

Correspondence.

Mr. R. GLANFIELD remarked that the increase of efficiency in Mr. Glanfield. rock-drilling and a reduction in cost of 5s. per foot advanced during the last 2 years were remarkable achievements. He would appreciate greatly a detailed description of the "hole director" mentioned by the Author, or an indication where information might be found; also more information on the methods of sharpening and tempering steel drills. Whilst he realized the difficulty of selecting a rope compatible in strength and size, yet a factor of safety of only 6·5 to begin with was surprising. In some parts of the world—probably including South Africa—the mining regulations demanded a factor of safety of not less than 6; it would seem, therefore, that the life of the ropes must be short. He would be interested to learn how it was determined when the safe limit had been reached.

Dr. M. A. HOGAN remarked that the winding-arrangements for Dr. Hogan. the 4,500-foot wind at the City Deep mine described in the Paper were of interest to all concerned with the raising of large quantities of mineral. At those great depths the weight of the rope constituted more than half the total dead load; hence efforts must be made to reduce the weight of the rope, whilst maintaining the necessary strength. At City Deep that had been done by employing steel wire of very high tensile strength—134 tons per square inch—in the rope. Mining engineers in Europe had generally considered that the use of hard-drawn steel wire with a tensile strength greater than about 120 tons per square inch should be avoided if possible, because that material was thought to be unduly susceptible to deterioration by fatigue. The current Prussian mining regulations, issued in 1928, prohibited the use of winding-ropes made of wire with a tensile strength exceeding 121 tons per square inch, for that reason. In view of the advantages which might be derived from the use of lighter ropes of high-tensile steel it would be very interesting if the Author would give some information with regard to the life of and the tonnage raised by the ropes of 134-ton steel. With reference to the spin in the ropes, it was stated that whilst the rope had a certain amount of spin at first, after a few weeks' use it became practically non-spin. Were the ropes ever allowed to untwist during that period; if so, how much twist came out, and what elongation accompanied the untwisting?

Dr. Louis. Dr. HENRY LOUIS regarded the Paper as an excellent account of modern practice on the Witwatersrand. The Author had carefully confined himself to an accurate statement of facts, and the Paper was therefore not one that lent itself to much discussion. Perhaps exception might be taken to the title. The Paper dealt not with "Some Methods," but with "One Method" of gold-mining, because the Witwatersrand deposits were practically unique in the world, and the methods employed in mining them were therefore different from those in use in any other gold-field. Conditions most nearly resembling those of the Witwatersrand were perhaps to be found in the Wassaw gold-field of West Africa; but even there the differences were sufficiently marked to require considerable differences in the methods of mining. The methods employed in the Witwatersrand (and the results obtained by those methods) could not be duplicated elsewhere. Had the Author had any experience in the use of detachable drill-bits? It would appear that the Witwatersrand was particularly suitable for the introduction of those, to judge by recent American experience. Thus the Year-Book of the American Institute of Mining and Metallurgical Engineers for 1930 contained on p. 139 an account of such detachable bits, in which it was shown that in one set of mines at Butte, Montana, the weight of steel handled had been greatly reduced by their use. According to the Paper in question it was only 19.294 per cent. of the weight of drill-steel of the ordinary type. The Author showed on p. 10 that the cost of distribution of drills came to 8*d.* per fathom broken, so that the adoption of detachable drill-bits should save something like 6*d.* per fathom on that item alone. The same American Paper showed a total saving, per cubic foot excavated, amounting to about 35 per cent. by the use of detachable bits, and that would obviously be an important item on the figures given by the Author. Whilst experience in one field did not necessarily apply to an entirely different type of deposit in another field, it would seem that where such a subject as rock-drilling was involved the important economies to which he had referred deserved, at least, careful investigation; and it would be interesting to know whether any work in that direction has been done in the Witwatersrand.

Mr. Martin. Mr. H. STUART MARTIN suggested that the Author should give a full and complete description of the hole-director, more particularly as applied to driving hard headings. Very little was known—or, at all events, little advantage was taken in England—of the successful experience in driving hard headings on the Rand; and that was due chiefly to the lack of more detailed information as to the use

of the hole-director and the method of its application. Fuller Mr. Martin. information as to the tempering of drilling bits and the type of machine used would be very acceptable in many quarters in England. The economy of labour effected on the Rand by the improvements referred to, during the period 1923-27, was wonderful.

Mr. HARRY W. MILLER remarked that in 1899, when he was Mr. Miller. living in the Cape Colony, a refugee from the Transvaal, he wrote a Paper advocating the raising of ore in stages from the deep mines on the Witwatersrand, which he submitted to the Association of Engineers and Architects, then the only technical institution in the Transvaal. It was then justifiably considered from bore-hole data that a depth of 6,000 feet vertical would be capable of accomplishment. A factor that bulked very largely in the matter was the serious responsibility thrust upon the mine owners and managers of suspending large numbers of men many times daily on wire ropes to enable them to reach their employment, as at that date hoisting-cables were not as substantially manufactured as they were now, nor was the material of which they were composed of the high grade obtainable to-day. Further, at that date very few mines had reached depths beyond 3,000 feet. Taking 6,000 feet as the maximum depth that it seemed sensible to contemplate at that time, he postulated a shaft with an upper stage of 3,000 feet and two lower stages of 1,500 feet each, with the idea that if a greater depth were found to be possible, the two lower stages would be converted into one, and further sinking resumed under preceding conditions. At that time, with very few exceptions, all shafts were rectangular in section, a form which lent itself to the use of suitable ore-bins in the shaft for the transfer of the material at the stages fixed upon. Electrical engineering was then sufficiently advanced to enable the use of electric power for winding in the lower stations to be considered, and compressed air was an alternative method; if its thermal efficiency was lower than that of the former method, it had the advantage of helping ventilation by the exhaust from the hoisting-engines. It was resorted to in many instances where motive power was required underground, and it was employed for auxiliary hoisting and pumping. That elementary attempt on his part had been followed in 1902 by Mr. Hans C. Behr's Paper¹ on "Wind-ing Plants for Great Depths," which was regarded as a classic. It had been customary with the earlier mines, when the main vertical shaft reached the reef, to turn it on the underlie and follow the reef down on the dip of the vein. It was soon discovered that

¹ Trans. Inst. Mining and Metallurgy, vol. xi.

Mr. Miller. the wear on the ropes round the turn in the shaft and the necessity for carrying the compartments in the incline shaft of the same dimensions as those in the main vertical shaft, produced conditions too arbitrary in many instances.

The development of electrical energy at very moderate cost had been an important aid to improvements in winding ore from the deeper levels. The main vertical shafts were employed to take the ore from the bottom station to the surface, and these were supplied from incline shafts sunk in convenient places at the level where the vertical shafts terminated, and from which the lower development work took place. So that in one sense stage winding came into being. Some of those inclined shafts were well equipped with electrically-operated hoists of large capacity and capable of keeping the hoists at the surface of the main vertical shaft fully employed during the whole of the working shift. That system allowed of more latitude in determining the most suitable point underground to place the winding-plant and the dimensions of the shaft and ore-skips to suit the reef conditions there encountered. Not content with a mining depth of 6,000 feet, the City Deep mine had boldly taken the initiative and adopted the course so well and succinctly described by the Author. The engineers responsible for the carrying-out of this work, involving the sinking to a vertical depth of 7,000 feet, very wisely decided to adopt the circular form of shaft, for the reasons given in the Paper, and in his opinion the smooth surface of a circular shaft lined with masonry was materially helpful to the passage of the air needed for ventilation, in addition to the other advantages set forth by the Author. Mr. W. Elsdon-Dew, M. Inst. C.E., the chief mechanical and electrical consulting engineer of the controlling corporation, had been largely associated with the planning of the details in connection with the hoisting-plant described in the Paper, and the lay-out of the plant generally. In a Paper¹ before the South African Institution of Engineers on the 16th May, 1929, Mr. Elsdon-Dew had described this first application of stage winding in a main vertical shaft on the Witwatersrand gold-fields. It aroused considerable interest, and Mr. Miller had dared to predict that the conglomerate ores of the main-reef series on the Witwatersrand gold-fields would be profitably mined at a depth of even 10,000 feet. The rock-temperatures and general conditions prevailing underground, combined with efficient ventilation, would enable the ore to be extracted at that great depth.

A point which he considered bulked largely in that connection was that the City Deep shaft at 7,000 feet depth below the collar was

¹ Journal S. African Institution of Engineers, vol. xxvii, p. 230.

only 1,000 feet below sea-level; and as the Morro Velho mine in **Mr. Miller.** Brazil went more than 4,000 feet below sea-level,¹ and the workings were being safely continued at a depth of more than 7,000 feet below the surface, it seemed sound to assume that on the Witwatersrand an equivalent depth could be reached by the aid of modern ventilating and air-cooling devices, combined with the skill and courage of the engineer. When the cost of sinking and equipping the City Deep shaft, amounting to nearly one million pounds sterling, was considered, it was obvious that there must be not only the prospect of opening up a quantity of mineral far in excess of what sufficed for a shaft of moderate depth, but also the value of the ore must not fall below the cost at which it was now being won; for the capitalist who risked money in those deep mines rightly demanded a higher rate of interest. The plant at the City Deep was capable of handling 3,000 tons per day, or, in round figures, 1 million tons annually, and to amortize that on a 10-year basis would mean a sinking-fund charge of 2s. per ton milled. It was evident that the plant at the City Deep was fully capable of dealing with ore to a depth of at least 9,000 feet: even at that depth it should be possible to sink a shaft of suitable dimensions to handle a million tons of ore annually for a smaller capital outlay than the figures stated in the Paper. It seemed probable that where a deep shaft must be sunk, especially where large quantities of water could confidently be anticipated, the rectangular shaft would prove to be the most suitable, with steel sets to ensure durability and avoid risk from fire. A great deal of the future developments on the Witwatersrand mining area would be on the East Rand, where the dolomite formation was met with, in which water abounded; but provided the value of the ore continued in the neighbourhood of 30s. per ton, he was convinced that the gold could be recovered at a price that would yield a good return on the money invested.

It was somewhat astonishing that the actual cost of winding ore from these deep shafts was so small a factor, but the figure stated by the Author, namely, 6d. per ton in June, 1928, was within the safe limit. That was largely due to the reasonable charge made by the Power Supply Company to the mines and to industry generally.

Adequate ventilation was the most important factor in determining the ultimate depth at which the ore from the gold-mines of the Rand could be won, and from the data known and published

¹ A. G. N. Chalmers, "Mining Methods Past and Present in the Morro Velho Mine, etc." Minutes of Proceedings Inst. C.E., vol. 226, p. 189.

Mr. Miller. *it seemed likely that the rock-temperature at a depth of 10,000 feet in the Witwatersrand quartzites could be in the neighbourhood of 110° F. In the Morro Velho mine, at the lowest and deepest level, the rock-temperature was 127° F. when the level was first opened and, as before stated, that point was 4,000 feet below sea-level, although it was but 7,000 feet from the surface. But the temperature fell rapidly after good ventilation was arranged. On the Witwatersrand the 10,000-foot level would be only 4,000 feet below sea-level and, from a depth point of view alone, conditions no worse than at Morro Velho, and probably considerably better, would be encountered, owing to the rock-temperature being more favourable. Generally speaking, he would consider the rock formation on the Rand more favourable to a reasonable working-temperature prevailing at that depth than was the formation at the Brazilian mine. But with the knowledge now existing of mine-ventilation, and the modern apparatus available to cool air at a moderate cost, he felt confident it would prove possible to give the mine workers good air that would enable them to perform their work—strenuous as it was—in healthy comfort. The ever-increasing use of compressed air for drilling in stopes as well as development headings, and its employment for lashing the broken ore to reduce still more the physical exertions of the men underground, combined with the increasing development of electrical transmission and apparatus required in connection with mine-workings, would all aid in accomplishing what everyone hoped for and what technical men were confident would be attained in the near future, and long before the depth postulated in these remarks was reached. And there would be a goodly margin of profit to those who had ventured their money in these undertakings.*

A very ingenious method had been devised recently to enable the mine air to be rendered cool and hygienic for those engaged in development work in dead ends where the main ventilating-currents could not be led. It was a simple and inexpensive machine, devised by the Mechanical Section of the Engineering Department of the Central Mines Corporation. It was based upon the principle of compressing the air at a pressure of 50 lbs. to 60 lbs. per square inch and, whilst in that state of pressure and raised temperature, cooling it by passing it through a multitubular vessel of convenient shape. The cooled air was allowed to expand in another section of the plant, where it did useful work by helping to drive the compressor. The air, thus further lowered in temperature, could then be sent to points where men were engaged in development work or into dead ends. The rotary compressor and expanding-vessel, directly connected to a high-speed electric motor, enabled a complete plant in small units

to be constructed at a very moderate cost, and those units had the advantage of portability. Although that method, formerly designated the "mechanical dry-air refrigeration process," was not thermally so efficient as either the CO₂ or anhydrous ammonia methods, it had the great advantages of being simple in design and working, avoiding the use of any chemicals, and being easy to operate; and at the price paid for electrical energy in the Witwatersrand, it would not prove too costly to work. It could be made robust and yet light, and could be built in small units of compact form. The power which it was necessary to purchase was that needed to make up the loss between the compression and expansion vessels. He estimated that the use of apparatus of that type, whilst effectively aiding the ventilation of the lowest workings of a mine, would not materially add to the cost of developing the ore. The cooled air from such auxiliaries could be delivered, by suitable light fans of modern design and high efficiency, to the points where it was needed, and the capital outlay involved would not be excessive. When the development ends came into stoping use, they would receive their quota of air from the main ventilating system.

Mr. EDWARD J. WAY remarked that, having been engaged in mining in the Witwatersrand from 1891 to 1923, he had seen most of the changes which took place during that period. In 1891 the average vertical depth of the mines then under exploitation could not have exceeded 300 feet to 400 feet. Now, at the Village Deep mine, which the Author successfully managed for many years, the vertical depth exceeded 7,500 feet (1·42 English mile), probably the greatest vertical depth achieved so far in gold-mining. The Paper was a statement of facts in tabloid form. It had one outstanding feature, in that the Author has actually carried out such work as was set forth, and had probably a greater inside knowledge of the scientific management of deep-level mining than any other living person. Since the late Mr. Hans C. Behr wrote his classic Paper¹ on deep-level winding, followed years after by Mr. Vaughan, there had been no published record which so succinctly epitomized the main features of the subject. And whereas Messrs. Behr and Vaughan had principally specialized on winding, the Author dealt with the whole subject of deep-level mining. The following appeared to summarize the Author's views on that subject and Mr. Way's comments upon them:—

(1) For mining at great depths the Author advocated the circular shaft. In speed of sinking (a very important matter) no other

¹ Trans. Inst. Mining and Metallurgy, vol. xi.

Mr. Way. method could compete. Mr. Way had once held the record for inclined rectangular shaft sinking at Kleinfontein—namely, 231 feet sunk and equipped in 29 days.¹ But that record had soon been completely eclipsed by the 386 feet sunk in a calendar month in a circular shaft at Randfontein.

(2) The Author advocated the use of the jackhammer drill, and all mining men would agreed with him.

(3) For main shaft equipment he advised the use of one very large hoist and one smaller hoist, and was in favour of the Ward Leonard system. That was without doubt correct, in spite of the extra capital cost involved.

(4) The Author's findings in regard to stage winding could not be criticized.

(5) His remarks about ropes led to the belief that he was in favour of the locked-coil rope. That rope, especially in humid climates and wet mines, had advantages in every way over any other.

(6) Centrifugal pumping had been proved to be the best method of dealing with large volumes of water from great depths.

(7) The Author advocated that main levels in which electric haulage was used should be driven well in the footwall. That was correct. The question of overhead electric haulage versus haulage by storage-battery locomotives might be open to discussion.

(8) It would be interesting to have the Author's views of mining work in other climates. For instance, where the daily temperatures at the surface averaged 90° F. to 100° F. saturated, and temperatures at 2,000 feet vertical were as high as 110° F. saturated, in spite of well-designed ventilating and other appliances.

(9) The "hole-director" was from the practical and scientific point of view absolutely sound. Twenty-five years ago Mr. Way had experimented with a drill called the "Gordon drill," which did the work of twenty natives when using the ordinary $\frac{7}{8}$ -inch octagonal steel hand hammer drill. The Gordon drill failed owing to certain peculiar rock conditions. But the new hammer drill now in use did the work of twenty-five natives without undue trouble and had brought about extraordinary economies in working-costs.

(10) The composition of steel for drill-bits was the subject of an inquiry many years ago by a committee convened by the Witwatersrand Chamber of Mines. The Author would no doubt acknowledge that practically everything he stated was the outcome of the

¹ Trans. Am. Inst. Mining Engineers, vol. xxxv (1905), p.1397.

findings of that committee. It was directly due, in a very large measure, to the fact that those findings had been applied by the Author, that the consumption of drill-steel per ton mined was so small on the Rand as compared with other mining fields, when the hardness of the Rand rock was considered. Mr. Way.

(11) The statements with regard to metallurgical practice and recovery of precious metal were borne out by the official records of the Witwatersrand industry.

This important Paper set forth modestly, from the Author's actual experience, the best methods and appliances necessary for use in connection with its subject. There was an entire absence of dogmatism, which the Author's rare knowledge might have justified. The Author might with great advantage lay down exactly what he considered to be the main essentials for shaft-sinking, development, and mining at great depths. Such a work would be invaluable for those who came after, and who doubtless, as further research and experience were achieved, would find much to guide them, and possibly to save them from initial errors which so often hampered, if not extinguished, many enterprises.

The AUTHOR stated that in replying to the Correspondence he would also refer to some points raised in the Discussion which want of time had prevented him from dealing with then. The Author.

The progress made during recent years in the use of jackhammers was of such importance that it was not surprising that several members had referred to it. Dr. Horwood had suggested that the advance was due principally to the great improvement of the drill, and the Author would like to correct that impression. The improved results were due rather to the better exploitation of that type of drill, and more particularly to improvement of the drill-bits. As early as 1913 it had been realized that holes similar to those drilled by hammer boys could be bored with a jackhammer with a considerable saving of labour. At the same time, the powder-consumption in blasting those small holes would correspond closely to that in hand hammer work, which was considerably less than the quantity consumed per ton when breaking ground with large reciprocating machines. That forecast had now been realized, but the present-day efficiency of breaking had only been reached gradually. In the early stages it had been thought that such drills could be better exploited in the stopes by supporting them with a rest. It had soon become evident, however, that such an addition limited the work of that type of drill, which, to obtain the best results, should have the freedom of the hammer drill. By using the drill in that way,

The Author. much time was saved in moving from bench to bench and in commencing drilling. Whilst the design of hammer drills had been improved during recent years, the outstanding improvement had been in the treatment of the drill-bits. A measure of that improvement was the number of bits required for the drilling of a hole. Until recently several bits had been required for that purpose, whereas to-day, drilling in hard rock, the improved bit was able to drill the entire length of one hole, and was often used for a second hole. The speed of drilling had greatly increased, and the reduced size of the bit and the small clearance required were largely responsible for that. Those improvements were due to the heat treatment to which the bits were now subjected. A complete account of that development would occupy more space than was available here, and he would refer members who desired further information on the subject to the Paper by Mr. E. C. J. Meyer,¹ which would give the information asked for by Mr. Jenkins as to the treatment of steel, and would correct his impression that the striking velocity of the hammer of the drill determined the results that could be obtained. He would emphasize once more that, with all the improvements which had been made in jackhammer drills, the best results could not be achieved unless the steel used in the bits had received the very careful treatment which experience had shown to be necessary. Professor Lawn had suggested that the advantage obtained by the use of jackhammer drills was not one of cost but rather a saving of native labour. The Author would point out, however, that as native labour was not available for hand drilling, the tonnage broken in the mines of the Rand would be very seriously reduced but for their use. That would result in a correspondingly large increase in costs. Further, the results obtained indicated quite definitely that from the point of view of cost the advantage lay on the side of machine drilling.

With regard to the preparation of machine bits, in the Author's opinion bits prepared in the way mentioned by Mr. Trewartha-James would not give satisfactory results, since experience had shown that the intensive hammering to which bits were subjected in the modern sharpening machine was responsible for the results obtained in hard rock.

Several members have referred to the use of hole-directors in the breaking of ground. They were used in development and also in

¹ Proc. Third (Triennial) Empire Mining and Metallurgical Congress, Pt. ii, p. 443. Johannesburg, 1930.

stopes. In development the apparatus consisted of a centre pin The Author. which was fixed at one end in a small stamp hole in the centre of the drive that was being excavated, the other end being held in a small clamp mounted on a small arm clamped to the machine bar. On the pin were mounted the various hole-directors, which were free to rotate on it. The directors themselves had a tubular guide-piece in which a dummy jumper was placed, and the machine was lined up on to the dummy shank in order that accuracy of direction could be obtained. The hole-directors were so formed that by their use each hole was correctly placed, thus avoiding the possibility of one hole running into another or, on the other hand, too large a burden being placed upon a hole by reason of its departure from the correct position. In designing a director for any particular development end the principal limiting factors to be taken into consideration were the dimensions of the tunnel, the length and size of hole drilled, and the nature of the ground. Each of those had its effect upon the number and position of the holes. The use of directors in development work aimed at the standardization of rounds, and it had been found essential, if the best results were to be obtained, to systematize every operation involved in drilling, so that each round was identical with every other one. Operators should perform the same cycle of operations in exactly the same manner day after day, as the ideal aimed at was that the drilling of rounds should become straightforward repetition work. The effect of that in practice was that when once the correct round had been arrived at, consistently good results were obtained. For directing holes in stopes a simpler arrangement sufficed, consisting of a pointer indicating the direction in which the hole was to be drilled, which ensured that the burden at the bottom of the hole was approximately the same as at its starting-point. That was achieved by having attached to the pointer a curved arm which made contact with the face ahead of the point at which the hole was to be drilled. The arm was adjusted to give the required burden to the hole throughout its length. When the direction of the hole had been fixed, the hanging wall was marked with chalk and the apparatus was then taken to the other drilling points in the stope. The machine man, when drilling at any particular bench, took notice of the direction as indicated by the chalk mark and followed this line.

The use of detachable bits for drilling had been referred to by Dr. Louis. Experiments with detachable bits had been made from time to time during the last 20 years. In the earlier design small bits had been fixed on the end of the required length of steel and,

The Author. after use, discarded. Economically that method had been unsuccessful. At a later date a detachable bit had been developed by Mr. Jenkins, of the City Deep mine. The detachable portion was about 1 foot in length, and was returned to the surface for sharpening. Economically that method had been more successful than the earlier type, but the necessity for a socket at the point where the bit detached interfered with the drilling-speed. More recently experiments had been made in welding on a small length of special steel at the point of the drill, with a view to minimizing the quantity of more expensive material used, and at the same time obtaining the benefit of its special cutting qualities. The remarkable improvements which had been made in the heat treatment of ordinary steel, however, left little scope for the introduction of such refinements, and it would appear that more profitable investigation would be in the direction of correct heat treatment of ordinary steels, rather than the use of special steels welded on, or in the form of detachable bits.

The use of delay-action detonators for blasting in shaft-sinking operations has been suggested by Mr. Forster Brown. That system of firing had been used in shaft-sinking on the Witwatersrand. At the City Deep, where the system was installed, a serious accident once took place, due to premature ignition of the charges, caused by the conductors from the surface becoming charged during a thunder-storm. In a country where such storms were common, that system could not be recommended.

The concentration of stoping operations in as limited an area as possible was to be recommended from the point of view of both economical working and the support of ground. Mr. Jenkins had referred to the question of support, and the Author would say that in deep mining such concentration was an advantage, in that the speed of advance of the face was increased, and the effect of weight in the working-place was reduced. At great depths care must always be taken that no pillars of ore were left in such a position that they were able to punch into workings or excavations below them. That was particularly important when two reefs were being mined, and care should always be taken that no irregularities of the face in the one stope were able to exert unequal pressure on the other. Similarly, main haulages which were being driven in the footwall should be protected by the mining of the ore above them, and on no account should a pillar be left in the vicinity of such haulages. The hanging of the stopes was generally supported by pigsties filled with waste. That was a convenient system where narrow reefs were being mined, and where the width broken

considerably exceeded that of the reef itself. More recently a system of reef-packing had been developed, the broken ore being packed into the stope and added to day by day by blasting-operations. The ore was recovered from behind as the face advanced, there remaining always a considerable width of broken rock. That system affords good support at the face, and, provided the breakage of the hanging wall did not prevent the withdrawal of the ore at a later stage, it was satisfactory. The cost of stope support in a deep-level mine ranged between 25s. and 30s. per square fathom of area. The Author.

The centralization of mining operations on the Rand, and the control of the industry by a small number of groups had been referred to by Dr. Horwood. There was no question that such centralization had been of great benefit to the industry, particularly as the conditions under which it worked, and to which Mr. Forster Brown had referred, made such a system particularly applicable. Such control rendered impossible the abuses to which Dr. Horwood had referred. The ore reserves of a mine were sub-divided into tonnages of various grades by the Consulting Engineer, and in a mine where the average of the reserves was, say, 10 dwts., the classification would show a certain percentage above 10 dwts., between 9 and 10 dwts., between 8 and 9 dwts., and so on. Each month the tonnage mined from each class of ore was recorded, and it was a simple matter to compare the percentage of each grade mined with the percentage of each class contained in the reserves. If the percentage of high-grade ore mined was in excess of its ratio to the whole ore reserve, the manager's attention was immediately drawn to it. In that way complete control was exercised. There was, therefore, no need to depart from the system of expressing costs as per ton of ore mined, and the Author agreed with Professor Lawn that that basis was far more satisfactory than one expressed in terms of gold recovered. Whilst variations existed between mine and mine, allowances could be made for them when comparing costs; and it was helpful both to the managers themselves and to the engineers to have a basis on which comparisons between mine and mine could be made.

Several members in referring to the equipment of shafts had alluded to the use of a cage as against skip hoisting. He would point out that as mines increased in depth the hoisting of men and material became a more important operation than when mining at shallow depths. The shafts equipment had, therefore, to provide for that increased service. Circular shafts had been sunk in a number of instances, and in some of them wire-rope guides were

The Author. installed. Such practice did not permit of the use of several hoisting-engines in one shaft, and in consequence a system had had to be devised whereby a single engine would afford the hoisting facilities required. Mr. Stewart Martin, in the equipment of a shaft at the New Modderfontein Gold Mining Company, first installed a system of hoisting by cages into or from which a truck carrying 6 tons of ore was mechanically pushed. With that arrangement it was possible to hoist considerable quantities of ore, and without loss of time to use the same engine for hoisting large numbers of men. In other instances circular shafts had been equipped with rail guides, and similar large cages used for hoisting men and material, whilst in two other compartments skips had been installed for the hoisting of ore. A third arrangement existed at the Crown mine where at a shaft through which as much as 11,000 tons of ore was raised daily, a quick-change arrangement had been installed at the surface whereby skips were replaced by cages at the end of the shift, when large numbers of men had to be hoisted to the surface. When the hoisting of ore was the principal consideration, skips had certain advantages to which Professor Lawn had referred. In these days of deep mining, however, there were so many other considerations, apart from the hoisting of rock, that no fixed rule could be laid down; but in the case of deep mining there was no question that cages afforded many advantages and would be used in the future.

The fact that on the Witwatersand the earth surface was about 6,000 feet above sea-level had apparently misled certain members, who had discussed the question of the air-temperatures underground. It must not be forgotten that the Witwatersand was situated several hundred miles from the sea. Further, whilst the temperature increment in depth was small, the rock-temperature at a depth of 7,500 feet was about 100° F. With such rock-temperatures the air-temperature at those depths was approximately 85° to 90°. Such a temperature did not appear startling to those who had not known its effects underground, but it became more serious when the large number of deaths that had occurred among men working under those temperatures were borne in mind. Owing to the moisture in shafts, the air soon approached the saturation point when it reached those deep workings, and experience had shown that only with the greatest difficulty could operations be carried out under such conditions. The efficiency of labour was seriously reduced; and that raised the point made by Mr. Forster Brown as to what really governed the maximum depths to which these mines could

go. Hoisting was purely an economic question. The Author The Author. was of the opinion that by careful methods mining could be carried to even greater depths than at present practised, in spite of the increased pressure which must be faced. The limitation of depth, however, would be found in the condition of the atmosphere in the workings. It had not been realized by those who had contributed the discussion on the Paper that the use of water was essential, both in drilling-operations and in the moving of rock, to keep down dust. Government regulations laid down very strictly that that should be done. In those circumstances the temperatures which already existed in the deeper mines were almost a limiting factor. That disability could to some extent be overcome by underground air-drying methods, provided the value of the ore to be mined were sufficient to pay for their installation. Generally, that was not the case, and for that reason, in his opinion, mining would not be carried far beyond the present limits. Mr. Way had asked what the main essentials were for shaft-sinking development, and mining at great depth. In view of what had been said, it would be clear that circular shafts so lined that the minimum of moisture could reach the surface of the walling would be beneficial from the point of view of ventilation. They were, in addition, the least expensive to sink and maintain, and where the depth of any length of shaft did not exceed 3,000 feet, rope guides would prove the least expensive to install and the most satisfactory in operation, provided shaft area was available for the adoption of that system. Development should be carried out on broad lines, with a view to the concentration of ore transport, and the haulage levels should be driven in the footwall. In that way they were protected from pressure by the removal of ore above them, and they acted as main airways and so assisted in the distribution of the fresh-air supply. The system of mining had already been referred to briefly, and must be carried out according to a well-defined scheme.

It had been suggested by Mr. Jenkins that 3,000 feet was a great depth over which to use rope guides for cages. Their use at that depth, however, had proved quite satisfactory, though the Author regarded 3,000 feet as the limit of depth for which they should be installed. Rope guides were now being used at New Modderfontein, Crown Mines, Durban Rodeport Deep, Modderfontein Deep, and Modderfontein East. Mr. Jenkins was right in his assumption that the 20,000-volt current supply was taken to a station underground and transformed down for use at the various points to which the

The Author. current was distributed. Storage-battery locomotives had proved very satisfactory underground, and their use would no doubt become more general. For main haulages, however, the trolley system was more economical, though it could only be installed where large quantities were handled, since the tunnel must be driven with a height of about 9 feet in order to afford sufficient headroom for the overhead wire. When using storage-battery locomotives the batteries were charged in a small station underground, which was equipped with lifting-gear so that the change of battery could be made without delay.

In reply to Dr. Hogan's question as to the lift of the 2½-inch diameter ropes used at the City Deep circular shaft, the original ropes, which were of 134-ton steel, and had been installed 4 years ago, were still in service and had done more than 250,000 trips. They were not allowed to untwist.
