the concentration could be rendered equally efficient, the combined processes would probably supersede all other in gold-mining districts. A modified form of the Calumet separator referred to by the Author had been used by Mr. H. Jennings for separating the slimes from the tailings in connection with the cyanide process. The presence of slimes had been found detrimental to the proper percolation of the cyanide solution, and it was necessary either to break them up and to thoroughly mix them with the tailings, or to separate them, the latter process being the one most favoured by those whose experience of the cyanide process had been most extensive.

Mr. Richardson. Mr. J. Richardson endorsed what had been said by the last speaker as to the Frue vanner, for although he had tested a good many Frue vanners he had never succeeded in getting so good a result as 80 per cent. He believed that it could be done with some classes of minerals but not with Johannesburg ore, which contained gold so extremely fine that it floated away with the water. That was the reason for the smaller percentage of gold recovered by the Frue vanner in the Transvaal. Mr. Richardson.

Mr. GEORGE GREEN asked the limits of size to which ore could be jigged with the bedding. He understood there was a maximum and a minimum limit with metallic ores. He had himself jigged iron ores up to 1 inch in diameter, and lead ores up to $\frac{3}{4}$ inch with a metallic or mineral bedding, and lead ores, very strongly mixed with iron pyrites, down to a size that would pass through a hundred holes to the lineal inch. In illustration of the Paper, he exhibited a model of a machine in which gold ores from the West Coast of Africa had been concentrated. They were first pulverized to a size that would pass through a hundred holes to the lineal inch, and after having passed over about one half the distance of one of the compartments of one of these small machines, there was no perceptible quantity of gold left in the stuff. He did not say the whole was or could be extracted, but, so far as could be ascertained, there was no gold of practical value contained in the tailings. Of course if one could jig up to $\frac{3}{4}$ inch in diameter for galena and down to a size which would pass through a hundred mesh, all intermediate sizes might also be dealt with, and, as far as his practice went, he found the sizing had always to be adapted to the nature of the ore to be treated. There were some ores where the gradations would not vary greatly, the sizes being very nearly alike. These were difficult ores; but some ores, where the matrix was light, need not be classified in that manner. It might be as much as two or three millimetres variation in each stage, and the sizes could thus be graduated until they got to the finer sizes. That was the result of his practice, extending over twenty-five years, he having supplied machines to a great number of mines. No doubt there were methods for very complex ores, by which better results could be obtained than with metallic or mineral bedding. Mr. Green

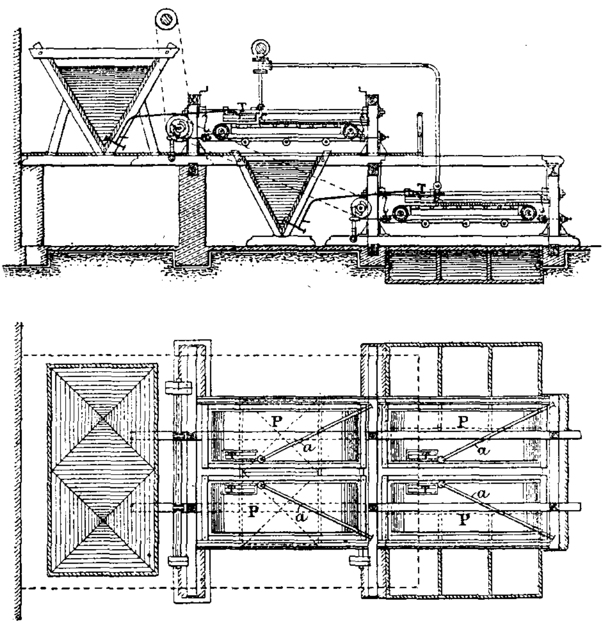
Dr. J. BUSS, referring to the question of the concentration of ores, said, without going into details of the appliances and apparatus described in the Paper and discussing their merits and practical value, he would like to mention that almost all modern dressing-plants which gave good results were constructed on the principle of gradual reduction of the ore, and subsequently, close sizing of the broken mineral, the chief feature of well-designed plants and apparatus being to save the valuable mineral in as Dr. Buss.

Dr. Buss. large sizes as possible, and to avoid as much as possible the formation of slimes. Plants designed on those principles, which had been laid down in the classical works of Rittinger, were, if properly arranged and well adapted to suit the ore under treatment, sure to give far more satisfactory results than any other system of ore concentration. Those principles had been specially developed in the Lührig system of ore concentration. Its practical value and superiority had been proved in the working of about thirty-five plants erected in recent years on the Continent, Australia, Africa, and elsewhere. Those plants were treating various kinds of minerals, and the total working capacity amounted to fully 8,000 tons per day. The special features of the system were careful gradual reduction of the minerals, careful close sizing, automatic work to economise labour, high saving of the valuable mineral in as large sizes as possible, avoiding the formation of slimes as much as possible, and the use of comparatively small quantities of water. In short, the very low working expenses, combined with highest possible saving of valuable mineral, enabled even very low grade ores to be successfully treated by the Lührig system where many others had failed. The results obtained by any concentration plants would depend upon the ability and experience of the designer, who must correctly recognize and understand the nature and character of the ores he had to treat, and must be capable of selecting really suitable appliances for their treatment. The requirements that a systematically-arranged and well-erected concentration plant had to fulfil were to concentrate the valuable mineral to the best possible market value, at least cost and least loss, as was done by the Lührig system. As to the question of slimes, unfortunately it was impossible to avoid the formation of fine slimes altogether, but by using good slime-treating apparatus it was possible to reduce that loss to a very great extent. There had been made in recent years great efforts to improve slime-dressing appliances, and he had pleasure in showing by diagram a new compound vanner, the invention of the late Mr. C. Lührig of Dresden.

The special advantages claimed for the Lührig vanner were that intermediate products could be continuously and automatically drawn off, and subjected to further concentration on a lower vanner. The Lührig vanner differed from other machines of a similar type, in that the direction of travel was horizontal, in that several products were continuously drawn off instead of only one class of concentrates, and, lastly, in that the narrowest dimensions (the width) of the belt were in the direction of the downward flow of the purifying water or, in other words, at right angles to the horizontal line of travel. Of these vanners there were at the present time 800 at work at silver-lead and zinc mines. Dr. Buss.

The action of the machine would be seen on examining *Figs. 42.* The ore-pulp was delivered on to the travelling-belt P from the grader X, through the distributor T. The belt was driven slowly and continuously from right to left, and was supported by small wooden rollers. The frame upon which these rollers rested received quick percussions in the direction of the

Figs. 42.



LÜHRIG VANNER.

line of travel of the belt. The percussion was imparted to the frame supporting the belt by means of the cam I acting upon the lever H, which served to draw the frame back and at the same time compressed the spring K, and by acting on the ratchet-wheel W and hook O imparted motion to the belt P. When the lever H was released by the cam, the resistance of the spring K suddenly drew back the frame with a sharp percussion. Having been fed on to the belt, the ore was carried towards the left, and in travelling was also acted upon by the water from the jet-pipe

Dr. Buss. Q. There were usually three classes of products delivered from the upper belts:—(1) the tailings which left the vanner almost opposite the feeder at the top end; (2) the middle product, which was worked from the central section of the belts into the grader underneath the upper tables, and was fed from there on to a second belt below upon which the product was re-treated; (3) the clean ore, which was held by the belt until it reached the lower end, whence it was delivered into a receiving vat.

Mr. Head. Mr. JEREMIAH HEAD remarked that an inspection of the title of this very valuable Paper would lead to the supposition that the Author had in his mind only the concentration and sizing of those minerals which were habitually subjected to crushing operations; but inasmuch as he referred to hand-picking and washing, which were operations performed previously to, and not necessarily connected with crushing and sizing, he (Mr. Head) would not perhaps be out of order in speaking on what interested him most, viz., the minerals connected with the iron industry. The importance of their concentration would be readily realised by reference to the fact that no less than 2,000,000 tons of iron ore came into this country every year from Spain alone. So important was the maintenance of the percentage of iron in the ore deemed by those who used it that they were accustomed to give a premium on every per cent. of iron over and above 50, and to make a corresponding deduction in the case of all that was below. With regard to the silica in ore they were also accustomed to make a deduction if it was above 8 per cent., and an addition if it was below. The value of each one per cent. of iron varied from 3*d.* to 6*d.* a ton—say an average of 4½*d.*, and that of silica 1½*d.* per ton. Adding these together (for less iron meant more silica, and *vice versâ*) and taking the same at 6*d.* a ton, on that 2,000,000 tons of ore imported into this country every year, the difference of every 1 per cent. more in richness meant £50,000 a year to this country. To put it in another way: supposing that it was brought in ships containing on an average 2,000 tons each, then for a given amount of produce of pig-iron if it was 1 per cent. richer it would do away with no less than twenty of those 2,000-ton cargoes in a year. The Author of the Paper had alluded to the first process of hand-picking, whether aided by mechanical means or not. That, undoubtedly, was of very great importance, and it was carried out in Spain to some extent and also at the magnetite mines at Gellivara, in Sweden, without any mechanical aid. In the Cleveland district broad belts had been lately introduced, on to which the tubs coming from the mines full of ore were emptied.

This greatly facilitated hand-picking, and by this means the Mr. Head. produce of the poorest mines had been raised up to that of the richest and best. In Spain there was great difficulty in hand-picking in wet weather, owing to the red colour of the hæmatite being washed over stones, making them appear as if they were ore. For this, and for other reasons, it was considered that the ore emanating from Spanish mines had in recent years deteriorated, so that they could no longer rely on a higher average than about 49 per cent. In this country, as far as he knew, no iron ore was washed at all; but in America that process was extensively used, principally with the inferior ores of Pennsylvania, and with those of Alabama and other Southern States. The common plan was to have an inclined trough, 28 feet long, 2 feet 6 inches broad, and 1 foot 6 inches deep. It was only the small ore that was washed by means of this trough. Revolving in the trough was a rough wooden shaft mounted on iron gudgeons and studded with knives set askew so as to work any ore tipped in up towards the top end of the trough. Above was a water-pipe, which poured water in mainly at the top end, so that the stream of water went in an opposite direction to the ore. By the time the ore reached the top end it was clean; it then tumbled on to a grating, where it was also hand-picked. These troughs, which were exceedingly simple in construction, were capable of washing from 40 to 80 tons in twenty-four hours, the amount of water required being about 3,000 gallons per ton, and the cost was generally taken at about 5*d.* per ton. In Spain there was very little washing of iron ore; but a very efficient installation, designed by Mr. F. Kensington, Assoc. M. Inst. C.E., had within the last two or three years been put up on the San Salvador mines near Santander. The San Salvador mines were composed of a kind of gravelly ore which did not contain more than 20 per cent. of iron as it was dug out, but when washed it yielded no less than 59·5 per cent. Considering the great value of every per cent. of ore, it was probable that the system of washing the ore in Spain would in future be increased wherever there was plenty of water and a place where slime could be deposited. The washing at the San Salvador mines cost about 6*d.* per ton on finished ore. Magnetic separation which had been alluded to in the Paper, and was mainly applicable to magnetite, or magnetic iron ore, had to encounter several difficulties in practical operation. In the first place, magnetite was usually a very rich ore, and therefore not the most advantageous for concentration. It was also very solid and hard to crush. At the Witkowitz Iron Works in Austria, lately presided over by

Mr. Head. Mr. Kupelweiser, a gentleman well known in this country, they actually had been using as much as 60,000 tons of Gellivara hand-picked magnetite per annum, notwithstanding the great distance it had to come. This Gellivara ore, when hand-picked, contained about 61 per cent. of iron. It was used at Witkowitz without being crushed at all in the proportion of about one-third to two-thirds of other ore of spathic origin, which had been calcined, and was in a loose and dusty condition. Another difficulty in the way of using magnetite ores which had been concentrated in this way was that they generally required to be crushed very fine, and iron-smelters did not like small ores; in fact, they could not use above one-third of the burden composed of small stuff. The reason was, that when put into the furnace, the pressure of blast which was blowing upwards through the furnace continually, was apt to blow any dust that came off right down the gas downcomers, and so losing it, and occasioning a good deal of inconvenience afterwards. Then, again, magnetic separation was only applicable to magnetic minerals, and in the case of iron ores to magnetite. In the course of the Paper something was said about taking peroxide of iron, roasting it, and forming it into magnetic oxide. That could only be done with a very high heat and at great cost, and was scarcely a practical process, except where a small proportion of iron had to be separated as an impurity from some more valuable mineral. With regard to magnetic separation, he had in America seen three systems. The first was at Edison's experimental works at Menlo Park. It was called the Edison-Dickson Patent. It consisted essentially of a broad india-rubber travelling belt, something like that of a Frue vanner, but arranged vertically. Behind the sheet there were electro-magnets, and in front there poured down a broad stream of pulverised magnetic ore. Whatever was magnetic stuck to the broad sheet, was taken over the top and fell down behind. What was not magnetic fell down in front. The second was the Wenström separator, which was at work in the Cranberry ironworks in North Carolina. The iron ore had been previously roasted and crushed, and was being supplied to the machine in sizes about equal to walnuts. A broad stream of this fell down through the magnetic field just above a plate provided with a knife-edge top, and placed in such a way that the non-magnetic parts fell on the one side, whilst those which were attracted by the electro-magnets were diverted and made to fall on the other side. The best of all the machines was that known as the Ball-Norton separator. In that there were two drums 2 feet diameter and about 2 feet

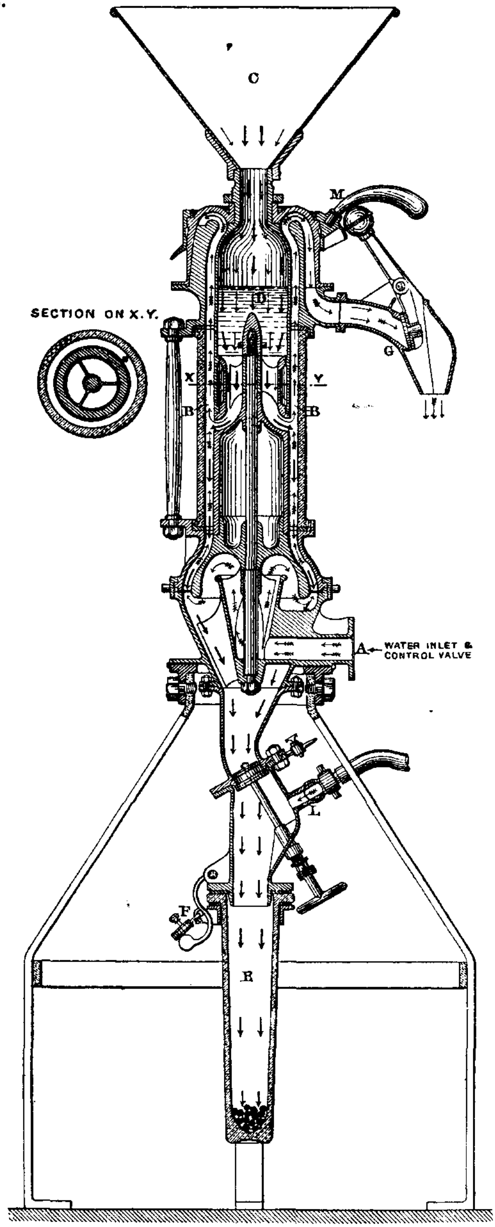
Mr. Head.

long, arranged with their axes in parallel in the same horizontal plane. These drums were covered with thin wood, or something of that kind. Inside them were electro-magnets, arranged with their poles close to the barrel surface. The crushed ore was brought down and made to pass round outside the revolving drums, so as to pass through the magnetic fields. That which was magnetic passed forward, and that which was non-magnetic fell straight down, and was separated. One such machine as he had described, taking about three horse-power to drive it, and to supply the current for the magnet, was stated to deal with 6,000 cubic feet of crude ore in twenty-four hours. If that crude ore weighed about $1\frac{1}{2}$ cwt. per cubic foot, half ore and half gangue, one machine would yield about 225 tons of ore in the twenty-four hours, which was as much as one ordinary hæmatite blast furnace, making 700 tons of pig iron per week, could use without any other ore. The effect of these magnetic concentrators was certainly very marvellous in many ways. In the course of separation not only was the richness of the iron increased in the ore, but the phosphorus was largely diminished. Washing the ores did not do this—at all events to the same extent. The probable reason was that in the magnetic ore the phosphorus was in the form of apatite (calcium phosphate), and that, not being magnetic, tumbled down with the gangue. In fact, the magnetic separators seemed to pick out the ore which was pure magnetite and to reject all the rest. Another curious thing was, that whatever might be the percentage of iron in the ore dealt with, the concentrated ore seemed to have a maximum richness. This would be better seen by the results of five analyses which he had selected as typical. These were as follows:—

——	——	Iron per cent.	Phosphorus per cent.
1. Republic Magnetic Mine	Crude	66·60	0·075
	Concentrate	71·46	0·043
2. Gellivara, Sweden	Crude	65·76	0·954
	Concentrate	70·11	0·020
3. Port Henry Old Bed	Crude	58·70	2·250
	Concentrate	71·10	0·037
4. Benson lean ore	Crude	40·51	0·190
	Concentrate	68·62	0·010
5. Sea-sand containing magnetite	Crude	13·04	..
	Concentrate	71·60	..

Mr. Lockhart.

Fig. 43.



Scale 1 inch = 1 foot.
AUTOMATIC GEM-SEPARATOR.

Mr. W. S. LOCKHART said he wished to refer more particularly to the subject of concentration by gravitation. *Fig. 43* represented a machine that he had recently had occasion to design for dealing with very close ranges of specific gravity, more especially in connection with the separation of gem stones from the worthless gravel with which they were associated. The machine was the newest departure in upward current separators, and was of the class of a continuous upward current class; rather a separator than a concentrator. Water was run in at the point A, through a carefully graduated valve, by which the current could be controlled. Following the course of the arrows up the machines the water was turned down under a circular deflector or cup. Again turning upwards it reached an annular channel, B, the outer casing of which was formed by a glass tube. It then passed over a circular weir at the top, and away to the outlets, which were provided with valves. The glass tubes were very accurately bored, and the brass cores inside carefully turned. In section X Y on one side there was a spot showing a gem supposed to be passing through, the point being that anything passing through had to take its speed from all the currents that might be running, because, the material having been carefully sized, and the size of the annular channel having been graduated so as to be just a little larger than the gravel passing through, practically no current could flow past any particle of gravel without taking effect upon it. The water, of course, had to be at constant pressure, which was easily secured by means of a carefully devised head-box, supplying a steady current. The pressure required was such as would be due to a head of 5 or 10 feet, and not more. The gravel was let in at the top; with gems a closed tube was used, but he had shown a hopper for convenience. Having been fed into the hopper at C, the gravel followed the course of the arrows, starred over the cone D, and so out at the circular mouth, being thus fed evenly and continuously into the annular current. At B the separation took place; the light particles being swept upwards over the weir, while the heavier ones, which were the gems or ores, made their way down through the current and into a glass receptacle at the bottom. That receptacle might be made larger, if necessary, for coarser ores. The work of the machine was to separate out gems which were in gravel of very nearly their own specific gravity. In the case of rubies or sapphires there was a difference of specific gravity from 2·6 to 3·7, or even up to 4, and with so long a range, the machine dealt very easily. For diamonds, with such material as Kimberley blue, which the Author had referred to, this machine was to be set to work after the "pulsators." It took up the work where hand-picking began. It was rather a curious phenomenon that this machine took off some material actually heavier than the diamond, namely, a good deal of iron pyrites. That could not be due to gravitation, but probably to friction. The water being kept close in the annular space, friction in some way came into play, and pieces of iron pyrites were lifted while diamonds were dropped. With this machine very careful sizing was absolutely necessary, and he endorsed most fully the Author's remarks on that point. The nearer the specific gravity of the particles to be separated, the more close the sizing had to be. The sizing he had adopted varied $\frac{1}{32}$ inch from size to size, but that was not sufficient, and it was necessary for some materials to subdivide each size again. Thus the material that would pass through, say a $\frac{3}{16}$-inch slot, could be Mr. Lockhart.

Mr. Lockhart. redivided by passing over $\frac{3}{16}$-inch round holes, $\frac{3}{16}$-inch squares or slots of different lengths. The round holes were not found of much use, but the square holes, and short and long slots were of very great value. The difference of the product that would pass through a square $\frac{3}{16}$ hole and a $\frac{3}{16}$ slot was very marked. He would suggest to the Author one more "class" in the various types of sizing machines. Seven types had been given, and if he might suggest an eighth, it would be cylindrical screens which both revolve and plunge. He had made a machine of that sort in which the screen revolved slowly and at the same time jigged at considerable speed, the action being both that of a jig and of a revolving screen. The screen was horizontal, and the motion forward along it was effected by a worm or helix. The effect so far as he had gone seemed to be very good.

Mr. Seymour. Mr. L. I. SEYMOUR said he was afraid he could not throw much light on the question of sizing of materials and their classification, nearly all his experience being in connection with diamond-bearing material. In dealing with that they were confronted with a problem greatly different from jigging ore. It was necessary to save all the particles of diamonds, and a machine which would save only a majority of the product would not do. When it was considered that in diamond-bearing ground they would produce in the richer mines one carat weighing less than 4 grains to a ton of material, it would be seen that machines for treating this material must be very exact, and that it could not pay to try to classify too fine, as might be the case with metallic ores. He was very much interested in seeing the automatic gem-separator, which appeared to be a distinct improvement on the jigs described by the Author. At the Kimberley mines the final classification up to the present by mechanical appliances was by those jigs. Every 4 tons of material brought to the jig was reduced to 1 ton, and that when done was taken and sorted by hand several times over, in the first place, by carefully picked white men, and after that by convicts. The automatic gem-separator would seem to take the product after leaving the jigs and reduce it, so that the very tiresome work of picking over the same particles of rock would be much reduced; the previous operation of the jig being a series of washing-pans resembling in some respects the circular tables described by the Author. The absolute necessity for not losing diamonds was so apparent that the question of sizing the material received very careful thought. The first material which went into the stirring-pans was concentrated about 100 to 1 in a rough sort of manner, and after being drawn out of the bottom of the pans was taken to the jigs. There the sizing was done about 4 to 1, that was to say, 4 tons of mineral coming from the preliminary pans were sized into one ton. When it was remembered that the output of some of the principal diamond mines was as much as 8,000 to 10,000 tons of material per day the question of concentration became a very serious item. A further system of concentration was now being adopted at the diamond mines. The material was crushed, in the first place, to a size about $1\frac{1}{4}$ inch and then jigged. This point might have a bearing on the remarks made by Mr. Green. Then the material was further crushed and jigged again, and went through several crushings, meanwhile hand-picking being resorted to, as it would be, manifestly, a serious matter to crush a large diamond. Mr. Seymour.

Mr. FREDERICK J. KING said he took considerable interest in the question of the magnetic dressing of ores. As long ago as 1874 he had put up in the Isle of Man magnetic machines for the purpose of separating the spathic ore from the blende. Both were of nearly the same density, and could not be separated by water-dressing. He found, by heating the spathic iron ore, it became magnetic. He put up a magnetic machine, and was able to separate the blende from the iron, and to get £4 a ton for the resulting blende. That was, he believed, the first attempt in this or any other country to extract iron ore that was not naturally magnetic, but had been made so; and it was well described in the late Robert Hunt's work on British mining. He had constructed special machines to separate in South Africa copper ores from magnetic iron, it being absolutely necessary that none of the rich copper ore should be taken out with the iron. It was found that all the direct-acting machines did take out a considerable portion of the non-magnetic material, and the result was that such machines were useless. He introduced a preliminary separation by compelling the magnetic particles with the other ore to pass over a plane in which, as the magnetic particles passed over the alternate poles, they had to turn a somersault, and were ultimately brought into a perfectly distinct layer; and when they came to the magnetic separator, not a particle of non-magnetic material had been taken out. These machines had been at the Namaqua Company's mines for five or six years, and he was now building machines for the Cape Copper Company. Although probably in England there was no great field for the operation of such machines, it should be known that valuable minerals could be entirely isolated from iron, whether magnetic or capable of Mr. King

Mr. King. being made magnetic—which nearly all iron ores were—leaving the more valuable ore in a saleable condition. He had employed only permanent magnets, because he found that, with machines such as he was now sending to the Cape Copper Company, a drum 26 inches by 20 inches gave an attractive force of 10,000 lbs. —*amply sufficient for all practical purposes.*

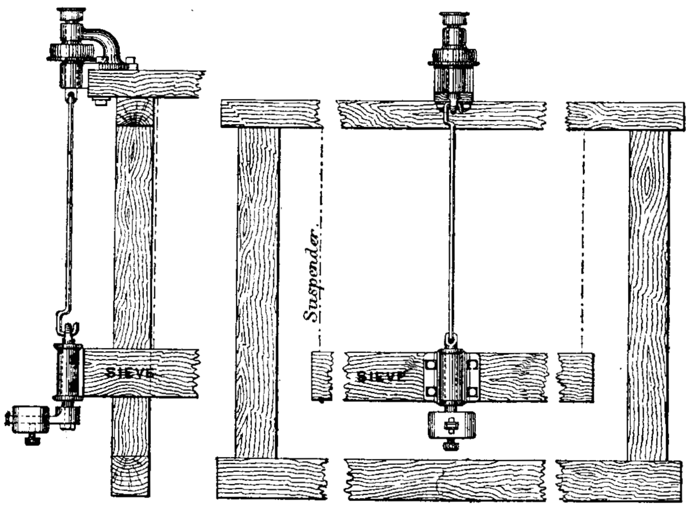
Mr. Sanderson. Mr. H. J. SANDERSON thought the Paper must commend itself to every one interested in the matter. There was one point on which a little more light might be thrown—namely, the statement that the screening of particles less than $1\frac{1}{2}$ to 1 millimetre in diameter could not be advantageously carried out in practice. That did not seem to be quite correct. He had recently in Germany had the opportunity of making experiments with a machine devised by Nagel and Kämp of Hamburg, where they had been sifting silver ore very finely ground through perforations, or meshes of less than $\frac{1}{4}$ millimetre, and where no less than 47 lbs. had been dressed through this small mesh per square foot per hour, which he considered a very creditable performance. He imagined that the Author referred particularly to the blocking of the fine mesh, which was found so troublesome in ordinary practice; but in this particular machine, which had a vibrating sieve, that difficulty had been overcome, and he thought in future it would be found very useful.

Mr. Beaumont. Mr. W. WORBY BEAUMONT exhibited a model (*Fig. 44*) explanatory of a movement which he thought would interest members concerned in the construction of machinery of the description referred to in the Paper, particularly machines in which parts had to be moved in a gyratory or reciprocating fashion at high speed. In the usual way this was done either by an eccentric or crank, and it became necessary at high speed to balance the crank or eccentric shaft and the reciprocating parts very carefully. Even then it was difficult to work such machines at a very high speed, because each push and pull given to the part that had to be moved was equally and oppositely imposed upon the framing of the machine carrying the crank-shaft by which the motion was secured. The model showed a means of working shaking-tables or screens simply and of utilising the force that hitherto had been wasted in shaking the framing or floor upon which the machinery had been placed. The model did not relate to mining machinery; it showed the action for flour-mill separations, but would answer for the other purpose. The screen had to be moved, and in the ordinary way such screens were moved at a high speed, the highest number of revolutions of the crank-shaft being about 600 per minute. To

Mr. Beaumont.

do that the machinery had to be made with the greatest possible care, and the balancing was a very delicate operation. He dispensed with the crank-shaft and connecting-rod and actuated the machine partly by what he might call the influence of a mechanical by-product in the form of hitherto wasted energy. The screen was not a very light one, but the model represented the whole of the machinery necessary for working it. It could be easily worked at 1,200 revolutions or 2,400 strokes per minute, and the only connection between the driving mechanism and the thing that actuated the screen was a fine wire connecting-rod used only in torsion. The belt, to dignify it by that name, was

Fig. 44.



THE VIBROMOTOR.

just one piece of cotton thread, and that piece of thread had now been used to work the model probably for two or three million of strokes, but was still in sufficiently good condition to do the work. Simply by the influence of a piece of metal out of balance that screen could be made to work as far as he knew at any speed that might be necessary for any purpose. The model shown made as nearly as possible 1,000 double strokes per minute. The motion at one end was strictly gyratory; at the other end it was less so, and was more a reciprocating motion. That was sufficient to set in motion light material such as bran, which, except at a very high speed, would ride with a sieve. In

Mr. Beaumont. this case, however, when a speed was reached of more than, say, 600 revolutions a minute, almost every separate flake of bran was separated from the flour and could be seen making all sorts of curious evolutions. By other applications of the apparatus in different positions, it could be shown that with granular materials —flour, bran, and so on—the very fine material such as flour would travel off in one direction, and the larger parts, disclaiming all connection with the flour, would go in the other direction. By running the machine at 3,000 strokes a minute most remarkable effects could be obtained in the sorting and separation of material. He drew attention to the fact that the screen was made to move simply by the influence of the out of balance of a thing rotating on that which had to be moved. There was no abutment used anywhere, so that the framing, although the screen was moving at 2,000 strokes per minute, was not sensibly affected. The screens were being used in flour mills where the sieves were simply hung up from the joists by leather or other suspenders. The driving belt was taken from any convenient position to rotate a vertical swinging spindle; and to show how small was the power required he would mention that sieves weighing 110 lbs. were worked by means of a rotating piece or hooked steel rod of only $\frac{3}{8}$ inch in diameter, whereas in previous cases, when worked in the ordinary way with a connecting-rod and so on, a very great strength was necessary. Proof positive was given by the cotton-thread that very little power was taken to operate the screen worked in the way described. He named the apparatus a vibromotor.

Mr. Garland. Mr. JOSEPH GARLAND said the Author had referred to underground hand-separation, which he said was rather of a rough character. That was quite right, and the reason assigned was the lack of light and the limited time. He (Mr. Garland) was inclined to think that was not the main reason; it was, he feared, the indifference and carelessness of the miners, arising often from the nature of their contract. Most of this was done on tutwork, and when the miner was paid by measurement it was clearly not to his interest to devote much of his time to hand-picking the ore. What happened was this, that he devoted as much time as possible to drilling and blasting, and as little as possible to hand-separation. He had known instances of large quantities of good rich ore left underground in the rock débris in this way. Partly for this reason the tribute system was sometimes more advantageous than the tutwork system. By the tribute system it was the miner's interest so save every pound of ore, seeing that he got a certain percentage of its value. Tributing, however, was not generally adopted, except for the poorer ground, whilst the richer parts of the lode were almost invariably worked on tutwork. Without strict supervision it was difficult to see how the men could be got to do much in the way of hand-separation underground when working on tutwork. The Author referred to "halvans," which he designated "barren rock." This was not exactly a correct description. The word "halvans" was a Cornish term signifying rock containing a little ore, but too poor to bear the expense of ordinary dressing. The "halvans" were usually put aside until they could be dealt with in an inexpensive manner. It often happened in Cornwall that the "halvan" heap was let on tribute to disabled miners who, by employing simple appliances and cheap labour, that of girls and boys, managed to earn a living. The Author naturally devoted a good deal of space to jigging, and he was undoubtedly right in regarding that process as the most important operation in ordinary ore-dressing. There were, however, two or three points in which he differed from the Author's views. He did not think that it was necessary or that there was any advantage whatever in giving the jigger bottom a forward inclination. The ore would go forward with sufficient facility without such aid, and in the case of jigging with a bedding it would be decidedly a disadvantage to incline the screen, because the effect would be to make the bed of unequal thickness. As to which was the better, the punched steel or copper plate or brass woven wire for the sieves, he should give the preference to the steel plate; the copper plate being so much more expensive was, he believed, seldom used. He should prefer a punched plate with round holes rather than the wire screen, because it was stouter and more durable, requiring less repair and attention. One objection, however, to the punched plate with a very fine mesh was that it would have a tendency to become choked, especially if rusting action set in. As to the bedding, the specific gravity should not only be greater than that of the gangue, but also greater than that of the middlings or mixed products. He was inclined to think there was an advantage in having the bedding of a greater density than the concentrates themselves. Hence metallic bedding was sometimes used, as they had been reminded by Mr. Green. If the bedding was too light, some of the mixed products, and certainly some of the gangue, would find its way into the hutch, and thus depreciate the concentrates. He did not agree that the form of the particles of the bedding was of nearly as much importance as the specific gravity. His idea of perfect jigging was to jig the concentrates through the sieve, not on the plates, using Mr. Garland.

Mr. Garland. when possible suitable bedding—a bedding a little coarser than the sieve mesh, which should be equal to the grade of ore to be jigged. He agreed that for jigging coarse material it was better to collect the concentrates on the sieve. Grids for supporting wire screens should be of wood, not iron, because if iron were used the sieve would speedily cut through. With regard to the Frue vanner, it undoubtedly was an excellent machine for concentrating the finer sulphurets coming from the stamp batteries. The machine, however, was not adapted to the treatment of very coarse material, for the use of which the percussion table took precedence. The chief objection to the Frue vanner was its cost. It was a machine which required to be carefully adjusted and well looked after. He had recently had an opportunity of seeing a number of these machines at work at Ballarat. At one of the largest gold mines, the Band of Hope and Albion Consols, the tailings were first passed over a percussion table, which caught 60 per cent. of the pyrites. They then passed into a large round buddle and were afterwards treated by the Frue vanner, which extracted another 25 per cent. of the pyrites, making altogether 85 per cent. The concentrates of the Frue vanner were, he was informed, richer than those of the percussion table, viz., 1 oz. 16 dwts. against 1 oz. 12 dwts. per ton. At this mine they thought very highly of the Frue vanner. At an adjoining mine, Star of the East, the largest in the whole district, where they had 100 heads of stamps at work and twenty-four Frue vanners and nine percussion tables, they had taken a dislike to the Frue vanner and preferred the percussion table, and had decided to replace the one by the other as the vanners wore out. He gathered the following facts. Two Frue vanners were required for each battery of five heads; two percussion tables were equal to four Frue vanners; the Frue vanner cost £150, while the percussion table cost £90, and a new india-rubber belt for a vanner cost £70. The Frue vanner required skilled labour, while the percussion table did not. The percussion table concentrated in a cleaner manner than the Frue vanner. For example, 100 tons of tailings yielding 10 tons of concentrates by the percussion table would give 12 tons of a slightly lower grade by the Frue vanner, and seeing that each ton concentrated would cost £3 per ton to treat subsequently at the customs-mills, where the gold would be extracted, the relative result would be £30 as against £36.

Mr. Smith. Mr. Hamilton Smith said his only recent experience in concentrating had been with gold ores. In the mine called the Alaska Treadwell, with which he had been connected for some time, they had 240 stamps at work. Ninety-six Frue vanners were connected with them, and had done admirable work and were perfectly well adapted to that particular ore. The ore was of very low grade, assaying only 4 pennyweights per ton on the average, but the tailings, after they had escaped from the Frue vanners, assayed less than half a pennyweight—about one-third. That showed that the heavy particles caught by the vanners contained the gold. In the Transvaal, in the mines near Johannesburg, the case was very different. The gold was in very small particles, and any concentration which caught the coarse particles having a superior specific gravity, did not by any means catch all the gold, so that concentration there had been more or less a failure. In reply to a question by the President as to whether it was possible to treat at a profit ore assaying only 4 dwt. per ton, Mr. Hamilton Smith noted that at the Alaska Treadwell mine for the last six months the bullion yield was about $3\frac{5}{8}$ dwt. of gold, whilst the gross expenses had represented $1\frac{1}{4}$ dwt. Concentration there did not cost more than $2\frac{1}{2}$*d.* per ton. Mr. Smith.

Major Ricarde-Seaver briefly stated the results of his observations in South Africa on the treatment of auriferous conglomerates. The systems in use for extracting the precious metal were amalgamation, treatment of tailings, and chlorination of concentrates. So far those processes had given profitable results; it still remained, however, to be learned whether the first and second of them were necessary, and whether it would not be more economical to dispense with the costly system of amalgamation and chlorination, treating the whole mass of ore by a system of dressing so as to get rid of the barren matrix, and treating the resulting concentrates, containing both the pyritic and free gold, by the cyanide process only. The advent of such process would depend entirely upon the perfection and concentration of the ores. It was from that point of view that he regarded the Paper as a factor in the solution of the problem. As a further result of his observations in South Africa, it appeared that the tendency was towards a much coarser crushing of ore than had been previously regarded as essential to the extraction of the maximum quantity of gold. In South America thirty years ago no one thought of using sieves of fewer than sixty holes per linear inch, whereas in South Africa, he believed, in no case were more than thirty holes per inch used, the object being to pass through the mill as large a quantity of ore as possible, so long as the limit of the extracting capacity of mercury and potassium cyanide should not be exceeded. Major Ricarde-Seaver.

Mr. T. Rickard wished to refer to what Mr. Lockhart had called Mr. Rickard.

Mr. Rickard. the automatic gem-separator. It had been assumed that this machine was new. The principle appeared to be precisely the same as the Spitzlutte, a very well-known appliance, and one applied to many a dressing-mill with a result with which most engineers were acquainted. The same appliance was used at the great Monteponi Mine, where they dressed a mixture of calamine with a specific gravity of only 3·50, and rock matter with a specific gravity about one less than that. The concentration was very nearly perfect. That of itself was a proof that it was possible to continue the separation much farther than the limit of one millimetre assigned by the Author. There, he thought, was one of the defects of the Paper. No doubt, if the jigging-machine had one merit more than another it was that it enabled the dresser to follow the fine stuff further down than any other apparatus short of the various washing tables. There was very much less manipulation, and consequently less loss and cost. He was at variance altogether with the Author as to the classing, believing that sizing was no suitable preparation for jigging. Jigging was worked by a percussive movement, by a sort of counter-pressure, and if a classification was to be made to suit the operation of the jig it certainly ought to be by the same method. There could be no doubt that the most effective classing was counter-pressure, and the best form of counter-pressure hitherto obtained was by the Spitzlutte. The Author had given in very carefully worked-out equations, the equal falling density of the particles of ore, and they were led to suppose that the classing for jigging was almost perfection. In point of fact, it was about the roughest kind of approximation possible. It was very clear that if the ore stuff was always in a granular shape the sizing would work well enough, and the jig would be a fairly perfect machine; but when they had to deal with ores that came off in foliated or acicular form rather than granular, it was evident that the whole process from beginning to end, on account of this defect in the classing operation, was vitiated. One thing more necessary than perhaps anything else mentioned in the Paper was the initial separation of the slimes. No doubt the greatest loss in dressing was by the loss of the slimes. These slimes without an initial separation were carried from one process to another and filtered through the tailings, until the particles that were really valuable were retained in those materials, and were lost. No dressing operation could pretend to any degree of perfection that did not set out with an initial separation. He thought it rather a pity that there should have been a confusion of terms in the Paper.

Without wishing to say anything otherwise than complimentary, there was a good deal in the way of terminology to which they were not accustomed, and which he thought no improvement on the old terms. He did not see why they should not keep to "milling" or "dressing" or "mechanical preparation." The French called it *preparation mécanique*, and the Germans *Aufbereitung ;* the English "mechanical preparation," and he thought it would be well to adhere to the old term. Mr. Rickard.

Mr. R. E. Commans in reply expressed his gratification at the friendly criticism and kind remarks of appreciation the Paper had elicited. He was pleased, too, at its having been the means of drawing attention to several novelties like the highly ingenious separator of Mr. Lockhart, the improved Lührig compound shaking-table, and the gyrating apparatus of Mr. Beaumont. Mr. Commans.

With regard to the remarks of Mr. Farrar, it would seem that the results of concentration obtained by him in South Africa indicated an unusual condition of affairs, and one which needed careful examination to prevent hasty conclusions from being drawn as to the general results of concentration. If it was true that the Frue vanner would only save on the Transvaal ores one-third of the total amount of sulphurets, it was quite certain that the conditions of working must be very different from those in other parts of the world, as the Frue vanner would never have established the reputation which it had done for close saving if such results as these represented its normal work. In many cases in California this concentrator had been put into mills under agreement for a guaranteed saving of ninety per cent. of the sulphurets freed by crushing from the quartz, and in general practice in other parts of the world a saving of from eighty to ninety per cent. is considered only a proper duty. The specific gravity of the Johannesburg conglomerates did not differ materially—as far as he was aware—from that of ordinary quartz. One must therefore look to some other conditions for such a poor result, from a concentration point of view, as that indicated by Mr. Farrar's figures. He was inclined to think that in the first place exact statistics as to the percentage of saving of the freed sulphurets were possibly still wanting; and, furthermore, that in many cases the question of the saving of gold was confused with that of the saving of sulphurets, with which it did not necessarily have anything to do. In some of the early mills in the Transvaal, two Frue vanners were used to each battery of five stamps, although the stamps were crushing twice as much as they did in California (and that too with a coarser screen), where

Mr. Commans. the proportion of two vanners to five stamps was adopted. Of late it had been the custom, he understood, for three concentrators to be used to each five stamps; but even that would still leave proportionally more work to be done by the machines than in California. In the case of the African ores, what was required were careful experiments to determine the condition in which the gold was lost. It was quite certain that it would be improper to draw general conclusions as to machines, or processes, from the results in the African mills. No concentrator could be successfully used for the saving of anything but the heavy mineral, which was actually separated from the quartz by the crushing. As a consequence the only means of forming an opinion as to perfection of concentration was by mechanical panning-tests on the tailings of the concentrator used, and not by assays as to gold contents. The coarse particles of rock carried off a certain percentage of attached sulphurets which it would never be worth while attempting to save by a concentration process. No concentrator was ever likely to be so perfect as to save the whole of the fine sulphurets produced in crushing. The Author's experience had shown that if the tailings of a Frue vanner contained any large percentage of the original amount of sulphurets by panning, the machine was certainly not doing what was to be expected of it under proper conditions of working. It would appear from this, therefore, that if in other countries a high percentage of the freed mineral could be saved by the vanner, the same result should be obtainable in Africa, although the conditions of operating might, perhaps, not be exactly the same. Owing to the immense quantities of ore treated in the Transvaal, and the comparative coarseness of the crushing, it was a question whether a system of taking out the coarser sand before concentration, could not be used with advantage both in lessening the number of concentrators and in improving the conditions under which they would work. The loss in the tailings of the Johannesburg mills was, doubtless, partly in the form of very fine free gold in suspension in the water (which no concentrator would save after the pulp had passed over copper plates in proper condition), partly in the form of free gold, and particles of sulphurets attached to the coarser particles of rock, and partly contained in the freed sulphurets. It was only in the saving of the gold under the latter head that concentration would be practicable, and it appeared that this became rather the general question of what could be done by concentration than a matter as between one concentrator and another, on which point different millmen had

Mr. Commans.

different ideas. It was quite clear, however, that the South African results, with the present amount of information at command, could not be used either for general conclusions as to concentration, or for the purpose of deciding the relative values of different concentrators. In asserting that the Author in his Paper stated complete separation could be effected without previous classification, Mr. Farrar appeared to have misunderstood the meaning intended, namely, that the Frue vanner had been successful in the treating of unsized pulp below forty mesh, on which other concentrators under the old German system would have required classification to give the best results. The Author had endeavoured to explain the reason why the greater margin in sizes was possible on the Frue vanner than on these well-known machines; and his conclusions, he considered, were justified from the fact that, whereas it was the custom in Germany to classify such a pulp, the method was not employed throughout the United States and other parts of the world where the Frue vanner was used after stamps. Of course the commercial question could not be neglected in such matters, and the abandonment of classification below a certain size was influenced, perhaps to some extent, by that necessary consideration. It was quite certain, however, that the German systems of slime concentration and classification were perfectly well understood in the United States, and were adopted in a great number of cases in the past, but that the practice had resulted in an abandonment of them in favour of the simple single treatment without sizing, on machines of the Frue vanner class, and that such a practice would hardly have been universally adopted if Mr. Farrar's figures, as to work of the vanner, held good outside of Africa. Such trials, as Mr. Farrar mentioned, that the Johannesburg Chamber of Mines might possibly carry out with various forms of concentrators, would undoubtedly be of great value, provided they extended over a considerable period, and that each machine was put to work under exactly the same conditions.

It would appear that Mr. Green had misunderstood him in supposing that he suggested that a hard and fast extreme maximum or minimum limit could be fixed for the size of jigging ore. The size, undoubtedly, in each case was determinable by the size and nature of the rich particles of mineral in the ore under treatment, and he considered that in the case of a friable material, like galena, the method of collecting the concentrates over, rather than through the sieve, should, wherever possible, be adopted, more especially if the percentage of rich mineral were small. The

Mr. Commans. Author, when speaking of the difficulty of screening particles less than $1\frac{1}{2}$ to 1 millimetre in diameter, was referring to screening in a wet condition, as commonly was the case with ore, and did not intend to refer to the screening or sieving of dry material, as Mr. J. H. Saunderson would seem to suppose. On the other hand, undoubtedly, even with dry material, a difficulty was often experienced with fine sieves of the meshes getting choked; and if that was obviated in the machine referred to by Mr. Saunderson, it was certainly a step in the right direction. With Mr. Garland's remarks about the jigger bottom having a forward inclination, he quite agreed. That plan should never be adopted, and whatever fall was required to assist the movement of the ore should be obtained by slightly lowering each successive sieve, or the depth of the bedding, the sieves themselves remaining horizontal.

Correspondence.

Mr. Bartsch. Mr. W. J. Bartsch, of Siegen, supplemented the Author's description by some details of results obtained with the Bartsch concentrator. As would be seen from *Figs. 45*, that appliance consisted of a convex circular table carried at the centre on a bearing *b*, and at the circumference by rollers *c*. Radial blows were imparted by a cam *f*, and the slime and wash-water distributors revolved over the table, the main water-pipe being bent in a parabolic curve. The usual diameter of the table was $13\frac{1}{2}$ feet. For every 30 revolutions of the shaft, 120 bumps were imparted to the table, in which time (one minute) the distributors made half a revolution of the table. The movement of the table was from $\frac{3}{8}$ to $\frac{5}{8}$ inch, and could be regulated at will. The advantage claimed for the adoption of the bumps was that, the material being kept in agitation, a quicker separation was effected, whilst, as there was no liability of the slimes clinging to the table, no brush or similar appliance was required to remove them. The advantage of the parabolic water-distributor was that the washing action was greater at the centre of the table than at the periphery. At the Lohmannsfeld mine at Neunkirchen, and at the Glanzenberg mine at Welschenennest, in Westphalia, six Bartsch tables had been in successful operation, as much as half a ton (dry) being concentrated per hour. The lead ore products were concentrated to 65 to 68 per cent. of lead with 3·5 to 3 per cent. of zinc, the spathose zinc ore to 19 per cent. of zinc with 1 per cent. of lead, and spathose slimes were obtained containing 5 per cent.