Discussion.

Mr. W. H. PREECE, C.B., President, said it was his pleasant duty to propose that a vote of thanks be awarded to the Author for the very practical Paper that he had submitted. The Institution was always gratified, in these days of severe foreign competition, to hear that an English firm had fitted a mine in a distant country with apparatus designed in England, and the members were much indebted to the Author for having given so fully and completely all the details of the measurements, of the power exerted, the efficiency, and the other conditions realized by the machinery. He called the members' particular attention to the fact that in all the Papers on electric machinery and electrical appliances brought before the Institution, the one striking element was the fact that means and instruments were applied to measure, with the greatest possible accuracy, every factor in that machine. There was nothing that tended so much to improve machinery of any kind as a system of measurement of that character.

Mr. ESSON, having exhibited on the screen a series of photographs of machines described in the Paper, referred to the method of driving from two turbines on one countershaft. It left much to be desired, and had only been adopted because the engineers of the Sheba Mining Company insisted on using some old plant that was on the ground. If the two turbines had been of the same size the disadvantage would not have been so great, but with turbines of two sizes, working on a common countershaft, there was a great difficulty in proportionally distributing the load between them. Accordingly a loss of about 5 per cent. was incurred in driving the countershafting. Instead of a return of 70 per cent. at the mine, 75 per cent. might have been realized if a method had been adopted whereby all the countershafting and driving-gear could have been dispensed with. In the Burma ruby mine installation there was a low fall as at Sheba, but each alternator was directly driven by ropes from a single Pelton wheel, and consequently nothing intervened between the wheel and the alternator but one set of ropes; there was no countershafting to drive. All the wheels were controlled by one governor, and that was essential. The only proper way of governing a number of Pelton wheels, driving alternators which had to work

Mr. Esson, in parallel, was to control all by one governor. In another transmission installation in the Straits Settlements, upon which Messrs. Johnson and Phillips were engaged, 300 HP. had to be conveyed to a mine $7\frac{1}{2}$ miles distant. There was a high fall, and the Pelton wheels were running at a speed of about 400 revolutions per minute, so it was possible to couple the alternators direct on to the Pelton-wheel shafts. That was by far the best method of working, and it had been also arranged that one governor governed the three wheels. The type of generator shown in Figs. 3, Plate 2, had been recently modified by interlacing the coils as in the motors, because it was found that then a much smaller fall of potential between light load and full load was obtained than when the coils were wound singly. The machine shown in Figs. 3, Plate 2, consisted practically of two single-phase alternators, the top half of the armature constituting one machine, and the bottom half the other; but with the interlaced coils a much better result was obtained than with the type of machine shown. Again, the field-magnet described in the Paper had been changed. It was a very good one for machines which ran on a non-inductive load, that was, on a load of lamps, but on an inductive load there was too much magnetic leakage, so it had been abandoned, and now a field-magnet of radial poles, each having a separate coil wound on it, was used. A much smaller fall of potential was thus secured than with the type of field-magnet used at Sheba. With regard to the relative outputs of two-phase and single-phase machines, if a non-inductive load was put on a two-phase machine, undoubtedly its output was higher, quite one-half more, than with the single-phase machine; but generally, the two-phase machine had to work on an inductive load, and there was not the advantage which would be obtained from working on the non-inductive load. First, for a given output, the impressed electromotive force had to be about 25 per cent. greater than the terminal electromotive force when working on an inductive load. Again, a current 25 per cent. in excess of that which would accord with the watt output of the machine had to be generated. There was thus obtained from the two-phase machine, working on an inductive motor load, just about the same output as was obtained from a single-phase machine of the same size, working on a non-inductive load. He had not, in the Paper, touched upon the application of the induction-motor to coal-mining; but in this industry it had a distinctly important bearing, as in gold-mining and gem-mining. One of the great advantages of the induction-motor was that it

had no commutator, and there was practically nothing to go Mr. Esson. wrong about it. He was surprised to find that in fiery coal-mines, where there was liability of explosion, the direct-current motor should still be employed. It was necessary with it to take the greatest precaution to prevent an explosion by enclosing the commutator in a gas-tight casing. The induction-motor was ready to hand, it had no commutator, and it did not matter how it was treated. The short-circuited armature or rotating part of the induction-motor might be steeped in water, and it would suffer little damage. One of the most interesting points about power-transmission plants was the way in which the line was guarded from the effects of lightning. A lightning guard had been devised by Messrs. Siemens and Halske,¹ which consisted of two curved copper forks mounted on two insulators, one being connected to earth, and the other to the line. If lightning struck the arrester an arc was formed in the small space at the bottom between the two forks, and the current of air made it rise quickly to the top of the forks, where it could not be maintained. It thus acted quite automatically. That arrester had done very good service in the Randt, and it was now being adopted in an installation Messrs. Johnson and Phillips were erecting in the East. Replacement arresters were not adapted for transmission of power work and were always giving trouble. Here the arrester was always ready to act. At the Sheba mine, Wurtz arresters were employed; they were made in America and consisted of composite metal cylinders, fulfilling the same conditions, and the apparatus required no replacement.

Prof. W. E. AYRTON thought that one of the most interesting Prof. Ayrton. features of the Paper was that it showed that English engineers were at last becoming alive to the importance of the vast field that lay open to them of the transmission of power by polyphase electric currents. He had been very much struck, while travelling through America in 1897, with the use that was there made of the electrical transmission of power, particularly in connection with mining; over as great distances as 100 miles, and at 30,000 volts, or even, as he had heard in one case, of some 35,000 volts for 100 miles. The advantages possessed by the polyphase motor were rightly emphasized by the Author. The only regret was that this should be necessary in England at the latter end of 1898. These advantages had been realized and utilized for the last seven or eight years on the Continent of Europe and in the whole of

¹ Electrotechnische Zeitschrift, vol. xviii. p. 214.

Prof. Ayrton, America. Since engineers were shown in 1891 the transmission at Frankfort of more than 100 HP. over more than 100 miles at an efficiency, very carefully measured, of about 75 per cent. by means of polyphase currents, engineers in England ought to have grasped, as Europe generally and America had grasped, the importance of that method of solving such problems. The Paper also brought out the fact that while a few years ago the education of a mining engineer would have been regarded as satisfactory if it embraced merely mechanical engineering principles and practices, it was now quite clear that if a mining engineer was to extract the ore and deal with it economically, he must know a good deal of electrical technology in order to be able to utilize the neighbouring water-power by bringing it to the mine and so saving the consumption of coal. The generating station at Sheba seemed to possess a considerable number of faults, the mass of counter-shafting, the use of rope-driving for the turbines, the use of belts for the other parts, the jockey pulleys, and so on; but the Author had said he would not have used the method had he not been compelled. With regard to the dynamo, he would hardly like to criticize a machine which was designed by so eminent an engineer as Mr. Gisbert Kapp, but at the same time it seemed susceptible of improvement. Much of the circumferential space in the dynamo appeared to be wasted by the distance-pieces which had been inserted to produce the difference in phase, Figs. 3, Plate 2. There was not merely on the left-hand side an idle space, but there was a very large idle space on the right-hand side, which meant a considerably diminished output for the size and for the weight. Why, also, should those air-gaps be made, between the sector plates, about as large as the air-gaps between them and the pole-pieces? The air-gaps had distinct disadvantages, as they were included in the magnetic circuit. One air-gap was necessary in the magnetic circuit of a rotatory machine, but why have more? In addition to increasing the reluctance of the circuit, it also apparently caused the coils to be much less embedded in the iron than would otherwise be the case, and therefore induced a certain drag on the coils which the Author rightly pointed out would not exist if the coils were entirely buried. He had not made any experiments or seen the particular dynamo, but he should predict, from the shape of the pole-pieces and the shape of the coils, that it would give a peaked form of wave, which was a bad shape of wave, since for a considerable period there was a low electromotive force arising from the particular shape of the ends of the moving pole-

pieces which led to the number of lines of force produced by a pole and embraced by a coil not altering for some time, and, therefore, producing no electromotive force. Perhaps, also, the Author would explain why the corners of the sector plates were cut off; this tended, apparently, to increase the gap. It would at any rate have seemed preferable to bring them up and not cut them away, the object being to get as nearly closed a magnetic circuit as possible in that direction. There seemed to be a special object on the part of the designer in making an extra reluctance in the magnetic circuit. He supposed the Author's expression "boiled in paraffin" was only figurative; paraffin wax should not be boiled, for its insulating property was thus seriously diminished. It should not be heated above a temperature of 110° C.; and even when only heated to that temperature, as in the manufacture of condensers to drive off the water-vapour, the whole of the paraffin wax was sold daily for candles and was not used the next day, because even heating to 110° C. was sufficient to seriously diminish the insulating quality of paraffin wax. Were it raised to the temperature of boiling wax, it would be almost ruined from an insulating point of view. He was much interested in the suggestion of synchronizing alternators by means of two hot-wire volt-meters, and he would be glad if the Author could describe the exact method he employed. The wires that he used on the exciting coil in the generator were round, whereas flat wires were used in winding the stationary coils. That, again, perhaps, was for some good reason, but why round wires in the stationary coil? With regard to the conductors which connected the generating station with the motor station, he noticed that four conductors were employed in two separate cables. Was that preferable to using three conductors only in one cable? With the two-phase system three conductors could be employed by making one of twice the cross section, the current being about 1.4 times that in the two others. He did not understand why lightning conductors were required when the cables were laid 3 feet under the ground. He thought in that position they would be sufficiently protected.

Mr. W. H. PREECE, C.B., President, said they were just as liable to disturbance when 3 feet underground as when placed on poles.

Prof. AYRTON supposed that the Author's expression "There is no fall of potential due to self-induction in these concentric cables," was used figuratively, for there was certainly a small fall of potential. As to the use of oil in the transformers, the impression was

Prof. Ayrton.

Mr. Preece.

Prof. Ayrton.

Prof. Ayton. conveyed that oil had proved a failure. He thought that the breakdowns in the insulation might not be attributable so much to the oil as to the method in which the transformers were originally wound, and that the improvement noticed at about the time he dispensed with the oil was due to the introduction of the very much better system of winding to which he referred in the Paper. The method used originally was to wind the wire in continuous layers along the whole length of the core; there was thus great difference of potential between the ends of successive layers. That method had been abandoned 30 or 40 years ago in connection with the winding of the induction-coil. It was realized that the layers must be divided by ebonite disks which divided the coil into several short sections. The wires had thus to be wound in little pockets, and the difference of potential between the ends of successive layers was correspondingly reduced. It might be only a coincidence that when the Author took the coils out of the oil he found that the breaking down was discontinued, seeing that very shortly afterwards he introduced the system which he had described—certainly a very much better one—of winding with edged flat copper, for in that case no two convolutions differing much in potential would ever be brought near together. There was one reason why the introduction of resistance coils was so important in starting an induction motor which had not been perhaps generally realized. The resistance prevented large currents being induced in the stationary portion which would be injurious and would weaken the field; but another reason for introducing resistance was that it diminished the time-constant of the circuit, that was, the currents in the stationary and rotatory parts of the motor were brought more into phase with one another. The same effect was produced as in a steam-engine if the greatest admission of steam was combined with the most efficient position of the piston. The lag that occurred in ordinary alternating current working was analogous with having a considerable pressure of the steam when the piston was in a bad position near a dead point, and clearly if that could be removed and the greatest amount of steam or the greatest pressure in such case could be brought about when the piston was at its best position, a better arrangement would result. The introduction of resistance—he did not know that he had ever seen that pointed out before—in starting an induction-motor had the effect of diminishing the time-constant and bringing the currents more into phase, so that the large currents in the stationary portion and the large currents in the moving portion were nearer together and

could act better in producing a large starting torque. The Prof. Ayrton. Paper appeared to be one of considerable interest, and the results achieved had a practical and important economical bearing, as would be obvious to every Englishman, seeing that the Author said, at the beginning of his Paper, that the installation described had saved the Sheba Company £10,000 per annum.

Professor G. FORBES regarded the Paper as one of very great Prof. Forbes. importance, as drawing attention to one of the principal applications of electrical transmission of power. In the last few years the fact had been more and more impressed upon his mind that the greatest application of electrical transmission of water-power which would be seen in the next few years would undoubtedly be for the purposes of gold-mining. The reason was obvious: first, many gold mines were capable of giving a large output, but had no means of getting fuel in their neighbourhood, and, consequently, the working expenses were too high. He could mention many gold mines which had come under his personal observation which were absolutely unproductive, and could not be worked for that reason. In consequence a very large price could be obtained at those gold mines for the power that was transmitted, and it therefore became possible to invest a large capital in copper to transmit power to very great distances when the return was so great. The second reason was that the demand for the power was continuous, day and night, all the year round; and, in such a case, the superiority of water-power became enormous over that of steam-power. The Author had cited some of the advantages of using electrical power for gold-mining, and to many engineers, who had not followed the progress of electrical practice of late years closely, it might appear somewhat startling that the induction motor was of all machines the least complicated, and, on account of its simplicity of construction, least likely to suffer serious injury or damage through rough usage. Of that there was not the slightest doubt. The induction motor was peculiarly suited to the rough usage it was likely to experience in a gold-mining district. It was to all other electric motors somewhat in the same relation as a "Pelton" wheel was to a turbine for its simplicity and absence of liability to get out of order. Compared with other machinery—steam-engines or machinery of that class—it was incomparably simpler and less likely to get out of order. In the Randt it might be taken that about 2 tons or 3 tons of ore per day were crushed per HP. The mean between those two

Prof. Forbes, amounts gave a cost of about 2s. per ton of ore crushed, which was a remarkably low figure. At Coolgardie a year or two ago the proprietors were willing to support any scheme where they would be obliged to pay 10s. per ton. That showed that transmission to a long distance—where the expenses were increased by the conductors—was likely to be successful, and to become remunerative. He had not much preference between 2-phase and 3-phase systems—either would work the induction motor satisfactorily—but he would support the view the Author had expressed—that the 2-phase was the preferable. The case mentioned by the Author could not be considered a long-distance transmission in any way, as it was only about 5 miles, and it went a circuitous route, owing to the fact of underground cables being used. If it had been overhead cables it would have been much closer; consequently, the pressure was only 3,300 volts, which was very moderate and did not give an indication of what would happen with long-distance transmission. He would ask whether the dynamo machine was not practically identical with that designed by Mr. C. E. L. Brown for the Lauffen and Frankfurt Exhibition in 1891. It consisted of two flat disks or wheels, facing each other, with an iron cylinder joining them, as it were, and the peripheries had the poles projecting inwards and alternating one with the other. He had understood that that type of dynamo had been abandoned because the magnetic leakage between the poles was found so great that it was not efficient. He understood that at Oerlikon their manufacture had ceased, and he should have thought that it was not so satisfactory a design as some which had been introduced later. It appeared from the Paper that the transformers were originally placed in cast-iron cases and were immersed in resin-oil, but that insulation failed; the oil was put in to keep out the water; but convection currents induced in the oil, due to heating, only served to circulate in a state of fine subdivision any moisture or water which might be present, thus creating the very evil intended to be cured, and, sooner or later, leading to a break-down of the insulation. In considering the tenders that were made for the very large transformers at the Niagara Works two classes had been put before him. One contemplated the use of oil like the circulating one shown by the Author, and the other was provided with an air-blast, the object in both cases being not to produce a high insulation, but because in transformers of a very large size the heating became very great. A very economical transformer was obtained, but artificial cooling had to be introduced. His own opinion was

that the oil had not had a sufficient trial, and he preferred Prof. Forbes, in the first place to trust the air-blast, and it had proved perfectly successful. Later on the oil had been introduced, and the experience with oil-insulation had been very satisfactory. He thought that the circulation of the oil which had been introduced in the last transformers at Niagara would not be the less likely to carry moisture with it than the stationary oil which he presumed was employed at Sheba. With regard to the conductors, he was surprised that in the Author's case it was found necessary to use underground cables. Electric transmission to a long distance would certainly not be possible in the immediate future by the employment of underground cables, because the cost of an underground cable was between four times and ten times the cost of a bare copper wire, and the cost of the copper in a long transmission line was a serious item of expense. Therefore it would be increasing the capital expenditure perhaps five or ten times. The Author said that the troubles experienced with the overhead wires used for lighting, due to the severe lightning storms in the Barberton district, induced the engineers to lay the cables underground, and they had since given no trouble. Professor Forbes could well believe they had not given any trouble, but he should be surprised if that practice would be followed by others. He had never seen such a place for lightning as the Transvaal. Thunder-storms were very severe indeed, and it was well known that Mr. Rhodes' telegraph line through Rhodesia was subject to continual interruption. There was seldom a day that some part of it had not to stop working. Also there had been great trouble with the electric-light works in Barberton and other places. Probably the Author was aware that, in the neighbourhood of the Sheba mines, there were other places which were using electrical transmission of power for their gold stamps, and they had at first been troubled with lightning. He had received reports from mines where a different mode of procedure to that adopted at Sheba had been followed. Instead of incurring the enormous expense of buying insulated cables and burying them, also at great expense, 3 feet below the ground, and most of it through rock, a bare overhead copper conductor was still used; but there were joined with that conductor all the wisest precautions which could be thought of, evolved from past experience, which would be likely to prevent trouble. Among other things the Siemens and Halske lightning arrester had been employed. The line was working at 10,000 volts to 11,000 volts, and other precautions besides the simple use of that

Prof. Forbes. arrester were taken. The special manner in which the arrester was placed, undoubtedly had some influence on the result; but the result was simply that there was no trouble whatever now. Ever since the change had been made—since the line had been protected in that way—he had felt, with perfect certainty, that there was no need for trouble in future about lightning in any part of the world, and that transmission lines could be made absolutely proof against this disturbance. Barbed wire was used at Niagara, but in the case he was speaking of barbed wire was not used. He would wish to have inserted it in a case like that which he had mentioned, as it was most desirable, but in that particular case wire was used for making an earth, because there was a difficulty to get earth at a good many points where it was wanted, and a wire was used, but it was not barbed wire. At the mine of which he had been speaking, which had not been established so long as the Sheba mine, but where 10,000 volts and 11,000 volts were used with a bare overhead wire, the generators had been lately running for 88 days continuously, 24 hours a day, 7 days a week. During that time—88 days—load had been lost about 30 minutes in all through line fuses melting. He should imagine it to be one of the worst places for lightning in the world, and any arrangement that would stand the lightning of the Transvaal would stand the lightning of any place he knew of.

Mr. Raven-
shaw.

Mr. W. H. RAVENSHAW noticed that the Author had stated his surprise that multi-phase work had not been more used by English engineers. For some years after the Frankfort Exhibition it was always understood that patents were held in a foreign country controlling the manufacture of multi-phase machines, but during the last 3 years or 4 years that matter had been cleared away, and several English firms had been taking up the subject. Many firms had not taken it up, however, because they had all been so extremely busy with continuous-current work. In the application to mining he thought that multi-phase working had many advantages, especially in fiery mines. He believed that, in South Wales, there was little electrical working in the fiery mines, simply owing to the fear of the sparking of the motors. The continuous-current enclosed motor was very difficult to build in any large size, and still more difficult to obtain. He thought the Author's machines would hardly have been suitable for that class of work. Mr. Esson said that his 50-HP. motors were pulled up with 65 HP. In winding, or, hauling up a steep incline, there was a great danger if the motor pulled up. It must go on; in fact, in many cases no fuses were used, and magnetic cut-outs were tied down.

If a train weighing 20 tons or 30 tons was coming up an incline of perhaps 1 in 10, the power must not fail, and if the motors were at all likely to give out, it would be extremely dangerous. The Author had also mentioned that he had improved on the dynamos greatly. He would expect to find that they would have a very heavy drop, and that was very bad for an induction motor. Consequently, he was not at all certain that it was not a good thing engineers had to wait a year or two.

Mr. A. C. CAMPBELL SWINTON had had considerable experience with transformers in which oil had proved exceedingly satisfactory. They were small, ranging up to 30 kilowatts, but there were about thirty, and the total power was considerably more than that which the Author referred to. They were in use at Scarborough and were mostly in pits under the foot pavements; some had been in use for 5 years. There had been three cases of a transformer failing, but in no single case could it be attributed to the oil. He thought, as Professor Forbes had said, the use of the oil was not merely for the purpose of keeping water out and keeping the insulation dry, but that it also had the effect of preventing local heating, which really determined the safe load at which a transformer could be worked, in the same way that the weakest link determined the strength of a chain. About 3 years ago he had occasion to examine the question of two transmission plants, one for a coal mine for the Armiston Coal Co., in Scotland, and the other for dock-pumping at Smith's dock on the Tyne, and in both cases he studied most carefully the question of the relative merits of multi-phase and continuous currents. In neither case was the distance very great. In the case of the coal-pit the maximum distance was 1,500 yards, and in the case of the dock, which was a floating one, where 500 HP. had to be transmitted, it was only about 200 yards. There were other points to be considered, but the cost entirely turned the balance against the multi-phase system in each case. After the estimates were reduced to a common denomination, the multi-phase motors, generators and cables, came to something like 20 per cent. more in first cost than did continuous-current plant. He did not know why that should be, and he thought they ought really to be cheaper. He supposed it was because, at that time at any rate, manufacturers were largely engaged in making continuous-current machinery in England, and could not produce multi-phase machines so cheaply as continuous-current machines. At any rate, they did not wish to take the risk without charg-

Mr. Raven-
shaw.

Mr. Swinton.

Mr. Swinton. ing a very large price. The advantages of the multi-phase motors were quite undoubted in certain instances, but when the large difference in cost was considered, the advantages did not warrant the extra cost in the particular cases quoted, because although commutators might be troublesome to some extent, still, if machines were properly made, they really did not, after all, require very much attention. He might mention that in the pit in question about 500 HP. was transmitted. It was not a fiery mine, and therefore it was simply a question of first cost on the one hand and upkeep of commutators on the other. In the case of the dock there was the further point that a variable speed was required for the motors, which rendered multi-phase currents unsuitable.

Mr. Ristori. Mr. E. J. RISTORI had lately seen at work some turbines and dynamos of about 800 HP., working both continuous and alternating currents, and running at only 50 revolutions per minute; and he thought it should not be difficult to arrange machinery so as to have any speed suitable for any special water-power. He thought that a considerable amount of water-power was going to waste, which might be very usefully employed in mines or in other works. He recollected in 1892 or 1893, when he was seeking for water-power in England, he was advised by engineers who knew the country well that there was no possibility of getting it. They told him he might get 200 HP., or thereabout, but even if he found that, it would be much easier and cheaper to work with coal. In the last few years matters had greatly changed. Water-power was being used of several thousand HP., and installations were in preparation for 20,000 HP. and 30,000 HP., and there was any amount of small horse-powers which could be used to great advantage. There were many places in which 300 HP., 400 HP., and 500 HP. could be obtained, and by suitable transmission-plant, these installations would be found considerably cheaper than if the power were obtained by boilers, engines and dynamos. The idea was still held that water-power was not so cheap as power generated by coal at the pit's mouth, but it was gradually disappearing. It would be a good thing if engineers would take a lesson from the installation described by the Author, and tried to see in how many cases they could imitate it in England.

Mr. Parker. Mr. T. PARKER (Wolverhampton) remarked that manufacturers were constantly on the look-out with regard to the various new applications, and they would certainly begin to manufacture if they found they were being disturbed by the multi-phase system;

but, as yet, that did not seem to be the case. There was no difficulty whatever in building continuous-current dynamos to give 2,000 volts or 3,000 volts; that was being done every day, and also transformers. The manufacturers found the demand greater than they could supply, and therefore it was hardly time for them to halt and adopt something before they were sure it was a great deal better. In comparing an installation of continuous currents with an installation such as had been described by the Author, in the particular case mentioned that system might hold its own; but if it came to be increased, he thought difficulties would soon arise which were not met with in continuous currents. For instance, no engineer would consider great extension of synchronizing plant desirable. It was known that an engineer managing an alternating-current station did not sleep so comfortably while that station was running as an engineer who was managing a continuous-current station. The use of alternating currents, if greatly extended, would mean a great disadvantage as compared with the use of continuous current. Other difficulties were met with the cables. With continuous currents there was very little induction, and there was not the same maximum pressure upon the insulators. There was far greater simplicity in the three-cable system of continuous currents than there was in the three conductors required to carry out the system in use in the Sheba mine. Induction was everywhere, and unless care was taken to balance it, as the Author pointed out, there might very easily be no current reaching the terminals at all. With continuous current only two wires were carried everywhere, except where they were taken back to the dynamos. Therefore there was no comparison between the two systems of conductors; in simplicity, and in every point that concerned practical use, there appeared to be an absolute disadvantage in the multi-phase system. With reference to the motors, an admission had been made by the Author that the double working load was a serious consideration; in fact, he sketched out a 65-HP. motor as necessary to do 50-HP. work successfully, and double torque would be a very serious matter to meet with. With continuous motors five or six times the torque could be met without damage. As to the difficulty of commutators, his firm had a great number in use, but he never heard anything about them; they went away, and people seemed to manage them easily and find no great difficulty in the matter. Another point which seemed to be fatal to the application of the system in a general way was the great idle current that was needed to run the motors without work or small

Mr. Parker.

Mr. Parker. loads. The advocates of the system pointed out that it was wattless, but that that was immaterial? Current could not be carried without conductors, and, if there was a disturbance of the whole conductor system by useless current having to be carried, copper was required. He would not recommend any mining engineer to put the induction motor, or any other motor, into a dangerous place in his mine. It could not be said that that or any electric motor was absolutely certain; it might have a mishap at any moment which might fire any ignitable gases. Cables could not be carried about indiscriminately; they must be protected carefully. With regard to pressures, it was considered by Professor Ayrton that continuous current would never be seen where great pressures were wanted. He should be very glad, however, to execute orders for 10,000 volts continuous current, and he would give a higher efficiency by the system described there, with far less complexity. As a manufacturer, he certainly looked upon the multi-phase system as one of complexity, and, therefore, he should still advocate continuous currents until more definite results were obtained.

Mr. Steiger. Mr. A. STEIGER desired to refer to the question of governing turbines for electrical transmission plants. In the early working of electrical transmission plant in Switzerland, it was very soon found that an ordinary automatic governor was unsatisfactory, and means were sought to govern the turbines in a more efficient manner, with the result that the speed was now varying not more than 4 per cent. if 25 per cent. of the full load was taken off, not more than 6 per cent. if 50 per cent. of the full load was taken off, and if the full load was taken off the turbine suddenly the speed would not vary more than 8 per cent. of the normal speed. He thought those figures were quite satisfactory and sufficient for the requirement of electrical transmission plants. The arrangement of such governors was simply the connection of the ordinary governor with a Servo motor, which was provided with a valve, and acted on the gate, admitting the water to the turbine. To give one instance analogous to the Sheba mines, he might mention that Messrs. Escher Wyss & Co. of Zürich had supplied two turbines to a mine in the Transvaal for a fall of 18 feet, each giving 210 HP. Those turbines, he believed, worked stamps in a gold mine, where exactly the same thing happened which the Author had mentioned—that part of the stamps would suddenly stop, and then the speed of the engine would increase, and there would be trouble with the dynamo. Another instance he might mention was the generating station at Davos, in

Switzerland, where four turbines worked under a fall of 330 feet, Mr. Steger each turbine of 200 HP. The pipes were 2,400 yards long. If an automatic governor was applied under such a high fall a sudden extensive change of load would cause the gate of the turbine to be shut very rapidly, the sudden change of velocity of the water in the pipes would produce a shock, or excess of pressure, called water-hammering, which was all the more dangerous the longer the pipes. To prevent that in the first instance, there was a large air-vessel of about 4 feet in diameter and 40 feet high, connected with the main pipes, and also a special contrivance, connected with the automatic governor, to open automatically the waste-water valve, so as to allow the water to run to waste as soon as the governor acted on the gates of the turbines, and thus to remove all danger to the pipes. In that instance, if the full load was taken off suddenly, the normal speed of the turbine, and therefore of the dynamo, did not change more than 4 per cent., which he thought the Author would consider satisfactory. If water-power was used under a lower fall—and there were now many such places in Switzerland, as at Chèvres and Rheinfelden—the head of 4 to 15 metres would not be sufficient to obtain the necessary pressure for the Servo motor. In that instance a special pump was provided, which was connected with each Servo motor attached to the governor. That pump, instead of being filled with water, was filled with oil, and it served two purposes at the same time—while governing the turbine it also lubricated the foot-step. It was arranged so that the oil from the pump circulated in the foot-step passing between the plates of the foot-steps from the centre to the periphery; the pressure was about 350 lbs. to the square inch, and a thin film of oil practically carried the whole weight. In the instances just mentioned, the turbine-shaft being vertical and the dynamo directly connected with the shaft of the turbine, the load on the foot-step was about 55 tons, so that the provisions for the lubrication of the foot-step were particularly important, and justified the combination of the pump for the Servo motor with the lubricating arrangement of the footstep, and using oil instead of water. The accuracy of the governor had been found so reliable that in cases where there was a large water-power, and the water distributed over a number of turbines, each turbine was provided with its own automatic governor, and the dynamos could, without danger, be connected in parallel. Therefore, from that point of view also, he believed, as adopted in the plants mentioned, that proof had been given that the new system of governing turbines had been found efficient.

Mr. Griffith. Mr. W. R. GRIFFITH remarked that in England the use of electricity for the transmission of power in mines was generally confined to coal mines; the continuous-current system had been in use for 10 years fully, and its use was increasing. He would be interested to know whether there was a multi-phase electrical-transmission power-plant at any colliery in the United Kingdom? He had been enquiring for some time, but had not been able to hear of one. The advantages of the multi-phase motors were known, and he need not recapitulate them; but were there corresponding disadvantages? He had been told that he could see multi-phase generators and motors at work in Westphalia and Silesia, but he should rather like to see some at work nearer home if he could get an opportunity of doing so. Electricity as a motive power was not yet being used in his own collieries, but he was about to erect an installation of 400 HP., and he was in doubt as to whether continuous or multi-phase current was the preferable system.

Mr. May. Mr. JOHN MAY ventured to think that the arrangement of the power station at Sheba was probably the only one which would have answered the purpose in view. The alternators must run in parallel to give the desired result at the mine; if they were coupled separately to the turbines it seemed certain that they would not do so, because the turbines were admittedly very bad governors; and the load came on, when the crushers were set to work, very violently and with sudden jerks. He had had a good deal of experience of parallel running of alternators, and he knew many cases where even under favourable conditions, they would not run together; and in one particular case, the worst he had ever known, there was a star-field, the Oerlikon field, similar to that of the Kapp alternators. The known weakness of this form made him think that possibly that might have had something to do with it. In one case the machines would not run in parallel, even though they were driven by ropes, which were supposed to be a very flexible form of coupling and to give special advantages. In that case it was the governor of the engine which was at fault, and it was not until about 12 months' constant tinkering at the governor that the plant could be got to work satisfactorily. He thought that was ample justification for the engineer who designed and put in that big counter-shaft. With regard to synchronizing, he should like to ask the Author if he had any difficulty in getting alternators into synchronism at the first trial with the clutches, because it seemed that there were about a thousand chances to one that the machine would not be

put into phase at the first attempt, that it was bound to slip some- Mr. May.
where; it could of course slip either in the clutch or on the belt,
and he should like to know which form of slip the Author aimed
at. If it was in the clutch the gear was a slow screw gear, and it
seemed that the alternator would be likely to slip out again before
it was got in. He thought Mr. Kapp's arrangement for paralleling
alternators was too complicated. In electric-lighting stations it
was often found that the load came on much too quickly to enable
plugs and switches to be used here, there, and everywhere; in
fact, as a rule the alternators were paralleled straight off. He
noticed that the Author had mounted the switches on a teak base,
and he justified that course on the ground that the transit to the
mine was difficult. He thought if delicate instruments, such as
ammeters and volt-meters and so forth, could be taken to the mine
without damage, a slate could have gone as well. In fact,
although he regarded teak as a very good insulating material, he
had known of cases where teak boards had actually burnt up, and
he should quite expect that with 3,300 volts a similar experience
might be found some day at Sheba. Any one who had seen even
a 2,000-volt arc with a fairly big power behind it knew what a
mess it could make. In London, in the last 3 years, three works,
he believed, had been burnt down simply through fires at the
switchboard. He had had some slight experience of transformers
in oil. He knew a works where three or four different makes had
been tried, and he believed three out of the four failed. He came
to the conclusion that it was due to the oil, but he had no parti-
culars, and did not know whether he was right or wrong.

Mr. ALEXANDER SIEMENS believed that in all discussions of Mr. Siemens.
the various systems of transmitting power one mistake was
usually made, viz., that the advocates of any one system desired
to see that system adopted everywhere, and deprecated any com-
peting scheme and said there was no good in it. He believed
the same thing was taking place in the controversy about the
3-phase system and the continuous-current motors. They both
had their good sides, they both were the proper things to
be employed in their proper places, and he believed that the
Author had given an example of where, to a certain extent,
the 3-phase system was absolutely justified. To his mind, the
alternating currents—and he meant by that the machinery,
transformers, cables, and everything included—had the great
advantage that the currents could be generated at a low voltage
and then stationary transformers, in oil or otherwise, could
be used to transform up to a high voltage. It was then

Mr. Siemens, possible to use thin conductors, which were cheap, to transmit the current to a distance where it could be again transformed down to low voltage and the motors employed at a low voltage. But he did not think that the 3-phase induction motors were very applicable in many cases. Their great drawback, about which Mr. Griffith asked, was that they really gave their best efficiency at one particular speed. The next drawback was that which Professor Forbes mentioned and the Author admitted, that if they were slightly over-worked they stopped. The continuous-current motors were entirely free from those defects. One of the speakers had said that he had tried to introduce 3-phase currents and had found that the cost of the 3-phase motor was very much higher than that of the continuous current motor, and he ascribed it to the ignorance of English manufacturers or their not being used to the things. That particular point had been the object of his careful consideration for years, and he was particularly well placed with regard to the matter, because the firm of Siemens and Halske, with whom his firm had friendly relations, although they were perfectly independent, had been very strong advocates of 3-phase currents. They had themselves established one rather large transmission of power in the Transvaal with 3-phase currents; they had also employed them in Silesia and other places, and they had been urging his firm for years to adopt 3-phase currents and introduce them into England. His answer to that had simply been that he had sent them the inquiries for transmission of power which were received by his firm from this country and from foreign countries under all sorts of conditions, and said: "Give us an estimate of what you can do this transmission of power for at 3-phase current." He had invariably found that, for any small distance like 200 yards to 1,500 yards, the continuous-current plant which his firm could supply was infinitely cheaper than 3-phase plant; but, for large distances, the calculation came out differently. The great ease with which the continuous-current motors could be regulated and run at different speeds, and the very good efficiency at which they worked when running at different speeds had induced him to be a strong advocate of always using continuous-current motors. If power had to be transmitted to a great distance, by all means let there be used for the main line 3-phase currents or 2-phase currents, or any alternating currents thought desirable, for the reasons he had already mentioned, and get the power 10 miles, 12 miles, 15 miles, or

20 miles away from the place of origin; but for the actual Mr. Siemens' motors in the customers' houses continuous currents were preferable. Another reason why he advocated that was that the use of 3-phase currents for lighting purposes was not as simple as the advocates of the 3-phase current wanted to make out. The current must be always kept in the three branches exactly equal, and if that were not done there was a disturbance. Of course that did not happen if motors were used, because each motor used the three currents equally, and therefore the addition of a motor would not disturb the equilibrium, but the addition of lights did. That was the point which he found usually was not mentioned by the advocates of the 3-phase currents. Again, the plan he proposed for long distances was to use 3-phase currents, then transform them into continuous currents, and use them locally. Such a combination had been made available in Silesia, where the tramway, which was run from the central station, was worked by continuous and not by 3-phase currents. Incidentally, perhaps, he might say that, in London, the Metropolitan Electric Supply Company, he thought, was putting down a separate system of mains to distribute power by continuous currents, although they had got the alternating current handy everywhere. Then he wanted to say a word about the use of water-power in England. He did not think that English engineers were so very ignorant because they had fought shy of water-power. It was not everywhere in England that it could be used. As a matter of fact, his firm tried to light the town of Godalming by electricity driven by water-power—he was afraid almost to say the year, but he thought it was in 1882 or 1883. It was the first town, anyhow, in the whole world which was lighted throughout by electricity. It was found very soon that there was either too much water or too little, and it had to be supplemented by steam, and eventually it was entirely transformed into a steam station. Then came financial differences of opinion with the Town Council, and the lighting was abandoned. But every street in Godalming was lighted by electricity before any town in the United States, Germany, or anywhere else, thought of it. That gave him some insight into water-power. Another independent illustration which he might mention was a central station in the Transvaal put up by Messrs. Siemens and Halske, at Brakepan. It was originally designed to be a water-driven station, but after all the circumstances had been carefully considered the plans were altered and it was converted into a steam-driven station. It was all very well for gentlemen like Mr. Steiger, in a very favourably-

Mr. Siemens. situated country like Switzerland, where water-power could be obtained. In summer the glaciers and the snow melted and there was plenty of water and in winter it rained. In England there were droughts occasionally, and then the water-power was nowhere, and if reserve steam-power had to be used, why use water-power at all? There had been very much said about the simplicity of the induction motor, but he might remind the members, as a matter of fact, that the winding of the continuous-current motor and of the induction motor was absolutely the same. By putting three rings on a continuous-current motor and connecting the commutator plates 120° distant from each other, the three-phase motor was obtained. Of course there was the additional complication of having a commutator on the continuous-current motor; but, as Mr. Parker had said, if a commutator was properly made, and the whole machine was properly constructed, it gave no trouble. He might mention that on the locomotives which were made by his firm some years ago for the City and South London Railway the commutators had as hard work to do as could possibly be, but he did not think that any one of them had been renewed, and they had been in use now for at least 5 or 6 years. They had never been touched. That was nothing exceptional or to be particularly proud of, because any decent continuous-current constructor would make commutators like that. It was only the badly-made machines that gave trouble. Lastly, he wanted to call attention to a phrase which Mr. Griffith used, viz., that he thought it was all very fine for the people in Silesia and so on to use a 3-phase current, but he would like to see the things a little nearer home. That sentiment marked the great difficulty of introducing new things into England. Everybody fought shy of a new thing, and always wanted somebody else to pull the chestnuts out of the fire, and nobody had got the pluck to do it himself.

Mr. Beaumont. Mr. W. W. BEAUMONT desired to point out that the dynamos were designed by Mr. Gisbert Kapp as long as 4 years ago, and that English engineers could, if they had thought it worth while, have recognized fully the importance of that system. Three large firms were asked to construct the machines, and there was only one, Messrs. Johnson and Phillips, who would then undertake their manufacture. He did not know if all or either of the alterations suggested by Prof. Ayrton were made, the actual efficiency of the machines would be improved. The recognition of the system might appear to be slow in England, but all the English engineers had been busy, and it might not

necessarily be because they were unable to recognize, but that Mr. Beaumont. there might be doubts about the system. For some classes of work the machines were specially useful, and not necessarily superior in other work to the continuous-current machines. English engineers, as represented by Messrs. Johnson and Phillips, did, as long as 4 years ago, recognize the importance of the system. At that time Mr. Kapp was almost the only engineer in England advocating that system, which was unfavourably looked upon then; if there were any shortcomings, they might be explained by the earliness of the design.

Mr. Esson, in reply, said he might first answer the questions Mr. Esson. that had been asked about the alternator. Professor Ayrton asked why should such a great circumferential space be wasted? That depended largely on the type of the machine, and it mattered very little, so far as output was concerned, whether the wires were spread along the whole of the interior surface, or whether they were congregated in groups at different points. The real thing which determined the amount of wire put on the armature of the machine was the fall of potential between no load and full load, and it was very important in those machines to keep the fall as low as possible, because an alternator working on a non-inductive load, with a fall of 4 per cent., would very probably, when working on induction motors, have a fall of at least 20 per cent. The wave of the machine was not exactly of the form conjectured by Professor Ayrton. The curve was of the saw-tooth form with a slight ripple at the top forming a double peak. The rectangular form of the wires for the armature was simply to get the wires into a smaller space than the round wires would take. The reason why there were not three wires instead of four for the underground cables—in fact, why a triple concentric cable was not used instead of two concentric cables—was that the triple concentric cable created a dissymmetry throughout the whole system with two currents in quadrature and using a common return; and the way to get no bad effects due to induction was to use two concentric cables, one for one phase, and the other for the other. It was quite true that the particular field was introduced by Mr. Brown in his transmission from Lauffen to Frankfort. The only part Mr. Kapp claimed as novel in the design of the alternators was the armature, and the particular point about that was that the sectors with their coils were capable of removal. This was a high-pressure machine, whereas the Lauffen machine was a low-pressure machine, and the armature conductors con-

Mr. Esson. sisted of round rods inserted into holes in the core and insulated with paper. With regard to the breaking down of the transformers due to the oil, in the initial stage, as he explained in the Paper, there were great difficulties with the governing of the turbines, and very often the pressure ran up to twice or three times the proper working pressure, owing to their racing. The breakdowns were coincident with those two circumstances, the oil being used and those rises in pressure; in what proportion each cause contributed he could not say, but when the oil was done away with there was no more trouble. In other cases, with other transformers, similar trouble had been experienced as regarded oil, consequently it had been abandoned altogether, because, although with a great deal of care the oil might be satisfactory, it was better to do away with it when it might not always receive that care. He did not think there was any good in oil, and he believed the air-blast was superior in any case. There was this, however, about Mr. Parker's offer to transmit power by direct-current machine at 10,000 volts, that he had not done it yet, whereas on the polyphase system transmissions had been carried out at 10,000 volts, and had given no trouble. No doubt Mr. Parker would remember what difficulties Mr. Marcel Deprez had in his early experiments with direct currents at a pressure of 6,000 volts, when he transmitted power from Creil to Paris. He did not mean to say that dynamos had not been enormously improved since Deprez tried his experiments, but he was not aware that any machines had been constructed for 6,000 volts. It was not a question of alternating- *versus* continuous-current machines, the one having difficulties and the other not; but it was a question of alternating-current transmission with its difficulties *versus* impossibility, because it would be an impossibility to work at all with continuous currents some of the schemes now being operated with alternating currents. The case had been stated very well indeed by Mr. Siemens in his fair-minded speech. Polyphase currents were not to be advocated in the face of everything. Direct currents had their uses, and their sphere of use was continually increasing; but there were cases in which polyphase currents could only be used, and in which continuous currents would be quite out of place. The particular example of the Sheba mine transmission could be applied to a great many more mines, and he agreed with Mr. Siemens that for long distances in any case the transmission should be carried out by 3-phase or 2-phase currents, and that then, if necessary, it should be converted into direct currents

for distribution. He should never advocate polyphase currents Mr. Esson. for working tramway motors, because direct currents were for this purpose so much more simple; but in the particular case of the Sheba Mine it was thought better to use the induction motor as being far more suitable for the purpose than the continuous-current motor.

Correspondence.

Mr. C. F. HEATHCOTE observed that the Author had mentioned Mr. Heathcote the difficulty of transport to the mining fields, and the necessity of keeping as few spare parts as possible; but he thought the difficulty of obtaining skilled labour was not sufficiently emphasized, and was seldom taken into account by English manufacturers of mining machinery. It was of greater importance than a slight increase of efficiency that all machinery intended for new or "one-mine" fields should be simple in construction, easily repaired, and suitable for constant running, by having reliable dust-, dirt- and water-proof bearings with sight-feed lubrication.

Mr. ALFRED E. HUNT noticed that the Author referred only to Mr. Hunt. copper as an electrical conductor, and desired to point out that aluminium was now, especially in the United States, rapidly finding favour in such application on account of its cost rendering it a cheaper conductor. The specific gravity of copper was 8.93, and its electrical conductivity when pure was 100 in the Matthiessen scale, but as ordinarily used in electrical conductors it was 97.61. Its tensile strength was between 16,500 lbs. per square inch and 65,000 lbs. per square inch in hard-drawn bars, and its cost was 14 cents per lb. in the United States, the equivalent selling price being 130 marks per hektogram in Germany, for wire, bars, and rods such as were used for electrical conductors. Aluminium had a specific gravity of 2.68, an electrical conductivity in commercially pure metal of 63.0, a tensile strength in pure soft wire of 26,000 lbs. per square inch, and in hard-drawn rods of wire of 40,000 lbs. per square inch. The Pittsburgh Reduction Company in the United States were selling rods, bars, plates, and wire drawn down to 0.08 inch in diameter, in large orders for electrical conductors at the rate of 29 cents per lb. at their works. This price was below the regular rate for aluminium, offered for the special purpose of meeting the price of copper for electrical conductors alone, in order to favour the adoption of aluminium for this purpose and to overcome the