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.

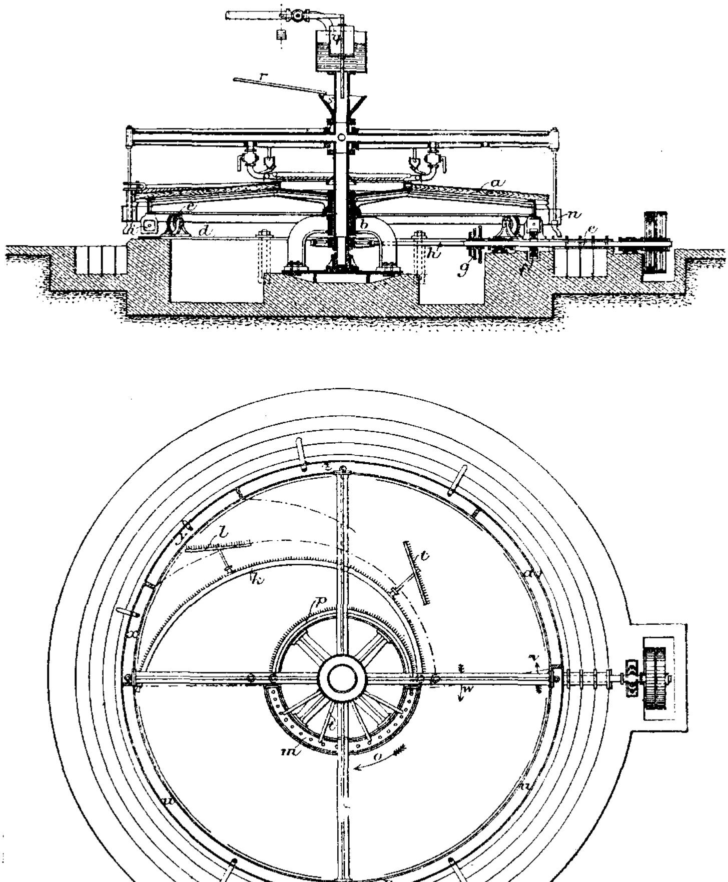
Correspondence.

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.

of lead and 7 per cent. of zinc. Trials made at the Kremnitz Mr. Bartsch.
gold mines in Hungary gave the following percentage yields :—

91·06 in 70 per cent. concentrates.
6·40 in intermediate product.
2·54 in tailings.

Figs. 45.



Scale $\frac{1}{75}$.
BARTSCH CONCENTRATOR.

The yield of concentrates was thus very high and the loss very

Mr. Bartsch. low; whilst the quantity of the intermediate products was but 2·1 times as great as that of the concentrates. A second treatment of the intermediate product gave the following percentage yields:—

96·882 in 70 per cent. concentrates.
0·492 in intermediate product.
2·626 in tailings.

The slimes treated measured under 0·5 millimetre in grain, the amount dealt with being 10 to 12 tons in twenty-four hours. The consumption of power was $\frac{1}{4}$ HP.

Mr. Brough. Mr. BENNETT H. BROUGH remarked that from the description of the Frue vanner given in the Author's exhaustive Paper, it would appear that that machine was applicable solely to the ores of the precious metals. In the recently published Eleventh Report of the State Mineralogist of California, however, there was an interesting account of the application of the Frue vanner to the treatment of chrome-iron ore at the Mendenhall mine. The ore was of a low-grade character, assaying 44 per cent. of chromic oxide. Concentration on the Frue vanner raised this percentage to 54. In an encyclopædic Paper like the Author's, it was obviously impossible to deal fully with every branch of concentration. It was, however, to be regretted that the important subject of magnetic concentration was dismissed in two pages. In the United States, and in Sweden, magnetic concentration had become of growing importance since 1889. According to the United States census returns the amount of iron ore concentrated in 1889 was 95,425 tons. Jigging machines were employed to a limited extent to cleanse some of the red hæmatites and magnetites. Greater attention was, however, devoted to magnetic concentration, and many of the machines devised for that purpose exhibited great ingenuity. Appliances with fixed magnets were but little used, the more productive and more costly electro-magnet machines being preferred. Of the latter, two types were employed: (1) machines in which the current is interrupted at certain moments in order suddenly to release the magnetic particles of ore, and (2) those in which the current was constant, and the particles were removed by passing out of the magnetic field. In describing machines of the latter class, the Author expressed no opinion as to the relative merits of working wet or dry. It would appear that more rapid work could be done dry, but that a cleaner separation would be effected with the ore in a wet condition. The water would act as a lubricant and cleaning medium, and, consequently, the cost of repairs and renewals should be less in the wet process.

Mr. Charleton.

Mr. A. G. CHARLETON remarked that the Paper traversed a field of special interest to him, owing to his having recently been engaged in designing a concentrating plant for a complicated ore, when he found it no easy task to decide what machine would be best adapted for the particular purpose in view. There was so little English literature available on ore-dressing that the Author's Paper must be welcomed by all engineers who have not had an opportunity of acquainting themselves with the German works of Gaetschmann, Rittinger, and Linkenbach. Even those who had done so would find the two older works mentioned antiquated, and would be glad that by the Paper the range of enquiry had been considerably narrowed down. Almost the only branch of the subject (excepting crushing) with which the Author had not exhaustively dealt was a consideration of the main principles which should be kept in view in designing concentration-plant. Rittinger, in 1867, laid down several rules which, with certain modifications, could advantageously be recollected. 1. "Choose the apparatus and machines which under existing conditions can easily be constructed and maintained." That rule was framed when it was the custom in Germany to build most of the machinery used in dressing-floors on the spot, and contemplated the possession of extensive shops and skilled labour. Machinery makers, and the increasing use of metal in the construction of machines formerly made entirely of wood, had modified, however, modern practice, and the rule above quoted might now perhaps be somewhat altered to read: Providing that they can be furnished at a reasonable cost, choose the most efficient apparatus or machines for the purpose in view, which possess simplicity and lightness, combined with strength of construction, as well as cheap and handy replaceability of such parts as are exposed to more or less wear and tear. 2. "The more valuable the products to be obtained, the more perfect should be the arrangements adopted." It might be added, however, that the highest perfection in laying out works was quite as important, if not more so, when the problem was to treat a large quantity of low-grade mineral at a profit, as when it was a case of handling a small amount of high-grade stone. 3. "The capacity of the machines and apparatus must be rightly proportioned to the quantity of material *of a given kind* to be treated." The words in italics were no doubt intended to be understood by Rittinger, but the addition had been made to make the rule clearer, as the character and grain-size of the constituents of an ore largely affected the capacity of different machines. 4. "If the site of the dressing-floors is not predetermined, let it be so chosen

Mr. Charleton. that the transportation of materials to be treated in the works shall be as simple as possible." The selection of a site enabling suitable differences of level to be taken full advantage of should usually have more weight than simplicity of transport in other respects. On the Continent water-hoists were largely used for elevating the ore in wagons, to convey it from a lower section of the works to an upper one; but this should be avoided when possible by placing the buildings so that the crude products could descend from step to step as their treatment advanced to completion. In some cases the choice of a site might be affected by the question whether it was cheaper to convey the ore a little further to secure a convenient position for the storage of water, or to diminish "the head," or the length of line, the supply for dressing purposes required to be pumped. 5. "The several apparatus and machines should be relatively so arranged that the middlings of each can be carried forward in the shortest and simplest way to the next following operation. Especially should care be taken not to let the middlings descend unnecessarily, that they may not have to be re-elevated." For elevating wet coarse stuff bucket-and-chain elevators were recommended; for fine sands and coarse stamp-slimes, double raff-wheels; and for fine slimes, centrifugal pumps. For dry, coarse material, leather or rubber belts, to which steel or malleable-iron buckets are riveted, are largely used; whilst for handling large quantities of fine dry ore, such as magnetite, when practicable, it seemed best to employ horizontal or inclined carrying-belts travelling over concave rollers. The greatest inclination at which a belt would elevate effectively appeared to be only 27° to 30°, and, consequently, length of belt and space were necessary to elevate to any height. Such belts should be coated with an elastic composition on the carrying side to protect them from abrasion. 6. "The simplest and cheapest motors should be used to drive the several machines. Motors driven by water-power belong, as a rule, to this class, and only where water-power is not easily available should steam-power be employed." Moreover, the position of the motor should be central, so that the machinery demanding the greatest amount of power might, as far as practicable, be nearest to it. 7. "Too many machines ought not to be operated by one and the same motor, since otherwise operations might be seriously interrupted by the stoppage of this one motor, and also because it is difficult to regulate the running of the individual machines." Where there was an ample supply of water, which could be delivered from one motor (such as a turbine or Pelton wheel) to another, by collecting the tail-water in reservoirs and utilizing it over again, or where there was enough to supply several motors from one source, this rule could often be advantageously applied, and the same might be said where power could conveniently and cheaply be distributed by electricity. When steam was employed it was rarely expedient to employ more than one principal motor, but even then one or two small supplementary engines could often be advantageously employed in large works, for operating delicate machines like slime-tables, which were largely affected by very slight variations of speed, or for treating at night accumulations of material collected in works that were mainly run on single-day shifts. Where work was carried on continuously night and day, as it generally ought to be, accumulations of the kind might frequently be treated also with advantage in small auxiliary departments by themselves, independent of the main plant. Mr. Charleton.

8. "By means of suitably placed windows, and a proper position of the working rooms, provision should be made for adequate interior lighting by day. At night the end must be sought by a liberal lamp illumination." In modern plants as large a lighting surface as possible should be secured, and overhead lighting was certainly the best. When side illumination was employed machinery requiring constant attention and regulation should be so placed that the workman standing with his back to the light would have it thrown on the machine from behind. It was probable that in a northern latitude a good top south light would be better than the north one advocated by the Author, as it would enable works to be run for longer hours of daylight and be warmer in winter. Electric lighting at night minimized risk from fire. It possessed greater capacity for distribution, and greater convenience, and was in almost all cases less costly than oil. Glow-lamps should be used over separate machines and arc-lights for packing tables, yards and waste-heaps. In localities where there was a heavy snow-fall the roofs of buildings should have a much higher pitch than in more temperate climates. Too great stress could not be laid upon having solid foundations. In short, to quote Professor Bilharz, the arrangement of dressing-works must be comprehensive, logical, and easily calculated to insure continuity of operation for the whole range of the business.

In order to obviate the disadvantages attending the use of revolving picking tables, Mr. Charleton had lately designed a new form. Briefly described it was a circular iron table revolved round a shaft of masonry or brickwork containing the ore, with a stationary circular table of wood or iron fitted round the revolving one. The bottom of the central shaft or hopper was coned, and

Mr. Charleton. the ore was fed forwards towards the doors or openings set round it. The ore to be sorted was tipped in direct from trucks running above on a line of rails and, passing out at the openings, fell on to the inner ring of the table, which travelled on a carriage, and was rotated by a wire rope passing round it underneath, on the same principle as the Linkenbach table, or by other gearing. Underneath the outer fixed part of the table were a number of bins to contain the various products sorted out, and these were drawn from time to time into a truck, which ran round the bins on a circular track at a lower level. Above the table there was a water-spray to clean the ore as it passed down in cases where it had not been previously washed thoroughly. The action of the revolving section of the table, aided by a fixed set of scrapers, was to move the ore as it fell out of the hopper slowly forward towards the sorters, who dropped the various products picked out into openings in front of them, which were connected by shoots with the bins below. A scraper attached to the rim of the interior table each time it made a complete revolution removed the waste from in front of the different pickers. The stone as it was fed forwards could be rapidly sorted over, and the work should be done better than when the ore was liable to be moved away whilst a lump was being examined. The growth of the heap in front of a neglectful picker showed if he was shirking his work, and an examination of the products from the different bins would indicate who was the delinquent, if the sorting was carelessly done.

Mr. Collins. Mr. ARTHUR L. COLLINS thought that although, in considering the action of the ordinary jigging machine, the Author had gone a little into the theoretical considerations generally supposed to govern its working, no one of practical experience could help feeling that these accepted formulas, based on the action of free-falling bodies in still water, did not explain all the observed facts. All the crushed ore from the rolls could, for example, be treated direct on a jigging machine without any sizing whatever, and yet practically nothing be lost in the tailings. It was true that the concentrate so obtained was far from clean, and needed re-treatment; but if the Author's formulas alone applied, the smallest ore-grains would not be found with the concentrate at all, but would be washed away with the coarser tailings. The truth was that the particles on a jig-sieve were not free-falling; every grain really fell in the interstices between its neighbours. Thus laws deduced from the action of free-falling bodies could not explain all that occurred in jigging. The Author had referred to Munroe's investigations into the rates of falling of ore-grains in narrow tubes, and these results deserved the close attention of all concerned with practical ore-dressing. As to sizing, even after the most careful sifting by trommels, the particles obtained were by no means of equal volume. The differences, such as they were, were constant; and they were often of the greatest importance to the ore-dresser. In fine slimes, the perfect cleavage of some sulphide ores tended to produce minute flakes, easily caught by tables or other machines involving stranding on a surface. In the coarser sizes, many ores broke into granular pieces, approximately spherical or cubical, while the pieces of gangue with the same area were often materially flatter, and consequently less in volume. A comparatively large flake of slaty rock might thus be carried off with the tailings of a jigger, being supported by virtue of its area; while, if it were turned on to its edge, it would at once begin to sink into the bedding by virtue of its absolute weight. A case had recently come under his notice where this difference was of great importance. An ore of zinc blende, as intimately mixed with siliceous matter as to have a specific gravity of only 3·69 (taken on small fragments of clean ore), had to be separated from a gangue consisting largely of pyritous and garnetiferous hornblende rock, the specific gravity of which often rose to 3·55 (taken on the heavier pieces picked out from the waste). Under ordinary circumstances, a separation of these would have been impossible. According to the Author's formulas, sizing by trommels differing only by a size-ratio of 1·055 would have been necessary. But it was found that the slight slaty cleavage of the pieces of hornblende rock so reduced their volume, as compared with the blende passing through the same trommel, that a separation by very ordinary sizing and jigging (eight sizes of trommel from 10 mm. to $\frac{3}{4}$ mm.) was not only possible, but fairly easy. The jigging process was of great and growing importance. Its cheapness and wonderful adaptability to varying conditions would always give it a prominent place in ore-dressing. But with all its simplicity in practice, its action involves so many factors, differing in such varying proportions, that it was not easy to reduce it to a mere question of a formula. Mr. Collins.

Mr. H. G. Graves noted that very little appeared to have been done in the application of percussion tables to the preparation of coal for the market. Some attempts had, however, been made in the United States, apparently with a certain amount of success. A form of end bump table, known as the Campbell coal-washer, had been used in Kentucky for treating some of the coals pro- Mr. Graves.

Mr. Graves. duced in that State. The same machine was also used in the Lake Superior copper district for dressing copper ores. The table of the machine was made with a false bottom of perforated metal or wooden slats, and had a peculiar curve. It was about 8 to 10 feet long and 30 inches in breadth. The stroke ranged from 3 to 6 inches, the table being driven forward by a cam and falling back against a bumping-block. Water was supplied under the false bottom, and also above it, by a spraying-pipe. The action was continuous, shale and dirt passing over the head, and coal being carried by the water over the tail end of the table. The capacity was stated to be 40 to 45 tons daily, with an expenditure of $\frac{1}{2}$ HP. and 300 gallons of water per ton.

The Humboldt Engineering Company. THE HUMBOLDT ENGINEERING COMPANY, of Kalk, near Cologne, would fix 16 millimetres ($\frac{5}{8}$ inch) as the lowest limit for hand-picked sizes. If the ores were fairly rich, it was advisable to hand-pick them below $1\frac{1}{4}$ inch, as all unnecessary reduction should be avoided with such ores in order to reduce to a minimum the losses in the slimes. On the Continent in many ore-dressing mills the ore was hand-picked down to 20 millimetres ($\frac{3}{4}$ inch). The illustration of the Linkenbach table (*Fig. 36*) showed an obsolete construction. The refining sprays, formerly covering 270° of the table, were now concentrated in a smaller angle. The delivery troughs were in consequence shorter and could be suspended from two arms, so that the large carrying framework (shown in *Fig. 36*) was no longer necessary. The slimes, too, could be fed into the distributing troughs from above, instead of from below as formerly was the case, so that the expensive foundation and underground tunnel were dispensed with. In the old construction, the slime feed-pipes occasionally choked, and the slimes had to be very thin. Now the feed-pipes could be made as large as desired, the slimes might be much thicker, and the tables might have a larger capacity. Naturally, the Author could only mention some of the more important magnetic separators. It was however, a matter of surprise that the Kessler separator was omitted, as it was working satisfactorily in more than a hundred different places. *Figs. 46* and *47* showed its construction. The iron shaft A was magnetized by the electro-magnet B, on each side of which were endless chains of iron, C C, running over the wooden roller D. They were made of flat bar-iron connected by the belts O. On the upper surfaces of the bars were pins which were placed alternately at angles of 90° to one another from bar to bar. The roller A turned in the direction shown by the arrow. In passing over that roller, the chain was magnetized, and on approaching

The Humboldt Engineering Company.

the wooden roller the magnetism became gradually less. The consequence was that grains of ore containing particles of magnetic mineral fell off sooner than grains which were wholly magnetic. They fell into E as middlings and were treated again after further comminution. The magnetic particles fell into F, and the non-magnetic into H, direct from the feeding-shoot G. The

Fig. 46.

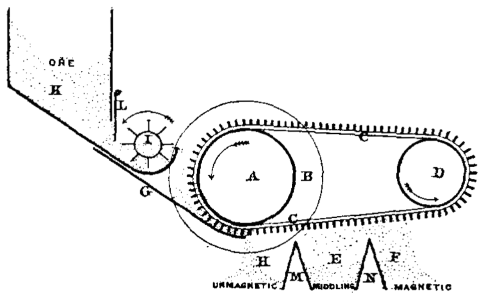
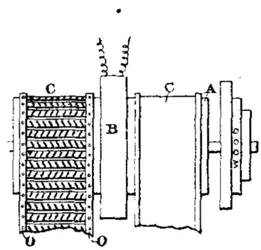


Fig. 47.



KESSLER MAGNETIC SEPARATOR.

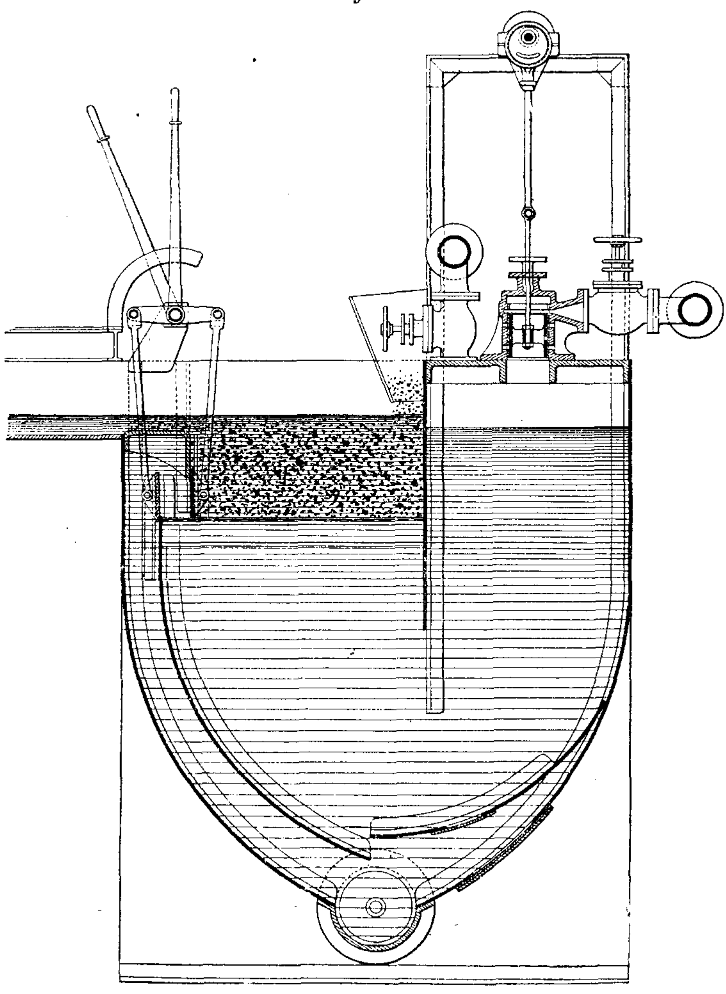
feed from the box K was controlled by means of blade-wheels J, the quantity being regulated by the slide L. The apparatus could thus be easily adjusted to all kinds of ore. The division plates M and N could also be adjusted horizontally by means of hand-wheels.

Mr. Jefferson.

Mr. J. CLARK JEFFERSON pointed out from carefully plotted curves that if the time of fall of coal and clay slate in still water was limited to three-fortieths of a second, the separation took place practically irrespectively of size and shape and only according to density. There was, consequently, no difficulty in separating clay slate from the unscreened coal over so large a range as $\frac{5}{16}$ inch to $2\frac{3}{4}$ inches (8 to 70 millimetres) in one jigging machine. In coal-washing, the influence of the flat shape, in which the clay-slate for the most part occurred, deserved more attention than had hitherto been paid to it, and pointed to the adoption of apparatus in which a vertical current was used as highly suitable for coal-washing. In that case the slate particles presented themselves and fell edgewise to the current, whilst in jigging-machines they were compelled to lay themselves at right angles to the current on their line of motion. In the former case, if the current was so regulated that the clay-slate fell at the same rate as the coal rose, the influence of the flat shape facilitated the separation of the clay-slate, whilst in the case of jigging-machines it retarded the

Mr. Jefferson. separation. The jigging-machine of the Baum machinery-works of Herne in Westphalia (*Fig. 48*), in which the water was actuated by the admission and exhaust of compressed air (1·5 lb.

Fig. 48.



Baum Hydro-Pneumatic Jigger—Transverse Section.

per square inch) above the surface of the water into the closed-in upper parts of the side water-box, appeared to fulfil most nearly the theoretical and practical requirements of a good jigger. The

Mr. Jefferson.

inlet and exhaust of the compressed air were effected by means of a piston-valve actuated by an eccentric. The Baum jigger sorted fine coal under 2 millimetres without any felspar bed, and more rapidly than the ordinary felspar bed jigging-machine. It was in operation in this country at the West Riding Colliery, Altofts, near Normanton, and at the Middleton Colliery, near Leeds. A few statements in the Author's exhaustive Paper were, perhaps, open to criticism. For example, the remark that P. von Rittinger did not appreciate the possibility of separating in jigs particles varying considerably in size appeared unjust to Rittinger, whose work treated and emphasized that point, besides illustrating it with diagrams. The remarks, too, as to the fall of equal-sized and equal-falling particles of different density required modifying in the case of ascending currents by the words "provided the current is sufficient to raise the denser as well as the lighter particles." In the case of centrifugal separators, theory indicated that for equal separating particles $d_1^3 \rho_1 = d_2^3 \rho_2$, or, for the case of coal and clay-slate, $d_1 : d_2 :: 1 \cdot 21 : 1$. From this it was evident that a slight difference in size made a considerable difference in the separating force, and consequently a centrifugal machine was a very bad form of separator in the first instance, though it might be very useful as a supplementary machine after the materials had been to some extent sorted in a jigging-machine or classifier. If employed in the first instance, it would require excessively close sizing and grading as a preparatory operation. The theoretical requirements above indicated were fulfilled in the case of fluids, and hence centrifugal separators acted extremely well for such purposes as the separation of cream. In the case of all jigging-machines, since the time of any one upward or downward movement was very short, the general equations (1) and (3) given by the Author for constant velocity were only very partially applicable, whilst those for the period of accelerated velocity were the most important. The rules given by the Author for this period offered a better explanation of the action of "jigging through a bed" than the vague and incorrect one of a "filtering medium." It was advisable that the material of the bed should be only slightly denser and larger than the denser of the materials to be separated, and that the velocity or speed should be considerable. If the velocity of the induced downward current was sufficiently great, then the smaller of two equally dense pieces fell at first more rapidly than the larger. This explained the penetration, say, of clay-slate through the felspar bed. In the case of a similar rapid upward current, the material of the bed being, if only

Mr. Jefferson. slightly, greater and denser, equal falling, rose more rapidly than the material to be separated, so that during the upward stroke also the denser of the materials to be separated penetrated the bed. In other words, during the up-stroke the larger pieces of the clay-slate, and during the down-stroke the smaller pieces of the clay-slate, penetrated the bed. A better arrangement for discharging concentrates than those shown by the Author in Figs. 13 and 14 was that shown in *Fig. 48*, which consisted of two adjustable slides. It was advisable that the lower edge of the inner slide should be slightly below the dividing line between the clay-slate and the coal, whilst the upper edge of the outer slide should be slightly higher. The above arrangement allowed the slides to be adjusted to suit the relative heights of the layers of coal and clay-slate, the speed and stroke of the machine, and the length of the sieve, all of which affected the discharge. If too much material was placed on the sieve, the separation was incomplete; if too little, the dividing line was too low, and in both cases coal would pass away with the clay-slate. The pipe-discharge arrangement was sometimes made practically equivalent to that shown in *Fig. 48* by having two short concentric vertically sliding pipes.

Prof. Köhler. Prof. G. Köhler, of Clausthal, considered that the Author's exhaustive work presented but little that was open to criticism, except as regarded the jigging process. There the Author was of opinion that the separation of the lifted particles of mineral was due to the acceleration acquired by them when falling during the first fraction of a second. He (Professor Köhler), on the other hand, agreed with Hoppe, that the most important factor in the separation was the upward impulse and not the acceleration in falling—firstly, because the height fallen through was so small; and secondly, because of the mutual interference of the particles. Munroe was certainly right in assuming that the particles in a jig acted as if they fell in narrow tubes or channels, whereas the theories of Rittinger and Sparre were deduced from trials made in wide vessels with single particles falling through great heights. In the absence of further experiments, he was disposed to believe that a sizing prior to jigging was only warranted by the fact that a large particle required long and slow strokes, whilst a fine particle required short and quick ones.

Mr. Krom. Mr. S. R. Krom, of Jersey City, New York, noted that the Author considered water a better medium than air, on account of its greater density, and on account of the difficulty of obtaining dry ores for treatment. The greater density of water was an advantage in the concentration of ores coarsely crushed; but within the limits of the capacity of the pneumatic jig, as at present constructed, air had advantages over water as a concentrating medium. Pneumatic concentration could successfully compete with water in all cases where the ore required to be crushed fine before concentrating; and minerals which had so small a difference in specific gravity as to defy separation by the wet system, could be successfully separated by the pneumatic. The present pneumatic jig would treat only ores that were not crushed coarser than to pass an 8-mesh screen, and the limit in fineness was 130 to 140-mesh to the linear inch. With the pneumatic jig close sizing was less essential than with water; two sizes, or at most three, were sufficient. It was only necessary to give air velocity to produce resistance equal to that of water, and then the absence of all adhesion of dry particles of ore made it possible for smaller grains to be concentrated on the jig; and the separation took place more rapidly, as the impulses (500 per minute) could be administered more rapidly. It was usual in Papers on concentration to quote the laws governing the free fall of mineral grains in still, or moving, air, or water; and to argue that on that law the present system of wet concentration was based. Of course, the fact that minerals fell in air, or water at different velocities demonstrated that they possessed different densities; but no such demonstration was required to prove the fact. Separation of ores by jigging was based on a more energetic force than "free fall," viz., "The dynamic effect of the living force produced by an upward jerk, which had a more energetic effect than free fall." In relation to dry ores for treatment, he considered it of sufficient advantage to have the ore dry for crushing and screening to pay for the cost of drying, without any reference to the system of concentrating which might be afterwards employed. In conclusion he wished to endorse the Author's new name for rolls, namely, "revolving stamps." Perhaps if rolls were always considered as revolving stamps (which in effect they were), it might be possible surreptitiously to overcome the prejudice of mill-men against rolls as a substitute for the stamp battery. Mr. Krom.

THE FRIED. KRUPP-GRUSONWERK CO., of Buckau-Magdeburg, pointed out, with reference to the Author's description of the Stein table, that they now made that appliance, as improved by Bilharz, entirely of iron. It was thus more stable and more durable, whilst by increasing the width of the india-rubber belt to 3 feet the effective area of the table and its capacity were much increased. The Fried. Krupp-Grusonwerk Co.

The Fried. Krupp-Grusonwerk Co. Under the head of centrifugal separators, the Author had omitted to mention the recently-invented Pape-Henneberg process of dry separation. That system consisted in scattering the pulverized ore from a rapidly-revolving disk, exhausting the dust, and regulating the opposing blast. The various products from the circular collecting-troughs were concentrated by means of screens, and the coarse screened products concentrated by the wet process on tables. The process was well adapted for the treatment of poor gold quartz ores, containing free gold, in countries where water was scarce.

Mr. Lawn. Mr. J. G. Lawn considered that the Author's statement that copper ores with 5 to 15 per cent. of pyrites were usually concentrated to about 70 to 80 per cent., was open to correction. The loss would certainly be far too great. The annual returns of copper ore raised in this country from 1800 to 1881 showed only one case (1808) in which the average produce reached 10 per cent., the average would more probably be 7·5 per cent. The Rio Tinto Company smelted copper ores with but 3 per cent. of copper without any preliminary concentration, as was also done by the Mansfeld Company in Germany. To cite the case of iron and copper pyrites as an example of minerals requiring separation was unfortunate, for, as a rule, no attempt was made to separate them. Thus, while the Rio Tinto ore contained but 3 per cent. of copper, it often had as much as 40 per cent. of iron, both minerals existing as sulphides. There were many better examples which might have been quoted by the Author. Mispickel in tin ores, for instance, rendered the dressing operations longer and more costly, but it had to be removed before the ore went to the smelter. The equation given by the Author for the velocity of a body falling in still water was really that for the velocity of a body falling in vacuo, and though approximately correct in air, when h was within any reasonable limit, it was not true for a body falling in water, inasmuch as the equation indicated a constant acceleration or retardation depending directly upon $\sqrt{h}$; but as the Author pointed out immediately afterwards, there was no acceleration after the first fraction of a second, but a constant velocity was obtained independent of h. The possibility of that was not indicated by the equation, and therefore the equation for the fall of a body in still water could not take that form. In the equations which followed, only two factors were considered, the effect of gravity and the resistance of the water. There was, however, a third, the surface adhesion of the water to the particle, which, although probably unimportant with large particles, was not so with small ones, for the volume of a sphere decreasing in proportion to d^3, the surface decreased only in proportion to d^2. Thus, a small particle had a much larger surface in proportion to its weight than a large particle, the effect of which was to render it more buoyant. With very fine particles indeed, the surface tension of the water was probably important in preventing them getting below the surface. These points were of interest in considering the treatment of slimes. With regard to the concentration of iron ores, there appeared to be an impression that there were no washing plants erected for that purpose in this country. That was not the case, as there were two or three such plants at work in Furness for concentrating poor hæmatites, with sand and clay as impurities. The ore was taken in wagons to the top of a building by means of an endless rope working an incline. Thence it passed through a stone-breaker into a revolving cylinder, 19 feet long and 4½ feet in diameter, supported on two sets of small wheels. The cylinder was inclined slightly towards the stone-breaker, and the ore was made to travel up it by means of a spiral of angle-bar, while a stream of water entering at the upper end travelled in an opposite direction to the ore. The upper end of the cylinder was perforated with ⅝-inch holes, so that all stuff of less size than that dropped through into a shoot and thence for classification through a series of trommels and pointed boxes. The classified stuff was jigged in a series of six or seven Harz jigs. The larger stuff from the end of the cylinder dropped on to a shaking-table, and after having been hand-picked fell into a wagon placed below. A plant treated about 100 tons per day of ten hours. The chief difficulty was in dealing with the clay which, in the cylinder, balled and enclosed pieces of ore. There were two sources of loss—(1) in the " dradge " (mixed hæmatite and sand from the jigging), brought about because no means of comminution other than the preliminary stone-breaker was used; and (2) in the fine stuff, for the treatment of which propeller-knife buddles were tried but without marked success. It would readily be seen that with an ore selling at 10*s*. or less per ton, the limit of refinement to which dressing could profitably be pushed was soon reached. Moreover, very fine ore was objected to by the smelters. Mr. Lawn.

Mr. D. A. Louis observed that the Author did not give particulars of the power required nor of the relative wear and tear of the apparatus, the supporting parts and machinery by the use of plunging as compared with piston-jigs. If their jigging powers were the same, that seemed to be the point upon which their comparative value depended. A modified form of jig for Mr. Louis.

Mr. Louis. coarse material he had seen in successful operation had not been mentioned in the Paper, and he should be glad to learn whether that was because it was considered less efficient than the central outlet form described. In the modification alluded to, the sieve was made too short for the box so as to leave a gap between the end of the sieve and the partition separating one compartment from the next. The end of the sieve was furnished with a low sill, whilst a ∧-shaped weir was employed, which could be adjusted so as to permit any desired quantity of the heavier material to pass under it and over the sill into a special launder or receptacle beneath the gap, the lighter material in the meantime escaping over the weir in the usual way. The Author was right in his surmise that Collom jigs were used at the Anaconda dressing-floors. There were many hundreds installed there, and they certainly were more accessible for inspection and adjustment than an equally large battery of Harz jigs would be. Throughout the Paper great credit was given to German inventors of concentrating machinery. It might, however, be noted that the siphon separator had been claimed to be the invention of one John Wilkin, a Cornishman. It was curious that in 1887 a percussion table, exactly similar to that illustrated in *Fig. 32*, was introduced into Gilpin and Clear Creek counties in Colorado by a man named Hayes, who was regarded as the inventor. Its efficiency and simplicity made it very popular. The riffling of the belt of vanning-machines, and the three-tier arrangement of Linkenbach tables were mentioned in the Paper without adverse criticism. He, however, was of opinion that the riffling was of doubtful advantage, inasmuch as although the yield of concentrates was increased, their richness was considerably decreased by such an addition to the vanner. He considered, too, that the three-tier arrangement of tables, on account of inaccessibility and other inconveniences, was scarcely to be recommended. With regard to coal-screening, he questioned whether the regularity of the Coxe gyratory screen would not be disturbed by any accumulations of dust in the paths of the cones.

Mr. Meinicke. Mr. C. Meinicke, of Clausthal, stated that, with regard to the question as to how far close sizing prior to jigging was advantageous, he advocated the retention of screens or similar appliances for two reasons. Firstly, most ores were met with in the mine varying in composition and in richness, and it frequently happened that a portion of the ore demanded excessive comminution, whilst with another portion that was not the case. If sizing prior to jigging were adopted, the financially safe limit to further comminution could, with a little practice or by assay, be rapidly and accurately determined. Thus it would sometimes be possible, by *jigging 30-millimetre sizes, to remove one portion of* the ore from the barren rock, whilst with a second portion it would be found advisable to jig at 8 to 12 millimetres, and with a third possibly at 2 millimetres. If, however, the ore were treated without sizing, that sharp separation would not be possible, and it could easily happen that, although the tailings were comparatively poor as a whole, a certain quantity of ore yet worth dressing would be lost, because its further treatment in admixture with a large quantity of poor ore would be unprofitable. Moreover, sizing rendered possible a more careful mode of working and a greater yield, quite apart from the fact that the jigging could be more easily and accurately checked in the case of the treatment of sized material than in that of unsized ore. A second argument for the retention of sizing was that the rolls, which were frequently employed for crushing ores over 2 millimetres in size, and other machinery used for comminuting had a far greater capacity when the ore was fed into them of uniform size than when it was in the form of pieces of very unequal size. That was a matter of very great importance in dressing-floors, for the cost of comminution was the heaviest item. Against those two advantages of sizing were the disadvantages of the cost of the installation and the working of the screens. If, however, it was borne in mind that those costs in a well-designed plant were comparatively low, and that even in the treatment of unsized ores the employment of screens could hardly be dispensed with for certain subsequent operations, it would readily be seen that on those purely practical grounds sizing should be retained in all cases in which it was not a question of perfectly simple conditions and easily dressed ores. That care was to be taken over the selection of the size of grain would be well known to all experts in ore-dressing, and if investigation were made into cases of exaggerated close sizing, it would perhaps be found that they were due to theorists who were not sufficiently conversant with the practical requirements of dressing. Mr. Meinicke.

The Nagel and Kämp Iron-works Company.

THE NAGEL AND KÄMP IRON-WORKS COMPANY, of Hamburg, found that their experience was not in accord with the Author's statement, that the screening of particles less than $1\frac{1}{2}$ to 1 millimetre could not advantageously be carried out in practice. Extended and careful experiments with finely pulverized silver ore on vibrating sieves of their construction gave the following results:—

The Nagel and Kämp Iron-works Company.

No. of Wire-Cloth = No. of Wire to the Inch.	Width of Mesh in Millimetre and in Brackets Diameter of Sifted Product.	Capacity of Sieve per Square Metre per Hour in Kilo-grammes.	Capacity of Sieve per Square Foot per Hour in lbs. Avoirdupois.
25 (30)	0·508 (0·423)	10,500	2,148
30 (35)	0·423 (0·362)	6,000	1,230
35 (40)	0·362 (0 317)	4,000	820
40 (50)	0·317 (0·254)	2,300	471
50 (60)	0·254 (0·211)	1,600	328
60 (70)	0·211 (0·181)	1,150	238
70 (85)	0·181 (0·149)	730	150
85 (100)	0·149 (0·127)	460	94
100 (120)	0·127 (0·105)	230	47

The actual results, as stated in the above Table, obtained with the vibrating sieves were compared with those obtained, expressed in brackets, with a hand-sieve. Thus, the product of No. 100 on the vibrating sieve corresponded with No. 120 on the hand-sieve, or in other words, the particles had in that case a diameter equal to or less than 0·105 millimetre. The sifting was quite satisfactory, seeing that the material remaining contained but 8 per cent. of the material treated. In the vibrating sieve, a frame covered with wire-cloth of any desired mesh was set in motion by means of revolving cams which imparted a rapid vibrating action to the sieve. The intensity of the action might be regulated at will.

Prof. Richards. Professor Robert H. Richards, of Boston, Massachusetts, gave a few facts bearing upon the question whether close sizing should precede jigging or not, developed partly by others and partly by himself, in a recent investigation, the results of which would shortly be published in the Transactions of the American Institute of Mining Engineers. His tests had been limited wholly to particles which would pass through a sieve with ten meshes to the linear inch, and the results had led him to a different conclusion from that advanced in the Paper. If a vertical glass tube, 1 inch in diameter and 60 inches long, was charged with mixed sizes, all of which would pass through a sieve having holes $\frac{1}{10}$ inch in diameter, of two minerals differing in specific gravity, and if an upward current of water was allowed to hold the particles in gently-moving suspension, or in other words, as "quick-sand," it would be found that, where quartz was one of the minerals, the ratio of the diameter of the heavier to that of the lighter mineral particle which was in equilibrium adjacent to it, Prof. Richards. would be as indicated in the following Table:—

Mineral.	Specific Gravity.	Ratio of Diameter of Heavier Particle to Diameter of Lighter based on Quick-Sand.	Rittinger's Ratio based on equal-settling Particles.
Native copper . .	8·479	8·59	4·56
Galena	7·586	5·84	4·01
Wolfram . . .	6·937	5·15	3·64
Antimony . . .	6·706	4·89	3·48
Cassiterite . . .	6·261	4·69	3·22
Arsenical pyrites .	5·627	3·74	2·82
Copper pyrites . .	5·334	3·11	2·64
Magnetite . . .	4·987	..	2·43
Pyrrhotite . . .	4·508	2·80	2·14
Zinc-blende . .	4·046	2·12	1·85
Epidote	3·380	1·70	1·45
Quartz	2·640	1·00	1·00
Anthracite . . .	1·473	5·61	3·47

Each result in the "quick-sand" columns was computed from thirty weighings. The balance of particle against particle thus shown was the ultimate effect of the pulsion of the jig, and the ratios would be found to differ very considerably from those obtained by Rittinger from equal-settling particles. When the plunger returned, and a downward suction replaced the upward pulsion, the larger grains, consisting of quartz, for example, if quartz and galena were under consideration, would immediately bed themselves upon the jig, and between these particles there would be interstices down through which the suction-water would rush. And since the galena particle was smaller than the interstices in the quartz, it could easily pass down through the quartz bed and the sieve into the hutch. If, however, zinc-blende be the specifically heavier mineral, then the diameter of the particle of blende, which was balanced beside the particle of quartz, was larger than the interstices, and would, therefore, be only very imperfectly sucked downwards, and a complete separation would be impossible. The natural conclusion from the above observed facts was that the higher in the series of minerals the work was conducted, the more perfect would be the work of jigging mixed sizes. The sizing necessary as preparation for jigging quartz and galena should be, after the fine slimes had been removed, simply that dictated by convenience. For example, it might be found better to put nut size upon one jig, pea size upon another, and

Prof. Richards. sand size upon a third; in such case, sieves would be used accordingly. But in regard to the minerals towards the lower end of the series the conclusion was quite different. There the closer the sizing preparatory to jigging the better would be the work. But even there by the aid of suction an approximate separation could be made without any preliminary sizing.

Mr. Roberts. Mr. Charles Roberts pointed out that it had not been the mere use of electro-magnets but the adoption of them in an alternate multipolar field that had rendered magnetic separation satisfactory. The most efficient machines were those in which full advantage was taken of the action occurring, due to the induced polarity of the particles treated. The arrangements shown in Figs. 37 and 39 gave the non-magnetic particles no chance of freeing themselves, as the gangue particles could only imperfectly separate themselves into a layer next the drum or belt. If the machine (Fig. 37) was arranged with the magnets in the lower left-hand sector of the drum, and if the rotation of the drum was in the opposite direction to that shown, there would be the essential conditions of the best machines now made. Similarly, the machines shown in Fig. 39 would work much better if they were arranged upside down so that the gangue particles would have an opportunity of falling away. Early inventors and subsequent imitators seemed to have been afraid to trust the force they were using—a fear probably due to the use of permanent magnets that were found to be wanting in strength or to become weakened. In the Ball-Norton machine, there were employed two drums of the improved Heberle type, working parallel and next to each other, the magnets occupying the lower sectors of the drums. The first drum might be revolved at about 80 revolutions, and the second at 60 or 40 revolutions. By that means, a very large quantity was treated and the greater part of the separation was done on the first drum, the high rate of revolving of the drum throwing out the non-magnetic particles, and thus assisting the action of gravity. The concentrate was taken from this drum by the magnets of the second drum, and the speed of this drum being lower, any particles which were partly gangue and partly ore, or were impure compounds of less magnetic susceptibility, were dropped out. That action might be increased by lowering the speed or by lowering the force of the magnets in the drum. With that arrangement all the ore did not need to be crushed to the absolute fineness of the smallest magnetic particles—a condition necessitating great cost and not always advantageous, especially for iron ores, as the compound particles could be thrown out as a middlings and afterwards recrushed and again separated. It was that differentiation of the magnetic product that was the critical operation in converting many non-Bessemer into Bessemer ores by the elimination of the phosphorus and other impurities. In treating large quantities of finely crushed ore, with drums revolving at high speeds, it was necessary also to have a strong air-current drawn through the drum-chest in opposite direction to the passage of the ore, or the fine dust would be carried into the concentrates. Machines of that kind, with about 30 inches diameter drum with 24 inches face, would pass about 20 tons per hour of fine material, and the power required per machine was about 3 HP. including electric current. Machines of the Buchanan type were not found to work satisfactorily, as the ore falling on the rolls was attracted and took with it gangue and dust particles, the non-magnetic particles only being separated when the material was fed very thinly and evenly. Mr. Roberts.

Mr. G. SAUTTER noted that the Author had omitted to mention the magnetic separator constructed by Messrs. Sautter, Harlé Mr. Sautter.

Fig. 49.

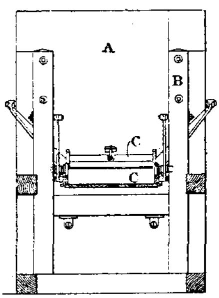
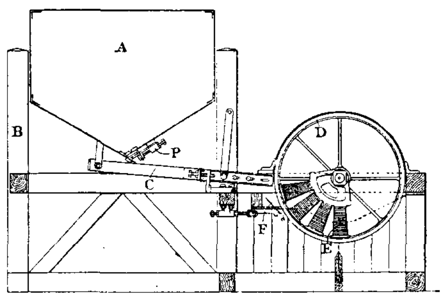


Fig. 50.



SAUTTER MAGNETO-ELECTRIC SEPARATOR.

& Co., of Paris, and successfully employed at the Pierrefitte and Friedrichssegen mines for the separation of blende and magnetite. The machine consisted of a hopper A (*Figs. 49* and *50*) into which the crushed ore was tipped. The ore passed on to a shaking tray C, to which a reciprocating motion was imparted. In traversing the trays the ore encountered a certain number of stationary electro-magnets E, which retained the ferruginous particles. The particles accumulating at the rotating drum D, which was made of copper plate, followed it in its rotating movement by magnetic adherence. When they had passed the vertical axis and were free from the last magnet, no longer being held by magnetism, they fell into the second compartment of the box

Mr. Sautter. placed below the drum. The non-magnetic particles, on the other hand, passed along the inclined plane S into the first compartment of the box. At Pierrefitte the most convenient velocity for the machine was found to be 64 revolutions per minute; 4 to 5 tons of ore were treated per hour. The current necessary was 16 amperes and 110 volts, representing an electrical energy of 2·3 HP.

Mr. Schmitt-Manderbach. Mr. A. SCHMITT-MANDERBACH, of Biebrich on Rhine, pointed out that the Author's description of the Schmitt-Manderbach spiral screen was only partially correct. In treating ore, a screen of that type, worked by one man, could easily deal with 30 to 40 tons in ten hours, and deliver seven to twenty-one sizes, from 35 millimetres down to 0·1 millimetre, of material; whilst in the cases of coal and coke, the capacity was 200 to 250 tons, five to six sizes, from 35 to 2 millimetres, being delivered by one man. Even the models of the screen of one-sixth and one-fifth full size, constructed for the various Schools of Mines, clearly exhibited the great capacity of such appliances. The capacity as stated in the Paper was tenfold too low. Under the conditions specified by the Author, instead of 8 to 12 tons per hour, 200 to 300 tons could easily be dealt with. At the present time about one hundred Schmitt-Manderbach screens were in successful operation.

Mr. Commans. Mr. COMMANS, in reply to the Correspondence, observed that in the Paper he had only briefly referred to Rittinger's formulas, and had not thought it necessary to show how they were deduced—especially as the calculations were lengthy. He had carefully abstained from laying too great stress upon those formulas, because he felt the only satisfactory way to investigate the question of the sizing and separation of crushed ore by jigging, was by experiment; and he fully appreciated all that Professors Hoppe and Munroe had done to combat the growing tendency of carrying sizing to extremes. The remarks of Mr. C. Meinicke clearly showed how from commercial and practical points of view, sizing, within certain limits, was, undoubtedly, of very great importance. Concentration to 70 per cent. was, perhaps, as Mr. J. G. Lawn had suggested, rather high in the case of copper pyrites, though not uncommon with galena. The tests of Professor R. H. Richards, from the short allusion made to them, would appear to realise more closely than any hitherto made, what actually occurred by jigging. His results would be of great value. They would be looked forward to by all who were interested in the subject of ore-dressing, and would mark another step forward on the road of scientific research. Practical research of that kind in England had been neglected in the past, as the makers and users of the various machines had seldom the time or the opportunity to carry out a long series of accurate tests. It was to be hoped that action would be taken in the matter by the mining schools. If only a small percentage of the capital annually invested by Englishmen in mines all over the world were devoted to organizing and equipping a National Mining Laboratory, and endowing travelling scholarships, to enable students to acquire two or three years' practical experience, tens of thousands of pounds would be saved annually, which were at present lost and muddled away through the ignorance and incompetence of persons holding responsible positions at home, and in charge of the properties. The importance of a combined, sound, scientific and practical training in most branches of engineering was now fairly generally recognised, and there was no reason why the important branch of mining-engineering should not receive the support it deserved—mining being one of the greatest of British national industries. Mr. Commans.

After the meeting of the 9th January the President and Council held the first monthly Reception of the Session. The list of exhibits on that occasion will be found on page 114.

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16 January, 1894.

ALFRED GILES, President,
in the Chair.

The discussion upon the Paper on "The Concentration and Sizing of Crushed Minerals" was resumed and concluded.
