Discussion.

Sir John Wolfe Barry.

Sir JOHN WOLFE BARRY, K.C.B., President, thought the members would all agree that a vote of thanks was due to the Author for his very interesting Paper, describing the outfit of electrical plant as applied to coal-mining. It was one more evidence of the great convenience which electricity supplied in the transmission of power from a central station to the place where it could be profitably used. The important question of the risks of sparking in a fiery mine would no doubt be raised. The particular mine mentioned in the Paper was said to be somewhat fiery; and it struck him at first sight that there must be danger from sparking, especially in trolley-wire working as liable to cause explosions. There might be means that he was not aware of for meeting that contingency, and it might be that the mine in question was not liable to the danger. He did not know whether that matter had been fully considered by the Board of Trade in connection with the working of mines by electric installation; but it appeared to be probably one of those questions which must have already received careful attention at the hands of those who were contemplating electric installation in coal-mining. While regretting that the Author was not able to be present, he was sure it would be a matter of gratification to those present to know that he was an Associate Member of the Institution. He begged to move that a vote of thanks be given to him for his interesting Paper.

Mr. Ravenshaw.

Mr. H. W. RAVENSHAW considered that, as the motors employed in mining work were generally of somewhat special character, it would have been interesting if the Author had described those he had adopted, as well as other portions of the machinery. In the plant described small motors of 5 HP. or 6 HP. were used; none were much larger than 20 HP. or 30 HP. But when large motors were required, they had to be specially made, as it was practically impossible to lift anything in a mine. Many makers were now building machines for mining work, in which there was no lifting of the armature; the whole of the parts were made to slide horizontally. With regard to the use of locomotives, he imagined that the mine could not be a very fiery one, although the Author stated that there was some gas, because he should expect to find that the use of a trolley, with a certain amount of inevitable sparking, would be dangerous. He did not think there was reason to believe that the sparking at the brushes of a good motor would ignite firedamp; in fact, the results of experiments made by Messrs. Ll. B. & C. W. Atkinson [1] and of Messrs. Wüllner and Lehmann [2] at Aix-la-Chapelle were fairly conclusive. The brushes of a motor might, however, become displaced and cause dangerous heating, and a short-circuited coil in the armature would generate heat and flame which would certainly be dangerous. For this reason it was imperative that the whole armature should be entirely enclosed in a perfectly gas-tight case, where there was any chance of a sudden outburst of gas. In main roads and engine-rooms, which were remote from the working face, the covers were often dispensed with on account of the lower temperature and greater facilities for cleaning. All connections to high tension shunt coils should be carefully protected owing to the great flash due to self-induction on breaking these circuits. Concentric cables were generally used in Great Britain when they were carried along the more fiery parts of the mine, and he had used fluid switches with considerable success, the spark at breaking and the number of connections being reduced to a minimum. In most of the mines of which he had had experience, haulage by either continuous or main-and-tail ropes had been adopted, and this method appeared, from his results, to be the more economical. As an instance, he might quote the Hickleton Main Colliery, where the total length of haulage by rope was about 1 mile. Most of the haulage-lines referred to in the Paper were about that length. In the Hickleton Main Colliery, about 1,800 tons were hauled, and the average current was between 80 amperes and 100 amperes at 450 volts, or about 50 HP. Each of those locomotives appeared to take about 50 HP., and sometimes much more, and was only hauling 1,000 tons; so that the continuous haulage in that particular case was doing the same work with about half the current. It also had the advantage that the current was distributed more regularly. There were not heavy trains coming along the road at one moment and no load at another, and there were no bare wires. The fact that a man had been killed by a shock from the trolley pointed out the great danger of having bare wire in a low heading like that of a colliery. Mention was made of serious overloading, through ignorance or malice, soon after the plant had been started. In almost every electric colliery plant with which he had Mr. Ravenshaw.

[1] Minutes of Proceedings Inst. C.E., vol. civ. pp. 169 and 181.
[2] *Colliery Guardian.* Feb. 20, 1891.

Mr. Ravenshaw. had anything to do, the same thing had occurred. When the plant was first started, there had been great trouble from overloading. In certain cases the motors had been a great deal too small, and that was a very common failing; but in many cases with a continuous rope a great number of tubs were coupled on to the rope at one moment, and very few at another. In many instances a system of tickets had had to be used, or some system by which not more than a certain number of tubs could be coupled to the rope at one time, and, when that was adopted, the trouble disappeared.

Mr. Dolby. Mr. E. R. Dolby thought the Author regarded the question rather from the mining than from the electrical point of view. In the first instance he appeared to have taken a special period when the work was being done by men with picks, the transport being effected by mules, and the pumping by steam. Then he considered another period in which the whole of the means had been replaced by electrical apparatus, and said that the coal-mining machinery was returning 50 per cent. upon the outlay; and that a part from those mining machines the rest of the plant was paying about 25 per cent. In the face of these facts, it seemed strange that the electrical coal-mining machinery in Great Britain had made so small an advance. One of the principal reasons was, curiously enough, the action of the very persons who had desired to place the machinery on the market. So far as he was aware those machines could be purchased in the United States in the same way as other machines, whereas in Great Britain those interested in the machinery had always wished to place them upon the basis of a rental or upon royalty per ton excavated. He knew from certain cases that had come under his notice that hardly sufficient prospective profit was allowed to the mining manager to induce him to take up that machinery. With regard to the plant it appeared from *Fig. 2* that the boilers were connected by one large steam-pipe, from which separate branches passed to the engines. The installation was an extremely important one for such a large set of mines. It appeared somewhat strange that there should be only one service of steam to each generating unit; as it appeared obvious that if the main steam-pipe failed from a bad joint the whole of the plant must come to a standstill. Then again the units, consisting of an engine and a dynamo belted to it, differed considerably from the practice which would no doubt have been followed in Great Britain. Each engine had only a single cylinder, whereas in Great Britain probably it would have either two or three. He thought particulars of the regulating mechanism and the starting switches would have been of interest. These were generally perhaps the most important part of the plant, and he thought that was clearly shown by the fact that part of the plant had suffered serious damage from overloading. Mr. Dolby.

Mr. W. G. WALKER thought the results given by the Author in Table II, Appendix II, clearly showed that the ventilation by furnaces was less efficient than ventilation by fans. The tests of the two fans were given fairly fully by the Author. He had, however, re-checked the mechanical efficiency and had found it take 52 per cent. instead of 65 per cent., as given by the Author. The method which he employed was explained in two Papers he had read on the 3rd November before the Institution of Mechanical Engineers. He wished to ask the Author how he found the mechanical efficiency of the two fans. A calculation was also given in the Paper of the work in the circulating air, which he gave at 11 HP. He wished to ask the Author how he obtained that result, because, from his calculations, it appeared to be only 9·4 HP. He thought a recognized standard for comparing the efficiencies of fans was badly wanted. Three experimenters out of every four seemed to use a different method of calculating the mechanical efficiency of fans; and he thought it would be a great benefit if a recognised standard could be adopted. Mr. Walker.

Mr. JOHN DAVIES, of Derby, remarked that the reason why the type of coal-cutting machine described by the Author had not been more largely used in Great Britain was, that in America the system of working coal was the pillar and stall system, whilst in Great Britain it was the long wall system. The Jeffrey machine described by the Author had been designed and constructed for the pillar and stall system, and, he believed, it was only lately that a machine had been designed by the Jeffrey Company suitable for the system which was generally in use in Great Britain. With regard to Mr. Dolby's criticism of the method of purchasing the machines, he thought that gentleman was under a misapprehension. He knew that the Jeffrey machine was bought and sold in the same manner as other machines. Mr. Davies.

Mr. E. R. DOLBY had intended to refer to British machines. Mr. Dolby.

Mr. J. N. SHOOLBRED considered the Paper interesting on several points, particularly with regard to the use of the comparatively low voltage, as far as the United States was concerned, which was there advocated and apparently used with advantage. It was encouraging to engineers in Great Britain to find that was the case, since the pressure named in the Paper, 500 volts, had been Mr. Shoolbred.

Mr. Shoolbred. adopted pretty universally, and it was likely to be considerably extended. Likewise the fact that direct current was employed was another very significant fact, and encouraging in the light of the practice adopted in Great Britain. With regard to the arrangement of the plant at the central station, he agreed with some of the previous speakers that there were a good many points on which English practice differed from that mentioned in the Paper, and certainly on the one which had been referred to with regard to the boiler and steam-pipe service, the arrangement had been considerably improved upon. He thought the Paper one of considerable interest, not merely in connection with mines, but with power stations generally. Because it might just as well be applied to the distribution of power and plant for a variety of matters, whether for tramway purposes or utilization of power for working, above ground as well as underneath. With regard to the remarks of the President, as to the danger which might occur through the use of bare-copper conductors, he might say, that the matter fell within the province of the Home Office and not of the Board of Trade. The former of these Departments, among their Reports on "Dangerous Trades," had issued one especially on the Electric Lighting Industry, which dealt very fully with the matters referred to by the President.

Mr. Handcock. Mr. H. W. Handcock noticed that sheet-iron chimneys had been adopted by the Author. They seemed to be preferred in America, and he would like to know the arguments in their favour other than that of cheapness, because they were viewed in England with anything but favour. He was struck by the absence, in American practice, of mechanical stokers. He would have thought, in view of the expensive labour and the quality of coal in America, the mechanical stoker would be particularly advantageous, but he noticed the general practice was to fire by hand. It might appear from the Paper that the system described was that generally adopted in America. He scarcely thought that was correct at the present moment. There seemed extremely little to choose between the general arrangement of the largest American plants and the methods adopted in England. The tendency was the same in the two countries, the general arrangement now favoured seemed to be that of engines coupled direct, running at high speed, and with high pressures. He had recently heard an English marine engineer advocating the employment of 250 lbs. per square inch pressure and five cylinders, in which case he would be willing to guarantee a coal consumption of 1·15 lb. per I.HP. per hour. With regard to the question of the adoption of accumulators in the present instance, it was possible, if the question had been reconsidered, something might have been found to recommend them, for it certainly would have enabled a much more compact plant to be used, and reduced the consumption of 6·5 lbs. of coal per HP. hour mentioned in Appendix II. The Author did not say whether that was indicated brake HP. or electric HP. hour, but in any case it seemed rather high. Mr. Handcock.

Professor W. C. UNWIN remarked that the Paper described a very interesting example of a successfully carried out transmission by means of electricity. He noticed that the Author had had to deal with pumping as one of the kinds of work to be performed by electrical machinery, and, as was generally done in those cases, he had been forced to gear the dynamo to an ordinary reciprocating pump. It did seem to him rather barbarous that when pumping work had to be done by a fast-running motor, it should be necessary to interpose heavy and clumsy gearing between the dynamo and the pump; and he was inclined to think that when the adaptation of electricity to works of that kind had further advanced, engineers would revert in such cases to the centrifugal pump driven by the electric motor. The two went together exceedingly well, and there was no reason why the efficiency of a centrifugal pump should not be good. Where high lifts had to be dealt with, there was no reason why twin or triple centrifugal pumps should not be adopted. He found, introduced here and there in the Paper, remarks as to compressed-air transmission. Although he was not an advocate of compressed air, he did believe with regard to compressed air, and some other modes of transmission, that they had their special field, and that although much greater adaptability of electricity to various kinds of work was recognised, still there were other methods of transmission which were better in particular cases. He noticed that when an advocate of electrical transmission referred to compressed air, he almost always went exclusively on the question of efficiency. The remarks in the Paper referred to the lower efficiency of compressed air as compared with electrical transmission. There were two things to be said with regard to that. The first was that, in a large number of compressed-air transmissions, the efficiency was most unnecessarily low, and that it was not fair to compare a bad air transmission with a good electrical transmission. The other was that the question was not by any means purely one of efficiency, but much more often one of cost. The efficiency was only of importance so far as it was one of the factors of cost. He was in the United States 3 years or 4 years ago, when one of the best engineers there Professor Unwin.

Professor Unwin. told him that in some mines, where the plant was probably almost the best in the world, he had put in an electrical transmission, which had worked perfectly successfully, and he was entirely satisfied with it; but it had cost so much that he was then going back to compressed air. He had received not long ago, from California, Papers in which exactly the opposite story was told from what was given in the Paper as to compressed air. In the North Star Mine, Mr. Foote had erected a very large compressed-air plant, something like 1,000 HP., and he was entirely satisfied that it was twice as good as an electrical plant which he intended at first to adopt, and he was there getting, according to careful experiments, an efficiency of about 80 per cent. between the power given off his water-wheel shafts and the power delivered at the motors in the mine.

Mr. Gresley. Mr. GRESLEY, in reply to the Discussion, stated that the largest motors in use underground at the collieries referred to in the Paper were of 25 HP., namely, those with which the locomotives were fitted. If one of the two motors on each locomotive failed in the mine the other could take the locomotive out and into the round-house, where facilities were provided for rapid handling of the heavier pieces when making examinations and repairs. Rope-haulage was not used in this plant, on account of the narrowness of the headings, the great size of the cars, the complications at junctions, curves, &c., and probably the higher labour cost. Respecting the electric locomotive referred to in Appendix I, he had learnt from the Jeffrey Manufacturing Co., the builders, that during the week ending the 13th November, 1897, that machine had hauled an average of 1,623 tons of coal and fifty wagons of dirt and slate per day, the average distance being about 4,700 feet. This tonnage meant twenty-seven round trips per day, or 48 miles run by the locomotive. As to explosive gas in these mines, since it had not been encountered except in out-of-the-way corners in the "gob"—areas exhausted of coal—and at the roof at the faces of headings in course of extension, the trolley did not pass near it; while the electrical parts of the coal-cutters being on the floor were out of harm's way. Moreover the pillars were taken out with picks, machine-work being inapplicable. He believed it had yet to be shown that an electric spark would ignite the fire-damp of coal-mines. Some of the overloading of motors had been caused by ignorant or heedless men in making the locomotive pull derailed cars back on to the track upon curves and up-grades, so as to save themselves trouble. The mechanical efficiency of the electrically-driven fans was the quotient obtained by dividing the HP. in the air by that utilized to drive the fan, including the belt. With reference to coal-cutters, the methods of working the coal were almost entirely opposite in England and America; he had spent twenty years in England in connection with "Longwall" systems before going to reside among the "room and pillar" methods in the United States. The builders of the coal-cutters used in this plant had pointed out that at present their machines were producing in the Pittsburg district, and under practically similar conditions to those at Scott-Haven, an average of about 25 per cent. to 50 per cent. more coal than at those mines. In one particular instance four cutters were mining between 1,200 tons and 1,600 tons per day, and a good deal of their work was narrow, as the mine was new. But the production from the Jeffrey machines in these Scott-Haven collieries would have been greater had not a good deal of bad roof been encountered; obligation to leave solid coal, or to take out ribs and pillars been necessary, all of which, of course, curtailed the usefulness of the machines. Better results were, however, now being obtained; the Paper referred to conditions one year or more ago. While the seams in America suited to machine-cutting existed in the most favourable way for their very extensive application, he had in mind many seams in England in which he believed coal-cutters would be a decided success. As to the regulating mechanism and starting switches with which the motors are equipped, he had learnt from the electrician that "the motors on the locomotives are run in multiple and are operated through a five-point rheostatic controller, which, as the handle is moved in a circle, cuts out five separate portions of the resistance, till on the fifth or last notch there is no resistance in series with the motors, and they are then running in multiple direct from the trolley. The fans and pumps are started with the ordinary iron wire rheostat in series with them, there being an additional safeguard of an automatic release for the rheostat contact lever. The contact arc is worked against a spring, and is held, when fully on, by means of a magnet, which is connected in series with the shunt fields of the motors." The reason why sheet-iron smoke-stacks were so common in America was that they are very cheaply made, transported, handled and erected. He found that a 60-foot chimney of this kind cost about 15*s*. a year to paint and maintain. Properly maintained they last eight or ten years. No foundations were required, at least, when attached to the boilers as at Scott-Haven. Mechanical stokers did not lend themselves to irregular firing, when boilers required "pushing," as those at Scott-Haven Mr. Gresley.

Mr. Gresley. sometimes did, and when the character of the fuel was liable to vary. Direct-connected generating sets were not considered so suitable as belt-driven generators, where immense fluctuations of load had to be dealt with, *Figs. 10* and *11*. The fuel consumption per HP. at Scott-Haven was computed from readings taken at the meters on the main switch-board at the power-house, it was therefore electric HP. As yet, the steam-pipes and boilers had not been coated. It appeared that an objection to the use of centrifugal pumps was that excessive wear was caused by grit in the water; moreover, the pumps installed at Scott-Haven were designed to force the water through vertical shafts or boreholes direct to the surface if required; under which conditions the centrifugal type would have been less suitable.

Correspondence.

Mr. Buckley. Mr. J. N. BULKLEY, of Schenectady, N.Y., thought that a few particulars in regard to the cost of working electric mining plants in other districts of the United States would be of interest. At the Green Ridge Colliery a $6\frac{1}{2}$-ton locomotive was installed. It worked over about $1\frac{1}{4}$ mile of road, with short sections of heavy gradients against the load, at one place there being 150 feet of 7 per cent. gradient, and at another 350 feet of $5\frac{1}{3}$ per cent. gradient against the load. The output per day of this locomotive was 288 tons, and the cost per ton 2·76 cents. The cost for mule haulage in the same place was 7·15 cents per ton. The mileage per day of this locomotive was about 30 miles. In the cost per ton of haulage, interest, depreciation and repairs had been included. At the New York and Scranton Coal Company, Sturges Shaft, a $6\frac{1}{2}$-ton locomotive operated over about 4,500 feet of road with an output of 250 tons. The cost per ton was 2·62 cents; the cost of this output with mule-power being 6·58 cents. The daily mileage was 32. At the Ontario tunnel of the New York and Scranton Coal Company there was another opening in which there was a 6-ton locomotive. The output was 600 tons, the cost per ton being 1·07 cent, while the cost with mule haulage was 2·35 cents. At the Mount Pleasant Colliery, with a $6\frac{1}{2}$-ton locomotive, an output of 550 tons was obtained at a cost of 1·27 cent per ton; the cost of this output with mule-power having been 2·95 cents per ton.

In computing the cost of haulage for these plants the cost was taken for 200 working days per year, which would be about