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THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS AND THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

JOINT MEETING,
HELD AT THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD,
JANUARY 30TH, 1904.

MR. H. B. NASH, PRESIDENT OF THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS, IN THE CHAIR.

The following gentlemen were elected to the Midland Counties Institution of Engineers, having been previously nominated:—

MEMBERS—
MR. JOSEPH CLARKE, ROSCKENWYN, PINXTON.
MR. GEORGE HERBERT FOWLER, MINING ENGINEER, HALL END, TAMWORTH.
MR. S. H. McCONNEL, COLLIERY OWNER, STRETON HOUSE, ALFRETON.

ASSOCIATES—
MR. J. O. COOPER, UNDER- MANAGER, TINSLEY PARK COLLIERY, NEAR SHEFFIELD.
MR. JAMES KNIGHTON, UNDER- MANAGER, TINSLEY PARK COLLIERY, NEAR SHEFFIELD.
MR. JOHN PARKINS, COLLIERY SURVEYOR, CLAY CROSS, CHESTERFIELD.
MR. JOSEPH SWAIN, UNDER- MANAGER, CLAY CROSS, CHESTERFIELD.

STUDENTS—
MR. ARTHUR SELBY, MINING PUPIL, TINSLEY PARK COLLIERY, NEAR SHEFFIELD.
MR. PERCY WHITE, MINING PUPIL, TINSLEY PARK COLLIERY, NEAR SHEFFIELD.

The following gentlemen were elected to the Midland Institute of Mining, Civil and Mechanical Engineers, having been previously nominated:—

MEMBERS—
MR. HUGH B. PLAYER, ELECTRICAL ENGINEER, 50 AND 61, BLONK STREET, SHEFFIELD.
MR. THOMAS COOK, COLLIERY MANAGER, MOUNT PLEASANT COLLIERY, WOLLONGONG, NEW SOUTH WALES.
Mr. Josiah Stephenson Ward, Colliery Under-manager, Tankersley, near Barnsley.

Mr. Samuel H. Gibson, Mechanical Engineer, Wheldon Road, Fryston, Castleford.

Mr. Samuel Wane, Mine Surveyor, 29, Bank Street, Lodge, Brymbo, near Wrexham.

Mr. Thomas Seaman, Colliery Manager, The Gables, Lodge, Brymbo, near Wrexham.

Mr. Thomas Taylor, Mechanical Engineer, New Moss Colliery, Audenshaw, near Manchester.

Mr. Philip Buckley, Mechanical Engineer, Ashfield Road, Morley, near Leeds.

Mr. Percy C. Greaves read the following paper on "An Electrical Heading-Machine": —
In venturing to read a paper on a heading-machine the writer claims no special success, but he simply makes a plain record of what it has done for the colliery which he represents. Some three years ago, he had occasion to lay out the pit, to win an area of coal which had been recently added to the coal-field; and, to do this, it was necessary to drive strait work for a considerable distance. The men were working on a price-list, which had been settled a few years previously with the miners union; and, when the men were ordered to do this class of work, they refused and demanded higher payment. The price-list specified that they were to be paid as follows:—For strait work, 5 feet wide, end on, 1s. 7d. per ton; cutting per yard, 2s. 2d.; widening to 9 feet, 6d. per yard; plus 47½ per cent.; and a bonus of 4s. if a man did 6 yards in a week. These prices work out to 9s. 7d. per yard of heading, 9 feet wide. The men demanded 1s. 10d. per ton, 2s. 6d. per yard, 2d. per tub for filling muck, and 6d. per yard for widening. These prices represent 11s. 3d. per yard of heading, 9 feet wide.

The writer is unable to give the average wages of men working in strait places, because very little of that kind of work had been done of recent years. Previous to the "good times" no trouble had been experienced in getting such work done, and the men were readily satisfied. Of course, the management could not agree to so large an increase in cost, the men, thereupon, refused to drive any more strait work, and went on strike.

As it was imperative that the work should be driven, and as electric power was used in the mine for hauling and cutting coal, the writer's thoughts naturally turned to that power, but he found that there was not a single British electric header on the market. There were several headers driven by air-power, but
that means of driving could not be adopted owing to the great capital cost for the small amount of work to be done. The writer heard of two American machines, the Jeffrey and the Morgan-Gardner, and it was arranged to make a trial with the Jeffrey electric heading-machine.

The section of the seam is as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Ft. Ins.</th>
<th>Ft. Ins.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard black scale, with ironstone-balls</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>COAL</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>COAL and dirt,</td>
<td>...</td>
<td>2 0</td>
</tr>
<tr>
<td>12 inches to</td>
<td>...</td>
<td>1 2</td>
</tr>
<tr>
<td>COAL, full of pyrites, &quot;Dicks&quot;</td>
<td>...</td>
<td>0 3</td>
</tr>
<tr>
<td>White stone</td>
<td>...</td>
<td>3 5</td>
</tr>
</tbody>
</table>

The Jeffrey machine was started on April 1st, 1903, and has been at work ever since. The machine is 18\(\frac{1}{2}\) inches high, but it is 21 inches high on the runners, and weighs approximately 30 cwts. It consists of a moving frame, round which the chain travels, with the motor and gearing fixed on it. This frame travels through guides on a stationary frame, 9 feet long, which is fixed in the direction of the cut by means of two jacks; one at the front is placed against the coal-face and set at an angle, in order to take the thrust of the machine as the chain is entering the undercut; the other jack is set from the back of the stationary frame to the roof; and the two jacks hold the frame firmly in position. The motor, of 15 horsepower, runs at a speed of about 900 revolutions per minute; it lies at right angles to the coal-face, and drives through bevel-wheels a vertical shaft, carrying a worm and a small pinion. The latter gears into a large toothed wheel on a shaft, fixed below the motor, and here also is fixed the driving-sprocket for the chain. The worm on the first vertical shaft drives two worm-wheels on shafts set at an angle, and at the other end of these shafts are two more worms, which gear into worm-wheels running loosely on a shaft fixed across the frame. The worm-wheels are fitted with slots in the side with two or three steel driving-pins, and they are geared to run in opposite directions. A pin-clutch, sliding on a key, is placed between the worm-wheels, and the machine-driver can therefore run this cross-shaft in either direction. On the ends of the cross-shaft two small pinions are keyed; and they gear into racks fixed on the sides of the stationary frame, so that the machine may be fed in or out and may also be
allowed to run idle. The rate of feed for cutting was 2 feet per minute, and it has been reduced to 1 foot per minute, but the withdrawal of the machine can be made in 30 seconds.

The chain is composed of links and tool-holders, the latter being set at different angles, so that straight tools can be used, but it was found advisable to bend the top cutters and make them pick-pointed. The section of the steel being \( \frac{3}{4} \) inch by \( \frac{1}{2} \) inch. There are 45 tool-holders, and the chain runs at a speed of about 300 feet per minute. The tools are fastened into the holders by means of set-screws.

The motor is of the four poled type, with two shunt-coils, for a current of 500 volts. The motor is of the open-running type, which is not desirable; but the writer has arranged to convert it into a closed motor, although a little trouble may be caused by its becoming heated. The connections for the trailing cable are plugs, fitted with a bayonet-socket arrangement so as to prevent them from being inadvertently pulled off. The trailing cable is attached to a diamond switch-box.

As the chain runs from right to left, it is advisable to work the machine from left to right, and in this way it works with the tools on a loose side, after the first cut. As soon as the machine has made the first cut, the jacks are released and it is pushed, by means of iron bars, into a position ready for the next cut, and the jacks are re-fastened. After the machine has made three cuts, it is lifted by means of an ingenious jack, the runners are moved back a little, and it is pulled back a few feet from the face by means of a Sylvester chain, fastened to a prop, so as to enable the shots to be fired in safety and the coal to be filled. The depth of the undercut averages 5 feet 7 inches, the width is 3 feet 8 inches, and the thickness of the cut is 4\( \frac{1}{4} \) inches. The cut is made in the dirt lying immediately above the "dicks."

It was found inadvisable to cut the holing as fast as the machine was originally speeded to do, as it took too much current. At the present rate of cutting, the machine takes 26 ampères at 480 volts, or say 16\( \frac{1}{2} \) horsepower. It will be seen that the motor is somewhat overloaded, and in the writer's opinion it would be advantageous to adopt a motor of larger size. Of course, as no run exceeds 6 minutes, the motor has plenty of time to cool.
The writer found that, in the three months ending December 31st, 1903, the machine made 226 cuts to an average depth of 5 feet 7 inches, 223 shifts had been worked, and 415 yards had been driven. Two men are employed at 6s. 6d. per yard, without percentage, the driver earns about 8s. per day, the assistants are paid 5s. per day, and in addition, the men are paid for shifting the machine from one heading into another.

After the cut has been made, as much as possible of the loose dirt is removed, then the electric drill is fixed so as to make a hole at either side of the heading, and it takes 5 minutes to set the machine and drill a hole, 6 feet long. This drill weighs 170 pounds, and is driven by a motor of 3 horsepower: and when running it takes 5 amperes at 480 volts. The drill is easily moved by two men, and after the second hole is drilled, it is removed a few feet back so as to be placed out of danger. The shots are then fired, the coal is filled, the "dicks" taken up, and the machine drawn forward for another cut. The coal, worked by the machine, is very much larger than that formerly produced by hand-labour.

The machine is moved from one heading to another, every 150 or 200 feet, and during the time that the machine is working in the back heading, ripping is being done in the main heading. The slits are also driven by the machine. The machine is only worked two shifts daily, because a greater distance is driven per shift than when three shifts are worked daily.

A test has been made to ascertain the length of time required to make the cut, and, though the writer places it on record, he prefers to take the results of three months' working to that of any single day. The machine lay 8 feet from the face, and the men spent 8\(\frac{1}{2}\) minutes in placing it in position, 5 minutes were taken to prick the roof for the back jack, 2 minutes to fix the machine and run the motor light, 7 minutes to make the undercut and withdraw the chain, 6\(\frac{1}{2}\) minutes to move over and fix the machine for the second cut, 8\(\frac{1}{2}\) minutes to make the second cut, 5\(\frac{1}{2}\) minutes to move over and fix the machine for the third cut, 7 minutes to make the third cut, 6 minutes to remove the machine from the face, the total time being 55\(\frac{1}{2}\) minutes.

The machine saved the sum of 4s. 9d. per yard, taking the prices demanded by the men, towards power, interest on capital, depreciation, and repairs: or 3s. 1d. per yard, taking the price-
DISCUSSION—AN ELECTRICAL HEADING-MACHINE.

It is difficult to ascertain the cost of power, because the machine is actually running for less than 30 minutes per shift. The machine has not been running long enough to determine the interest and depreciation. The total repairs, exclusive of sharpening the cutter-teeth, have amounted to £9 13s. 9d. since April, 1903; but this amount does not include the wages of the colliery-mechanic employed in replacing broken wheels. An average of 20 teeth required sharpening after each shift.

In conclusion, the writer would like to say that he has no financial interest in this or any other heading-machine, but he cannot close his paper without thanking Mr. R. Hood Haggie for his general assistance, and Mr. Waterhouse, the manager of the pit, for collecting the data upon which the writer has founded this paper.

Mr. J. Gerrard (H.M. Inspector of Mines) moved a vote of thanks to Mr. Greaves for bringing the subject before the members in so excellent a paper.

Mr. W. B. M. Jackson observed that he had had some experience with the Morgan-Gardner—a machine of this type. Their machine was one of the first of the kind introduced into this country, and they had obtained excellent results from it. Mr. Greaves stated that the coal worked by the machine was much larger than that formerly produced by hand-labour: but he (Mr. Jackson) had not found that to be the case. The coal had been undercut and then blown down, without cutting the side; and he asked the writer whether the coal had been nicked or sheared after it had been undercut by the machine.

Mr. Percy C. Greaves replied that the coal was undercut and then blown down, and the improvement of the sample was marked. Some slits had been driven by hand, and the difference in quality was so great that it could be readily recognized. At another colliery, with which he was connected, the seam was thin, and the men cut everything to slack with the pick; but with the machine, very respectable coal was obtained, even after shots were fired—the coal was not so good as that produced from banks, but it was much better than slack.
Mr. W. B. M. Jackson said that much depended on the condition of the seam. He had a seam 4 feet 2 inches thick, and when the coal was efficiently cut by hand, it produced a larger quantity of round coal than it had done since the electric cutter was used.

Mr. H. Rhodes remarked that he had used a Stanley heading machine, and the methods of working which he had adopted were somewhat similar to those described by Mr. Greaves. The seam was nearly 6 feet thick; but, owing to a band of dirt in the centre of it, sometimes containing large lumps of iron-pyrites as big as a football, the working of the Stanley machine was abandoned. It was found that it could do two or three times as much work, with an increased cost of about 50 per cent., compared with hand-labour. If a heading machine were again introduced into that seam, it would be a machine of the Jeffrey class, even if it were driven with compressed air. The Stanley heading-machine had to face every portion of the seam at some period of its cut, and if it happened that a boulder appeared in the middle band at each side of the heading, there was no other resource than to stop the machine and to cut round the boulders by hand-labour.

Mr. R. Holiday (Ackton Hall Colliery) said that Mr. Greaves' paper exactly confirmed his own experience. They put in a Jeffrey heading-machine, worked by a three-phase motor, although the makers stated that a three-phase motor could not run the machine, and that a small fortune had been spent in America in the attempt to make it do so successfully. It was found that the feed was exactly twice as fast as it should be; the motor was of 15 horsepower, and to run the machine with the feed as arranged would require 30 horsepower. In consequence, the machine was fed at half the rate, just the same as Mr. Greaves did. It was also found that the feed of the drill was twice as fast as it should be. The machine was worked in a seam, 2 feet thick, and it did extremely well. There was one question as to how far it mattered on which side the cut should be made: and Mr. Greaves suggested having a free side after the first cut. He thought that the cut should be made so that the chain would bring out the stuff. By this arrangement, the sliding frame was less likely to become jammed,
DISCUSSION—AN ELECTRICAL HEADING-MACHINE.

and there was less liability of the machine sticking. The coal was taken down in the same way as described by Mr. Greaves, but the holing was made a little farther into one side than the other, so as to make the coal come down somewhat more easily.

Mr. W. Hay (Shirebrook Collieries) said that they had cut about 27,000 feet of heading with a Jeffrey heading-machine. The cost of minor repairs, over 9 years, including a new armature, was about £150. The machine saved an average of about 6s. per yard over hand-labour, and the round coal was increased by 20 per cent. The cut was made on one side and the shot placed in the other. The machine had given great satisfaction, and it was worked at the original speed of the gearing.

Mr. G. Blake Walker (Wharncliffe Silkstone Collieries) said that, in driving wide places, they found that the Jeffrey heading-machine did more economical work than in narrow places, 6 feet wide, because there was less time spent in removals in proportion to the work done. The speed of the cut was about 1 foot per minute. There had been no trouble with the machine, which seemed to be well made, and would cut across a place, 36 feet wide, in about an hour, or a little over. The one drawback from their point of view was that this machine required a width of about 14 feet to work in: this was rather a large spread of roof to uphold unless the roof was exceptionally good; and some little delay took place in setting the timber behind the machine. Further, every time the machine was shifted, two or three props had to be taken out and replaced, if the roof would not stand without propping.

Mr. M. W. Waterhouse (Exhall) remarked that, in his experience, he had found an increase in the percentage of round coal. At a Warwickshire colliery, with which he was connected, a considerable reduction of cost was effected as compared with hand-labour—probably more than Mr. Greaves mentioned, because in their case the cost of hand-labour was very great.

Mr. R. Hood Haggie (Derby), quoting from the price-list for 1903 in Indiana, U.S.A., said that the cost of hand-labour, including loading, was 3s. 9d. per ton. Cutting, with a machine of the Jeffrey type, cost 5d. per ton; and with a machine of
the Sullivan or Ingersoll-Sargeant type, 7½d. per ton. Loading, etc., using hand-drills, cost 2s. 1½d. per ton; and with machine-drills, 2s. per ton. Drilling by hand cost 1½d. per ton; and by machine, 1¾d. per ton. The cost with a punching-machine, with hand-drills was 2s. 10½d., and with machine-drills, 2s. 8¼d. per ton; and with a machine of the Jeffrey type, 2s. 8½d. with hand-drills and 2s. 6½d. per ton with machine-drills. Consequently, there was a saving of 1s. 2½d. per ton by using a machine of the Jeffrey type, and machine-drills over hand-labour. In Indiana, the machine-men removed all sprags, took out the cutters from the machine and got it ready for removal to another place. If the room was wet the men were paid 1½d. per ton extra; but that did not affect the saving, because the same allowance was made in respect of hand-labour. With regard to the rate of feed of the Jeffrey machines, everyone had learnt of late years that different headings required different rates of feed. In many seams, a machine would cut 6 feet under in 3 or 3½ minutes, while in others it did not cut more than 1 foot a minute or perhaps less than that. The proper feed could be best decided by trial, but it entailed no structural alteration in the Jeffrey machine.

Mr. W. H. Pickering (H.M. Inspector of Mines) enquired whether Mr. Greaves had found any difference in the number of shots required in headings driven by machine and hand-holing. Although they were now well used to machines for coal-getting, he did not think that the advantages of machine-heading were sufficiently appreciated at the present time.

Mr. Percy C. Greaves, replying to the discussion, said that Jeffrey machines had been air-driven, and it was a remarkable circumstance that in another pit, with which he was connected, an air-driven machine had been taken out because it produced so much sparking at the chain. There was a little pyrites in the seam, where it was cutting, and it produced a stream of sparks along the length of the chain; and as it was a fiery mine, they durst not continue the working of the machine. It must be admitted that more shots were needed in a heading cut with the machine than with hand-holing: It meant two shots were fired in each length of 5 feet 7 inches, or practically one shot for every 3 feet: but with hand-holing he did not
think that it would average a shot for every 10 or 15 feet; he could not, however, give the exact number, as a record had not been kept. The increase in the number of shots was a disappointing feature, but it could not be overcome, until they had a machine which would shear at one side and probably cut a little bit at the roof as well, because the coal adhered very strongly to the roof in some thin seams.

The Chairman (Mr. H. B. Nash) agreed with Mr. Pickering that sufficient attention had not been given in England in the past to the use of heading-machines. Coal-cutters had been chiefly confined to the longwall-face: but in mines which could not be worked on the longwall system or headings which it was difficult to work by hand-labour owing to the hardness of the coal, etc., the heading-machine would successfully and economically replace the men. He agreed with Mr. Greaves that it was disappointing to find that the use of the heading-machine had led to an increase in shot-firing, because that was one of the dangers which should be curtailed to the greatest extent possible. If a machine could be made to cut on one side of the road, as well as undercut the coal, it would enable the coal to be brought down in the ordinary way by wedges, and shot-firing could be abolished. He had pleasure in seconding the vote of thanks to Mr. Greaves for his paper.

The resolution was cordially adopted.
pail-system had been advocated as being an effective method, but it was thought better to make places similar to refuge-holes, well cemented on the sides and floor; they could be emptied and disinfected every day, and the contents would be removed with the stable-manure. If that were done, they would render the pit-bottom and the main roads more healthful and pleasant for the men, and at the same time they had taken the most effective steps possible for guarding against the development of the disease if it were unfortunately imported into the mine.

Mr. G. Elmsley Coke (Nottingham) thought that this paper could only be fully discussed by medical experts, but the precautions clearly explained by Dr. Court could be appreciated and adopted.* Some managers appeared to think that there was no danger of this disease invading our district—but he (Mr. Coke) hoped that no reasonable precautions would be omitted, more especially when the conditions in any part of the mine are favourable to the propagation of the worm. In his experience, few of the deep mines are absolutely dry, water being usually met with at faults, and a wet place with a temperature of over 68° Fahr. might become a centre of infection. By adopting proper sanitary arrangements, and by prohibiting anyone from an infected district from working underground, one might reasonably hope to secure immunity.

Mr. Isaac Hodges (Whitwood Collieries), speaking of West and South Yorkshire collieries, said that they had little to fear, as in most of the shallow mines the temperature was below 68° Fahr., and in most of the deep mines there was not much moisture. At a recent well-attended meeting of colliery-managers of the district, it was felt that it was necessary to improve the sanitary condition of the mines, and many managers, at the present time, were providing underground closets. A difficulty arose from the fact that no one cared to provide a portable water-closet or even a portable pail, as the removal of the excreta was a labour that no one was particularly anxious to perform, and consequently there was some

difficulty in getting workmen to attend to this duty. At the pit-bottom, the stables were the best position, as a stall, with a concrete floor and sides covered with flue- or peat-moss dust, made an excellent closet, and the excreta could be sent out of the pit with the horse-manure. At congested places on the haulage-planes, a manhole, with a concrete floor, could be fitted as a closet; and, nowadays, the inbye-stables, at the end of the haulage-planes, could be utilized in the same manner. Such a system of closets would greatly improve the present methods at pit-bottoms and on haulage-roads. At the faces, there was not much difficulty, as the men usually selected a dry place in the goaf, and the offensive matter became buried under the falling roof in due course. In German mines, owing to the seams being steeply inclined and worked from various levels the infected faeces, deposited on a higher level, were carried down by the complete system of watering, common to German mines, to the lower levels, and the disease was thus disseminated and communicated to the workmen in a way which could not possibly occur in Yorkshire mines, where the seams lie at flatter gradients. Personally, he was glad that the fear of the outbreak of ankylostomiasis had focussed attention on the subject of underground sanitation, because it was one to which British colliery-managers must give great consideration. They had been trained under certain conditions, and they were apt to regard those conditions as those that would always apply; but he could not see why congested places underground should not be kept in a clean and sanitary condition just as on the surface. With the improvements now being introduced, he certainly believed that Yorkshire mines had no reason to fear the outbreak of such an epidemic as had occurred in Germany.

Mr. H. Rhodes said that he had assisted Mr. Pickering to take the temperatures in several mines, varying in depth from 2,000 to 2,400 feet, and he had only found one mine, in which there was any danger of the spreading of the disease, if it were introduced. The temperature, in the case of the mines tested, varied from 78° to 83° Fahr. in the main return-airways.

Mr. G. J. Binns (Derby) said that he had the privilege of being present at the Home Office conference, when they were favoured with a number of details indicating the extreme incon-
venience, to the workmen especially, of carrying out the precautions which were observed in Germany; and Dr. J. S. Haldane amplified his paper very materially. There had been a discussion in the German Reichstag on the subject, and he noticed that one of the labour members suggested the establishment of an 8 hours' day as a cure for the disease.*

Mr. C. Chetwynd Ellison (New Monekton Collieries) pointed out that the stables were generally the warmest place that they could find in a mine, and a closet placed there would be favourably disposed for the propagation of the disease. As this disease had already made its appearance in this country, in Scotland and Cornwall, whence men were likely to come in search of work, the best plan that they could adopt would be to insist upon receiving a sort of character or bill-of-health with every man, so that they would know whence he came. If they wanted to stop the disease coming into this part of the country, the only recourse was to stop the employment of men coming from infected parts. No one thought of engaging a domestic servant without a character, and although it might be difficult to carry out in the case of miners, still if the disease were so serious, it would be well worth trying. Moreover, it would be a great advantage, in more ways than one, to the colliery-manager to know the man whom he was employing, and whence he came.

Mr. G. J. Binns remarked that the case reported to have occurred in Scotland had not been identified—at least it had not been so at the time of the Home Office Conference.

Dr. J. S. Haldane wrote that he was glad to see, from the remarks of the Chairman and other members, that steps had already been taken in many collieries to limit the pollution of the ground. He would like to take this opportunity of correcting the statement in his paper that the larvae of *Ankylostoma* probably did not develop to the infective stage at temperatures under about 70° Fahr. This statement was based on data collected in Westphalian collieries and on laboratory-experiments

DISCUSSION: THE BEARD-MACKIE GAS-INDICATOR.

made in connection with the outbreak of the disease there. Recent experiments by Dr. Boycott and himself had, however, shown that the infective larvae will develop at as low a temperature as 61° Fahr.; and from the report giving the results of the Belgian Government enquiry it appeared that, out of 41 infected mines in the Liége district, the temperature at the working-face was under 68° (60° to 68°) Fahr. in 16 cases. The percentage of infected men in these sixteen mines varied from 4 to 52. It seemed, therefore, that the disease might break out even in cool and shallow mines.

DISCUSSION OF MR. W. H. HEPPLEWHITE'S PAPER ON "THE BEARD-MACKIE GAS-INDICATOR."

The Chairman (Mr. H. B. Nash) asked Mr. Hepplewhite whether he considered that it would be of practical value to the miners themselves, if this gas-indicator was fitted into each safety-lamp, and whether with the ordinary knocking about which a lamp received, the indicator would not be liable to be broken, and thus become inoperative? Of course, when a deputy used this indicator, when testing for gas, he would take more care than an ordinary miner; but at the same time he was doubtful whether it would be safer to trust to that indicator with the possibility of the wires becoming broken, than to rely on the old-fashioned method of drawing down the wick and noting the length of cap upon the reduced flame, combined of course with the practical knowledge which came with long experience. With the liability to danger which was ever present, they were always on the look out for anything that would assist in detecting gas; and if this instrument was likely to prove of any benefit in that direction, then the British colliery-manager would quickly adopt it, but if not, he would preferably continue to use the old methods.

Mr. G. H. Ashwin (Sheffield) said that he had had an opportunity of trying this lamp, but the results were different from those which Mr. Hepplewhite had described. He had tried the lamp in a return-airway where he could find no trace of gas with an ordinary lamp, and he found with this lamp an elongation of the flame before a glow appeared on the first

of the wires: while Mr. Hepplewhite appeared to have seen a glow on the wires, but no elongation of the flame. He had tried the lamp in many places, but in each case there was an elongation of the flame before the glow appeared on the wires. At one place, he got an elongation of the flame extending to the height of the third wire, and a red glow, not incandescence, on the fourth wire of the ladder; but he could not perceive any elongation of the flame on an ordinary lamp. He thought that the lamp would find very small quantities of gas, and he was of opinion that it would prove a very useful lamp for managers and under-managers when ascertaining the condition of the air in return-airways.

Mr. G. J. Binns observed that the use of platinum-wire for detecting small quantities of gas was very old. Many years ago, a description was published of the Liveing fire-damp indicator.* The cost was £7 10s., and he had, at one time, 12 of them. He was not wilfully extravagant in getting so many, but he was at the time in the service of a Colonial Government, and being asked whether he knew of any device for detecting a small quantity of gas, he looked up the matter, and ordered two. In the office of the Ministry of Mines, however, the "two" was altered into "twelve." He had used one of the indicators, which was very heavy, and contained two spirals of platinum-wire, one on each side of a photometer; one spiral being placed in free air, and the other in the atmosphere of the mine. The instrument was cumbersome, taking several hands to work it, and finally the spiral wires were burnt out and it was thrown aside.

Mr. W. H. Hepplewhite said that the fact that the wires became blackened was a very great drawback to this gas-indicator, but this partly depended upon the kind of oil which was used, and the oil used at some pits was very unsuitable. Good results were obtained if sperm or best refined colza-oil was used, with a round wick. The lamp exhibited was fitted with a flat wick, ½ inch wide, in a round burner. He thought that Mr. Ashwin must have had over 3 per cent. of gas when the flame was elongated, and that all the wires would then be glowing.

Mr. G. H. Ashwin replied that, in the place referred to, with an ordinary lamp he could find no trace of gas; but with this lamp, burning sperm-oil, there was an elongation of the flame.

Mr. W. H. Hepplewhite said that the lamp would be most useful for making examinations in return-airways or in old workings, as it would enable anyone to detect a quantity of gas which was too small to show on the flame of an ordinary lamp. He would not advise that the gas-indicator should be put into workmen's lamps or even into those of every official, but it would be valuable for use by managers or chief deputies.

Mr. W. E. Garforth said, with regard to the principle that a platinum-wire burnt with greater brilliancy in an atmosphere of gas than in pure air, it seemed to him, that the American inventor had built his lamp on the knowledge obtained by Prof. E. H. Liveing, who was really entitled to the credit of the application of this discovery.
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MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE QUEEN'S HOTEL, LEEDS, APRIL 16TH, 1904.

Mr. H. B. NASH, President, in the Chair.

The following gentlemen were elected, having been previously nominated:

Members—
Mr. Maurice Georgi, B.Sc., Electrical Engineer, Edinburgh.
Mr. Henry Vernon Haigh, Mining Engineer, Bruntcliffe Collieries, near Leeds.
Mr. Charles E. Smith, B.Sc., Mining Engineer, 20, Baker Street, London, W.

Student—
Mr. Peter Booth, Mining Engineer's Pupil, 45, Richmond Avenue, Headingley, Leeds.

Mr. W. McD. Mackey read the following paper on "Slack-washing: Preliminary Treatment for the Extraction of Fine Dust";—
SLACK-WASHING: PRELIMINARY TREATMENT FOR THE EXTRACTION OF FINE DUST.

By W. McD. MACKEY.

Introduction.—During the last few years there has been a decided increase in the amount of small coal, containing "duff" or fine dust, sent to the coal-washer; and, as riddles are generally being taken out of the pits, coal-owners are becoming more and more aware that in fine coal there is a valuable smudge suitable for coking, if it can be economically washed.

As a consequence, the washing-department has to contend with the disposal of the slurry in a more aggravated form than obtained, say, 10 years ago. The requirements of the altered conditions have not yet been met, and the problem is beset with many difficulties, as coal, probably the cheapest (or, at any rate, one of the cheapest) materials that is washed, must be dealt with not only in large quantity but with great simplicity in handling, if the washing is to be commercially successful. Efficient washing includes not only the production of a properly washed coal, and a dirt containing no coal or at most a negligible quantity, but also the recovery of what may be termed the "float-coal" in a condition suitable for coking or firing, and—what is included in the recovery of the fine coal—the clarifying of the water, whether it is run to waste or used over again in the washery.

The importance of obtaining a clear water for further washing—apart from the question of a clear effluent, if any is run to waste—is sometimes strangely overlooked, especially in small plants. The clarifying of the water that is to be re-used in the washer is vital to good washing, and should always be aimed at; but, when dealing with smudge containing much fine dust, this is often a matter of great difficulty.

Slurry, which is formed when smudge containing much fine dust is washed, is usually found, at least as far as the writer’s experience goes, to contain as high a percentage of dirt as the original unwashed coal, and often more. The fine dust in coal
doubtless usually consists of coal mixed with fine shale, in about
the same proportion as in the bulk. But, in washing, a large
proportion of the fine shale or dirt seems to be carried forward
with the water, and thus it passes on, along with the fine coal-
dust, and forms slurry or sludge. This dirt is largely masked,
when, by any suitable system of filtering the wash-water through
a layer of the larger washed coal, the bulk of the fine dust in
suspension is caught. The fact that much fine dirt, even of high
specific gravity, is carried forward with the water is easily
demonstrated, when there is much fine pyrites in the coal, by an
examination of the trough by which the water flows to the well
or settling-pond.

The points that have been urged may be summarized as
follows:—(a) The importance of clarified water for re-use in
the washer; (b) the difficulty of obtaining clarified water, when
the smudge contains much fine dust; (c) the imperfect washing
of fine dust; and (d) to these may be added the trouble of
dealing successfully with slurry, when once it is formed.
Further, the washing of smudge, containing much fine dust,
is under any circumstances necessarily tedious, and unduly
takes up what may be called the "washing capacity" of any
given plant.

The writer is aware that these considerations do not apply
equally to all coals, but his experience has led him to the opinion
that, in many cases, at least, it would be a decided improvement
if the very fine dust were extracted before washing, and either
added dry to the bulk of the washed smudge, or, possibly better,
burned as boiler-fuel at the colliery by any of the methods for
utilizing coal in the form of a dry powder. The attempts
hitherto made to burn sludge seem to have been more of the
nature of getting rid of a nuisance, than of actually obtaining
benefit from it as a fuel.

Extraction of Fine Dust.—Riddling or sieving is not a
practicable method of removing the fine dust. To take a con-
crete instance, a smudge recently came under the writer's notice,
of which considerably over 25 per cent. was capable of passing
through mesh of \( \frac{1}{8} \) inch, and smudges of this class are not
at all uncommon. It is impossible, in practice, to use a riddle
so fine as this, and in any case it would be undesirable to riddle
out such a large proportion. A specimen of dust is on the table,
double riddled through mesh of \(\frac{3}{4}\) inch and over mesh of \(\frac{1}{8}\) inch. It will be recognized that it is granular, and capable of successful washing, being far removed from the impalpable dust that gives serious trouble in the form of slurry.

The next method that suggested itself was the employment of a fan, as used in cleaning grain. This method has often been proposed, and the theoretical advantages are obvious, as in such a method a certain amount of separation of the coal from the heavier dirt-particles might be effected. No doubt, the reason why it has not been put in practice—at least within the author's knowledge—lies in the difficulty of catching the dust when floating in a current of air, and the danger of explosion under such conditions.

_Dust-separator._—Recently, while the writer was experimenting in connection with another matter, the following method suggested itself, but it is put forward with diffidence, as the author has not yet had an opportunity of testing its value on a large scale. The specimens of dust, here submitted, are the results of experiments made with a small apparatus roughly erected in a laboratory.

The suggested apparatus or plant has, at any rate, the merit of being very simple. It consists of a short endless band or belt, E, made of canvas or similar material (Figs. 1 and 2, Plate I.). This belt, of any convenient width, say, 5 feet, travels round pulleys, D, placed at a distance apart of about 4 feet, and set so that the upper surface of the belt travels towards the top pulley at an angle of 50 degrees; that being the angle at which the experiments were made. In practice, the angle would be varied till the best results were obtained. The smudge is dropped or fed from the bunker, A, in a thin stream, upon the belt, E, moving towards the top pulley, D2; and while the granular particles run down the belt, are caught on a shoot, H, and conveyed to the washer, the impalpable dust adheres to the belt, is carried round the top pulley and either falls off, or is removed by a stationary brush, F, into a shoot, G, which may convey it to the boot of the washed-coal elevator, or elsewhere as desired.*

* British patent, No. 3,233, 1904, William McDonnell Mackey, 33, Chancery Lane, London: improvements in apparatus for sorting and separating minerals and other materials or substances.
The results of experiments indicate that the degree of fineness of the dust extracted can be controlled by varying the angle and surface of the belt: and, on the other hand, the degree to which the smudge can be freed from dust depends on the careful distribution of the smudge in a thin and regular stream on the surface of the belt. In order to lessen any tendency to the formation of a dust-cloud, the stationary brush for removing the dust adhering to the under surface of the travelling-belt would be enclosed, and the belt would travel at as slow a rate as might be found convenient.

The wear-and-tear of the surface of the belt would be considerable; but it may be pointed out that, at the angle suggested, the granular smudge after the first contact with the surface rolls off, pressing very slightly on the belt. And, from experiments, it appears that it is the point of first contact with the belt that is effective in causing a separation of the dust from the more granular coal; and therefore no object is served in using a long belt.

The samples of dust submitted are as follows:—

(1) 2.82 per cent. of dust extracted, all of which goes through mesh of \( \frac{1}{3} \) inch; it contains 15.80 per cent. of ash. (2) 3.18 per cent. of dust extracted, nearly all of which goes through mesh of \( \frac{1}{3} \) inch; it contains 16.78 per cent. of ash. In both samples (1 and 2), the ash in the extracted dust approximates to that of the unwashed smudge. (3) 6 per cent. of dust extracted, all of which goes through mesh of \( \frac{3}{8} \) inch; it contains 20.50 per cent. of ash, and unwashed smudge contains 14 per cent. of ash. This is a smudge formerly washed by the writer on a large scale. The ash in the slurry taken from the well was found to rise as high as 26 per cent. in an air-dried sample.

The President (Mr. H. B. Nash) said that the removal of fine dust from slack was very difficult; and it was a very different matter experimenting with small quantities in a laboratory to dealing, in actual work, with several hundred tons per day. There was considerable novelty in Mr. Mackey’s suggestions for effecting this separation, and it might prove an incentive to further experiments being made on a working scale to prove their practical value.
Mr. W. H. Chambers said that he had given thought, for a considerable time, to the subject of Mr. Mackey's paper. He had discussed the dust difficulty with the makers of several coal-washing machines, and, at the beginning, they all stated that their machines would be able to wash the dust along with the other coal; but when they tried to do so in their machines, they found that it was impossible from some peculiarity of the substance. He had, recently, in Germany, practically demonstrated to the maker of a coal-washing machine that the washing of the dust, they produced, was impracticable, as, when mixed with the larger coal in the washing machine, the dust only created mud and rendered the washing of the other coal less efficient. He might say that, at the pits with which he was connected, although they had had coal-washing machines of large capacity—in fact, they washed fully half of the output—they had extracted the fine coal through a mesh of 3 millimetres, and that had just provided them with sufficient fuel for the boiler-furnaces. As their output was increasing, and as they were economizing the consumption of coal, the dust-problem might create a difficulty in the future. It had been running through his mind, therefore, to extract the finest dust before washing the coal, and he was glad to have the opportunity of considering Mr. Mackey's method along with others. He had considered the idea of inducing a current of air through the bars of the screens, and collecting the dust in that manner as the coal passed over the screens. This arrangement would, he thought, prevent the formation of the great clouds of dust, which usually existed about the pit-mouth, and, although it was not desirable, a great proportion of this dust was taken down the shaft by the air-current, which ventilated the mine.

Mr. Roslyn Holiday quoted an instance where the idea mentioned by Mr. Chambers was in operation. The current of air extracted the dust as it fell, removed it from the coal, and as the heavier dust fell first and the lighter afterwards, it was automatically separated. The dust, he said, was being sold for £1 1s. a ton at the foundries.

Mr. Walter Hargreaves thought that the question of the clarification of the water was the most important point connected with coal-washing; and, if they intended to wash the coal,
efficiently clarified water must be used. The idea put forward with regard to the slurry was also fairly new, and it would be interesting to ascertain the amount of slurry that the dust was likely to form; and knowing that they could make a calculation with the view of taking out the dust and adding it to the washed coal. He should also like to know how the addition of that dust would affect the amount of ash in the coke.

Mr. I. Hodges said that Mr. Mackey premised that "the fine dust in coal doubtless usually consists of coal mixed with fine shale, in about the same proportion as in the bulk,"* but the percentage of shale varied in different coals. In some coals, the proportion of dirt in the dust was three times greater than the dirt in the average sample of coal; and it was obvious, if such unwashed dust was added to the washed smudge, that the ash in the coke would be appreciably increased and the coke rendered less valuable. The calorific power of so dirty a dust made it useless as boiler-fuel, and, as it could not be used for that purpose as Mr. Mackey had suggested, there was no alternative but to wash such dust. The necessity for clarifying the water was one of the great difficulties experienced in coal-washing. At one of his coal-washing plants, the water was used continuously, filtering through large washed-smudge draining-tanks, and there was no overflow or leakage of water beyond the moisture carried away in the washed smudge to the coke-ovens. At another coal-washing plant, the conditions were so favourable that clean water was always used, and test washings of the same smudge in these plants shewed that the clean-water plant was the most efficient.

Mr. A. Lupton said that the particular method of dealing with any slack depended on the nature of the seam. Mr. Mackey's system depended simply upon gravity and adhesion; the smaller pieces, having less gravity in proportion to the cube of their diameters, were more likely to adhere to the cloth than the larger lumps, and, by diminishing the angle, the force of gravity could be diminished. He understood, of course, that the force of adhesion remained constant however the force of gravity varied, so that Mr. Mackey's apparatus had a nice adjustment, and that seemed to be one of the great features

appertaining to it. If the dust carried over was very dirty, it should not be added to the washed slack, because it would produce an unsatisfactory result by increasing the percentage of ash.

Mr. C. C. Ellison said that, in his experience, it was absolutely impossible to make high-class coke, if the fine dust was put into the coke-ovens without being washed, as it always contained a high percentage of ash. He was endeavouring to make arrangements, by fitting a hood to a new screen, for collecting the fine dust, which was made on tipping the coal, and preventing it from going down the shaft, and also for improving the light and ventilation at the screens, rendering it easier and pleasanter for the men to clean the coal. By this means he hoped to prevent a certain percentage of coal-dust from going to the coal-washer; but he did not see how he was going to extract the fine shale-dust, which, being of much heavier specific gravity, would not rise with the coal-dust in the air-current.

Mr. T. W. H. Mitchell said that, in his experience, if they provided a sufficient number of small washers, they would overcome the difficulty of the slurry and the small dust. He thought that they should give the washers fair play, and that they should not overload them. He also thought that there was no difficulty in burning the slurry in boiler-furnaces, and it had been proved at Cadeby colliery that the wet slurry could be used for this purpose.

Mr. J. Neal said that, in his experience, by having plenty of room in the wash-boxes, the fine coal could be passed through the washer. In a coal-washing plant, with which he was connected, it was found desirable that the duff or fine coal should be taken out through a sieve, with a mesh of 3 millimetres, in order that the coal might be efficiently washed; but, by providing an additional wash-box and rewashing, the duff could be passed through the washer, without materially increasing the percentage of ash in the coke. He must, however, admit that, since this change had been made, more fine dust was lost in the waste-water. He had ascertained by experiment that 11 per cent. of the duff passed through a mesh of 3 millimetres was carried away by the waste-water.

Mr. W. H. Chambers said that, irrespective of the dimensions of the wash-boxes, the fine coal could not be prevented
DISCUSSION—SYSTEMATIC TIMBERING.

from forming slurry. They had been driven to try and extract the fine coal without putting it into the water at all, and he was peculiarly interested in Mr. Mackey's method of removing it.

Mr. W. H. Pickering said that, as one of H.M. inspectors of mines, he was interested in the removal of the floating dust; and he hoped that Mr. Ellison and Mr. Chambers would enter into a friendly rivalry in its removal by air-extraction.

Mr. W. McD. Mackey, replying to the discussion, said that he had examined several plants, where the water had not been adequately clarified, and in each case he had found that the washing was not properly performed. The amount of coal lost by not attending to the water was a matter which, he thought, was sometimes not present to the minds of those washing the coal. Coal and dirt were not separated as efficiently with muddy as with clear water, and he would like to emphasize that important point. He had frequently analysed slurry, and he invariably found that it contained as much or more ash per cent, than the original unwashed coal. Thus, with unwashed coal, containing 14 per cent, of ash, he had found 26 per cent, of ash in the slurry. He spoke with diffidence as to the quantity of coal that could be treated in the apparatus, but he thought, without going into details, that a belt, 5 feet wide, should separate the dust from 300 tons in a working day of 10 hours.

DISCUSSION ON MR. W. H. PICKERING'S "NOTES ON SYSTEMATIC TIMBERING."

The President (Mr. H. B. Nash) said that the Coal-mines Regulation Acts clearly defined that it was the duty of each collier to protect himself and to keep his working-place safe by setting all timber necessary for this purpose; and the suggested rules were only intended to carry out this object in a systematic instead of a haphazard fashion. It was impossible to draw any hard-and-fast rule, as to the distance that props should be set apart, either in one direction or the other, because the roof of no two seams was alike; and the variations of the roof in different working-places in the same seam were so great that the manager must have discretionary power to vary the ordinary rules, when circumstances required it.

Mr. P. C. Greaves said that they had had systematic timbering in operation for the past 15 years, and when the new rules were framed, they had only to post the notice. They experienced many advantages from systematic timbering: the only drawback being that the men had to be constantly warned about maintaining the exact distance.

Mr. W. H. Pickering (H.M. Inspector of Mines) said that systematic timbering was a most important subject, both from the point of view of economy and that of safety. Were they going to have for ever these falls and consequent fatal accidents or were they going to make some effort to stop them? In Yorkshire, last year, there were 69 fatal accidents from falls. The most important thing that they had to do was to educate opinion amongst the miners on the question of proper pitmanship. They could all do that, and he thought that they were under a moral obligation to do it.

Mr. John Gerrard (H.M. Inspector of Mines) sincerely hoped that the members would, at some early date, seriously consider in what way the frightful number of fatalities from falls of ground could be reduced. It was one of the principal objects of the Institution to consider how to prevent accidents in mines, and those from falls of ground, forming so large a proportion, claimed first and serious consideration. He could not believe that the members were either content with the present conditions, or that they were of opinion that nothing could be done. Mr. Pickering’s excellent suggestions should form the basis of an earnest discussion.

About 130 of the members visited the engineering-works of Messrs. Graham, Morton and Company, Hunslet, and were subsequently entertained to lunch.
To illustrate Mr. D. Mackeys Paper on "Slack washing."

Fig. 1.—Side Elevation.

Fig. 2.—End Elevation

REFERENCES.

A. BUNKER.
B. DAMPER.
C. SHOOT.
D. PULLEYS.
E. TRAVELLING-BELT.
F. STATIONARY-BRUSH.
G. BOXED SHOOT FOR DUST.
H. SHOOT FOR SENDING GRANULAR SMUDGE TO THE WASHER.
I. SEGMENTAL ARC FOR REGULATING THE ANGLE OF THE BELT.

Scale, 20 Inches to 1 Inch.
ARTHUR MARSHALL CHAMBERS.

PRESIDENT OF THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS, 1885-1887.
MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT THE ARCADE HALL, BARNSLEY, JULY 23RD, 1904.

MR. H. R. NASH, RETIRING-PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

Mr. John Wainwright and Mr. Hiram Baddiley were appointed scrutineers for the balloting-papers for the election of officers, and also for representatives on the Council of The Institution of Mining Engineers for 1904-1905.

The following gentlemen were elected, having been previously nominated:

MEMBERS—
Mr. James Percival Critchley, Mining Engineer, Batley Hall, Batley.
Mr. Herbert Alexander Jones, Electrical Engineer, 40, Dalby Lane, Thornbury, Bradford.
Mr. George Norman Ackroyd Pitt, Colliery Manager, Bentleigh, New Mill, Huddersfield.

STUDENTS—
Mr. Frederick Alwyn Battle, Mining Student, 18, Clarendon Road, Leeds.
Mr. Harry Woolley Hopt, Mining Student, Glass Houghton Collieries, Castleford.
Mr. George Augustus Longbotham, Engineer Student, Walton Grange, Wakefield.
Mr. Frank Tiffany, Jun., Mining Student. 3, Kelso Road, Leeds.

The Annual Report of the Council and the Statement of Accounts for the past year were read as follows:—
ANNUAL REPORT OF THE COUNCIL. 1903-1904.

The Council have pleasure in presenting to the members of the Institute their report on the work of the past year.

The number of members for the last two years is as follows:

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<th>1902-1903</th>
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From this table, it will be seen that the membership has increased by 10 during the year, an increase which is fairly satisfactory.

The Council regret to have again to state that there has been during the year some irregularity in the payment of subscriptions, the arrears amounting to £21 due from 14 members. Of the £15 arrears of subscriptions due for 1902-1903, £4 10s. have been collected during the past year.

There is a balance in the bank of £240 8s. 1d. against £191 10s. 11d. at the end of the previous year, and all debts owing by the Institute have been paid.

The following papers have been read during the year:

- "Ankylostomiasis: The Worm-disease of Miners." By Mr. F. W. Gray.
- "An Electrical Heading-machine." By Mr. P. C. Greaves.
- "Slack-washing: Preliminary Treatment for the Extraction of Fine Dust." By Mr. W. McD. Mackey.
- "The Durr Water-tube and Improved Lancashire Boilers." By Mr. S. J. Thompson.

Several very interesting and valuable discussions have taken place upon papers read before other branches of The Institution of Mining Engineers.

It is with extreme regret that the Council have to call the members' attention to the great scarcity of papers. It is very important that this Institute, representing so large a district, should provide its fair share of papers towards the Transactions of The Institution of Mining Engineers, and the Council would be glad if members would consider this matter seriously with the view of submitting communications upon some practical subject in connection with their respective work, during the coming year.

The attention of the Council has been drawn by members
of the Institute to the great delay in the issue of the Transactions, and a portion of the blame is attributed to the fact that members do not prepare their papers and place them in the hands of the local Secretary early enough to have them printed before the meetings. It would be of great assistance, therefore, to the Council, and would help very much in the better and earlier production of the Transactions, if members could conveniently write their papers, say, a month before the meeting at which they have promised to read them.

The Council are very desirous of tabulating the various sections of strata which have been proved in this district, and with this object they have issued circulars and forms for the purpose. The Council hope that members will fill up the forms, giving all the information that they possibly can, so as to make the record a valuable one for future reference.

Mr. M. H. Habershon moved the adoption of the report.

Mr. H. St. John Durnford seconded the resolution, which was adopted.

ELECTION OF OFFICERS, 1904-1905.

The Scrutineers reported the result of the ballot, as follows:

President:
Mr. T. W. H. Mitchell.

Vice-presidents:
Mr. J. R. R. Wilson. | Mr. M. H. Habershon. | Mr. Isaac Hodges.

Councillors:
Mr. J. E. Chambers. | Mr. Roslyn Holiday. | Mr. Charles Snow.
Mr. H. St. John Durnford. | Mr. J. L. Marshall. | Mr. Thomas Stuebs.
Mr. Thomas Gill. | Mr. W. H. Pickering. | Prof. G. R. Thomson.
Mr. Walter Hargreaves. | Mr. Harry Rhodes. | Mr. W. Washington.

Representatives on the Council of the Institution of Mining Engineers, 1904-1905:
Mr. W. E. Garforth. | Mr. H. B. Nash. | Mr. W. H. Pickering.
Mr. J. R. R. Wilson.

The President (Mr. T. W. H. Mitchell) moved a vote of thanks to the Retiring President.

Mr. John Gerrard seconded the motion, which was unanimously approved.
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M. H. HABERSON,
THOMAS GILL,
Auditors.

July 19th, 1904.

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£696 5 1/2
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| £  s. d.       | 3 24 13 0        |                |                |

| Value of 115 copies of Narrative of Station-Outlines   |                |                |                |

| £  s. d.       | 5 15 0           |                |                |

| Value of 116 copies of Committee's Report on Safety-  |                |                |                |

| £  s. d.       | 5 16 0           |                |                |

| Value of 16 copies of Report of French Commission on  |                |                |                |

| £  s. d.       | 3 6 8 12 0       |                |                |

| Use of Explosives, at 3s...                           |                |                |                |

| £  s. d.       | 3 6 8 12 0       |                |                |

| Examin'd and found correct                          | M. H. HENDERSON, Thomas Gill. |

| £  s. d.       | 3 6 8 12 0       |                |                |
DISCUSSION OF MR. W. H. PICKERING’S "NOTES ON SYSTEMATIC TIMBERING."

Mr. I. Hodges said that, when reading Mr. Pickering’s paper, he was much struck with the fact that the number of fatal accidents was not a satisfactory basis by which to judge the safety of a mine. He had found that they had more notifications of accidents since the introduction of the Workmen’s Compensation Act, and as the collieries now get an absolutely true record of all accidents, they had much more information at their disposal than any inspector of mines could have. It was possible to have a series of fatalities in what was probably not the most serious year from the point of view of the number of accidents. At the same time, judging from the number of fatalities only, a colliery might be supposed to have had a good year, when serious accidents had left a number of men incurably crippled.

He had more reason to look into this matter, since Mr. Pickering’s paper was read, as he had gone thoroughly into the question at the pit where they had had the most serious accidents, and, although they spent a great deal on extra timber and systematic timbering, the number of fatalities had doubled. He found, however, that the number of accidents had shown a great diminution, and it was by sheer bad luck that the number of fatalities had turned out so large. He also found in the pits under his charge, that the extended use of large lids (22 inches by 10 inches by 3 inches) had led to considerable economy in the consumption of props. He thought that it was better that a small number of props should be securely set, rather than that the place should be overcrowded with much timber carelessly set. Cocker poles were useful to prevent coal from bursting off the working-face. The cost of bent bars was a heavy item, and the experiment that he had made with iron bars had not been economical.

Mr. M. H. Habershon said that he had once some time used face or bank bars, fixed as shown by Mr. Pickering in his plan,† and had found them very satisfactory, particularly in thin seams worked by coal-cutting machines. The bars, made of steel, were 5 inches wide by 1 inch thick.

† Ibid., 1902, vol. xxiv., plate III., page 100.
Mr. W. H. Pickering said he was glad to know that an effort had been made to deal with the important matter of systematic timbering—important both as regarded economy and safety. There were 69 fatalities in the Yorkshire mines-inspection district in 1903, and he believed that it would have been possible, if the miners and officials had been educated in proper methods, to have avoided a large proportion of them. The Coal-mines Regulation Act simply said that the inspector should be notified of all serious accidents, and different managers had different views as to what that meant. Mr. Hodges imagined that he was using big lids, whereas he (Mr. Pickering) could show him a mine where the lids were 45 inches long by 8 inches square. He did not describe the system shown on the plan as a model system, but only as an example of what could be done under a bad roof by systematic timbering. There was no theory or anything else about it: it was drawn from an actual working-place, and it was a method devised by a practical pitman before the phrase "systematic timbering" had ever been thought of.

Mr. Maurice Georgi read the following "Notes and Considerations on Systems having Work of an Intermittent and Irregular Character to Perform: Methods of Load-compensation":——
NOTES AND CONSIDERATIONS ON SYSTEMS HAVING WORK OF AN INTERMITTENT AND IRREGULAR CHARACTER TO PERFORM: METHODS OF LOAD-COMPENSATION.

By MAURICE GEORGI, B.Sc.

In the present notes, the writer's intention is not to treat of any subject in particular, but rather to give an elementary explanation of various questions that arise in connection with winding-engines, rolling-mills, etc., which might offer some interest to his fellow members; the more so that some of the problems that are dealt with to-day have not to his knowledge received as yet the attention which their importance would justify.

In this paper also will be found a somewhat lengthy explanation of the various compensating and starting devices for electrically-driven machinery, some of which may present a touch of novelty.

**The Maximum Winding Speed in Shafts.**

Let \( P \) be the weight of coal to be raised in a given period, \( T \); \( p \) the weight wound each time; and \( r \) the depth of the winding shaft. The time required to make one wind will be \( T \rho + P \) seconds. Let \( V_{\text{max}} \) be the maximum speed reached once all the masses are accelerated, and \( j \) the chosen coefficient of acceleration, noting, so as not to complicate the problem, that the coefficient of retardation is assumed equal to \( 1.5j \), which is as a rule the case. We therefore obtain the equation:

\[
\frac{T\rho}{P} = \frac{V_{\text{max}}}{j} + \frac{r - V_{\text{max}}^2}{1.5j} + \frac{K\rho}{V_{\text{max}}}.
\]

\( K \) is a coefficient equal to about 10, if tubs holding 10 cwts. of coal are used, and 5 if the same hold 30 to 35 cwts.

Reducing we get:

\[
5j V_{\text{max}}^2 - \rho V_{\text{max}}^2 \left( \frac{T}{\rho - K} \right) + r = 0.
\]
Methods of Load-compensation.

This equation, in \( p \) and \( V_{\text{max}} \), represents a hyperbola, whose centre is the origin of the co-ordinates and whose asymptotes are the lines:

\[
V_{\text{max}} = 0; \quad \text{and} \quad \frac{5}{6} V_{\text{max}} - p \left( \frac{T}{P - K} \right) = 0. \quad (2)
\]

We see that this hyperbola is a tangent to the lines:

\[
p = \pm \frac{4 \times 5}{6 \sqrt{T}} 
\]

as the curve can have but imaginary points between the two lines represented by this equation (Fig. 1, Plate IV.). Therefore, this value of \( p \) gives the smallest amount of coal that can possibly be raised at a time to maintain the given output, \( P \), in the given time, \( T \).

We see by the equation (1), that the speed \( V_{\text{max}} \) does not vary proportionately to the load raised each time, but along the arc of the hyperbola represented by the same equation (1). Now, the size and output of the engine must be calculated to overcome an effort proportionate to \( V_{\text{max}} \times p \), therefore it is much better to wind relatively heavy loads at slow speeds than otherwise, as thereby the diagram is better and the efficiency greatly increased. In other words, if 1000 tons must be wound in 8 hours by ropes of 3 tons from a given depth, and if the speed varied in an inverse ratio to the weight lifted per wind, to wind the same amount by ropes of 6 tons, the same power exactly would be required (the weight is double but the speed need only be half that in the former case). But this is not the case, as the engine in the first instance will have to develop all through the wind a much greater power than in the second, the steam-consumption for the same horsepower on the rope being also greater, as the work is done on a less favourable diagram.

Therefore, from a dynamical point of view, heavy lifts at slow speeds are always to be favoured. But here a limit has to be kept, as the bigger the lift the larger the size of engine, rope, drums, etc., so that the designer must choose a proper medium, compatible with a good dynamical efficiency, at the same time keeping the size and cost of the plant within reasonable limits.
METHODS OF LOAD-COMPENSATION.

This matter can be made clear by a practical example: Let us assume that we have to wind 1,000 tons in 500 minutes from 700 metres or 760 yards. To simplify things, let us take \( j \) equal to 1 and \( K \) equal to 10 (or 10 seconds allowed for decking 1 ton of coal). The maximum value of \( p \) is:

\[
p = \sqrt{\frac{20 \times 700}{6 \times 400}} = 2.4 \text{ tons.}
\]

This is the smallest amount of coal that can possibly be raised at a time, if we want our full output in the time stated.

The speed, \( V_{\text{max}} \), would then be equal to 29 metres per second. The diagram is one great peak of about 2,500 horsepower. As can easily be imagined, the working is uneconomical, although the amount of coal can be raised in the time stated.

If we now choose a \( 4\frac{1}{2} \) tons lift, the speed need be but 9.5 metres per second, this allowing 45 seconds for decking. The horsepower at full run is 700 horsepower, with a 1,300 horsepower-peak. With a 6 tons lift, we obtain 6 metres per second as the maximum speed, and, therefore, a 600 horsepower engine with a 1,200 horsepower-peak. In this case, a \( 4\frac{1}{2} \) tons lift would be very suitable. This is simply mentioned in order to explain a fact that has struck many engineers when visiting Continental mines where the winding speed is not so great as that which they are accustomed to see over here. This way of considering things is perfectly accurate, at least from a theoretical point of view.

Another factor to be considered is the inertia of the whole system. We must store up an amount of energy in the system proportionate to the total mass and to the square of \( V_{\text{max}} \); as it is difficult to recuperate effectively this energy at the end of the wind it is absolutely imperative that we should try and reduce these two factors, especially \( V_{\text{max}} \), as even should \( M \) be twice as great, with \( \frac{V_{\text{max}}^2}{2} \), the kinetic energy is only \( \frac{V_{\text{max}}^2}{4} \times M \times 2 = \frac{V_{\text{max}}^2}{2}M \) or half that with a small lift. We lose less time in accelerating, and can obtain a smaller peak-load, the efficiency being thus greatly benefited.

If we consider now the cycle of a winding-engine, we see that in starting we have first to overcome the torque due to the load,
and then to accumulate energy in the masses to put them into motion: the actual work done by the load during this period is out of proportion with the energy spent, and we obtain a peak the summit of which is reached with the full speed.

Once full speed is reached, we have but to overcome the effort due to the load: if the dead weight is balanced, this effort is constant, and the output of the engine also. When the cage is nearing the surface we have to retard, in other words cut off steam, and finish the wind by allowing the kinetic energy of the masses to drive the engine.

If we consider an ideal engine with no friction whatever, all the energy produced finds its equivalent in work done by the load: the efficiency being equal to unity. But, as a rule, we cannot recuperate all the energy of the masses (although this can be very nearly realized by an electric winding-engine, as we shall see later on), on account of the long time that it would take to retard, so part only is utilized, the other being absorbed by the brakes, counter steam, etc. Therefore, even if the friction-losses are nil, the kinetic efficiency is inferior to unity: it is equal to about 0.85. The work done by the load divided by the energy spent, being equal to 0.85, if we take a speed, $V_{max}$, of 28 metres per second. With an electric engine, as all the kinetic energy is recuperated (minus transformation-losses), the kinetic efficiency is about 0.95 under the same conditions. This is one important factor in favour of the electric winding-engine.

Compensating Devices.

Before going any further, it will be necessary to examine a most important question so far as winding-engines are concerned, namely, the compensating or equalization of the load on a motor or series of motors having work of an irregular kind to perform. The winding-engine can be taken as a type, although the same considerations apply indiscriminately to any other kind of work of this description, such as rolling-mills, tramways, etc.

If we consider the interval that elapses between the beginning of two winds, we notice that during this period (or cycle) the energy absorbed by the engine at two different moments is by no means the same. Nevertheless, each time, the total amount of power spent is constant for every cycle. If $P$ be the weight lifted, and $r$ the depth of the shaft, then $Pr$ is the work done by
METHODS OF LOAD-COMPENSATION. 41

the load: if \( \eta \) be the efficiency, then \( Pr + \eta \) represents the work done by the winding-engine itself.

If \( T \) seconds elapse between the time when we start raising the coal and the time when all is raised, the power expended or work done per unit of time would be \( Pr + \eta T \). Thus, the work done can be shown graphically by a rectangle, the base of which is equal to the total time, \( T \), and the side to \( Pr + \eta T \) (Fig. 2, Plate IV.). The surface of this rectangle is equal therefore to the sum of all the surfaces contained in the total number of cycles that occur during the time, \( T \).

Compensation amounts consequently to the following problem:—Given a work to perform that can only possibly be realized by making the engine work in an intermittent and irregular manner; find a device by means of which the demand on the generating plant is constant, whatever the instantaneous load may be (positive, negative or neutral), this demand being equal to \( Pr + \eta T \), \( \eta \) being the all-round efficiency.

Should we be able to realize this, then it is obvious that a winding-engine, rolling-mill, or other similar machine can, so far as the power-generating plant is concerned, be considered as a motor of constant output corresponding to the instantaneous values of the load equalized over the whole working period.

One method that has in some instances been successfully employed consists in placing a storage-battery in parallel with the winding-motor. The arrangement is as follows:—The dynamo feeding the winding-engine is, as we have already explained, calculated for the equalized load, it is connected directly to the winding-motor, and a storage-battery is shunted across the terminals (Fig. 3, Plate IV.).

When the call of the winding-engine for energy exceeds the constant output of the dynamo, the battery is made to discharge itself into the motor, so that the output of the dynamo and the output of the battery is equal to the output of the winding-motor. If the output of the winding-motor is equal to or greater than the output of the dynamo and the output of the battery, the dynamo is leading the battery, together with the winding-motor which has become a generator (electrical brakage of engine).

Several winding-engines are actually running on this system. Amongst others, the plant at the Thiederhall salt-mine, near
Brunswick, since August, 1899. The peak-load of this engine is equal to 200 horsepower. To drive the same, however, all that is in use is a 65 kilowatts belt-driven dynamo. The above is, let it be noted, a real winding-engine, having a Government permission to wind the men employed in the mine.

The only drawback to this arrangement is the cost of the battery, and the heavy insurance that has to be paid yearly for its upkeep.

But it has undoubted advantages, as the above figures show. For assuming that, all losses considered, a 200 horsepower motor needs a 180 kilowatts dynamo to feed it, should a direct drive be used, we would have to erect a 120 kilowatts dynamo with a 180 brake-horsepower engine, having 50 per cent. of overload-capacity. The primary plant would be cheaper perhaps (the battery disappearing), but the steam-consumption would be high, the steam-engine having to work on a very irregular diagram. The diagrams taken on the cylinder of the steam-engine at the Thiederhall salt-mine showed a line very slightly undulating, although practically horizontal in direction.

But it is only possible to use a storage-battery in conjunction with direct current: on the other hand, alternating current is coming very largely into favour, so that should we think it advisable to generalize the system, other methods must be used.

The writer would, therefore, like to bring before the members the following compensating devices, which are adaptable in every case.

(1) The Station generates Direct Current.—Let us consider an ordinary direct-current machine, whose armature-turns equal $n$, and whose field-intensity equals $F$. Running at $N$ revolutions per second, this machine will develop an electromotive force equal to $nNF10^{-8}$ volts at the brushes. This occurs either when the machine is being driven mechanically or is running as a motor: in this case we call the electromotive force "counter-electromotive force." Now if the terminals of a similar machine are connected to a net, the voltage of which is constant and equal to $E$, and the same left to run as a motor, it will develop a counter-electromotive force $(E - IR)$ equal to $nNF10^{-8}$, $I$ being the current inside the armature and $R$ the resistance of the same.

Now, supposing we strengthen the field, $F$, so that it becomes $F + f$, but keep $N$ constant, an extra voltage, $e$, equal to
\[ nN f 10^{-8} \] is induced. If \( e \) equals \( IR \), then the machine is neither receiving nor giving up current; and if \( e \) be greater than \( IR \), it is running at a higher voltage than the net, and therefore feeding the same. If the field is weakened, then the opposite phenomenon occurs: the machine has a tendency to absorb more current.

Therefore, the writer proposes to equip such a machine with a flywheel of sufficient inertia and branch it on to a net, in parallel with the motor, whose load we wish to equalize (Fig. 4, Plate IV.).

The machine is running at its maximum speed, and the motor is starting. In the leads coming from the power-house, we place an apparatus very similar in principle to an ordinary ammeter, which closes two different relay circuits if the current has a tendency to rise above or below the value fixed for the equalized load. When the machine is started, it will of course have a tendency to increase. Therefore one relay will be closed, thus bringing into action a magnetic clutch which takes out resistance from the field-circuit of the compensating machine: this operation, as we see, causes the machine to act as dynamo until the speed \( N_1 \) has been reached, so that \( E_1 \) equals \( E - IR \) equals \( nN_1 f 10^{-8} \) equals \( nNF10^{-8} \), and the flywheel by this drop in speed will have lost an amount of energy corresponding to \( \frac{1}{2} M (N^2 - N_1^2) \), which is sent into the net as electric energy. The action of the clutch ceases as soon as the overload is off. If we have an underload, then the clutch draws in resistance into the shunt-circuit, while the machine absorbs the excess-current and stores the energy produced in the flywheel.

At any moment we have, exactly as in the case of a storage-battery:—The output of the winding-motor is equal to the output of the compensor and the output of the dynamo.

The field of the motor can be regulated without difficulty or the slightest inconvenience within fairly large limits (about 50 per cent.), so that the flywheel-effect can be calculated for a drop in speed varying from 45 to 50 per cent. at least (the rest being used to meet the armature-reaction, increased ohmic losses, etc.).

Should alternating current be used instead of direct current, the problem can be solved just as readily. In this case, however, the writer proposes to use as a compensating machine an alternating-current machine of the commutator-type, receiving current both in the stator and in the rotor.
As Mr. Latour, who has given a complete theory of this type of machine, points out, the speed of a similar arrangement is equal to:

\[ N_1 = \frac{N}{p} \left( \frac{n_r - n_s}{n_r} \right) \] at no load,

\( n_r \) and \( n_s \) being the number of windings on the rotor and stator, \( N \) the frequency of the current, and \( p \) the number of poles per phase; \( n_r \) being greater than \( n_s \) (this is essential).

If we run the machine at a speed superior to \( N_1 \), it will be acting as a generator and sending current into the net.

Therefore by increasing \( n_s \) (by means of a transformer), the machine will have a tendency to run at a speed, \( N_2 \), greater than \( N_1 \), and until this latter speed is reached the machine is feeding the net.

Thus, by allowing a gradual drop of speed, from \( N_1 \) to \( 0.7 \ N_1 \), and by equipping the machine with a sufficiently heavy flywheel, the arrangement can be made to compensate any load imaginable. The inserting and disinserting of the transformer sections is done automatically, as the load varies.

We can take an elementary case to elucidate the above.

Let us assume that the diagram of a winding-engine is as shown in Fig. 6 (Plate IV.). The power used is equal to \((12,000 + 12,000) \ 24,000 \) horsepower-seconds. The equalized load is therefore \((24,000 \div 66 \ or) \ 363 \) horsepower. If \( 0.8 \) be the efficiency of transformation, the compensor will have to consist of a \((363 + 0.8 \ or) \ 450 \) horsepower machine.

Let the speed of the same vary from \( 700 \) to \( 500 \) revolutions per minute, to compensate completely the above load all that is needed is a \( 9 \) tons steel flywheel of about \( 6 \) feet diameter of gyration.

Assuming that the efficiency of the compensating set is equal to \( 0.9 \), then \( 13,000 \) horsepower-seconds are sent into the net from the same, \( 11,000 \) horsepower-seconds are coming from the dynamos in the power-house, completing thus the \( 24,000 \) horsepower-seconds needed for each wind.

The purchase cost of such an arrangement is low, as the compensating motor can run at as high a speed as can be desired, and the slip or variation in turns can be also high; as the efficiency is in no way modified by this factor.
Besides this, we have the Ilgner compensating device, the essential feature of which is a motor-generator equipped with a heavy flywheel, inserted between the winding-motor and the feeding main. Mr. Ilgner keeps the load on the latter constant by automatically varying a resistance in the rotor-circuit of the motor driving the flywheel set. This brings about a slip or decrease in speed: the flywheel therefore abandons a certain amount of energy which, added to that provided by the motor, is equal to the momentary demand of the winding-engine. In this case, however, we note that all the energy utilized by the winding-motor is transformed instead of only a portion of the same, as in the previous case, this disadvantage being more than compensated for by the fact that it is possible to start the machine economically (Ward-Leonard) and to recuperate part of the kinetic energy stored in the masses whilst retarding.

**Considerations on Starting of Electric Winding-engines, etc.**

We come now to this most important question, and will consider in detail the losses that occur owing to this fact, and how these can be in some instances reduced considerably.

The three main factors in this study are (1) the value of the masses in motion, (2) the maximum speed to be reached, and (3) the acceleration chosen.

If we use one motor connected to the mains and an ordinary starting resistance, we see that the amount of energy taken from the mains is constant during the time that the machine is being started, and proportionate to the torque required. Thus, if in starting we need a torque corresponding to 1,500 horsepower, at full speed, the energy or power taken from the main is equal to 1,500 horsepower, while the output or work done by the motor is but equal to $1,500 \times 15$ (the speed varying between zero and full). So that the losses each time are equal to $\frac{1}{2} \times 1,500 \times 15$, or half the rectangle ABCD or 11,250 horsepower-seconds (Fig. 7, Plate IV.).

Let $M$ be the masses in motion, $v$ the maximum speed, and $j$ the acceleration per second chosen.

The energy taken from the mains is used for two purposes:—

1. A portion equal to $\frac{1}{2} Mv^2$ is stored in the masses in motion (drums, ropes, pulleys, cages, etc.).
2. A portion equal to $mgv^2 + 2j\eta$ ($mg$ or weight of coal, and $\eta$ or efficiency), to cover the
work done by the load during the acceleration-period. (3) A portion equal to \((1) + (2)\) is absorbed in the starting resistance, as we have just seen. The loss is therefore:\[
\frac{1}{2}Mv^2 + mg \frac{v^2}{2\eta} \text{ with one motor; and }
\]
\[
2 \left( \frac{1}{2}Mv^2 + mg \frac{v^2}{4 \times 2\eta} \right) = \frac{1}{2} \left( \frac{3}{2}Mv^2 + mg \frac{v^2}{2\eta} \right) \text{ with 2 motors (series-parallel combination) and so on (Fig. 8, Plate IV.).}
\]

We have therefore the equation:\[
\text{Losses} = \frac{1}{2}Mv^2 + mg \frac{v^2}{2\eta}.
\]

This equation, taken as a function of \(j\) (acceleration chosen), represents a hyperbola, the asymptotes of which are parallel to the axis and the centre of which is the point:\[
j = 0, L_1 = \frac{Mv^2}{2};
\]
for \(j\) equals \(\infty\), the losses are equal to \(Mv^2 \div 2\), and as \(j\) approaches 0, the losses follow the branch of the hyperbola, becoming infinitely great as \(j\) becomes infinitely small (Fig. 9, Plate IV.).

We see, therefore, that it is in our own interest to accelerate as quickly as possible, the quicker the better, as far as efficiency is concerned. We are, however, limited in this respect by the overload-capacity of the motor. As a rule, \(j\) should never exceed 1 metre (3 feet 3 inches) per second, and it is often chosen inferior to this value, if the masses in motion and the maximum speed are considerable.

This does away with the impression which some people have that a rapid acceleration means large rheostatic losses; in reality, it is the contrary that happens.

We see besides that the losses vary with the square of \(v\) and proportionately to \(M\), and this is another very good reason to adopt slow speeds and heavy lifts. Thus, if by adopting a lift equal to \(2M\), we can reduce \(v\) to \(v \div 2\), the losses will have become \(2 \div 4\), or half as great.

In conjunction with these remarks, the question of course arises, how is it possible to reduce those losses that occur each time in starting?

Continuous current offers us in this respect invaluable advantages over alternating current, at least if we consider but the ordinary type of induction-motor.
Methods of Load-compensation.

If we use one motor, then we can excite the coils of the same to complete saturation; if \( v \) be the speed of this motor when the coils receive their normal excitation, then the maximum speed in this case will vary from 0.75 to 0.80\( v \). With a starting resistance, we reach this lower speed limit, then by bringing the field from saturation to its normal value (this occurs without loss) the speed is raised to its full value, \( v \). The rheostatic losses are but 0.56 to 0.64 of those that would occur otherwise.

By using two motors and a tandem parallel arrangement, the losses are reduced exactly by one-half.

By using a storage buffer-battery (Zollern II.), the same can be subdivided into a certain number of sections, let us say 5. By branching the motors on to one after another of these subdivisions in succession, the losses that will then occur will equal \( 5 \div 25 \) or \( 1 \div 5 \) of those should no special arrangement be used. This method has some disadvantages, which lie in the fact that the terminals of the battery must be inverted at each wind, otherwise the first cells, being longer in circuit, would be sooner exhausted than the last ones. So that by numbering the sections, counting from left to right, 1, 2, 3, 4 and 5, and by starting the machine in the above order, for the next wind we shall have to use the sections in the succession 5, 4, 3, 2 and 1. It is necessary, therefore, to equip the arrangement with a complicated commutator to this effect.

Another method that could very well be used would consist in, let us say, an arrangement of two double-wound machines, each having two commutators.

If \( M \) is the winding motor, one of its terminals is connected to the net, and the other, by means of the switches 1, 2 and 3, to the different sections of the system. Let us suppose that we have 500 volts between the outer wires (1 and 5), between 5 and 4 we have 125 volts, and between 4 and 3, the same (Fig 5, Plate IV.). Consequently, by closing the switches in succession we increase the voltage by 125 volts each time, and the speed in the same proportion. The compensation of the load occurs (as before) by acting on the field. The losses are a fourth of those that would occur should ordinary arrangements be used. We need by no means invert the terminals as in the battery, and we can run at four different speeds by leaving the motor on one or more of the subdivisions.
If we use alternating current, the case does not look very brilliant, at least not for the present. With three-phase induction-motors we can by means of a cascade arrangement reduce the losses in starting by 50 per cent.: but that is all: anything further is not to be looked forward to with this type of motor.

If we use a multiphase motor with commutator and brushes, we could start without loss whatever (transformer), but for large slow-speed motors this type will be too costly (thus for 25 periods, 1,000 horsepower-output, 60 revolutions, the commutator would be about 14 feet in diameter and receive 2,500 segments). For a higher speed (geared arrangement), the method is not only possible but offers a very great opening to this type of machine.

In all the foregoing considerations it has been implicitly assumed that the dead weights are perfectly balanced, which implies the use of a balance-rope should no special type of winding be used. Should this not be the case, the problem assumes a different aspect, as the losses can then become much greater (50 per cent. and more) than before, according to the inequalities in the dead weights on each side in starting. But as it is always possible in any case to use a balance-rope, we can consider the discarding of such as a personal fancy and assume that, at least as far as an electric engine is concerned, the latter is always present.

There are certain other methods, such as the Ward-Leonard, that do away with a starting rheostat. This method, however, needs a conversion of electric energy at a constant voltage to electric energy at a variable voltage, this being brought about by means of a motor-generator set.

Now, in the Ilgner process this set is essential, so that it at once occurs to us to use the Ward-Leonard process instead of a starting resistance. We can thus compensate in a certain measure the conversion-loss.

We will therefore now examine the question, What arrangement is to be preferred from a purely economical point of view—one using a starting resistance or a voltage-converter?

To answer this point fully, we will assume that we have to raise \( P \) tons of coal from a depth equal to \( r \) metres; let \( p \) be the net weight of coal raised each wind.
Winding-engine with one Motor and Starting Resistance (Preuss- sen II. Type).—The number of winds to be made is equal to \( P + p \).

The total rheostatic losses that occur are equal to:

\[
\left( \frac{1}{2} \frac{M v^2}{\eta} + \frac{p v^2}{2 \eta_1} \right) \frac{P}{\mu} 
\]

\( M \) being the total mass in motion at each wind, \( \eta \) the efficiency of the armature, and \( \eta_1 \) of the motor and winding-engine. Let it be noted that \( v \) is given by equation (1).

The losses in the motor and winding-engine are:

\[
\frac{P_r}{\eta_1} - P_r. 
\]

For acceleration-loss (kinetic energy that cannot be recuperated), we take:

\[
0.2 \frac{M v^2 P}{2 \mu}. 
\]

With an Ilgner arrangement, these losses are equal to:

\[
\frac{P_r}{\eta_1 \eta_3} - P_r \quad \ldots \quad \ldots \quad \ldots \quad (\beta)
\]

\( \eta_1 \) being the efficiency of the motor and the winding-engine, and \( \eta_3 \) the efficiency of the compensating set.

Let us consider the function \( f(v) = (a) - (\beta) \).

\[
y = \frac{1}{2} v^2 \left( \frac{M}{\eta} + 0.2 M + \frac{p}{\eta_1} \right) \frac{P}{\mu} - P_r \left( \frac{1}{\eta_1 \eta_3} - \frac{1}{\eta_1} \right). 
\]

This equation in \( v \) represents a parabola (Fig. 10, Plate IV.). The summit of this curve being in \( A \left( v, - P_r \left( \frac{1}{\eta_1 \eta_3} - \frac{1}{\eta_1} \right) \right) \). If \( y \) is greater than \( o \), then an Ilgner set is more efficient. If \( y \) is less than \( o \), a rheostat. If \( y \) equals \( o \), then both are equivalent. In this case (\( y \) equals \( o \)):

\[
v = \sqrt{v \left( \frac{1}{\eta_1 \eta_3} - \frac{1}{\eta_1} \right) - \frac{1}{2 \mu} \left( \frac{M}{\eta} + 0.2 M + \frac{p}{\eta_1} \right)}. 
\]

Thus we can assume, \( \eta_1 \) equals 0.72, \( \eta_3 \) equals 0.75 (allowing for a variable extra slip of 0 to 10 per cent.). Now, with a properly-designed engine, the writer has found that the ratio between the total masses in motion and the net load varies between 10 and 15, according to the depth, and if a Køepe or cylindrical drum, etc., be in use, a direct-current machine having a small momentum of inertia gives a lower value than an induction-motor, all things otherwise being equal.
We can therefore assume that $Mg + p = 15$ or $M = 15p + g$, therefore:

$$v = \sqrt{\frac{r}{2} \left( \frac{15}{\eta g} \times \frac{0.2 \times 15}{g} + \frac{1}{\rho_h} \right)}.$$

In the above case, we see that, if we do not want to have a starting torque more than 80 per cent. greater than the normal one, the acceleration $j$ must be taken equal to $0.8g + 15\eta$, as $\eta$ equals 0.8, $j$ equals $g + 15$ equals 0.7 metre per second in round figures, and $g$ equals 9.81 metres per second.

We can now, by giving to $r$ different values from 100 metres onward, obtain different values of $v$, which will correspond to the limit at which both systems are equivalent. The following table refers to this.

<table>
<thead>
<tr>
<th>Depth, $r$, Metres</th>
<th>Velocity, $v$, Metres per second</th>
<th>Depth, $r$, Metres</th>
<th>Velocity, $v$, Metres per second</th>
<th>Depth, $r$, Metres</th>
<th>Velocity, $v$, Metres per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>110</td>
<td>4.86</td>
<td></td>
<td>700</td>
<td>770</td>
</tr>
<tr>
<td>200</td>
<td>220</td>
<td>6.72</td>
<td></td>
<td>800</td>
<td>880</td>
</tr>
<tr>
<td>300</td>
<td>330</td>
<td>8.45</td>
<td></td>
<td>1,000</td>
<td>1,100</td>
</tr>
</tbody>
</table>

All these points lie on a curve whose equation is $v^2 = 0.255 r$. It is easy to see that the same is a parabola (Fig. 11, Plate IV.), whose focus is the point ($v$ equals 0, $r_1$ equals 0.0587). This parabola divides the plane into two regions; we call positive, the portion inside the parabola; negative, the one outside the same. Therefore, for a point in the positive region it is more advantageous to use a starting resistance, and for one in the negative an Ilgner arrangement.

Let it be noted that, if the standard output of fuel per hour is known, $v$ is a fixed quantity, so that in each case we obtain a definite position for the point in question. There is nothing arbitrary about it.

Of course, should we prefer to use a combination of two motors, these figures would be increased, but as a rule with a direct drive (three-phase) one motor is generally used, so that it is not always correct to assume that so far as general efficiency is concerned, the Ilgner process must have an advantage over the other; this is only the case if the speed exceeds a certain limit.
But, apart from trying to reduce as much as possible losses due to starting, we must not forget that another point is quite as (if not more) important, namely, that of keeping the load as constant as possible on the steam-engines driving the generating plant.

Should we not think it advisable to work on similar lines, then it is obvious that the steam-engines and generators will have to be so calculated as to be able to take up all overloads regularly and without any undue strain (considering just now the fact that the winding-engine is the only load on the steam-engine).

The flywheels will have to be of a considerable moment of inertia, for the following reason:—When the winding-engine is at rest, the engines are running with a very reduced steam-admission, when the overload is suddenly placed on the same, it is evident that before the regulator can have had time to operate properly a certain number of piston-strokes will have been made, there will be a certain drop in speed, and the flywheels will have to be calculated in such a manner that, in conjunction with the more or less sensitive regulators, this drop should be reduced to a minimum: in other words, they must be able to take up the load while the steam-engines are regulating.

We can easily imagine that the steam-consumption of even a good engine in these conditions will be anything but favourable. It is, however, only right to say that the matter presents quite a different aspect if we have two or three winding-engines running at once and a steady motor-load of fans, pumps, etc., besides. This is the more general case that we have to consider.

If we now erect a single, or at the most two, generating units sufficient to feed all the machines together, the arrangement will no doubt work in a satisfactory manner.

For that it is advisable that the peak-load of a winding-engine should not exceed, let us say, 40 per cent. of the total capacity of the engines.

Let us suppose that we have three winding-engines having each a 1,500 horsepower-peak and 800 horsepower normal load, 800 horsepower in fans, pumps, etc.

We choose either one 3,000 kilowatts set or two 1,500 kilowatts sets to deal with this load. At a given moment, two winding-engines are absorbing 1,600 horsepower, and the fans, pumps, etc.,
METHODS OF LOAD-COMPENSATION.

800 horsepower. If we now start the third engine, the load on the engines will become equal to 3,900 horsepower, instead of 2,400 horsepower as immediately before. The engines can easily take up the overload.

If such a large unit absorbs, let us assume, 5 kilogrammes of steam per indicated horsepower, running at constant admission, experiments have proved that under the above conditions the consumption will increase to 6 or 6\(\frac{1}{2}\) kilogrammes, or 20 to 30 per cent. Therefore, technically speaking, the arrangement is possible if we have a large colliery to deal with, and if the question of first cost is an essential factor.

If an Ilgner arrangement be now used, the first item that disappears is the starting resistance: this fact alone is an immense advantage (efficiency apart), for a really reliable and simple starting arrangement for large motors working in an intermittent manner has yet to be designed. The starter is the weak part of the direct method, and the portion of the installation that gives the most trouble, in conjunction, of course, with the switch for the main current.

By driving our electric winding-engines by the indirect method, a load of constant magnitude is placed on the power-station, the generating-plant is smaller and works much more efficiently.

Thus the three winding-engines examined previously could be run with three 450 to 500 horsepower sets, giving a 1,350 horsepower total load. Instead of a 3,000 kilowatts set, all that would be needed is a 2,000 kilowatts set. The price of the primary station will thus be reduced as well as the coal-bill, the engines running under better conditions.

The only drawback offered by the Ilgner system is its relatively high cost, if we compare it with the ordinary type of twin cylinder winding-engine generally in use. The costs are 25 to 30 per cent. greater, but are about the same if we take a tandem compound twin winding-engine, which is undoubtedly the best type of steam winding-engine.

The question of first cost intimidates in a large measure most people, especially when they have but one or two winding-engines to erect, and need very little power besides that. The pits, and consequently the machinery, are all very close together, so that apparently it would seem as if but very minor advantages would be reaped should we electrify the whole installation, at least so far as economy on paper is concerned.
To meet the above objection, which can easily be repudiated, the writer would propose the following solution, which overcomes the difficulty in both ways.

Assuming, to make everything quite clear, that we have, let us say, two winding-engines to erect, the distance between the same being about 1,800 to 2,400 feet, which means from 900 to 1,200 feet from the power-station placed midway between the two pits.

As a rule, in British pits, the winding-engines are at work during one shift only (day-shift), which means from 8 to 10 hours a day: the other machinery in the mine, such as fans, pumps, etc., runs the whole day and night through. Therefore, a priori, it is advisable, in any case, to have one set of engines to feed the winding-plant and another for the fans, pumps, etc.: this to ensure a good efficiency, the engines working at their most favourable grade of admission.

What the writer proposes doing would be to use in any case direct current to drive the winding-engines, even if three-phase current is used for the other plant: further, one dynamo per winding-engine. These dynamos can either be driven by separate engines or by one only. The regulator of this engine is arranged so that the steam-admission into the cylinders remains constant, whatever the speed of the engine may be between the two speed-limits, $I_1$ and $I_2$. The thrust or effort is therefore constant during this interval, or, to fix a figure, between 350 and 315 revolutions per minute. Should now the speed increase above 350 revolutions, then the regulator cuts off steam and keeps the engine at the superior speed-limit, preventing it thus from racing. It can also be made to admit more steam if the speed should have a tendency to drop below $I_2$ (315 revolutions).

On the shaft of this steam-engine, a steel flywheel, similar in every respect to those used with the Ilgner sets, is fixed. If such a flywheel weighs 30 tons, and the peripheral speed be 270 feet per second, then by dropping from 350 to 315 revolutions, the kinetic energy abandoned will equal 24,000 horsepower-seconds, which add themselves to the constant output that the steam-engine is giving during this drop in speed.

Let us take an example:—We have to raise 1,000 tons in 8 hours from a pit 760 yards deep, the net weight raised each time being equal to 4½ tons. If the efficiency of the winding-engine is
METHODS OF LOAD-COMPENSATION.

0.8, that of the motor 0.9, transmission-line and dynamo 0.85, then the number of horsepower-seconds to be produced by the steam-engine will be equal to 72,600 brake-horsepower, allowing 4,800 horsepower-seconds for loss in the bearings supporting the flywheel. As the interval between 2 winds is equal to 120 seconds, the equalized effort is therefore equal to 600 horsepower. The weight of the flywheel is 36 tons.

When the winding-engine is at work, we obtain a peak-load of about 1,800 horsepower, which drops down to about 1,000 horsepower during the run. The steam-engine, owing to the steam-admission being constant, works at a constant effort or thrust. Should the load be superior to this value (600 horsepower), the steam-engine will drop in speed, and in doing so the flywheel will give up an amount of energy, which, added to the output of the engine, meets automatically any instantaneous or momentary overload of really considerable magnitude.

When the winding-engine is at rest, then the steam-engine will be gathering up speed, energy being thus stored in the flywheel. Should there be a longer period of rest, such as an unforeseen stoppage, for instance, then once the higher speed-limit of the engine is reached, the steam is automatically shut off, keeping the engine running at a constant speed.

Let us note once for all that the governing of the winding-engine is in everything identical to that used with an Ilgner gear, this method being known as the Ward-Leonard.

The purchase-costs of such a plant are unquestionably very low; they will in all probability turn out inferior to that of an ordinary steam winding-engine, and will be much below that of a tandem compound winding-engine. In the above case, that is to say, the complete winding-plant, including boiler, steam-piping, steam-engine, dynamo, winding-engine and motor, cabling, switch-board, and all accessories, would entail an expenditure of £8,000.

A complete steam winding-plant of that capacity with boilers, etc., could hardly be had for that price.

So far as steam-consumption is concerned, as we can use superheat and condense, the coal-consumption would be equal to 4½ tons for 1,000 tons raised, assuming that 1 pound of coal produces 7½ pounds of steam. The writer would be prepared to guarantee 6½ tons any day and under any penalty. Of course, should we wind from half the depth or 380 yards, then all that is needed is a 310 horsepower plant; the costs would be
METHODS OF LOAD-COMPENSATION.

much reduced, and the coal-consumption would become equal to 2·6 tons, as the thermal efficiency of a 310 horsepower engine is, as a rule, worse than that of a 620 horsepower. With the Ilgner system these coal-consumption figures must be increased by 20 per cent. to meet the losses in the motor-generator.

It must also not be forgotten that the application of the above system is not so general as the Ilgner process, which is adaptable under any circumstances whatever.

RECUPERATION OF THE ENERGY STORED IN THE MOVING MASS.

Let us consider all the moving parts of a winding-engine, such as drums, ropes, cages, motor, etc. Let \( M \) be the mass of the same reduced to a common radius of gyration, that of the drums for instance.

If \( v \) be the speed per second during the full run, then to bring this system to rest we must absorb in some way or other \( \frac{1}{2} M v^2 \) kilogrammetres. In practice, part of this is used to finish the wind and part absorbed in the brakes. Not to be too wasteful, we limit this latter quantity to 20 per cent. of \( \frac{1}{2} M v^2 \).

The work done by the load, \( j \) being the chosen retardation, and \( P \) being the weight of coal, is \( P v^2 + \eta^2 j \).

Let \( \eta \) be the efficiency of the mechanical parts, etc., then we have the equation:

\[
\frac{P v^2}{\eta^2 j} = 0.8 M v^2: \quad \text{and} \quad j = \frac{P}{0.8 M \eta}.
\]

If we note that \( P = \frac{m}{M} \) and \( g = \frac{1}{\lambda} g \); if \( \lambda = \frac{M}{m} \), then:

\[
j = \frac{g}{\lambda 0.8 \eta}.
\]

The time, \( t \), taken to retard is \( v + j \).

Thus, if \( M \) equals 6,000, \( P \) equals 4,500, \( v \) equals 20 metres per second, \( \lambda \) equals 13·4, and \( t \) equals 16 seconds. This is a very long time, and should we wish to retard faster, it must be at the cost of the general efficiency (absorbing a greater percentage of the kinetic energy).

We see, therefore, how great the advantage would be, if we could retard quickly and without any loss. This can be done with an electric winding-engine, in the following manner:—

Let us consider the winding-engine running at full speed, and the winding-motor running with an electromotive force equal to
about 97 per cent. of that developed by the dynamo. If we weaken the field of the dynamo by drawing back the controller-lever, the following phenomenon occurs:—The winding-motor is running at a higher voltage than the dynamo, and is being driven by the masses in motion: a current therefore flows from the motor to the dynamo, and all the heavier, the quicker we draw back our controller-lever. The driving motor has become a generator, the driving engine of which is the kinetic energy of the masses, the energy recuperated is stored in the flywheel, as, while the electric brakage is going on, the dynamo is acting as a motor.

The losses incurred are those that take place inside the electrical machinery, and are constant.

The advantage of this arrangement is that we can retard as quickly as we like without fear of a bad efficiency, so we gain time and can make our wind in a shorter period.

At Zollern II., the coefficient \( j \) equals 2.5 metres per second, and here it is limited on account of the fear of the rope slipping, so that we can retard in 8 instead of 16 seconds. This is a very considerable gain.

The intensity of the brakage-current is easy to determine. The run is equal to 80 metres, the work done is \((80 \times 4,500 \div 0.8 \text{ or} 450,000 \text{ kilogrammetres.} \) In the masses are stored \((6,000 \times 400 \div 2 \text{ or} 1,200,000 \text{ kilogrammetres.} \)

Let 0.8 be the efficiency of conversion, then \((750,000 \times 0.8 \div 75 \text{ or} 8,000 \text{ horsepower-seconds are working on the flywheel shaft.} \)

As the time taken is equal to 8 seconds, the current in the armature is equal to 3,200 amperes at 500 volts.

**A Winding-engine without a Balance-rope**

(Fig. 12, Plate IV.)

Let \( P \) be the net weight of coal raised at each wind, and \( p \) the friction-coefficient of the pit, engine, etc., which the writer considers as a fraction of \( P \) (\( p \) equals \( \mu P \)). Let \( r \) be the depth of the pit, and \( w \) the weight of the rope per unit of length.

In starting, the torque or effort to be overcome is composed of

1. the static torque \([P(1 + \mu) + rw]R\);  
2. the torque necessary to overcome the pressure due to acceleration—the effort at a given moment, \( t \), corresponding to:

\[
\frac{d^2 M v^2}{dt^2} \text{—horsepower, or a torque } 716 \times \frac{d^2 M v^2}{dt^2} \times \frac{1}{n} ; \]

\( n \) being the speed of the drums.
**METHODS OF LOAD-COMPENSATION.**

**Torque during Acceleration.**—During the acceleration-period, which lasts \( t_1 \) seconds, the run of the rope after \( t \) seconds \((t_1 \text{ is greater than } t \text{ and } t \text{ is greater than } 0)\) is equal to \( \frac{1}{2}jt^2 \), \( j \) being the acceleration; therefore the torque at a given moment will be:

\[
y = [P(1 + \mu) + (r - jt^2)v]R + (2).
\]

This is the equation of a parabola.

To obtain the amount of power required, we must calculate:

\[
\left( \int_{t=t_1}^{t=0} \left[ P(1 + \mu) + (r - jt^2)v \right] \frac{jt \times 60}{2\pi \times 716} + \frac{1}{2}Mv^2 \right).
\]

This integral is equal to:

\[
\left( P(1 + \mu) + (r - j_1t_1^2)v \right) \frac{j_1^2 \times 60}{4\pi \times 716} + \frac{j_1^2t_1^4w \times 60}{8\pi \times 716} + \frac{1}{2}Mv^2.
\]

**Run at Full Speed.**—During the run at full speed, the torque, \( \theta \) after \( t \) seconds is equal to:

\[
\theta = [P(1 + \mu) + (r - j_1^2t - 2tv)v]R.
\]

The amount of power required is equal to:

\[
\int_{t=t}^{t=\theta} \frac{R\eta}{716} dt = \left[ P(1 + \mu)t_2 + (rt_2 - j_1^2t_2 - t_2^2v)w \right] \frac{R \times \eta}{716}.
\]

**Retardation.**—The kinetic energy contained in the masses is used for two purposes (1) to drive the load, enabling it thus to accomplish the journey; and (2) the surplus is sent back into the net in the shape of electric energy. The power needed by the engine during the retardation being at a moment \( t \) equal to:

\[
\frac{R \times \eta}{716} \left( P(1 + \mu) + (r - j_1^2 - 2t_2v - j_1t^2)w \right) dt.
\]

\( j_1 \) and \( n_1 \) being the retardation-coefficient and the speed of the drums at a given moment, respectively.

The total power needed during the retardation-period lasting \( t_3 \) seconds, if we call equation (5) \( \theta_1 \), is:

\[
\int_{t=t_3}^{t=0} \theta_1 dt.
\]

Solving we get:

\[
A = \left[ P(1 + \mu) + (r - j_1^2 - 2t_2v - j_1t^2)w \right] \frac{j_1^2t_3^4 \times 60}{4\pi \times 716} + \frac{j_1^2t_3^4 \times 60w}{8\pi \times 716}.
\]

If \( \eta \) is the transformation-efficiency, then the actual quantity of energy disposable in the system is equal to:

\[
\left( \frac{1}{2}Mv^2 - A \right) \eta.
\]
Let us take a numerical example:—Let $P$ be 4,000 kilograms; $\varrho$, 0.2; $w$, 10 kilograms per metre; $r$, 15 metres per second; $j_1$, 1; $j_2$, 2; $M$, 5,000; $n$, 60 revolutions per minute; $R$, 2.4; $t_1$, 15 seconds; $t_2$, 29 seconds; and $t_3$, 7.5 seconds.

Accelera-tion-period.—$(4,000 \times 1.2 + 6,000) \frac{225 \times 60}{12.6 \times 716} = 22,020$ horsepower-seconds.

Run at Full Speed.—$(10,800 \times 29 - 2,250 \times 28 - 841 \times 150) \times 201 = 24,200$ horsepower-seconds.

Retardation.—$(4,800 + (6,000 - 2,250 - 8,700 - 1,125) \times 0.74 + 3,158 \times 60 \times 10 \frac{25.2 \times 716}{2 \times 75} + 4 = \text{minus 520 horsepower-seconds, and minus 7,500 equals minus 8,020 horsepower-seconds. Therefore, (8,020 \times 0.8 or) 6,416 horsepower-seconds are effectively recuperated. The total wind needs, consequently (22,020 + 24,200 - 6,416 or), 39,884 horsepower-seconds.}

As a point of comparison, the writer assumes that we use a balance-rope, all figures remaining otherwise the same.

During the acceleration-period, the power needed at each wind is equal to $(980 \times 15 \text{ or}) 14,700$ horsepower-seconds. During the run at full speed, the power required is $(960 \times 29 \text{ or}) 27,840$ horsepower-seconds. And in retarding, the load absorbs to finish the wind $3,600$ horsepower-seconds. There remain $(7,500 - 3,600 \text{ or}) 3,900$ horsepower-seconds disposable on the winding-engine shaft, or 3,100 on the motor-generator. The total power needed is therefore $(14,700 + 27,840 - 3,100 \text{ or}) 39,440$ horsepower-seconds.

This is but slightly less than with an engine without balance-rope, the difference being about 1 per cent. This is easily to be accounted for by the fact that a greater quantity of power is recuperated without a balance than with one.

We see, therefore, that from a theoretical standpoint it is immaterial whether we use a balance-rope or not, as the power-station and motor-generator remain identically the same (the 1 per cent. difference being of no account). The driving motor for the
METHODS OF LOAD-COMPENSATION.

winding-engine has to be considerably larger, as the initial torque in starting is 50 per cent. greater than if we use a balance-rope. That is the only objection to be raised from a practical standpoint.

Should we now use a starting resistance with one motor on the winding-engine, it is easy to see that the case is hopeless from an economical point of view.

We lose in the starting resistance 22,020 horsepower-seconds, and cannot recuperate any energy at all in retarding. We cut off, however, sooner than before, to allow a longer retardation run, so that altogether the amount of energy absorbed per wind is equal to 62,500 horsepower-seconds in round figures, or 20 per cent. more than if a balance-rope were used, the consumption in this case being about 52,000 horsepower-seconds.

To sum up the situation, we have drawn up Table I. upon which the following remarks can be made:—The steam-consumption figures for the different types of steam winding-engines refer to the best of their kind, of first-class make with all modern improvements. The tandem compound engine is of the type used at the Scharnhorst pit, near Dortmund. This engine alone for 1,000 tons in 10 hours from 800 metres costs with seat over £8,500; so that one for 2,000 tons with boilers, piping, economizers, etc., would cost at least £14,000. The coal-consumption of such an engine is low, as compared with the steam winding-engine generally in use.

The figures given for a twin-cylinder engine are also favourable, and ought to be reached with an engine of good build and design.

It is, on the other hand, very easy to calculate the steam-consumption of an electric winding-engine, as innumerable tests have shown what a good modern steam-engine working under favourable conditions can give as regards steam-consumption. A triple-expansion engine or steam-turbine, with a moderate superheat, can easily be made to reach the figure of 12 pounds per brake-horsepower. This would give about 24 pounds per horsepower on the rope with an Ilgner arrangement, or 19 pounds if the author’s device be used.

We can thus economize as much as 8,300 tons of coal a year or £2,500, if coal at 6s. a ton is used (working in both cases, non-condensing and without superheat).

The cost of an electric winding-plant complete, that is to say with generating-plant, boilers, steam-pipes, cables, compensating
### Table I.—Winding-engine for 2,000 Tons in 8 Hours from 600 Yards, or 600,000 Tons a Year.

<table>
<thead>
<tr>
<th>Nature of Winding-plant used</th>
<th>Steam-pressure</th>
<th>Coal-consumption per 30 Days, allowing 6 Pounds of Steam per Pound of Coal and 30 per cent for Condensation in Pipes, Banking Fires, etc.</th>
<th>Cost of Purchase and Erection, including Seat, Engine and Accessories, Boilers, Economizers, Superheaters, Condensation-plant, Piping, Generating-dynamics and Engines, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Condening</td>
<td>Non-condensing</td>
<td>Condening</td>
</tr>
<tr>
<td></td>
<td>without</td>
<td>without</td>
<td>with</td>
</tr>
<tr>
<td></td>
<td>Superheat</td>
<td>Superheat</td>
<td>Superheat</td>
</tr>
<tr>
<td>Horizontal tandem compound four-cylinder engine</td>
<td>180</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>Twin-cylinder winding-engine</td>
<td>120</td>
<td>75</td>
<td>95</td>
</tr>
<tr>
<td>Electric winding-engine: Higer system</td>
<td>180</td>
<td>28</td>
<td>33(\frac{1}{2})</td>
</tr>
<tr>
<td>Electric winding-engine: Georgi system</td>
<td>180</td>
<td>22</td>
<td>27</td>
</tr>
</tbody>
</table>

Note.—Should no balance-rope be used, the steam-consumption of the steam winding-engines will increase 10 to 15 per cent., while that of the electric engines remains unaltered.
set, winding-motor, and all accessories would be £14,800. A steam winding-engine with seat-accessories, boilers, etc., would hardly cost less than £11,000. Therefore, as a matter of fact, the difference in price could be wiped off in the first year and the whole machine paid for at the end of 6 years, without the mine-owner having had to devote a penny for depreciation or interest, purely out of the saving brought about each year. The question of first cost is quite subsidiary, for, in the above case, after 6 years the electric winding-engine brings in an income of £2,000 a year and figures at Is. in the books, the comparison being drawn with a good steam winding-engine.

Mr. M. H. Habershon said that, in the table attached to Mr. Georgi's paper, the steam-consumption per horsepower with the Ilgner system was stated to be much lower than the figure used by Mr. Hird in his paper on "The Electrical Driving of Winding-gears."* He believed that at that time the system was hardly in full operation, and he should like to know whether results had been obtained in the interval which would justify the lower figure now given of the steam-consumption.

Prof. G. R. Thompson suggested that the system of equalizing the load of the winding-engine might be carried somewhat further with the steam-engine.

Mr. W. E. Garforth (Normanton) said that Messrs. Pope and Pearson had recently made a careful test and raised 1,272 tons from a depth of 1,020 feet in one shift, with a boiler-consumption of 6 tons 12 cwt.

Mr. W. H. Pickering asked what was the difference in the matter of depreciation between an electric and a steam winding-engine.

The President (Mr. T. W. H. Mitchell) pointed out that Mr. Georgi approved of the use of direct current for winding-engines, but he had always understood that multiphase current was the cheapest for that work.

Mr. Georgi explained that the steam-consumption in an electric winding-engine depended upon the primary plant, and

---

upon the consumption per kilowatt. The consumption of coal in raising 1,272 tons would have been from 2 to 2½ tons with an electric winder; provided that a modern engine, with a low steam-consumption were used: Messrs. Carels & van den Kerchove guarantee a consumption not exceeding 8.8 pounds of steam per indicated horsepower. The depreciation of steam and electric plant was practically the same, as the mechanical portions were almost identical.

Mr. I. Hodges stated that he had doubled his output for a less consumption of coal by the winding-engine. He was convinced, however, that electric winders would be the winding-engines of the future. Engineers were convinced theoretically, and they only needed to be convinced practically.
Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Tb illustrate M. M. Georgis Notes and Illustrations of Systems etc.
MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING.
HELD AT THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD,
NOVEMBER 8TH, 1904.

Mr. T. W. H. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:

MEMBERS—
Mr. Horace Sanderson, Mechanical Engineer, Boyne Engine-works, Leeds.
Mr. Robert Depledge, Engineer Surveyor, 19, Salisbury Avenue, Armley, Leeds.
Mr. J. W. Peel, Colliery Manager, Brancepeth House, Thornhill, near Dewsbury.
Mr. William Herbert Lewis, Assistant Mechanical Engineer, Beech Grove, Whitwood, Normanton, Yorkshire.
Mr. Matthew Charlton, Mechanical Engineer, Poplar Cottage, Whitwood, Normanton, Yorkshire.
Mr. MosesHorson, Colliery Manager, Beech Grove, Whitwood, Normanton, Yorkshire.
Mr. Matthew Charlton, Mechanical Engineer, Poplar Cottage, Whitwood, Normanton, Yorkshire.
Mr. Moses Horson, Colliery Manager, Beech Grove, Whitwood, Normanton, Yorkshire.
Mr. Harold W. Seymour, Engineer and Chemist at Bye-product Plant, Rotherham Main Colliery, Rotherham.
Mr. Robert Watkin, Colliery Manager, Dearne Valley Colliery, Little Houghton, near Barnsley.
Mr. Simon Stassart, Ingénieur Principal au Corps des Mines, École des Mines, Mons, Belgium.
Mr. John Fletcher Archer, Mining Engineer, 32, Church Street, Sheffield.

ASSOCIATE MEMBER—
Mr. A. J. Creswick, Gatefield, Sheffield.
ASSOCIATE—
Mr. George Walker, Under-manager, Hickleton Main Colliery, near Rotherham.

STUDENTS—
Mr. Charles Henry Hobson, Pupil to Mining Engineer, Beech Grove, Whitwood, Normanton, Yorkshire.
Mr. Francis Whitworth Wright, Pupil to Mining Engineer, Whitwood Collieries, Normanton, Yorkshire.
Mr. Augustus John Kennedy, Pupil to Mining Engineer, Whitwood Collieries, Normanton, Yorkshire.

The President (Mr. T. W. H. Mitchell) delivered the following address:—
I thank you for having elected me to the position of President of the Midland Institute of Mining, Civil and Mechanical Engineers, and I greatly appreciate the honour that you have conferred upon me. It seems a happy climax to the many years that my family have been connected with the management of the Institute. It is, however, with mixed feelings that I look back on the many changes that have taken place in the personnel of the Institute since my father was elected secretary in 1879; so many old and personal friends have passed away, who would have appreciated the honour you have done to their friend's son in electing him to the chair.

At the beginning of my secretarial duties in 1890, the number of members, including honorary members, was 174, and the output of minerals for the year ending December 31st, 1889, in the Yorkshire mines-inspection district was 22,457,749 tons. At the end of our last financial year, the number of members was 305, and the output for the year ending December 31st, 1903, was 29,168,792 tons. So many tables of statistics are put before you by the press, that I hardly think it worth while to wrestle with these at the present time; but it seems to me that this Institute must have been doing good work and creating an interest in acquiring information, when it is found from the above figures that at the present time there is one member for every 96,000 tons of output, while in 1890 there was one member for every 129,000 tons of output. I do not find that there is a corresponding increase in the interest, so far as contributing to the deliberations of the members of the Institute is concerned, as I notice that at the date of the Annual Meeting in 1890 twelve papers were reported as having been read before the Institute during the preceding year, against five mentioned in the last report, although the Council in their annual reports refer to the scarcity every year, and frequent reminders are sent out to the members during the year.
Past presidents, in their addresses, have touched so ably on the various difficulties and troubles met with by mining engineers that there does not appear to be very much left for me with which to deal. This applies more especially to a very excellent address lately delivered by our last President to the Institute, in which mining was brought up to the present day and the present was very ably contrasted with the past.

With regard to the future, I find it most interesting to read the reports issued by the present Royal Commission on Coal-supplies, and to consider the different opinions given with respect to the continuation of the British coal-industry, and the best methods of dealing with it now and in the future: but when all is said and done, it appears to me that the subject is all reduced to a question of £ s. d. The better seams have been, and always will be, worked first. Nobody, in my opinion, can appreciate to the full the mineral wealth of this country at the present time, because each succeeding exhaustion of a good seam appears to produce extra exertion on the part of the workers and users for dealing with the next best seam, most probably found at a greater depth. This all points to the fact that mining institutes must and should increase in value, if members will only give expression to their experience in meeting and dealing with the difficulties caused by the working of the deeper and lower seams, which, probably, require a large increase in the capital-expenditure for their development.

In connection with these deeper, and probably inferior seams, the risk of the worker appears to be very much greater than in the past, and the question of the terms of the lease and the system of making such a lease should be very carefully considered. The probable variation of the section and the quality of these other seams renders it necessary that the mining engineer should safeguard himself by obtaining reasonable clauses for enabling a reconsideration of the terms of his lease. I especially refer to this question, as I find that much capital is laid idle by the payment of long minimum rents in such a way that collieries have not the full opportunities which they should have of being developed. When dealing with these lower and worse seams, if safeguards are not made to keep down minimum rents and standing charges, the difficulty of working these seams will be very considerably enhanced.
Another point in regard to this question, is the unsatisfactory method of arranging terms with the men for working the coal. At the present time, there is very little inducement for the development of other seams, as the case generally is, that a hard-and-fast price-list is made, which more often than not is extremely in favour of the men, and is practically unalterable except by means of strikes or lock-outs. This, in my opinion, could be avoided if temporary arrangements, of fairly long duration, could be made. Such arrangements could be revised, at stated times, on the basis of the experience gained during the period of trial.

In connection with the Royal Commission on Coal-supplies, it is interesting to read the opinions given as to the causes of gob-fires. Some engineers state that depth is not a cause, and others that it is; others allege that pyrites has an influence, and yet others the contrary; again, others say that dry coal is more liable to spontaneous combustion than damp. I believe that the experience gained by our members, as shewn by papers, is that pressure and friction, say, against pillars and sides, are the chief causes, coupled with carelessness in leaving timber buried in the gob. I think, however, that a good discussion might be held upon this question, which in my opinion is a very important one.

One's own difficulties generally appear to be more important than those of other people. I venture, therefore, to mention a difficulty that has had to be faced at our own collieries in a most crucial form since 1895, that is, the rise-water question in the South Yorkshire district. The water is being dealt with at the present time, but as the thick-coal pits become exhausted, the head standing against the remaining collieries is gradually increasing, and it is therefore becoming essentially necessary that ample provision should be made to safeguard further developments.

It would be idle on my part to remind you of the various alterations in mining laws made whilst I have been secretary of the Institute, as regards explosives, timbering, compensation to workmen, etc. Thanks to the efforts of members of this Institute, it has been definitely decided that a testing-station for explosives shall be opened for the Yorkshire district; and this will no doubt form an additional factor of safety. In,
connection with timbering, on referring to the first presidential address given to the Institute in 1869, I find that the late Mr. T. W. Embleton called special attention to the loss of life under the heading of falls of roof; and during the past year a paper has been read dealing with systematic timbering by H.M. inspector of mines for this district (whom we are going to lose on his appointment as chief inspector of mines in India), which will call for your serious discussion this afternoon. There was one death for 1,226 persons employed and one for 335,000 tons drawn from 1872 to 1881; and one death for 2,005 persons employed and for 546,000 tons drawn from 1894 to 1903, shewing that, if the matter is carefully considered in the future by managers and men, there should be a further reduction in this very serious cause of loss of life. I think that at our collieries we are hardly as systematic as we might be, in the matter of calling the men's attention to the responsibility resting upon themselves in respect to this serious loss of life. Men do not, I think, at all times take the same care that they might do: for instance, if it comes to a question of taking out a difficult prop from a hard place in the gob, instead of protecting themselves by an advance-prop, they will do their best to pull it out. Almost invariably they pull something on to the top of themselves, and I consider that the management can hardly be blamed for such accidents.

The rules for recovering collieries after explosions have been fully discussed in the Transactions, but there is now established, not far from this room, a rescue-station, where qualified men are instructed in the use of pneumatophores and other appliances, enabling them to work in noxious gases; and the paper that you will hear read to-day will give you the results of the efforts of members of the Institute in this direction. I believe that most of you will soon be asked to take this matter up financially and practically, more or less on the lines of the admirable papers and discussions that have been before you at previous meetings.

There is another instance, in which this Institute has taken a leading position in improving the safety of the mine. Some years ago, a series of experiments were made upon safety-lamps, and there is no doubt that the report drawn up by Mr. C. E. Rhodes and others was a very useful guide to those who had charge of the management of collieries.
Many of these improvements have entailed increased cost, which have to be dealt with when working seams of inferior quality at greater depths, and there is less to meet these expenses than out of the thicker and shallower seams. There are, however, compensations for nearly everything, and it will be found that the loss of life is being minimized by these provisions, and that the great progress that has taken place in electrical machinery and air-compressing plant will assist very considerably in reducing costs in the pit; while, on the surface, the excellent arrangements that are now provided for washing and dealing with the coal, will considerably reduce costs there.

Next to working coal cheaply, the manufacture of coke and the extraction of all possible products out of the coking coal seems to be a panacea for the ills that attend the working of lower-grade seams, and it would therefore be very instructive if some member, having experience of retort-ovens and bye-product plants, would give a paper furnishing the commercial results of the process in this district. It is true that a paper has been read on the construction of retort-ovens. This information has been given in other districts, but as the constituents vary in various seams, the results of treating local coal-seams will be more interesting. Information as to the utilization of the waste-gases in gas-engines would also be interesting. This method of power-production seems to be coming into use, and it almost makes one think that the time of perpetual motion has arrived: if some power be applied to draw the first lot of coal out of the pit for the ovens, the ovens will supply the rest until the exhausting of the colliery-royalty.

With increasing depths and thinness of the seams, ventilation will probably form an important problem, and as the air will have to be carried through long distances, for shafts will not be sunk so frequently as now, it will probably be found that electrically-driven subsidiary fans will be of great use. I know that they have already been used, but the effect on the ventilation has not been described to the Institute, and I think that this information would prove most useful to members.

Further, the increasing depth of the seams raises the question of the method of winding, which forms subject-matter for grave consideration. I think that the more simple the engine, the better; although compound engines have their
champions, and electric winding has its friends. This last method has been tried in this district in a small way; and, as a paper has been promised upon it, there will doubtless be an interesting discussion.

Another serious question in regard to deep mining, is that of winding-ropes. The great depths require that large outputs must be drawn, and if the men gain an 8 hours' day, the output must be drawn in a very short time. This necessitates heavy loads, high speed and quicker banking, with its attendant sudden checking of speed, all placing great strains on the ropes and calling for greater size of ropes and consequent increase in dead weight. It would be interesting if a paper were read shewing how this can be accomplished with the least loss of useful effect. A suggestion has been made that, now that large-sized shafts are the fashion, the weight to be drawn should be divided so as to have two windings in one shaft, and the upcast shaft used more or less exclusively for the drawing of men and stores. I think that a very instructive paper could be read on winding-ropes, shewing the progress made from the time when hard-drawn iron-wire, with a breaking strain of about 28 tons per square inch, was used; next, how Bessemer steel was used; and the quality of steel that is now used with a breaking-strain up to 110 tons per square inch. In connection with this subject I think that some engineers scarcely realize the strains to which ropes are subjected. Most likely, an indication would be given in such a paper of the immense strains applied to a haulage-robe at the present time, when a block takes place in the engine-plane, or full and empty corves are locked together on the endless-haulage system, and the pit-corporal thinks that the best way of clearing the stoppage is to apply the full power of the engine. Personally, I have often been surprised at what the rope is expected to move, and should very often have liked to measure the strain exerted. The questions of the make of winding-robe, the re-capping, the greasing, and the changing of the same, all form subjects suitable for practical discussion.

Since the last Presidential address was delivered, the Coalmines Regulation Act has been amended, so as to allow those offering themselves for examination for certificates to produce college-diplomas, and I am glad to see that the colleges in which we are especially interested are on the Home Office list.
I have no doubt that this concession will be useful to many student mining engineers, and that they will avail themselves of the excellent tuition now being provided by the two local colleges.

I am afraid that I have detained you a long time, but if my cursory address results in any new papers being read or in any discussion being opened out in this Institute, I shall feel that my object has been attained. With your assistance, I will use my best efforts to ensure that the Institute does not suffer through the honour that you have conferred upon me, and for it I again thank you.

Mr. G. Blake Walker, in proposing a vote of thanks to the President for his address, said that the Council had passed a unanimous vote of thanks to Mr. Mitchell for the 14 years' work which he had devoted to the interests of the Institute; he was sure that every member felt as strongly as the Council did, that he had put them under a great debt of obligation; and he felt that in welcoming Mr. Mitchell as president, they should not forget to thank him for his services as secretary.

Mr. W. H. Pickering seconded the resolution, which was unanimously adopted.

The President (Mr. T. W. H. Mitchell) stated that Mr. L. T. O'Shea, of the Sheffield University College, had been appointed secretary.

Mr. M. H. Habershon read the following paper on "The Work of a Joint Colliery Rescue-station";
THE WORK OF A JOINT COLLIERY RESCUE-STATION.

By M. H. HABERSHON.

The reasons for the establishment of joint colliery rescue-stations and their constitution and scope were discussed by the writer in a paper contributed in March, 1901.*

Briefly stated, it was urged that groups of collieries or pits in the same immediate neighbourhood should have at hand, and always available, means by which a small number of trained men would be able to penetrate a noxious atmosphere for the purpose of exploration, and to perform such light work as the fixing of sheets or temporary stoppings, opening or closing doors, and the carrying-out of injured or helpless men, and that this would only be possible by the provision of improved pneumatophores, portable electric lamps, and a station at which men could be regularly trained, oxygen and other necessaries kept, and the apparatus maintained in proper order.

A building, such as that described in the paper referred to, has been erected jointly by the Barrow Hæmatite Steel Company, Limited, Messrs. Newton Chambers & Company, Limited, and the Wharncliffe Silkstone Colliery Company, Limited, in a central position conveniently situated for their respective collieries, which are in the immediate neighbourhood.

The trials made by Mr. W. E. Garforth in his experimental gallery at Altofts, with the Meyer helmet-apparatus, have clearly shown that men wearing that apparatus can climb over falls in a noxious atmosphere: but, owing to the comparatively short time during which they have been able to remain in the gallery, it was evident that an improved apparatus was needed before pneumatophores could be relied upon with confidence for either exploration or rescue-work underground in cases of real necessity. This was the feeling generally expressed by those who have had experience with them, and there is no doubt that the work accomplished has demonstrated weak points in the apparatus and

indicated the direction in which improvement was required. The discomfort of having the head enclosed in a helmet, the difficulty of both hearing and seeing, and the heat, and resulting headache, due most probably to the continual presence of an abnormal percentage of carbon dioxide immediately in front of the face, have been among the causes of this inability to wear the apparatus for a sufficiently satisfactory length of time. Another cause more recently discovered and remedied will be referred to later.

On the occasion of the visit of members of this Institute to the Düsseldorf Exhibition and the Westphalian coal-field in September, 1902, Mr. Meyer gave a demonstration at Shamrock colliery, Herne, with an improved apparatus known as the Giersberg pneumatophore,* a combination of the inventions of Dr. Giersberg and Chevalier von Walscher, and containing several features which make it decidedly superior to any apparatus tried in this country previously. It should be stated here that Mr. Meyer has abandoned the use of the helmet and that the apparatus was used with an indiarubber mouthpiece for breathing and a nose-clip.

The improvements referred to comprise:—(1) The substitution of solid alkali for the liquid formerly employed: consequently there is now no liability of any liquid getting up into the breathing-tube and causing burning in the mouth. (2) By means of a regulating-valve, the admission of oxygen is adjusted to the actual requirements of the wearer, and needs no attention or further adjustment or anxiety on his part. This valve allows 2 litres (122 cubic inches) of oxygen to pass per minute; the wearer is constantly supplied with this amount, he cannot get either more or less, and he is provided with a 2 hours' supply if the cylinders are properly charged. (3) A relief escape-valve is attached to the breathing-bag, so that when there is any accumulation of gas the wearer can get rid of it by a slight compression of the bag with his hand. This arrangement has been found to add materially to the comfort of the wearer, and has done away with one cause of the headache which was so often experienced.

On the completion of the building referred to, it was decided to obtain five complete sets of this improved apparatus, five being considered to be the number of persons which should form

JOINT COLLIERY RESCUE-STATION.

one properly-constituted rescue-party. Some account of this apparatus and the experience gained in the attempt to train men in its use will probably be of interest to the members.

The following are the particulars and cost of the equipment as ordered in the first instance:

- 5 pneumatophores: Giersberg 1901 model, two-cylinder type, arranged with mouthpieces for breathing, at £12 10s. each
- 6 sets of spare cylinders for the above, at £2 each
- 1 complete filling apparatus, consisting of large oxygen-cylinder of 5,000 litres (176 cubic feet) capacity, hydraulic force-pump, tripod, connecting pipes and pressure-gauge
- 5,000 litres of oxygen, at 6s. per 1,000 litres
- 5 sets of cooling apparatus, at £1 each
- 6 indiarubber breathing tubes, with mouthpieces, at 2s. each
- 5 nose-clips, at 2s. each
- 5 sets of kieselguhr, at 1s. each
- 15 tins of alkali, at 3s. each
- Carriage

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
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<tbody>
<tr>
<td>5 pneumatophores</td>
<td>£62.10</td>
</tr>
<tr>
<td>6 sets of spare cylinders</td>
<td>£10.00</td>
</tr>
<tr>
<td>1 complete filling apparatus</td>
<td>£30.00</td>
</tr>
<tr>
<td>5,000 litres of oxygen</td>
<td>£114.10</td>
</tr>
<tr>
<td>5 sets of cooling apparatus</td>
<td>£5.00</td>
</tr>
<tr>
<td>6 indiarubber breathing tubes</td>
<td>£0.50</td>
</tr>
<tr>
<td>5 nose-clips</td>
<td>£0.50</td>
</tr>
<tr>
<td>5 sets of kieselguhr</td>
<td>£1.18</td>
</tr>
<tr>
<td>15 tins of alkali</td>
<td></td>
</tr>
<tr>
<td>Carriage</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£114.10</strong></td>
</tr>
</tbody>
</table>

It has since been found desirable to obtain three additional large cylinders for oxygen, and a supply of indiarubber breathing-tubes with mouthpieces of an improved type, and a number of portable electric hand-lamps; and these, with various fittings and tools, have brought up the total cost of the apparatus to about £175. This, however, can only be considered as an instalment and not as a complete equipment, which should consist of at least double the number of apparatus. The station being somewhat in the nature of an experiment, it was decided to limit the apparatus in the first instance to the number mentioned until further expenditure was justified by experience.

A retired army-sergeant was engaged as caretaker and instructor, and by the kindness of Mr. Meyer, he was thoroughly instructed at Shamrock colliery in the use of the apparatus.

The first attempt to wear the apparatus at the station was a failure, owing to the tendency of the breathing-tube to buckle; this so interfered with the freedom of breathing that the apparatus could only be kept on for a very short time, even by a man who subsequently showed himself capable of wearing it for a couple of hours with perfect ease. When the cause of this difficulty was discovered it was easily remedied, and with
the improved type of breathing-tube now in use the trouble cannot occur again.

During the last twelve months, practices in wearing the apparatus at the station have been held with fair regularity every week. The apparatus has been worn in the practice-room by about 50 men, and the results obtained may be roughly summarized as under, namely:—Ten men or 20 per cent. have been able to wear the apparatus for periods approaching to 2 hours; these men have taken part in the underground practices. And 10 men or 20 per cent. for shorter periods; these will probably improve with practice. Of the rest, some have been found unsuitable, and others have not persevered beyond wearing the apparatus for short periods of about 15 or 20 minutes. These results agree fairly well with the experience obtained at Shamrock colliery, where it has been found that out of 100 men tried, approximately 20 per cent. are found to be suitable and to make good men for the purpose, and about 35 per cent. are found to be constitutionally unsuitable.

One evening in the week has been set apart for each of the three subscribing collieries. As the apparatus requires to be washed out after each practice, and the cylinders have to be recharged, it has not been found possible to arrange for more than three practices per week. Four or five men have been present at one time, and those found suitable have been encouraged to attend until they have become capable of wearing the apparatus for about 1½ hours, or in some instances for a longer time. On the first attempt, men usually can only keep the apparatus on for 10 to 15 minutes. Some never get beyond this, being constitutionally unsuitable, and after about the third attempt continued perseverance on their part is useless, however willing they may be, or anxious to succeed. Usually men who are found suitable can extend the time to ½ hour on the second occasion, if they will adhere to the instructions given, and can afterwards do light work such as wheeling heavy stones in a barrow if they will take it steadily and not hurry—any attempt to rush about will quickly result in failure, as has been clearly proved on more than one occasion. In several cases, the apparatus was worn for 1 hour at the first attempt, and in one instance for 2 hours at the second attempt, without any discomfort or after ill-effects. In all cases, after the
apparatus has been worn for about 15 minutes, a slight tightness in breathing is felt: if the wearer keeps quiet for a minute or two this feeling passes away; and, afterwards, he seems to have got warmed up to the work, breathes with greater ease, and the uncomfortable feeling does not return.

It must not, however, be generally expected that men will be able to accustom themselves to breathing in this artificial manner without some inconvenience; but with men who are constitutionally suitable the liability to headache with the most recent type of apparatus has been, it is now believed, almost eliminated. If any discomfort or difficulty is experienced, relief can be immediately obtained by removing the nose-clip so long as the practice is being conducted in an ordinary atmosphere. In the smoke-chamber at Shamrock colliery, men are required to practice until they are able to wear the apparatus for 2 hours, and during this time perform an amount of work equal to about 20,000 foot-pounds. A wheel-and-axle arrangement is employed by which a weight is raised, and in this way the work can be measured. The practices are carried out with military discipline, to which German officials and workmen are accustomed. In the joint station under consideration, the training so far has been voluntary, and the men have come some distance to the practices. The only work attempted at the station has been the wheeling of heavy stones in the practice-room, and it has not yet been found convenient or advisable to follow out all the rules suggested by the writer in his former paper on this subject.

By the kindness of Mr. W. E. Garforth, an opportunity was afforded of testing the Giersberg apparatus in his experimental gallery in a noxious atmosphere. Two men remained in the gallery for a considerable time without any discomfort or after ill-effects, excepting a smarting of the eyes due to the smoke, and this could have been avoided by the use of goggles. One man remained in the gallery for about 1 hour and only came out when requested. He expressed himself confident of his ability to have remained for the full 2 hours; but, this being the first attempt, it was thought sufficient, the object being to demonstrate and obtain confidence in the practical utility of the apparatus. This test has clearly shown that the apparatus is reliable.
It was then considered desirable to have some trials conducted underground, so as to show what could be done in the way of travelling in the roadways of a mine. On the occasion of the first trials underground, an old roadway containing a fall of roof and several slight obstacles, the length being rather over 300 feet, and also a somewhat longer distance in a slightly inclined roadway, were selected for the purpose, both being ventilated by return-air and fairly warm. Three men wearing the apparatus carried a stretcher to the distances stated, and there placed a man on it and carried him back to the starting-point. The roadway over the fall was fairly low, and the stones were slippery. This was successfully accomplished in about 15 minutes, but the work was arduous, due to the weight carried and the lowness of the roadway in places, and in the second case to the weight having to be carried up a slight incline, and also to the fact that none of the men had previously attempted to wear the apparatus and walk with it in a pit. It was, however, thought desirable to make the trial fairly analogous to what might be expected in a case of real necessity. These trials were repeated several times, and clearly showed the desirability of having underground practices to accustom the men to travel the roadways wearing the apparatus, before expecting work to be done, which in the ordinary way, without any artificial breathing apparatus, would be by no means easy.

In a subsequent underground practice, two sets of three men proceeded from the pit-bottom up an inclined drift of 1 in 5, for a distance of 270 feet, and along a level roadway, 810 feet, into a working-place and returned to the pit-bottom, in 19 minutes, the roadway at the far end being only 3½ feet in height. This work was accomplished quite easily, the men not being exhausted, and stating that they could have gone further or made a second journey. In a more recent practice, three men, carrying brattice-cloth, proceeded up this drift, climbing over some corves, which had been overturned in the road and fetched a pony from a point, 405 feet from the top of the incline, nailed up two sheets across the road, and returned to the starting-point, having to move several corves out of the way to enable the pony to pass: the time occupied being 19 minutes. One of these men returned with two others: they took down the sheets, carried the brattice-cloth back, and moved corves out of their way as
before: the time occupied being 14 minutes. This trial was arranged to see whether work of this sort, which involved concerted action, could be done. The whole was easily accomplished, without any difficulty or unusual effort. No headaches have resulted from the underground practices.

Within the last eighteen months, Mr. Meyer has been using a modified apparatus, which he considers has now reached comparative perfection and to be a decided improvement on the pattern seen by the members on the occasion of their visit to Shamrock colliery. (1) In this type, there are three small oxygen-cylinders of reduced length instead of two. For convenience in travelling, it has been found desirable to keep the width of the apparatus within certain limits. It is also enclosed in a leather cover, and the weight is slightly greater. The oxygen is admitted into a ball-shaped enlargement of the breathing-tube; and the expired air passes into this enlargement through a contracted inlet on the principle of the injector. It was found from a number of analyses that the vitiated air did not get away from the breathing-tube with sufficient rapidity to avoid its being reinhaled, and that the oxygen was not sufficiently well mixed with it. Subsequent analyses have shown that the exhaled air is oxygenated very much more perfectly with the new arrangement, and the men wearing the apparatus are subjected to much less inconvenience, thus the tendency to headache is still further reduced. (2) The solid alkali is now introduced in the form of peas in gauze-holders, about 1 square inch in section; this provides a greater surface of alkali to act on the vitiated air, than in the older type in which the alkali is used in the form of sticks. The carbon dioxide is absorbed in consequence much more completely. (3) As an alternative to the nose-clip, the nostrils are fitted with plugs of cottonwool and lanoline, and a light leather cover or mask is worn over the nose. The writer is inclined to think that this arrangement is an additional discomfort, and has not found that the nose-clips have been objected to; this point, however, may be considered a matter of secondary importance. (4) A light cooling-tube has been introduced, through which the revivified air is caused to circulate.

In order to meet the preference for a mask, instead of the
mouth-breathing tube which has been found to exist in some cases, the makers have recently devised a mask-arrangement fitted with separate tubes for inhaling and expiration, and in which the volumetric capacity is reduced to a minimum: this is said to be giving satisfactory results, but the writer has not yet seen it. In Germany, the fire brigades have a preference for the mask, but collieries have chiefly used the mouth-breathing tube, although in some cases the mask is being adopted for collieries, and the makers say that opinion on this point is very much divided. The inability to speak seems to be the only real objection which can be raised to the mouth-breathing arrangement.

The weight of the two-cylinder apparatus, with the breathing bag complete, amounts to 28 pounds 6 ounces. The most recent type with three cylinders is slightly heavier, the total weight to be carried amounting to 33 pounds 11 ounces.

In the period under consideration, the chief items of cost in working the station have been about £15 for oxygen, including carriage of cylinders, £6 for alkali, and £4 for ordinary stores. The alkali is a special preparation, which is at present expensive in this country, as it is only obtainable from Berlin. About 6 pounds has been used on the average per week. The oxygen is compressed to a pressure of 120 atmospheres per square inch, and the apparatus must be charged to this pressure. The ordinary German cylinders of 5,000 litres capacity, however, do not conform to the British standard; and consequently the cylinders can only be charged in this country up to 80 atmospheres, which although sufficient for practices in the first instance, does not give a supply for the intended limit of 2 hours. For charging the apparatus, the storage-cylinders are fitted with connections at each end, by means of a force-pump water is introduced, and the oxygen is forced into the apparatus to the required pressure of 120 atmospheres by displacement with water.

The writer thinks that the experience gained points to the necessity for combined or joint action by several collieries, or an instalment on a sufficiently large scale to ensure that all the apparatus is maintained in perfect condition, and that there shall always be a man at hand who is thoroughly con-
A JOINT COLLIER RESCUE-STATION.

versant with every detail of the apparatus and its use. It has been suggested that in addition to the instalment at the station, extra apparatus might be kept at the various pits; but there is great probability that they would be only examined occasionally, and this does not meet the case. The alkali must be introduced into the breathing-bag shortly before the apparatus is intended to be used, and a thorough knowledge and experience of the details of the whole apparatus is necessary on the part of the operator; without this, nothing should be attempted. The writer is therefore of opinion that all pneumatophores should be kept at the station, where they can be systematically overhauled and used in rotation for practice-purposes. Such a station should be within easy reach of any of the places which it is intended to serve.

It is essential that an adequate supply of portable electric lamps should be always available, and these lamps must be kept charged and used occasionally; these may well be kept at the various pits, where they will be found extremely useful by the officials. If not kept in working order and regularly charged, they will become absolutely useless from corrosion, and not available if required in an emergency. A breathing apparatus can be got ready for use in a few minutes, if the cylinders are kept fully charged with oxygen, but a portable electric hand-lamp of suitable size cannot be charged in less than 6 or 8 hours.

For use with the pneumatophore, the writer has had a lamp specially made, to give as much light as possible consistent with a reasonable weight and bulk. The lamp consists of a small liquid-accumulator battery in ebonite, enclosed in an aluminium case, 3 1/2 inches by 3 1/2 inches by 3 3/4 inches, a bulb fitted with two filaments, an electro-plated reflector covered by a strong glass or bull’s eye, and locked with a leaden rivet. The lamp is carried by a leather hand-strap, and weighs 5 3/4 pounds. The accumulator, being nearly filled with dilute sulphuric acid (8 parts to 1 part) is charged from a 100 volts continuous current taking 1 ampere. The charging occupies 8 hours, and the lamp will give a light of 3 candlepower for about 6 hours. If the lamp is in good order, the light given is maintained for some hours without perceptible diminution. The cost of these lamps is £1 15s. each.
No difficulty has been found in getting suitable men to wear the apparatus and to practice until they can wear it a reasonable time, and the writer takes this opportunity of expressing his appreciation of the interest that the men have shown in the matter. The work done so far, however, can only be considered as preliminary, as a party capable of attempting serious work underground in an emergency cannot be formed until a sufficient number of men have had experience, not only in travelling in underground roadways and doing light work wearing the apparatus, but they must also have absolute personal confidence in the reliability of the apparatus in a noxious atmosphere, which latter can only be obtained with a smoke-chamber or a gallery such as Mr. W. E. Garforth's gallery at Altofts colliery. Unless the work is pushed on through this further stage, there is a danger that the interest will be found to flag, and it is at this point that encouragement is needed.

Sufficient experience has now been obtained with the apparatus to indicate that the object in view can be attained with perseverance. The progress made will be gradual, as the training must be thorough and complete; the nature of the work does not admit of its being partially or only half done, and it is necessary that the interest easily raised should be constantly maintained. The writer thinks that the result will be worth the trouble and slight expense involved, but would like to point out in conclusion that men who may be trained in connection with any station cannot be considered as available elsewhere.

Mr. G. Blake Walker wrote that Mr. Bernhard Dräger of Lübeck had written an interesting paper on the improvements that he had made in the pneumatophore, with the view of affording a sufficient supply of air to persons doing really hard work.* Mr. Habershon had pointed out the difficulties which he had experienced in his own experiments with the use of the pneumatophore, even in its most improved form, when really laborious work had to be done. Mr. Dräger had carried out a series of experiments with a spirometer constructed like a gasometer.

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and provided with a dipping bell and a large pipe fitted with a mask which covered the nose and mouth of the person experimented upon (Fig. 1). The bell is carefully balanced, and when the person puts on the mask the whole of the air exhaled is conveyed to the spirometer through the tube, and the bell is lifted a corresponding distance at each respiration. The quantity of exhaled air can be read on a scale attached to the bell, and the spirometer can be put out of action by means of a tap. Mr. Dräger conducted experiments upon three men weighing 175 pounds, 143 pounds, and 122 pounds respectively. The following are the results of these experiments:

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>Sitting still and doing nothing for 10 minutes</td>
<td>70.7 inches</td>
<td>65.5 inches</td>
<td>65.2 inches</td>
</tr>
<tr>
<td>Weight</td>
<td>Walking a distance of 820 feet</td>
<td>175 pounds</td>
<td>143 pounds</td>
<td>122 pounds</td>
</tr>
<tr>
<td></td>
<td>Do. do. 1,640 feet</td>
<td>1,831 cubic inches</td>
<td>2,319 cubic inches</td>
<td>2,319 cubic inches</td>
</tr>
<tr>
<td></td>
<td>Running a distance of 820 feet</td>
<td>1,831 cubic inches</td>
<td>2,319 cubic inches</td>
<td>2,319 cubic inches</td>
</tr>
<tr>
<td></td>
<td>Do. do. 1,640 feet</td>
<td>1,831 cubic inches</td>
<td>2,319 cubic inches</td>
<td>2,319 cubic inches</td>
</tr>
<tr>
<td></td>
<td>Two men together in stooping attitude</td>
<td>1,831 cubic inches</td>
<td>2,319 cubic inches</td>
<td>2,319 cubic inches</td>
</tr>
<tr>
<td></td>
<td>Rolling casks weighing 168 pounds</td>
<td>2,319 cubic inches</td>
<td>2,014 cubic inches</td>
<td>2,472 cubic inches</td>
</tr>
<tr>
<td></td>
<td>Racing a distance of 820 feet</td>
<td>3,173 cubic inches</td>
<td>3,722 cubic inches</td>
<td>3,600 cubic inches</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>40 seconds</td>
<td>42 seconds</td>
<td>42 seconds</td>
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The ordinary pneumatophore contains only about 366 cubic inches (6 litres) of air: obviously, therefore, a man doing hard
work requires a great deal more air than the pneumatophore contains. Therefore, for 3,660 cubic inches (60 litres) the same small quantity of air would have to circulate ten times a minute through the apparatus. Mr. Dräger thinks that the apparatus ought to be able to deliver 2,440 to 3,050 cubic inches (40 to 50 litres) of pure air per minute. He has accomplished this by one or two modifications of the apparatus. To remove any possibility of the exhaled air being breathed in again before it is purified, he divides the breathing-bag into two parts. One portion receives the exhaled air, and the other is used as the reservoir for the purified air. It is of the utmost importance that the person using the pneumatophore should breathe only air which is really pure, that is to say, which contains much less than 1 per cent. of carbonic acid. The more carbonic acid the air contains the quicker and deeper is the breath. At present, the supply of oxygen from the cylinders to the breathing-bag is a constant quantity, regulated with the idea of an average consumption, but obviously some regulation is required, seeing how much more air is necessary when hard work is being done, than when the man is resting or doing light work. Mr. Dräger's second modification is based on a suggestion of Mr. Meyer to have two oxygen-supplies, one being sufficient for moderate

**Fig. 2. — Front View of the Dräger Pneumatophore.**
DISCUSSION—A JOINT COLLIERY RESCUE-STATION.

exertion, and the other which can be used as an additional supply when doing harder work.

Mr. Dräger's apparatus consists of oxygen-cylinders, with supplying and circulating contrivances, alkali-cartridges to absorb carbonic acid, and a smoke-helmet used as a face-mask (Figs. 2 and 3). By using very wide and short pipes, by widening all the connecting parts, by arranging two cartridges parallel, and by making a better use of the oxygen, Mr. Dräger has been successful in producing in the apparatus a circulation of about 3,050 cubic inches (50 litres), and the apparatus delivers about 183,000 cubic inches (3,000 litres) of pure air per hour. To avoid the mixing of the purified air with the exhaled air in the face-mask, the principle of having only one breathing-bag has been abandoned, and two separate bags are used. In consequence of this arrangement, it becomes necessary to provide on the helmet an inhaling-valve for the bag of pure air, and an exhaling-valve for the bag of exhaled air. Mica-plate valves have proved very suitable for this purpose. The bag on the right-hand receives the purified air, and the bag on the left-hand will absorb the exhaled air. The two bags of the apparatus act like two regulators, out of which the circulating apparatus can draw, or into which it can blow the air proportionately, notwithstanding intervening respirations (Fig. 4).
As most persons feel themselves much inconvenienced (especially when doing hard work) if breathing through the mouth and nose is restricted, Mr. Dräger prefers the mask to the clips and mouthpiece usually employed. He believes that no inconvenience is really due to the use of the helmet, and that the assertion of the miners that they suffer by the heat of the helmet is a mistake. He believes that the inconvenience which these men feel must be ascribed to the effect of the inhaled carbonic acid, and the experiments that he has made appear to bear this out.

To obtain reliable comparative results, Mr. Dräger selected those kinds of labour which required a rather large amount of exertion, as for instance:—Wheeling stones on moderate roads, running, carrying a person in a stooping position, ascending and descending a ladder, and so on. He made a series of tests which demonstrated that the apparatus successfully fulfilled all working requirements. Neither indisposition nor headaches were felt in any case. Mr. Dräger had wheeled stones for 1½ hours, and was thus able to confirm the accuracy of the statements made by other workers. An experiment in wheeling stones on garden-roads for 2 hours, made by five persons at the same time, confirmed all previous observations. After having done this work, each man resumed his usual occupation without requiring any interval for recovery. Whether the experiments are performed in fresh air (Mr. Dräger made them during the hot days of July of this year) or in the smoke-chamber, has no important effect on the results, because the breathing organs are excluded from the outer atmospheric air. To prove the absolute tightness of the helmet, Mr. Dräger
allowed the persons who had been making the experiment to enter a chamber filled with sulphurous-acid fumes and no ill-effects were experienced.

It is of special interest to ascertain whether the alkali-cartridges, disposed in layers, are really capable of absorbing the large quantities of carbonic acid exhaled from the lungs in performing work. It is unnecessary to measure the capacity of the cartridges for absorbing carbonic acid if one ascertains that they deliver pure air, without any carbonic acid, from the beginning to the end of the working of the apparatus. Therefore one must take out of the right-hand breathing bag small samples, and ascertain whether they contain carbonic acid. The following method may be employed for this purpose: By means of a short pipe, a small sample of air is taken by a little glass-syringe out of the breathing-bag, which is supposed to contain pure air. In the nozzle of this syringe is a long thin pipe which is immersed in a thin test-tube half filled with clear lime-water. By pushing the piston of the syringe slowly down, the breathing air, which is to be examined, bubbles through the water. If carbonic acid is present in the air, even in very small quantity, the water becomes milky. In order to see the degrees of milkiness produced in lime-water by air which contains carbonic acid, one takes air, which has been once in the lungs, out of one's own mouth by the syringe, and the lime-water in the test-tube becomes quite turbid. By means of this contrivance for examining the breathing air, Mr. Dräger was able to ascertain that the apparatus still delivered air free from carbonic acid after 2 hours' working. Further, he had found out that the weight of two cartridges in an apparatus, used in the before-mentioned experiment, had together increased by 8'8 ounces (250 grammes). By treating the contents of these two cartridges with sulphuric acid, 5,736 cubic inches (94 litres) of carbonic acid were extracted, which was exactly indicated by the spirometer. Therefore it may be believed that a man produced in working about 2,868 cubic inches (47 litres) of carbonic acid per hour.

In confirmatory experiments it was found that (1) the gas obtained in the spirometer had, with the exception of a very small quantity, been absorbed by shaking in lime-water, by which it was demonstrated that it really consisted of carbonic
acid; and (2) the contents of a cartridge, which had not been used before, when treated with sulphuric acid, only produced vapour, which condensed at once, and had no influence on the spirometer.

The production of carbonic acid by a person and the work performed by him are evidently in direct proportion to each other; and in following out this idea Mr. Dräger was pleased to discover a measure for estimating the exertion of the persons tested by the increase in the weight of the alkali-cartridge.

When 122 to 128 cubic inches (2 to 2·1 litres) of oxygen were delivered in one minute, Mr. Dräger could not observe that the breathing-bag shrivelled. When the oxygen-cylinders were pumped up to a pressure of 125 atmospheres, in which case the twin-cylinders contained about 15,000 cubic inches (250 litres) of oxygen, the apparatus contained a quantity of air sufficient for exactly 2 hours; and from the beforementioned experiment it had been plainly demonstrated that this proportion was correct.

Mr. C. Chetwynd Ellison asked whether there was still a difficulty in obtaining sufficiently pure oxygen for charging the cylinders. He thought that the increase in the number of cylinders was a great improvement, but he noticed that there was an increase in weight of nearly 20 per cent., and this was a serious item when a man had already to carry over 28 pounds. He would like to know the cost of working a rescue-station, together with the cost of each man's practice, including the man's pay, as a man could not be expected to undertake this kind of work without being adequately remunerated. During the little time that he had used the helmet, he preferred it to the mouth-piece and nose-clip. The effect of stopping the breathing through the nose did not affect all persons to the same extent, and to some people it caused considerable unpleasantness; he also thought that, for many reasons, the helmet was preferable on account of the mouth being free. One of the objections to the use of the old helmet arose from the moisture of the breath which dimmed the glass-window of the helmet, and if the moisture were absorbed, it would effect a very great improvement. He desired to emphasize the point that owners, who had trained their men, must not be expected to allow themselves to be "sponged upon" (an expression of that sort was
the only way of describing what he meant) by other owners, who were going to sit on the fence and do nothing at all. He might be wrong, but, personally, he hoped that the Government would take up the question: every colliery-owner should be made to do something in this matter, in the same way as every owner had to keep an ambulance at his colliery. He agreed with Mr. Habershon that it would be a foolish idea for any one to start these practices, unless they intended to carry them out most thoroughly, as the apparatus was dangerous when used by inexperienced persons.

Mr. W. H. Pickering, in proposing a vote of thanks to Mr. Habershon for his paper, said that the question had interested him ever since he came to the district. He thought that it was most important that the Institute should organize rescue-stations throughout the district, and, as Mr. Habershon pointed out in his paper, it would not be reasonable for any one station, in the case of a disaster, to be called upon to send apparatus and workmen to another colliery, as they would no doubt feel bound to respond.

Mr. W. E. Garforth, in seconding the resolution, congratulated Mr. Habershon, and the three companies concerned, on the good work that they had done during the past year. They had in some respects improved upon the experiments made at Messrs. Pope & Pearson's collieries, which some of those present would remember seeing some two or three years ago. He considered that the improvements made by Mr. Dräger were most valuable, and he believed that the apparatus was still capable of further improvements. Since the Altofts experiments, he had the impression that the apparatus was not sensitive enough, that it should be made by a surgical instrument-maker, and that the position and weight of the various parts could be better distributed by having them stitched or sewn in the workmen's special coat. In this way, the efforts of the intended explorer would be greatly facilitated, and the exploration-work would be far less exhausting. In the Astley explosion, where 62 men were killed, and in the recent fire at the New Moss colliery, the latest design of life-saving apparatus would have been most valuable. He believed, if the experimental work was continued, that it would lead to the apparatus being gradually improved.
In its present condition, so many imperfections existed that he certainly could not recommend it to be used for any work in a highly noxious atmosphere, requiring more than 1 hour's time from the pit-bottom, or in case of much exertion for more than \( \frac{1}{2} \) hour, and then only when used by properly trained men. He sincerely hoped that the members of the Institute would continue to maintain their interest in all inventions having for their object the saving of life.

Mr. M. H. Habershon, replying to the discussion, said that he had found no difficulty in getting oxygen sufficiently pure for the purpose of the pneumatophore. The apparatus, at first sight, appeared to be rather heavy, but troops on the march carried a greater weight and for a longer period, and he did not think that too much ought to be made of that point. It had been found that it was not easy to perform hard work when wearing the apparatus in the low roadways of a mine, but there might be many occasions when it could be very usefully employed, if only for exploration, or light work. If only this could be accomplished at first, development would take place and they would probably obtain better results; but if they did nothing at all, they would still remain in the present unsatisfactory position. The new apparatus, on view before the members, as far as he was aware, was the only one in the country; and the old pneumatophore, which members might have bought some years ago, he believed, would prove useless and cause headache. There was no liability to headache with the newest type, and the analyses which had been made of the air in the breathing-bag were satisfactory. If men attempted to perform hard work, difficulties would be experienced: but a man could climb over a fall, carry a light article, fix up brattice-sheets, move corves, or even carry a man for a short distance. It became hard work, however, if a man was placed on a stretcher, and such a heavy weight was carried along a roadway only 3\( \frac{1}{2} \) feet high; and he did not think that it was reasonable to attempt such hard work without further practice and experience with the apparatus.
DISCUSSION OF MR. W. H. PICKERING'S "NOTES ON SYSTEMATIC TIMBERING.*

Mr. W. H. Pickering said that the model code of rules suggested in his paper,† embraced rules mostly in force at one colliery or another. The quantity of timber used was only a question of the first supply; and if a really good system was adopted and the props were fixed sufficiently close, most of the timber could be recovered and used again, particularly if substantial lids were used. A point which had not been mentioned in the discussion, and which he had had some diffidence in bringing forward, was that of supervision. He should like all the members to consider whether they had sufficient supervision as regards timbering. A good pitman and a member had told him that he had doubled the number of deputies and had thereby reduced his costs.

Although the discussion on his paper was now closed, he hoped that the subject would not be forgotten, as it concerned not only safety, but also economy.

The annual dinner was subsequently held.

† Ibid., 1902, vol. xxiv., page 98.
GENERAL MEETING,
Held at the Queen's Hotel, Leeds, January 24th, 1905.

Mr. T. W. H. MITCHELL, President, in the Chair.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:

**Members—**
Mr. Henry Blewitt, Underground Manager, c/o Messrs. Arnholder, Karberg & Company, Hankow, China.
Mr. George Auld Leitch, Colliery Manager, Pelaw Main, via West Maitland, New South Wales.

**Associate Members—**
Mr. William Robinson, 76, Clarkehouse Road, Sheffield.
Mr. Charles Blades Caverdale Storey, Lancaster.

**Associates—**
Mr. Robinson Eastwood, Under-manager, Lyndhurst, Crigglestone, near Wakefield.
Mr. Tom Fearnley, Under-manager, 1 Dawgreen Avenue, Crigglestone, near Wakefield.

Mr. W. H. Pickering's paper on "The Dust-danger" was read as follows:
THE DUST-DANGER.

By W. H. PICKERING.

The importance of dust, as a factor in colliery explosions, is now so generally recognized and understood that there is no need to sketch, even in outline, the dangers which are inherent in it. The Royal Commission appointed to consider the dust-danger in mines issued a very valuable report, and it has also been the subject of many papers read before mining engineers. The practical result, so far, has been the introduction of provisions in the Coal-mines Regulation Acts regulating the use of explosives in dry and dusty places, and the issue of the Explosives in Coal-mines Order by the Home Secretary. In a few mines, dust is systematically laid by watering, but no widespread effort has been made to strike at the root of the danger.

Permitted explosives are only relatively safe, for each one of them is capable of initiating an explosion under certain conditions, and it cannot be too often repeated and emphasized that a dust-explosion can be started in other ways than by an explosive. For example, an ignition of fire-damp may result from a naked light, from a damaged or defective safety-lamp, from a spark from a pick or from an electric spark, and this may be magnified by dust into a great explosion.

Dust also greatly increases the danger of underground fires. A few examples may be given to show how easily coal-dust can be ignited in favourable conditions. In a Lancashire colliery, sparks, from the brake-rim of the drum on an inclined plane, fired the dust lying on the floor; a fireman happened to be within 50 feet of the place, but before he could reach it there was a ball of fire as large as two fists in the dust; a bucket of water was dashed on it at once and the fire spurted in all directions; but it was soon extinguished. At a Yorkshire colliery, similar sparks, from a brake-rim, fired the dust deposited on the bars of a main haulage-road and there was a slight dull
explosion. At another Yorkshire colliery, the dust inside a hollow pulley carrying the tail-rope of an intake haulage-road took fire from the friction of the spindle, and a most serious fire would have resulted, if a deputy, who chanced to be travelling out-bye, had not extinguished it.

Obviously the only radical way of remedying the danger is to keep the mines free from coal-dust by cutting off the supply, or by other means. One may therefore consider:—(1) What are the chief sources of dust in mines? (2) Where is it most dangerous? (3) Present or suggested methods of dealing with it; and (4) Practical difficulties to be overcome.

(1) Chief Sources of Coal-dust.—A little coal-dust is made at the working-faces in the process of coal-getting, and some is shaken from the tubs on the tributary roads. In main haulage-roads and in the winding shafts, the dust is shaken from the tubs or is swept off them by the air-current during their passage. The full tubs usually meet the air-current, and in mid-shaft it often passes them with great violence, as the speed of the cages in mid-shaft in some deep mines varies from 40 to 50 miles an hour. A considerable quantity of dust is carried down the shafts from the screens by the intake-air.

(2) Where the Dust is Most Dangerous.—The dust at the coal-face and on tributary roads is usually mixed with stone and fire-clay dust, and is thus rendered somewhat less dangerous. There is not often much coal-dust in return-airways. The greatest danger lurks in downcast-shafts and on main haulage-roads. Here, pure coal-dust is deposited on the roof, sides and floor, and the air is full of floating dust of most extraordinary fineness.

(3) Methods of Dealing with Dust.—At present, the principal methods of dealing with the dust are (a) by means of water-tubs, which water the floor and sometimes spray the water over the roof and sides; (b) by means of movable hose-pipes attached to water-pipes laid along the main roads; (c) by sprayed water, designed to saturate the atmosphere in the intake-air-ways and downcast-shaft; and (d) by watering the tubs before
they begin their out-bye journey. The water is sometimes sprayed by means of compressed air, and salt-water has been used with good effect.

(4) Practical Difficulties and Objections.—In some Welsh mines, the dust is thoroughly laid and rendered harmless, by means of water-pipes laid along the main haulage-roads, and by means of water-tubs. There are mines where miles of pipes are laid and the water is applied with an unspARING hand. In one Yorkshire mine, the air is thoroughly saturated by means of sprays of water and compressed air: this mine is shallow and cool.

The first method could not be adopted in many mines, as such a liberal application of water would cause the floor to lift or heave, the roof and sides to crumble, and the timbering to fall or reel out, and the expense of keeping the roads from collapsing would be prohibitive to its use. Saturation of the air in hot deep mines, even if practicable, has grave objections.

**Table I.**—Hygrometer-readings in South Yorkshire Coal-mines.

<table>
<thead>
<tr>
<th>Place of Measurement</th>
<th>Temperature</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry Bulb.</td>
<td>Wet Bulb.</td>
</tr>
<tr>
<td>I. Mine: 2,280 feet deep—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>58</td>
<td>54</td>
</tr>
<tr>
<td>Intake-airway: near the pit-bottom</td>
<td>69¹⁄₄</td>
<td>62</td>
</tr>
<tr>
<td>Intake-airway: 3,000 feet inbye</td>
<td>78¹⁄₄</td>
<td>68¹⁄₄</td>
</tr>
<tr>
<td>Main return-airway</td>
<td>85¹⁄₄</td>
<td>74¹⁄₄</td>
</tr>
<tr>
<td>II. Mine: 1,791 feet deep—</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td>51</td>
<td>45¹⁄₄</td>
</tr>
<tr>
<td>Intake-airway: near the pit-bottom</td>
<td>61</td>
<td>54¹⁄₄</td>
</tr>
<tr>
<td>Main return-airway</td>
<td>86</td>
<td>75¹⁄₂</td>
</tr>
</tbody>
</table>

Table I., recording the readings of a hygrometer in Yorkshire mines, shows that the air in the intake-airways is often remarkably dry, and could only be saturated, or the dust kept damp, by a most liberal and constant application of water.

The watering of roadways in Westphalia has been held largely accountable for the spread of ankylostomiasis, and although recent observations seem to discount this theory, a hot humid atmosphere is likely to affect seriously the health.
of those who work in it. The legislature has recognized that such an atmosphere is deleterious to health, and there are provisions in the Factory Acts prohibiting excessive humidity in factories. It would be futile to sacrifice health to safety.

The writer suggests that the following methods, used in conjunction, can be installed without undue cost, and would largely remedy the dust-danger:—

1. The sides and bottoms of the tubs should be made dust-tight, so far as is possible.
2. The full tubs on the main haulage-roads should be watered or sprayed before commencing their out-bye journey.
3. The empty tubs should be watered before they are distributed to the tributary roads.
4. The full tubs should be sprinkled at the coal-face before they start on their out-bye journey.
5. The main roads should be frequently cleaned.
6. The screens should be watered and sprayed so as to prevent the dust from flying about the pit-top; or hoppers should be fixed and the dust collected by suction-fans, on the principle of seed-cleaners.

This plan was suggested in the discussion of Mr. Mackey's paper on coal-washing,* and as two members declared their intention of trying it, perhaps they would now give their experiences.

These methods are all designed to cut off the supply of dust, without injuring the roads by excessive watering: but where the roads will stand it, they may be sprinkled as well. It may be added that custom is the only reason for screening and cleaning the coal near the pit-top. This plant could, economically, be placed at a distance.

As long as dusty roads are allowed in mines, the coal-industry is under the dark shadow of a coming great disaster. The looming danger is recognized by all, and the writer submits that this period of peace and immunity is the time to take practical steps to avoid the danger. He believes that a discussion will show that it is reasonably practicable to keep most mines comparatively free from dangerous dust, and that this freedom will conduce to safety, and to health and comfort as well.

Mr. J. R. Robinson Wilson (H. M. Inspector of Mines) said that the dust-danger—unlike falls of roof and sides—did not exact the same yearly toll of lives, but when it did arise it was apt to be insatiable, and in some of the modern well-ventilated mines, one was almost appalled to think of what might happen if the dust were thoroughly ignited. He held practically the same views as the writer of the paper. Mr. Pickering went rather farther, however, as he advocated the watering or spraying of the tubs before they left the coal-face; that would be an effectual method, but managers would raise the question of practical difficulties. He thought that the air-currents in the tributary gateways were not usually strong enough to sweep much dust off the tubs; but in the main haulage-roads it was different. Fine dust also came down the shaft from the screens, and was carried far into the mine; and if prevention was better than cure, he suggested that the dust should be caught at each end. The full tubs might be sprayed with water as they left the pass-byes for the main haulage-roads: and it would be a matter for experiment to ascertain exactly how much water was required to last through the journey to the surface. This method had been applied at one Yorkshire colliery, and he believed that it met with great success. The interception of the dust in the downcast-shaft had, he believed, been tried successfully by Mr. R. Harle* at a Durham colliery some years ago. A perforated pipe was placed in the shaft, and the water-spray deposited the dust upon the sump-board. This spray could be placed under the control of the banksman or hanger-on, and turned off when men were riding in the shaft. The question of the injury to guides might be raised, but that difficulty was not insuperable. Iron guides were examined and greased; and wooden conductors, at any rate, did not rust.

Mr. Thomas Stubbs said that the question was one of the greatest importance, especially now that shafts were so deep, and temperatures so high in comparison with what they were in former times. In his experience, there was considerably more dust in proportion when working at a great depth, especially in gas coal-seams, than there was when working at a moderate depth. He agreed with Mr. Pickering that this question should

be dealt with on its merits, as his experience in watering roadways was of a varied character, and in some cases it caused upheaval of the bottom-stone.

Mr. R. Routledge said that he had been convinced for many years that coal-dust contributed largely to explosions; he first noticed it about 25 years ago, when he saw dust take fire on the wire-gauze of a Davy safety-lamp. He was one of the first explorers who descended the shaft after the Micklefield colliery explosion, and was then more convinced than ever of the dust-danger, and in the district where the explosion occurred they could write in the dust. He was surprised that some of H. M. inspectors of mines, who agitated very much about coal-dust, were actually in favour of the use of electric motors at the coal-face. He would never put an electric motor at the coal-face, particularly in a pit where there was any liability of an outburst of gas. He was afraid that the use of motors at the face would be responsible for a tremendous explosion, sooner or later.

Mr. W. H. Chambers said that the dust-danger had been in his mind ever since he had anything to do with mines. He had taken into consideration the question of preventing dust from going down the shaft from the pit-hill, and though he had not effected much, yet a great deal had been done. He had made many enquiries, but up to the present he had not realized his ideal of what ought to be, and of what could be done in that direction. The dust in the pit was a very difficult question to tackle; he had made many experiments in the way of watering, spraying and salting the dust. A spray fixed in the Denaby pit saturated the floor and sides for a distance of 600 feet, but beyond that distance the pit was as dry as ever. The air did not carry the moisture very far, and the wetting of the floor and sides caused considerable falls. They now wetted the floor, and that work was carefully done by hose-pipes from taps fixed on the main water-pipes. That system was carried out all over their pits, and they found it to be most effectual, as a man could exercise discretion regarding the amount of water required, better than a machine. With regard to the watering of the corves at the face, the members would recognize the difficulty mentioned by Mr. Wilson. Another matter was the arrangement with the men about the tare of the tubs; it might be awkward, but a reason-
able amount of expense should not be set against enhanced safety, though, at the same time, it was a matter for careful consideration before they could put the system into operation. As pits became deeper, there was more grinding of the coal than in shallow mines, and this question undoubtedly would have to be considered. There were many good suggestions set forth by Mr. Pickering in his paper, for which they were all much indebted to him; and he had no doubt that they would be used in trying to arrive at some method of dealing with this common enemy.

Mr. W. Walker (H. M. Inspector of Mines) said that, at one colliery belonging to Messrs. Bell Brothers, Limited, near Durham, the watering of tubs was done by mechanical means, from a cistern in the roof worked automatically by the tub-wheels passing over a lever in the rails, and by which a valve was opened. It was found, where the tubs were tight and well made, that about a quart of water per tub was sufficient to allay the dust in the tub, until it got out of the pit, about 1½ miles distant. The effect of this arrangement was very marked. Previously, the engine-plane was full of fine dust, but when this dust was removed and the tubs were watered as described, its condition became quite different,* and continued to be so. At another large colliery, about 1,800 feet deep, considerable trouble was experienced with the dust from the screens. Open gas lights were used at the pit-bottom, and they had to be removed on account of inflammations of the coal-dust, which went down the shaft. In that case, steam-jets were applied on the jigging-screens with good effect, and the quantity of dust going down the shaft was very considerably reduced. At other mines with which he was acquainted, salt was used in the main haulage and travelling roads, where water could not be used with satisfactory results, on account of its injurious effects on the roof and sides. He agreed with Mr. Chambers that wherever it could be adopted, there could be no better method of watering than by stand-pipes placed at intervals and combined with the removal of the dust-accumulations from the roads, it was much better than waterspraying or any other means.

Mr. I. Hodges thought that Mr. Pickering had given one of the principal solutions of the difficulty in his first suggestion,

namely, "that the sides and bottoms of the tubs should be made dust-tight." During the past two years, his firm had renewed the whole of their rolling stock at one pit with perfectly tight corves, having pressed-steel bottoms, and grooved side and end boards with iron tongues. He did not think that as much dust was blown from the top of a tub as was lost from a tub having defective sides. He had found with steel-bottomed tubs the disadvantage of a heavier tare, but they were able to carry a bigger load, and they were sure, when that load reached the pit-bottom, that the roads had been kept clean. As mines got farther inbye and were perfectly dry, it was not easy to get water to the end of the haulage-roads. It certainly entailed heavy expenditure, as pure water must be used to prevent "furring" of the pipes. With regard to dust from the screens, he had no doubt that all new screens would be placed as far from the pit-top as possible. He had found that by keeping the shaft-buntions wet, a large amount of dust was caught.

Mr. J. Gerrard (H. M. Inspector of Mines) said that there could be no discordant note as to the obvious danger of coal-dust. They had tried to prevent colliery explosions by improved ventilation; and possibly, in no branch of mining had greater advances been made than in this; but increased ventilation influenced the amount of coal-dust. Improvements had been made in the lighting of mines, and much had been done to diminish the danger from the use of explosives. In these three branches of mining, which, in times past, were associated with explosions, Yorkshire had taken the foremost position. But, so far as his knowledge of the county went, they were not in line with others in dealing with coal-dust. The great danger was proved at Micklefield collieries; it had also been proved at Altofts colliery; and Mr. Garforth had made it known far and wide, how coal-dust contributed to the loss of life at Altofts colliery. In South Wales, there was a long list of collieries where coal-dust was being tackled. At more than 40 collieries, pipes were laid in the roadways; at several, the total length established amounted to more than 60,000 feet; and much had also been done in Durham and Northumberland. So far as his experience went, he did not think that they could depend upon fixed water-sprays. Spraying, undoubtedly, was the easier
way, but it was not the most effectual, and he thought that the
definite conclusion had been arrived at that stand-pipes with
attached hose-pipes were the best. He did not think that the
remedy was altogether connected with the tubs: they wanted
something more, for if they had absolutely dust-tight tubs, a
large amount of dust would be taken from the top, more especially
in the case of high-speed haulage. Dust would have to be tackled
from all points: and, apart from the question of danger, much
more work was possible on a road free from dust, than on a
thickly-coated dusty road.

**Mr. W. E. Garforth** though that it was very much better to
deal with the cause than with the effect, and if they could
prevent dust from going down the pit, it was better than having
the dust accumulating on the bars and interstices of the roof,
to be dealt with by water-sprays. These were good for the dust,
but bad for the roads. As they knew, he (Mr. Garforth) gave
evidence before the Royal Commission on Accidents in Mines in
1891. It was a very exhaustive enquiry, and the result was
that especial attention was directed to the danger of coal-dust.
After referring to improvements in ventilating, lighting,
blasting, etc., he (Mr. Garforth) placed value on dust-tight tubs,
adding that if the directions mentioned by Mr. Pickering in
his paper, what had been said by previous speakers, and a
careful perusal of the Report of the Royal Commission on
Accidents in Mines, were combined, together with the exercise of
a little common sense, a great deal could be done to prevent
accidents from coal-dust. The quantity of dust that was
accumulated in some mines, 2,000 or 2,500 feet deep, was not as
great as it was in some mines at a depth of 1,000 feet. In some
deep mines, like the Roger mine in Lancashire, the coal was
strong, and very much less liable to make dust than the Silkstone
seam in Yorkshire; consequently, there was not the same danger.
In reference to Mr. Routledge's remark regarding the use of
electric motors at the coal-face, he (Mr. Garforth) directed
attention to the experiments that had been made on the subject
of electricity in mines. He would find that in a colliery, where
there was coal-dust, with a hermetically sealed motor, no danger
need be apprehended.

**Mr. A. B. Hewitt** (Stanton colliery) wrote that Mr. William
Galloway had stated that 1 pound of dust was inflammable, not
explosive, in 160 cubic feet of air, also, that an explosive mixture was formed in the presence of 1 per cent. of fire-damp. He would like to know whether, in the opinion of Mr. Pickering, an ordinary mine-official would be likely to discover 1 per cent. of gas. And, if he failed to discover this amount with his safety-lamp, and an explosion occurred, would it be put down to coal-dust? If the mine had been reported free from gas before an explosion, most probably the dust-theory would be introduced, whereas the origin of the explosion had been 1 per cent. of gas. He (Mr. Hewitt) would also like to know whether Mr. Pickering considered that all dust was dangerous. If not, where would the distinction be made? The removal of dust would tend to increase the danger, unless it had been thoroughly saturated. At some mines, as a preventive against the spread of an explosion, lengths of brick arching had been built at variable distances apart, kept clear from dust, and watered with salt-water, with the intention of preventing the explosion from passing over the wet part, provided that it was of sufficient length.

Mr. W. H. Pickering, replying to the discussion, wrote that the object of his paper was not to reiterate or review previous exhaustive papers and books on this subject, but to ask whether they, as practical men, were not bound to take some action to remove or at least to scotch a very grave and recognized danger. Apart from dust being a serious element in the spread of explosions, it was as inflammable as tinder, and if possible, should not be allowed to accumulate in mines. A fire in the main intake-airway of a modern colliery might be as disastrous as an explosion of fire-damp. He (Mr. Pickering) believed that such a fire would travel inbye in some dusty roads, at such a rate that it would be impossible to get the men out before they were overcome. At a recent fire on the surface at a Yorkshire colliery, an eye-witness stated that the flames ran along the dusty pit-frame as though the dust had been gunpowder.

The cost of watering the full tubs, before they left the face, would not be serious. A small watering-can with a fine rose might be provided. It would only be necessary to sprinkle the tubs with a quart of water or even less. Watered dust caked, and was not easily swept off even when dried by evaporation. The suggestion was only thrown out, however, as a possible
auxiliary to other watering. The shaft-spray would be effective, but the danger of damaging the winding ropes as well as the guides would have to be considered. This was not a very serious danger, if the ropes and guides were properly and regularly greased.

It was gratifying to find Mr. Routledge, one of the pioneers of the coal-dust theory, taking part in the discussion. Compressed air and water-sprays were now used at Micklefield colliery, and the dust was most effectually damped. Mr. Routledge was right in supposing that electricity had introduced a new and serious element of danger, but his remedy was perhaps, if anything, too heroic.

The temperatures taken by dry-bulb and wet-bulb thermometers were given, in order to show the practical difficulty of damping the roads of deep hot mines, owing to the dryness of the air passing. The experience of the effect of watering on many roads, causing the bottom to lift, etc., was a common one, and it was probable that few roads of the deep mines to be opened in Yorkshire would stand heavy watering. This was another argument in favour of cutting off the supply of dust.

The 10 or 12 degrees between the readings of the dry-bulb and wet-bulb thermometers at Denaby colliery proved that the water soon evaporated. He (Mr. Pickering) had seen at Cadeby colliery, how a few buckets of water thrown on the side of a road would cause a fall. Mr. W. H. Chambers thought that watering the tubs at the face would alter the tare; but the alteration, if any, would not be a serious one. Watering the tubs on the engine-plane was, however, more important.

The cases shewing the efficacy of watering the tubs mentioned by Mr. W. Walker were most valuable. Could that gentleman supply further particulars of the firing of dust by gas-flames at the pit-bottom? Did the dust flash at the gas-jets, and how far did the flame extend?

It was true that many shallow mines were as dusty as deeper ones, but on account of the heat and the dryness of the air in the deeper mines, it was more difficult to deal with the dust in these pits. Modern deep collieries were designed to raise 3,000 tons up one shaft, and if the seam happened to be naturally a dusty one, the danger would be great. At such collieries the screens should not be placed near the pit-top. The dustiness of a seam depended upon the structure as well as on the hardness of
the coal. Dangerous dust often consisted of the spores and seeds of the mosses, which flourished when the seams were formed.

Mr. Garforth in replying to Mr. Ruthledge, upon the question of electricity, pointed out that contrivances had been devised to reduce the danger from sparks from electric motors underground. In all probability, these would, eventually, be made effective, and other precautions would be taken at electrical installations. But the fact remained that electricity had introduced a new and serious danger into mines. Accidents would happen with the best regulated machines, and cables would be broken through careless handling, etc. A slight explosion of gas was recorded at a Yorkshire colliery in 1903, due to the cable of an electric coal-cutting machine being cut by a fall of stone.

It was difficult to say when an explosion begins and an inflammation ends: much depends on the speed of ignition. Neither an ordinary mine-official, nor anyone else, could discover 1 per cent. of fire-damp with a safety-lamp. Such a percentage would not form an explosive mixture in dust-free air; but, in conjunction with dust, it would form an explosive mixture. It was immaterial whether the explosion of such a mixture was called an explosion of dust or of fire-damp. It might properly be described as an explosion of dust and fire-damp, though dust would be the predominant partner, for it would be inflammable by itself whilst the 1 per cent. of fire-damp would be harmless in dust-free air.

He (Mr. Pickering) did not consider that all dust was dangerous. Fire-clay and stone-dust would not explode, but these dusts were injurious to health when breathed with the air. The removal of dust need not increase the danger of explosion, if it were done at the right time and proper precautions were taken. Wet zones had been formed in some mines with the object of preventing the spread of an explosion and ensuring a limitation of the explosion. Such measures did not, however, go to the root of the evil, and it was better, if possible, to cut off the supply of dust altogether.

The President (Mr. T. W. H. Mitchell) moved a vote of thanks to Mr. Pickering for his interesting paper.

Mr. M. H. Habershon seconded the resolution, which was carried.
DISCUSSION OF MR. M. GEORGI'S "NOTES AND CONSIDERATIONS ON SYSTEMS HAVING WORK OF AN INTERMITTENT AND IRREGULAR CHARACTER TO PERFORM: METHODS OF LOAD-COMPENSATION."

Prof. G. R. Thompson (Leeds) said that Mr. Georgi's paper assisted the members in forming opinions on a very important subject, namely, the application of electricity to winding, and by showing what could be done with the best steam-engine working under the best conditions would give users of steam winding-engines reason to ask whether their arrangements were the most suitable and economical. By suggesting such questions, it would of necessity tend to the improvement of steam winding-plants.

In connection with equation (1)† and Fig. 1 (Plate IV.), he would like to ask a question, which was rather of academic than of practical interest. It would be noticed that, for each value of \( p \), there were two values of the velocity, \( V \), of winding the given load, \( p \): one decreasing as \( p \) increased and the other increasing as \( p \) increased. The mathematical problem solved was really more general than the winding problem propounded, and he would like to know the construction that the author would place on the second value, and also the interpretation that he would give to the negative values of \( p \) and \( V \). Returning to equation (1), if the formula were applied to a winding-engine, it would be found that while the acceleration chosen was reasonably high, and possibly not exceeded by many winding-engines, the retardation in the latter would vary much according to the weight of the usually unbalanced rope relative to the coal wound. It would generally be found that, as the speed increased towards the middle of the wind, the average effective pressure in the cylinder of the winding-engine decreased, profoundly modifying in practice the peak-load shown on the diagrams. The equation (1) clearly indicated the advantage of heavy lifts and slow speeds, if the maximum variation in the demand for power only were considered; but, unless the gearing of the winding mechanism were modified, this would involve a large engine (one capable of giving a big turning moment) and

† Ibid., pages 89 and 112.
one developing comparatively little power for its size: a state of things which would lead to large radiation and condensation-losses in steam-engine practice, as well as to heavy machinery.

He (Prof. Thompson) considered that the methods proposed were adequate to throw a steady or practically steady load on the steam-engine, but he was doubtful whether this did not in some cases involve as many disadvantages as advantages; and he would ask whether the need for uniform power-demand from the central station could not be removed by modification in winding-plants, if electrical, and whether the steam-plant could not be in like manner improved. At the last meeting, it would be remembered, he pointed out that it was recognized that the load could be largely equalized by adopting excessive counter-balance. Since then a paper had been read at the Birmingham meeting by Mr. E. H. Roberton dealing with this phase of the question; * he (Prof. Thompson) need, therefore, only give as an illustrative example, a particular case of a steam winding-engine.

The engine winds a load of 5 tons from a depth of 1,260 feet and requires an effective steam-pressure on the pistons of 20 lbs. pounds per square inch to balance the load of coal. It requires an effective pressure of 14 pounds per square inch to balance the hanging rope, but this pressure decreases 1 1/4 pounds per square inch for each revolution. Allowing 10 pounds per square inch as the effective pressure required to overcome friction, an average effective pressure of 45 pounds per square inch is required to just start the wind. At the end of the last revolution, the effective pressure available for retardation is 17 3/4 pounds per square inch, since the pressure has been decreasing 1 1/4 pounds per revolution.

The moving masses estimated at their equivalent peripheral values are: Rope, cages, tubs, coal, etc., 63,800 pounds; two pulleys, equivalent, 12,000 pounds; and drum, equivalent, 43,000 pounds; a rough total of 120,000 pounds. By timing the wind, the acceleration found was g/12 or 2 7/12 feet per second per second, for this an average effective pressure of 17 3/4 pounds per square inch on the pistons is needed. The retardation is about the same as the acceleration. If, however, a tail rope had been used of equal weight to the winding rope the effective pressure to just start the

load would have been 31 pounds per square inch with the same at the end for retarding. Reckoning the same initial pressure as before for winding, the pressure available for acceleration is 32 pounds per square inch; the acceleration being therefore 0.15 g, and the retardation about the same. Any excess of counterbalance added, will increase both the acceleration and the retardation, and consequently will enable the engine to wind quicker or heavier loads. Thus, if a specially flexible flat tail rope of double the weight of the winding rope be used, the effective load and friction at the start should be made equal to 17 3/4 pounds per square inch effective steam-pressure on the piston and at the end to 44 3/4 pounds per square inch; or the acceleration would then be 0.29, and the retardation about the same. The acceleration could be reduced if desired, and the engine worked on expansion from the beginning of the wind, the retardation remaining unaltered and being sufficient to bring the machine to rest in 7 seconds from a maximum velocity of 45 feet per second, or in a little less than three revolutions.

By such means as this, a steam-engine could be made to work under its best cycle for fully six-sevenths of the wind. In this connection, he (Prof. Thompson) desired to point out another way of decreasing the steam-consumption in a winding-engine by equalizing the load throughout the shift, namely, by shortening the time of banking. Mr. Georgi allowed 45 seconds for changing 4 tons 10 cwt., whereas by adopting such banking arrangements as are in use at Cadeby colliery, the time can be reduced to 5 seconds, thus rendering fully 90 per cent. of the time available for active winding. Keeping the engine under steam for a longer portion of the winding time, would enable one to reduce its size and the size of the connecting steam-pipes, and to reduce the consumption of steam thereby. Such considerations apply equally to electric winding-engines and render the equalization of the load an easier problem, but one attended with less advantage.

He (Prof. Thompson), in considering the acceleration-losses,* had some difficulty in accepting the loss as infinitely great when $j$ is zero. The difficulty arose in taking $j$ to the limit, in which case, when $j$ equals zero, the velocity, $v$, could only be acquired

in infinite time and through an infinite space, whereas the wind is limited to the depth of the shaft. The diagram of work (Fig. 7, Plate IV.)* on which the loss in starting through a rheostat was based, was, however, open to question. In starting, an overload current is allowed to flow, this being kept from exceeding a maximum by means of a resistance, which is completely cut out when the counter electromotive force generated by the motor is capable of effecting this purpose. The machine is still overloaded, and its speed increases with increasing counter electromotive force and decreasing current. The loss of work must, therefore, not be reckoned on the final velocity, but on the smaller one at which the machine runs when overloaded. A diagram like Fig. 7 (Plate IV.) with the horsepower falling from 1,500 to 750, could only be secured by switching in resistance suddenly after the acceleration-period is passed. This change of diagram will of course vitiate the conclusions subsequently deduced regarding the relative advantages of starting resistance or voltage-converters.

SYSTEMATIC TIMBERING AT EMLEY MOOR COLLIERS.

___

By H. BADDILEY.

Systematic timbering is a subject that every colliery manager and every colliery official should consider very seriously, and the writer feels that colliery managers should use every endeavour to reduce the number of accidents from falls of roof and side, until they have established at their collieries the system of timbering that would best suit each particular seam or district under their charge. It is the duty of colliery managers to educate their officials, and they again, with the help of the former, should endeavour to educate the miners. After three years' experience the writer feels sure that this can be done. He has been hammering away at his men for the past three years; he is highly satisfied with the progress that has been made, and great credit is due to the miners for the way in which they have fallen in with the improved system of timbering.

Wheatley Lime Coal-seam.—For the purpose of explaining more fully the system of timbering in the Wheatley Lime coal-seam, under the writer's charge, sketches have been prepared (Plate IV.) shewing the systems adopted where coal-cutting machines are used; and where the coal is got by hand-labour.

Machine-faces.—In the machine-faces (Fig. 1, Plate IV.), two rows of props, A and B, only are left along the face, after the coal has been filled away (Fig. 2). A third row, C, is set behind the machine as soon as the coal has been under-cut (Fig. 3), and as the coal is filled away the filler sets another row, D, about 2 feet from the last one, C (Fig. 4). The two back rows, A and B, are then drawn out, leaving only the two rows, C and D, next to the face, about 2 feet apart. The distance from prop to prop along the face varies from 2 to 2\(\frac{1}{2}\) feet. The rows of props are set perfectly straight. As an instance, not long ago, measurements were taken in a face 675 feet long: (1) the distance, from
the coal-face to the first row of props, varied from $3\frac{1}{2}$ to 4 feet, the number of props set being 280; (2) from the first to the second row, the distance varied from 2 to $2\frac{1}{2}$ feet, the number of props set in this row being 136; and (3) in no case, along the face, was a prop found more than 6 inches out of a straight line. It was possible to set a mining dial at one end of this face, and take a bearing to the other end, 675 feet distant. This face had travelled over 1,500 feet by machine-work, and was advancing at the rate of $16\frac{1}{2}$ feet per week.

Previous to introducing this systematic method of timbering, the props were set in a rather irregular manner: the roof, being composed of strong bind, came on in very heavy weights, breaking the straggling props one by one, and finally came in along the face. Wood chocks were tried with better results, but as they proved rather expensive, the system of setting two rows of props close together in a straight line was tried. With double the number of props in the row, the roof now breaks off in a straight line, close behind the back row of props, and there is not half the trouble with the face falling in, in fact it is almost a thing of the past, and very few chocks are set now.

*Hand-worked Face.*—The system (Fig. 5, Plate IV.) in the hand-worked places is somewhat similar to that in the machine-faces, except that a row of props, $C$, 5 feet apart, is set along the face, close to the coal, before the coal is holed (Fig. 6) and two intermediate props are set between them after the holing is done and before the sprags, $D$, are drawn (Fig. 7).

*New Hards or Silkstone Coal-seam.*—The Silkstone coal-seam, 80 feet above the Wheatley Lime coal-seam, is worked mostly by shallow-cut machines, and the system of timbering is not quite the same as in the seam below. The roof being composed of a softer bind is broken off much more easily; and the seam, being thin, varying from $1\frac{1}{2}$ to 2 feet in thickness, is packed solid in the goaf, with the holing and ripping dirt. In this case, only one row of props is left to support the roof, after the coal has been filled away, but another row is set, as the holing is done. The props are set in a straight line, the rows are placed $3\frac{1}{2}$ feet apart, and the distance from prop to prop in any row does not exceed 3 feet.
**Blocking Coal-seam.**—This seam, 120 feet below the Wheatley Lime coal-seam is also a thin seam (coal, 20 inches and bottom-dirt, 6 to 8 inches) with a thick roof, composed of alternating layers of strong bind and sandstone. It is worked by coal-cutting machines. The system of timbering is similar to that adopted in the New Hards coal-seam. An ample supply of lids is sent daily to the working-faces: no prop being set without a lid. The lids are 12 to 18 inches long, 3 to 6 inches wide, and 2 inches thick. The lids save the props, and allow them to be more easily withdrawn.

**Barnsley Soft or Warren House Coal-seam.**—The writer has charge of a small colliery working this seam, and until about 2½ years ago it was worked on the bord-and-pillar method, because he was given to understand that the roof was too tender for the longwall method. However, he adopted the longwall method, although the workmen said that the face would be closed in less than one month; and when the first big weight came on, the men came out, remarking, that the face was finished, and that everything would be buried. However, very little damage was done, and the same face is still working.

This seam is worked by hand-labour. The section varies from 4½ to 5 feet of dirt and coal. The roof is composed of rather soft grey bind. Two rows of props are set along the face, 3 feet apart, and the distance from prop to prop is 2½ feet. Another or third row is set close to the coal, and the distance from prop to prop is about 5 feet. This row is set before the men commence to hole the coal; and, when the holing is done, intermediate props are set. Hard wood lids are used in this seam, 18 to 24 inches long, 6 inches wide and 1½ inches thick, and they obtain a good hold of the rather soft roof. The seam works very well on the longwall system, and the roof gives but little trouble.

**Conclusion.**—The writer feels sure, if the workmen are taught to set timber in a systematic way, and a strict supervision is kept over them by the officials, that the number of accidents from falls of roof can be most materially reduced.

Mr. A. J. Tonge’s paper on “A Colliery-plant: its Economy and Waste,” was read as follows:
To illustrate McII.Baddiley's Paper on "Systematic Timbering at Emley Moor Collieries."

FIG. 1.—Plan of Machine-face, with Coal partly filled.

Fig. 2.—Section of Working-face, ready for Holing by the Machine.

Scale, 60 Feet to 1 Inch.

Fig. 3.—Section of Working-face, shewing holed Coal.

Scale, 8 Feet to 1 Inch.

Fig. 4.—Section of Working-face, shewing fallen coal ready for Filling.

Fig. 5.—Plan of Hand-holed Face.

Scale, 20 Feet to 1 Inch.

Fig. 6.—Section of Working-face, ready for Holing.

Scale, 8 Feet to 1 Inch.

Fig. 7.—Section of Working-face shewing holed Coal.

Scale, 8 Feet to 1 Inch.
A COLLIERY-PLANT: ITS ECONOMY AND WASTE.

By A. J. Tonge.

Introduction.—The question of waste of coal has, of late, occupied a large share of the attention of mining societies. The Royal Commission on Coal-supplies has had the matter under consideration for two-and-a-half years, and its conclusions are awaited with interest. It is, however, with one branch only of the economy or waste at collieries that the writer proposes to deal in this paper, namely, that taking place in the boiler fire-holes, either from the efficiency or from the want of efficiency of the boiler, or of the engines which the boiler feeds.

It is certainly late in the day to point out that the calculation of the coal burnt in the fire-hole, as a percentage upon the amount of coal raised, affords no reliable guide to the efficiency of a colliery-plant. It signifies nothing to say that the coal-consumption is under 5 per cent. of the coal raised, for there is no attempt in this statement to estimate the actual work done, which is essential. And again, it is late in the day to suggest that the true basis of comparison should be that of the quantity of steam used (and not the quantity of coal consumed) to the amount of work done.

In a mine that is already fully developed, where there are full loads on all the surface-engines, it may be possible to effect savings by modernizing the engines and employing proper condensing arrangements, provided that the engines are comparatively close to the boilers; but this can only be thoroughly effective if the loads are fairly full and the engines comparatively modern. In a mine that is new and is developing slowly, it is not possible to have full loads on the engines, and there is greater liability to waste than in the former case.

It may be said that work at collieries is always in a progressive or retrogressive stage. This is fully recognized by those who erect large engines to provide for eventualities, and it is not
sufficiently recognized by those who erect small engines that are likely to break down, at an early date, because of overload. In any case, the economy of the plant suffers. This loss can not be avoided entirely under any system, but the writer is of opinion that it is possible, under certain conditions, to minimize this disadvantage to a large extent.

The figures contained in this paper, which it is hoped may be useful for reference, were obtained at a colliery that is not yet five years old from the commencement of the sinking, where the drawing of coal began only two-and-a-half years ago, and where the output has been systematically kept down, notwithstanding the greater capacity of the plant. The colliery may, therefore, be said to be working under average conditions, that is to say, it is a colliery with a rising output, with proper arrangements for duplicating and extending the body or trunk of the plant, and with a fair reserve for fluctuations and extensions on its limbs.

Winding-engines. — There are two winding-shafts, 1,320 and 936 feet deep respectively. The winding-engines each have two horizontal cylinders and cylindrical drums. There is no balance-rope under the cages, and the cages are brought to a stand without the aid of keps or a scaffold. The engines are supplied with steam from four Lancashire boilers, 30 feet long and 8 feet in diameter, at a maximum pressure of 100 pounds per square inch. Economizers are attached to the boilers. Table I. records the results obtained from extremely careful tests of these engines.

The best results are obtained from the smaller engine; but this is accounted for, to a certain extent, by the greater acceleration and the higher velocity of the moving masses in the larger engine, for, while the height lifted is 40 per cent. greater, the time of winding is only 25 per cent. longer. In the case of the smaller engine, the amount of steam used per horsepower-hour in the coal raised is probably about as low as can be obtained with an ordinary non-condensing winding-engine. Many other interesting figures can worked out from those set forth in Table I., but the writer has thought it best not to include them.
### Table I. — Consumption-tests of Two Winding-engines.

<table>
<thead>
<tr>
<th></th>
<th>No. 3 Pit.</th>
<th>No. 4 Pit.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Winding-engine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinders</td>
<td>No. 2</td>
<td>No. 2</td>
</tr>
<tr>
<td>Diameter</td>
<td>inches 32</td>
<td>inches 36</td>
</tr>
<tr>
<td>Stroke</td>
<td>feet 6</td>
<td>feet 6</td>
</tr>
<tr>
<td>Piston-rod, diameter</td>
<td>inches 5</td>
<td>inches 6½</td>
</tr>
<tr>
<td>Cylindrical drums,</td>
<td>feet 15</td>
<td>feet 18</td>
</tr>
<tr>
<td>Diameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of test</td>
<td>hours 7½</td>
<td>hours 7</td>
</tr>
<tr>
<td>Average steam-pressure per square inch</td>
<td>pounds 82-8</td>
<td>pounds 79-7</td>
</tr>
<tr>
<td>No. of cut-off revolutions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of revolutions with steam on</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average steam-pressure per square inch</td>
<td>pounds 65-0</td>
<td>pounds 68-5</td>
</tr>
<tr>
<td>Piston speed per minute, with steam on</td>
<td>513</td>
<td>540</td>
</tr>
<tr>
<td>Indicated horsepower, average value horsepower</td>
<td>881-5</td>
<td>1,291-1</td>
</tr>
<tr>
<td>Ratio of indicated horsepower to the coal horsepower, average values</td>
<td>3 35 to 1</td>
<td>4 1 to 1</td>
</tr>
<tr>
<td>Full time of winding</td>
<td>seconds 28:5</td>
<td>seconds 34:00</td>
</tr>
<tr>
<td>Average piston speed per minute throughout wind</td>
<td>478-9</td>
<td>481-7</td>
</tr>
<tr>
<td>Average rope speed per minute throughout wind</td>
<td>1,953</td>
<td>2,329</td>
</tr>
<tr>
<td>Weight of coal raised</td>
<td>tons 506:55</td>
<td>tons 573:4</td>
</tr>
<tr>
<td>Height of winding coal</td>
<td>feet 936</td>
<td>1,320</td>
</tr>
<tr>
<td>Weight of coal raised per hour</td>
<td>tons 75:54</td>
<td>53-3</td>
</tr>
<tr>
<td>Average horsepower in coal raised over whole test</td>
<td>horsepower 80:0</td>
<td>79-6</td>
</tr>
<tr>
<td>Total number of windings</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Weight of coal per winding</td>
<td>tons 1 888</td>
<td>1,753</td>
</tr>
<tr>
<td>Weight of cage, chains, empty tubs, etc.</td>
<td>3 ½</td>
<td>3 ½</td>
</tr>
<tr>
<td>Weight of rope, per yard</td>
<td>pounds 11</td>
<td>11</td>
</tr>
<tr>
<td>Steam consumptions, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam raised per hour</td>
<td>pounds 7,776</td>
<td>10,019</td>
</tr>
<tr>
<td>Steam lost per hour by boiler-leakages</td>
<td></td>
<td>432</td>
</tr>
<tr>
<td>Steam lost per hour through winding-engine valve, when shut</td>
<td></td>
<td>705</td>
</tr>
<tr>
<td>Steam used per hour by winding-engine</td>
<td></td>
<td>6,639</td>
</tr>
<tr>
<td>Steam used per horsepower-hour in coal raised</td>
<td></td>
<td>83</td>
</tr>
<tr>
<td>Coal used per horsepower-hour in coal raised</td>
<td></td>
<td>17 5</td>
</tr>
<tr>
<td>Steam used by engines per ton raised 1 foot</td>
<td></td>
<td>0 012</td>
</tr>
<tr>
<td>Steam used by engines per ton raised to bank</td>
<td></td>
<td>11 7</td>
</tr>
<tr>
<td>Coal consumed to coal raised</td>
<td>per cent.</td>
<td>0 70</td>
</tr>
</tbody>
</table>
Generating-plant.—The generating-plant comprizes two Parsons turbo-alternators supplied with steam from two Lancashire boilers, 30 feet long and 8 feet in diameter, at a maximum pressure of 150 pounds per square inch. These boilers are placed alongside the boilers for the winding-engines, and are also provided with economizers. Each alternator has a normal capacity of 300 kilowatts. For the two months ending December 31st, 1904, electrical work to the amount of 238,600 kilowatt-hours was generated, or, an average load of 163 kilowatts. The load varies from a maximum of 247 kilowatts with a steam-consumption of 23 pounds per kilowatt-hour to a minimum of 109 kilowatts with a steam-consumption of 28 pounds per kilowatt-hour. With an average load, the steam-consumption is 25 pounds per kilowatt-hour or 19 pounds per electric horsepower-hour. Table II. records the results of three tests of the Parsons turbo-alternators.

Table II. Results of Tests of Two Turbo-alternators of 300 Kilowatts, The Average Readings Are Recorded.

<table>
<thead>
<tr>
<th>No. of Test</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of machine</td>
<td>851</td>
<td>852</td>
<td>852</td>
</tr>
<tr>
<td>Load, kilowatts</td>
<td>314.4</td>
<td>311.2</td>
<td>106.5</td>
</tr>
<tr>
<td>Duration of test, minutes</td>
<td>150</td>
<td>202</td>
<td>122</td>
</tr>
<tr>
<td>Kilowatt-hours, No. 1 meter</td>
<td>383</td>
<td>512</td>
<td>95</td>
</tr>
<tr>
<td>Kilowatt-hours, No. 2 meter</td>
<td>406</td>
<td>545</td>
<td>120</td>
</tr>
<tr>
<td>Total kilowatt-hours</td>
<td>789</td>
<td>1,057</td>
<td>215</td>
</tr>
<tr>
<td>Power-factor</td>
<td>1</td>
<td>1</td>
<td>0.98</td>
</tr>
<tr>
<td>Volts</td>
<td>402</td>
<td>462</td>
<td>462</td>
</tr>
<tr>
<td>Amperes</td>
<td>391.1</td>
<td>389.3</td>
<td>157.5</td>
</tr>
<tr>
<td>Volt-amperes</td>
<td>391</td>
<td>389.3</td>
<td>157.5</td>
</tr>
<tr>
<td>Main-field amperes</td>
<td>9.6</td>
<td>11.3</td>
<td>9.8</td>
</tr>
<tr>
<td>Revolutions of turbine</td>
<td>3,010</td>
<td>3,040</td>
<td>3,060</td>
</tr>
<tr>
<td>Steam-pressure, pounds per square inch</td>
<td>144</td>
<td>147</td>
<td>149</td>
</tr>
<tr>
<td>Vacuum at condenser, inches</td>
<td>26.2</td>
<td>26.7</td>
<td>27.05</td>
</tr>
<tr>
<td>Height of barometer</td>
<td>30.05</td>
<td>30.07</td>
<td>30.07</td>
</tr>
<tr>
<td>Steam used per hour, pounds</td>
<td>6,996</td>
<td>6,837</td>
<td>2,991</td>
</tr>
<tr>
<td>Steam used per kilowatt-hour</td>
<td>22.3</td>
<td>22.0</td>
<td>28.1</td>
</tr>
<tr>
<td>Steam used per electric horsepower-hour</td>
<td>16.6</td>
<td>16.4</td>
<td>21.0</td>
</tr>
<tr>
<td>Load on plant</td>
<td>Full</td>
<td>Full</td>
<td>One-third</td>
</tr>
</tbody>
</table>

The writer records in Table III. how much of the useful electricity leaving the switch-board at the generator is lost, before becoming the mechanical brake-horsepower of the motor at the point where the power is applied to useful work. This corre-
sponds with the brake-horsepower of the ordinary steam-engine, and the comparison between the steam used per brake-horsepower of the motor and that used per brake-horsepower of the ordinary steam-engine, recorded in Table V., shews the economy or loss due to the use of motors or steam-engines. The writer has not taken into account, in this paper, the extra convenience afforded by the use of electric power for many purposes and for positions where the use of steam is debarred by the distances; and allowance has only been made for comparatively short lengths of pipes from the boilers to the engines in the case of steam-driving. In addition to the motor-load of 164 horsepower shewn in Table III., an average continuous load of 53 electric horsepower is supplied from the same generator for lighting purposes, making a continuous output from the generator of 217 electric horsepower.

Table III.—Cable-losses and Motor-efficiencies.

<table>
<thead>
<tr>
<th>Work of Motors</th>
<th>Hoistage</th>
<th>Screenine-plant.</th>
<th>Fans.</th>
<th>Ventilating-fans</th>
<th>Other Fans</th>
<th>Coal-cutters</th>
<th>Small motors</th>
<th>Saw mill</th>
<th>Briquettes-plant.</th>
<th>Totals and Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of motors ...</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Normal rating brake-horsepower ...</td>
<td>68</td>
<td>90</td>
<td>87</td>
<td>120</td>
<td>20</td>
<td>40</td>
<td>19</td>
<td>45</td>
<td>90</td>
<td>579</td>
</tr>
<tr>
<td>Average distance from generator, feet ...</td>
<td>1,230</td>
<td>216</td>
<td>402</td>
<td>1,371</td>
<td>282</td>
<td>3,234</td>
<td>288</td>
<td>255</td>
<td>1,110</td>
<td>924</td>
</tr>
<tr>
<td>Average working load, electric horsepower ...</td>
<td>30</td>
<td>48</td>
<td>71</td>
<td>100</td>
<td>16</td>
<td>49</td>
<td>13</td>
<td>26</td>
<td>83</td>
<td>432</td>
</tr>
<tr>
<td>Cable-efficiency, the electric horsepower being unity ...</td>
<td>0.98</td>
<td>0.99</td>
<td>0.98</td>
<td>0.96</td>
<td>0.99</td>
<td>0.95</td>
<td>0.99</td>
<td>0.99</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td>Motor-efficiency, the electric horsepower being unity ...</td>
<td>0.68</td>
<td>0.76</td>
<td>0.86</td>
<td>0.86</td>
<td>0.80</td>
<td>0.86</td>
<td>0.80</td>
<td>0.85</td>
<td>0.88</td>
<td>0.84</td>
</tr>
<tr>
<td>Combined efficiency, the electric horsepower being unity ...</td>
<td>0.66</td>
<td>0.75</td>
<td>0.84</td>
<td>0.83</td>
<td>0.79</td>
<td>0.82</td>
<td>0.79</td>
<td>0.84</td>
<td>0.84</td>
<td>0.82</td>
</tr>
<tr>
<td>Average load in brake-horsepower while working ...</td>
<td>20</td>
<td>36</td>
<td>60</td>
<td>82</td>
<td>13</td>
<td>40</td>
<td>10</td>
<td>22</td>
<td>70</td>
<td>333</td>
</tr>
<tr>
<td>Average continuous load on generator, electric horsepower ...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
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<tr>
<td>Maximum load on the generator, electric horsepower ...</td>
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<td>...</td>
<td>164</td>
</tr>
<tr>
<td>Minimum load on the generator, electric horsepower ...</td>
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<td>329</td>
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</tbody>
</table>

- Table III: Cable-losses and Motor-efficiencies.
Table IV.—Short Description of the Work performed by the Motors.

Haulage.—There are three separate haulage-plants fixed near the pit-bottom: one in each mine. The motors drive the ropes through gearing in two cases, and by belting in the third case. There are two motors of 30 and one of 8 horsepower.

Screening-plant.—There are two screens, driven separately by two motors, each of 45 horsepower. The parts actuated by these motors, include creepers, tipplers, shakers, travelling-belts and lowering-arms. The power absorbed in moving these various parts, when empty, bears a large proportion to that taken when full.

Pumps.—At a mouthing, 450 feet down the shaft, there is a three-throw ram-pump, with a capacity of 10,000 gallons per hour, driven, through gearing, by a motor of 45 horsepower. There is also a centrifugal pump for the turbine-condenser, direct-driven by a motor of 30 horsepower; a centrifugal circulating-pump, for water-softening purposes, direct-driven by a motor of 6 horsepower; and a three-throw boiler feed-pump, belt-driven, by a motor of 6 horsepower.

Ventilating Fans.—The ventilation is effected by means of three Sirocco fans, two being 45 inches in diameter and one 30 inches in diameter, rope-driven from motors. There are two motors of 45 horsepower and one of 30 horsepower. Arrangements have been made for changing the motors for larger ones as the load increases, the object being to keep the load on each motor as near the maximum as possible, and thus maintain the efficiency from the time when the mine is opening out to the time when the mine becomes more extensive.

Other Fans.—There is a forced-draught fan for the high-pressure boilers, two forge-fans and a shop-ventilating fan: all being electrically driven.

Coal-cutters.—A Diamond coal-cutter, with two motors, is undercutting to a depth of 4½ feet and a Hurd bar-type is also undercutting to a depth of 4½ feet.

Small Motors.—Four small motors are used, one for driving the mortar-mill, two in the workshops, and one at the economizers.

Saw-mill.—The saw is driven by a motor of 45 horsepower, allowance having been made for the application of an additional saw in the near future.

Briquette-plant.—This plant is belt-driven from two motors running in parallel, each of 45 horsepower.

Comparison between Existing Conditions and Old Methods.—The writer’s object is to set forth a series of figures, plain and reliable rather than elaborate, obtained from actual tests and experience, shewing the beneficial results of the electrical driving of colliery-plant from the standpoint of economy of coal-consumption.

It is difficult to arrive at an average figure upon which to base the steam-consumptions of ordinary small-colliery steam-engines, such as those employed for driving screens, creepers, pumps, small haulages, etc. Tests of two medium-speed non-condensing continuous-running engines, each of 150 indicated horsepower, were made at the colliery, and an average steam-consumption per hour was obtained of 39 pounds per indicated horsepower.
This result is better than the average results obtained from a number of separate tests taken at different works, and collected from various writers:—Mr. J. S. Dixon, in a test covering fifteen engines of 1,302 total indicated horsepower, including a compound-condensing engine for pumping and a compound-condensing engine for electric machinery, two winding-engines, etc., obtained a consumption of steam per hour of 44 pounds per indicated horsepower.* Mr. W. Geipel, at the Bristol wagon-works, with five engines varying from 8 to 100 indicated horsepower, obtained an average steam-consumption per hour of 50 pounds per indicated horsepower.† Sir T. Richardson, in thirty-one engines at his works obtained an average steam-consumption per hour of 51 pounds per indicated horsepower.‡ Mr. H. A. Mavor, in a test of nine small engines from \( \frac{7}{10} \) to 16 indicated horsepower (average, 5:2 indicated horsepower), obtained a steam-consumption per hour of 94 pounds per indicated horsepower.§ The average steam-consumption per indicated horsepower-hour, taken over these results, amounts to 56 pounds, and this consumption, on a mechanical efficiency of 85 per cent. amounts to 66 pounds per brake horsepower-hour.

Comparison of the Economy of Motors and Steam-engines.—Table V. has been prepared, in order that a comparison may be made between motor and steam driving. The load taken is that of 164 electric horsepower, representing the average load on the generators shown in Table III. Assuming that the preceding steam-consumptions are a fair estimate of steam-engine consumptions, it is possible to make a comparison of the two systems.

The writer has pointed out that there is great elasticity in the electric plant, and as the full rated power of the existing motors amounts to 579 brake-horsepower or 673 electric horsepower at the generator (the efficiency on this load being higher than on the lower figure as the motors would then be fully loaded), a further load of 34 per cent. can be put upon the motors. The

‡ Transactions of the North-east Coast Institution of Engineers and Shipbuilders, 1894, vol. xi., page 19.
§ Transactions of the Institution of Engineers and Shipbuilders in Scotland, 1898, vol. xii., page 319 and Plate XVIII.
lighting at present on the generator amounts to a maximum load of 125 electric horsepower, so that the generators are capable of taking this motor-increase. No further outlay of capital expenditure is, therefore, needed; and, with this higher output, the advantage of motor-driving would be still more pronounced.

**Table V.—Comparison of Motor and Steam Driving.**

<table>
<thead>
<tr>
<th>Description of Plant</th>
<th>Electric Driving</th>
<th>Steam Driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency: electric horsepower or indicated horsepower and brake-horsepower</td>
<td>0.82</td>
<td>0.85</td>
</tr>
<tr>
<td>Average electric horsepower at generator and calculated indicated horsepower at engine</td>
<td>164</td>
<td>158</td>
</tr>
<tr>
<td>Steam consumed per hour per electric horsepower at generator and per indicated horsepower at engine</td>
<td>19</td>
<td>56</td>
</tr>
<tr>
<td>Steam consumed per hour per brake-horsepower at motors and per brake-horsepower at engine</td>
<td>23</td>
<td>66</td>
</tr>
<tr>
<td>Steam consumed per hour for 164 electric horsepower or for 158 indicated horsepower</td>
<td>3,116</td>
<td>8,848</td>
</tr>
<tr>
<td>Coal consumed per hour for 164 electric horsepower or for 158 indicated horsepower, calculated at the rate of 6.3 pounds of steam per pound of coal</td>
<td>495</td>
<td>1,404</td>
</tr>
<tr>
<td>Ratio of coal-consumption, electric to steam driving</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Amount of coal-consumption per year</td>
<td>1,925</td>
<td>5,402</td>
</tr>
<tr>
<td>Cost of coal per year at 5s. 6d. per ton</td>
<td>529</td>
<td>1,510</td>
</tr>
<tr>
<td>Advantage on motor driving for 164 electric horsepower per annum</td>
<td>981</td>
<td>...</td>
</tr>
</tbody>
</table>

**Boiler-evaporation.—**In order to arrive at a fair estimate of the evaporation and duties ordinarily obtained from boilers at collieries, the writer has included in Table VI., as much for reference as for the purposes of his paper, the results of a number of tests of the evaporation of Lancashire boilers. The average water evaporated per pound of coal over the seven tests was 6.32 pounds. The average selling price of the seven qualities of coal was 5s. 6d. per ton.

**Economy of the Plant over One Week.**—The results of tests upon two winding-engines recorded in Table I. are only given for 7.5 and 7 hours respectively, for an output of 940 tons per day, during which time coal only was raised. There are still 16.5 hours out of the day, during which there is a continuous waste and an occasional use of steam for other purposes, such as raising and lowering men, stores, etc. Tests have been made, when the average conditions were prevailing, with the following results:—The total coal burnt during 16.5 hours was 12,007
<table>
<thead>
<tr>
<th>Boiler Tested</th>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
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<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
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<tr>
<td>Duration of test</td>
<td></td>
<td></td>
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<tr>
<td>No. of boilers</td>
<td></td>
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<tr>
<td>Boilers: Length</td>
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<tr>
<td>Diameter</td>
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<tr>
<td>Class of coal used</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Steam-pressure per square inch pounds</td>
<td>147</td>
<td>132</td>
<td>85</td>
<td>84</td>
</tr>
<tr>
<td>Total quantity of water evaporated</td>
<td>193,240</td>
<td>72,144</td>
<td>58,370</td>
<td>111,888</td>
</tr>
<tr>
<td>Total quantity of coal burnt...</td>
<td>27,776</td>
<td>11,872</td>
<td>7,700</td>
<td>10,528</td>
</tr>
<tr>
<td>Evaporation of water per pound of coal</td>
<td>6.95</td>
<td>6.08</td>
<td>5.50</td>
<td>5.96</td>
</tr>
<tr>
<td>Evaporation of water per hour</td>
<td>4.713</td>
<td>4.509</td>
<td>4.250</td>
<td>7.766</td>
</tr>
<tr>
<td>Temperature of feed-water degrees Fahr.</td>
<td>80</td>
<td>80</td>
<td>52.6</td>
<td>90</td>
</tr>
<tr>
<td>Temperature of water on entering economizer degrees Fahr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature of gases on entering economizer degrees Fahr.</td>
<td>80</td>
<td>80</td>
<td>52.6</td>
<td>211</td>
</tr>
<tr>
<td>Temperature of gases on leaving economizer degrees Fahr.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency of economizers: saving of total heat supplied to steam... per cent.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grate-area per boiler square feet</td>
<td>36</td>
<td>36</td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>Coal burnt per square foot of grate-area per hour pounds</td>
<td>18.8</td>
<td>20.6</td>
<td>24.4</td>
<td>9.7</td>
</tr>
<tr>
<td>Coal burnt per hour per boiler pounds</td>
<td>677</td>
<td>742</td>
<td>642</td>
<td>332</td>
</tr>
<tr>
<td>Character of load</td>
<td>Variable</td>
<td>Constant</td>
<td>Variable</td>
<td>Variable</td>
</tr>
</tbody>
</table>
pounds or 717 pounds per hour; and the steam raised during the
same period of 16\( \frac{3}{4} \) hours calculated upon the lowest result of
5\( \frac{1}{2} \) pounds of steam per pound of coal was 66,038 pounds or 3,943
pounds per hour.

The total steam used during a day of 24 hours is as follows:—
While coal is not being wound, 66,038 pounds; while coal is being
wound: boiler-leakage, 3,132 pounds; valve-leakage, 12,852
pounds; winding, 109,340 pounds; a total of 125,324 pounds:
the total steam used throughout the day of 24 hours being
191,362 pounds.

The total coal used throughout the day of 24 hours calcu-
lated upon 63 pounds of steam per pound of coal was 30,375
pounds or 13.56 tons.

There being 1,157 horsepower-hours developed in raising coal
in the day of 24 hours, the steam consumed per horsepower in
coal raised was 165 pounds per hour: the coal consumed per
horsepower in coal raised was 26.2 pounds per hour; and the
cold burnt to the coal raised was 1.44 per cent.

During a week of five working-days, and including two idle
days on which steam was wasting, the total steam consumed for
5,785 horsepower-hours in coal raised was 1,088,000 pounds; the
average steam used per horsepower-hour in coal raised was 188
pounds; the coal burnt per week was 77 tons; and the coal burnt
to the coal raised was 1.64 per cent.

Taking the electric load, on the average, at 164 electric horse-
power, the total amount of steam consumed by the generators
per week was 523,500 pounds; and the steam lost by boiler and
other leakages, 58,800 pounds; making a total of 582,300 pounds.
The average weight of steam used per horsepower-hour in the
cold raised was 101 pounds; the weight of coal burnt per week
was 41.2 tons; and the coal burnt to the coal raised was 0.88
per cent.

The coal burnt for winding and electrical purposes, including
wastage, was 2.52 per cent.

Electric Winding.——As the question of electric winding is so
much to the front just now, it may be of interest to note the
probable effect upon the consumption of coal previously described.
From figures supplied to the writer, as the result of tests of
electric winding-plant, it was found that the ratio between the
steam consumed per horsepower-hour in the coal raised by steam and by electricity is as 3 to 1. As this ratio applied only to the actual time of coal-winding, and as it was possible that there might be more loss during non-working hours with the electric winding-plant, an average ratio of 2 to 1 for the whole time would be a more reliable assumption.

At this reduced ratio, the saving in coal on the output on which the previous figures are based, amounts to 1,925 tons per annum, or, at 5s. 6d. per ton, a saving of £530 per year.

Conclusion.—The writer feels constrained to state that he has advisedly confined his remarks entirely to the economy or waste as between steam and electric driving upon the basis of fuel and steam-consumption only. The situations in which electric driving is more convenient than steam, or vice versa, or the places where some other power may be more convenient than either, have been purposely untouched; as it would not be possible even to attempt this in a paper of moderate length.

The writer records his especial thanks to Mr. W. B. Shaw, electrical engineer, and to Mr. J. Bateson, mechanical engineer, for the valuable help rendered to him, in the collecting together of the figures contained in this paper.

The President (Mr. T. W. H. Mitchell) moved a vote of thanks to Mr. Tonge for his paper.

Mr. J. R. Robinson Wilson seconded the vote of thanks, which was carried.
The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:

**Members—**

Mr. Austen King, Chief Mining Superintendent, Dominion Coal Company, Glace Bay, Nova Scotia, Canada.

Mr. Percy Sibebottom, Mining Surveyor, Thorncliffe Collieries, Sheffield.

Mr. Taro Tomita, Mining Engineer, Tokio, Japan.

The President (Mr. T. W. H. Mitchell) read the following "Notes on Capels for Winding-ropes": —
NOTES ON CAPELS FOR WINDING-ROPECES.

BY T. W. H. MITCHELL.

Owing to his attention having been called to the capeling of ropes, the writer sent several capels to be tested.

(1) The capel of an Elliott locked-coil rope was put on on March 20th, 1904, and taken off on February 4th, 1905, and the following is the result of the test:—Circumference of rope, 4 inches. Total number of wires, 98. With a load of 28·4 tons, the rope pulled rapidly through the capel; with a load of 29·39 tons, the rope broke inside the capel, and finally pulled through.

(2) The second capel of a locked-coil rope was put on on February 4th, 1905, and was taken off and sent to be tested on March 25th, 1905, with the following result:—Circumference of rope, 4 inches. Total number of wires, 98. The rope commenced to pull out of the capel with a load of 14·0 tons; with a load of 46·48 tons, the rope broke inside the capel, and finally pulled through. Seven of the outer layer of wires broke first, then nearly all the remainder of the wires broke together, clear of the fastenings. Several of the wires were broken at different places in the length of the rope.

These results are, to the writer, very disappointing, and it would be interesting to have the opinions and experience of other members in respect of the capeling of locked-coil ropes.

The writer has generally arranged for a workman from the makers to put on the capels, but the rope, the testing of which is first mentioned above, was capeled by colliery-workmen. The length of time that this capel had been in use may have something to do with the bad result; but the workmen contend that it may also have been owing to the split ferrule round which the wires are bent becoming iron-and-iron, when the collars were driven home. The capel would thus not get a proper grip over the whole of the rope, but would only be gripping the split ferrule.
In the second test, the capel had been working for 7 weeks. The portion of the rope that was tested for breaking-strain had sustained the strain of the testing of the capel, so that the reported breaking-strain of the rope must only be considered under these conditions, as the rope was sent out as one for a 90 tons breaking-strain.

In order to compare the locked-coil with the ordinary rope, the writer has had the following tests made:—

(3) This capel had been in use for 11 months. Circumference of rope, 4'05 inches. Total number of wires, 90. The first wire broke with a load of 22'0 tons, and, on the test being continued, several more wires broke. With a load of 32'10 tons, the rope pulled rapidly out of the capel, until, with a load of 42'40 tons, two strands and wires in the remaining strands of the rope broke together, clear of the capel. The wires were broken at different places along the length of the rope.

(4) This capel had been in use for 2 months. Circumference of rope, 3'75 inches. Total number of wires, 90. With a load of 15 tons, the rope had pulled out of the capel 0'11 inch; and the first wire broke with a load of 24'70 tons. The rope pulled rapidly out of the capel with a load of 27'35 tons; and, finally, with a load of 42'08 tons, the rope pulled out of the capel. There was a slight fracture on the capel after the test. After being pulled out of the capel, the rope was tested to destruction. Maximum stress, 46'22 tons. Three strands broke together clear of the fastenings.

The method of capeling is as follows:—

Locked-coil Rope.—Wrap the rope with soft, No. 13 gauge wire, commencing about 7 feet from the end, for about 3½ feet towards the end; then place the two conical wedges on the rope at the end of the wrapping, and make fast with wire. Unwrap the outside wires of the rope, take the twist out and straighten the wires, then turn them back neatly on to the conical wedges as snugly as possible, placing about four pieces of wire round them to hold them in their place. The next layer should be treated in a similar manner, but the wires should be cut shorter to form a taper, and also to allow of all the wires being gripped by the socket. All the remaining layers should be treated in a
similar way. The binding wires should be taken out in each case, except those on the conical wedges. Wrap the rope with one layer of tar-band; heat the capel at the bottom, having some water ready to cool it as you proceed to drive on the hoops, which should be driven securely home.*

Ordinary Wire-rope.—Wrap the rope with a single wire, commencing about 7 feet from the end, for about 3½ feet towards the end, then keep wrapping the wire over and over, until you have formed a knob of the size that you require. Unwrap the strands and straighten them out, turn them back neatly over the knob, as snugly as possible, cutting each layer shorter to form a taper. Wrap the rope with one layer of tar-band; heat the capel at the bottom and drive on the hoops, cooling the capel as you proceed. The hoops should be driven securely home.

Mr. W. Walker (H.M. Inspector of Mines) said that it was rather startling to find, after the comparatively short time during which the rope had been in use, with a load of less than 25 per cent, of the breaking-strain and not very much more than the working load, that the rope had drawn through the capel. The experiment spoke in favour of the periodical re-capeling of all ropes. The form of capel, described by Mr. Mitchell, was, perhaps, not the best that could be adopted for a locked-coil rope. The bending back of the wires round the ferrule was apt to cause damage, and the strain upon the different wires must vary considerably. The best form of capel had a hollow cone, made from a solid forging of Low Moor or other high-class iron. Into the cone, about 9 inches of the ends of the wires of the rope should be carefully and evenly spread out, and then fixed in position by running in good white metal. The end of the rope then became practically a solid cone, which could not be drawn out. On testing a rope with this form of capel, it was found, as a rule, that the rope broke just within the capel at strains varying from 80 per cent, and upwards of the breaking-strain. This capel was used at the Sheffield testing-works in the tests mentioned in this paper. Some rope-makers

stated that the effect of running in molten white metal was to destroy the temper of the wire, and this might occur if care was not used; he recommended that the white metal should have a low melting-point, such as type-metal, which had the additional merit of running fine.

Mr. H. Rhodes said that he had had a good deal of experience with locked-coil ropes, and the capping thereof. For sinking pits, the ropes are admirable, and for coal-work they have many advantages. The chief fault that he had to find with them was the difficulty of capping them satisfactorily. The first pair of ropes, of which he had any experience, were in use for over four years, during which time they were re-capped regularly by the colliery-workmen, and gave no trouble whatever. The next pair of ropes proved most unsatisfactory: they arrived from the makers' works ready capped, in the usual manner, by turning back the ends, and within three weeks of putting them to work one of the caps was drawn off the rope. The rope was drawn from the bottom of the cap, the wires breaking at the point where they were turned round to form a cone. The rope was re-capped by the colliery-workmen, and it worked quite satisfactorily for the usual period. The other cap supplied by the makers worked for a few months, and then a precisely similar thing occurred. There had been no trouble with the caps made at the colliery itself, and he thought that the others failed because the outside wrapping was of yarn, and not of wire. On his taking up this question with the makers, they said that yarn was used to enable the socket to bed better on the cone, but he (Mr. Rhodes) since then, when recapping, had lapped on wire over all.

Owing to the smoothness of the outer surface of the locked-coil rope, the friction between it and the turned-back wires was very little, and the whole of the weight was transmitted through the centre of the cap to the point of turning back the wires. With an ordinary rope, the turned-back wires lie in the interstices of the strands, and much greater friction between them and the rope was obtained.

With reference to the method of capping, by running in white metal, he (Mr. Rhodes) thought that there was great danger of an improper mixture of white metal being used,
necessitating a greater temperature to melt it, and it was possible that the temper of the rope might be affected.

Mr. R. Richardson said that the only difference between the method of capeling adopted at Barrow collieries and that at Mitchell's Main colliery* was that, after turning back the various wires, an iron plug, 7 inches long, was driven back into the centre of the rope, and it prevented the rope from shrinking. It would be interesting to have each method tested, for it was not necessary to use ropes of a breaking-strain of 100 tons, if the capels would break at one-half of that strain.

Mr. John Gerrard (H.M. Inspector of Mines, Manchester) exhibited sketches showing different forms of cappings in use. The ordinary form was that described by the President (Mr. T. W. H. Mitchell), the wires of the rope being turned back to form a bulge, then enclosed in a capping held by a number of hoops driven on as tightly as possible. From a number of tests which he had seen, the efficiency of this method depended upon the care taken in the operation, and the best capping gave only from 50 to 60 per cent. of the strength of the rope.

In another form, two machined feathers were introduced, the wires of the rope being turned back on these and carefully bedded, and the whole enclosed by a cap, surrounded by hoops as in the former case. If extreme care were taken, a higher percentage of efficiency was obtained, but in no case equal to the strength of the rope.

At the Chamber Colliery Company's pits in Lancashire, the whole rope was bent round a grooved plate, with grooved wedges on each side, the whole being held in position by another plate secured by ten bolts screwed through the plates and lock-nuts. In a test, this capping stood until the rope broke. They have been in use since 1889.

Another form of cap consisted in turning back the wires of the rope over an iron ring, placed within a solid socket, and white metal was run within to fill it solid. This method, under test, gave about 52 per cent. of efficiency.

In 1901, Mr. W. C. Blackett's method was described in the Transactions.† At three collieries in Lancashire, numerous

experiments had been made on lines following Mr. Blackett. Mr. F. L. Ward, at the Bradford colliery, Manchester, had completely succeeded in obtaining a capping stronger than the rope. He had seen three tests, in all of which the rope broke clear of the capping. The wires of the rope were opened out, well-cleansed with paraffin, into a warmed solid cap, a mixture of white metal was run to enclose the wires, and before pouring in the hot white metal, the wires were dusted with powdered resin. After completion, the cap was allowed to stand undisturbed until cool, so as to allow of the white metal setting. The best mixture of white metal had proved to be: lead, 60 per cent.; tin, 30 per cent.; antimony, 9 per cent.; and bismuth, 1 per cent. Antimony gave hardness, and bismuth lowered the temperature of fusion. It had been alleged that this method was open to the objection of the heat affecting the temper of the wires, but there was no real foundation for this statement, and many years of actual use had sustained this opinion.

Mr. J. Whittaker, of Messrs. George Hargreaves' Accrington collieries, had obtained very satisfactory results from a similar method. Mr. W. Pickup, of the Rishton collieries, had completely succeeded after numerous experiments, and was convinced that the white-metal cap was the best. Twenty years ago, Mr. Herbert Fletcher introduced, at Ladyshore colliery, Lancashire, a similar capping, which was still used at three pits.

It would be well, if any colliery owner desired to try this method, to make experiments, so as to obtain the necessary confidence by testing the efficiency. This can readily be done at a number of places, one, conveniently situated, being the Sheffield Testing Works, Blonk Street, Sheffield.

Mr. W. P. Abel pointed out that one might get the impression, on reading Mr. Mitchell's paper, that the first principles of engineering had been neglected in the matter of capels; but, as Mr. John Gerrard had pointed out, there was the fact that fewer accidents arise from capels giving way than from other causes. This was easily explained when it was remembered that there was a varying margin of safety in the rope during its life, and a constant margin during the life of the capel: for instance, there was a margin of safety of 10 to 1 for the rope, in order to provide against corrosion and
wear; whereas the capel (as Mr. Mitchell's investigations showed) had only a margin of 5 to 1. In practice, the rope wore out and corroded, but the capel, and the rope in it, did not; so that, although this might be considered bad engineering at the outset, actually in the working-life of the rope there was no weak factor present.

To obtain uniform strength of the capel and the rope, the following engineering principles required attention: The material should not be deteriorated by high tension, temperature or torsion, and the elasticity should not be impaired. It was easy to make a capel much stronger than the remainder of the rope by simply bending back the wires and splicing them again for several feet into the rope: thus practically making the capel contain double the number of wires, but this made a clumsy job and was quite unnecessary. Mr. R. Richardson had asked what was the use of using a rope with a breaking-strain of 100 tons, if the capel could only stand half that strain; but he (Mr. Abell) thought that at the end of the working-life of the average rope the capel would be found the strongest part. The 100 per cent, capel adopted by the Sheffield testing-house appeared to introduce two great elements of uncertainty: for instance the variation in the composition of the alloy and the keeping of the melted alloy at the proper temperature would be well attended to in the hands of leisured experts; but they were liable to be overlooked during the busy time of putting on a new capel at a colliery; and variation in these two requisites would make a capel that would draw and thus become dangerous.

Mr. Isaac Hodges observed that he did not think the deterioration of a winding-rope was nearly so rapid as Mr. W. Price Abell had stated. He had recently had a winding-rope tested at the Leeds University Engineering Laboratory after a life of 4½ years, having lifted 330,000 tons from a depth of 1,200 feet. It was found that the circumference of 4 inches had only been reduced by wear to 3½ inches, and that the breaking-strain had been reduced from 70 to 60 tons only. The tensile and torsional tests of the rope were practically unaltered: the deterioration being solely due to the lessened area of the wires. It was extremely startling to him as a colliery manager to learn that the capel was only half as strong as the winding-
rope. He was, however, anxious to know whether Mr. T. W. H. Mitchell had discovered any difference in the percentage of safety between ropes of small and ropes of large circumference, because he noticed that the tests detailed by Mr. Mitchell did not extend beyond a rope 4 inches in circumference. He could not conceive a better method of capeling a rope than that given by Mr. John Gerrard, assuming that the metal mentioned would stand wear-and-tear. He (Mr. Hodges) considered that the question was very important, and that the Council should appoint a committee to report upon it. The matter was a serious one for them all, and he was afraid that they had been running more risk than they knowingly would have done.

Mr. W. Hattar wrote that the results of the tests carried out on cap-ends were such as to cause no small amount of disquiet to users of all makes of winding-ropes. Some time ago, he visited a colliery in Staffordshire, where three tests had been made:—Two cappings of locked-coil ropes, and one capping of the style generally adopted for ordinary or Lang lay ropes. The strengths of the cappings of the locked-coil ropes were less than 50 per cent. of the actual breaking-strains of the ropes, as given by the makers, and that of the ordinary rope was 57 per cent. In all three cases, the caps were carefully prepared, under proper supervision, for testing purposes. He (Mr. Hattar) examined the cap-ends and could find no fault in the method of their preparation, especially in the manner of turning the wires, but he certainly thought that the length of capping was extremely short for ropes of the sizes in question, namely, locked-coil, 5½ inches in circumference; and Lang lay, 6½ inches in circumference.

The problem then arose, by what means the cap-ends could be made, if not quite so strong as the rope, as near as is practicable to the strength of the rope. He (Mr. Hattar) had estimated 75 to 85 per cent., as the strength of the capping, in relation to the strength of the whole rope; tests of wires taken from a capping, which had raised over 500,000 tons, in addition to other work incidental to colliery-usage, gave good results. Mr. John Gerrard had described a class of capping, which might be all that was desired so far as strength went, but it occurred to him (Mr. Hattar) that considerable trepidation would be felt by anyone adopting this style for large
winding-ropes, owing to the care required, in manipulation, to make a thoroughly sound cap-end. He (Mr. Hattar) thought that much could be done by way of increasing the percentage of strength in the cap to a nearer proportion of the strength of rope, namely:—(1) By using ropes built of the best material, and thereby ensuring in the first place the maximum amount of strength, consistent with the temper at which the wire was drawn. (2) By adopting the longest length of capping permissible, so as to increase the grip to its greatest extent. (3) By keeping the ropes closely adjusted to the load-length, and thus avoiding slack chain and the resultant shock, due to sudden "snatching of the load"; if there were difficulties in the way of the length of the ropes being so adjusted, then by taking up the slack chain steadily, and other means being taken to recover the time so lost, by increasing the speed-acceleration in the shaft. The stresses put on a rope by the sudden lifting of the load must, in a great number of cases, be nearly as great as that attained when the cap fails, and a rope subjected to these added strains would, when submitted for testing purposes, be in the worst possible condition, owing to material-fatigue. (4) By having the ropes frequently re-capped, and examined at least once a week, in addition to the ordinary daily examination, at the point where the internal wires could be seen.

The appointment of a committee to investigate this question had been suggested; and he (Mr. Hattar) sincerely hoped that it would receive due consideration at the hands of the Council. If the committee were appointed, he would do all that he possibly could to assist the committee in acquiring information on the subject.

Prof. G. R. Thompson said that he would not have advocated an excess-counterbalance of a winding-engine by the tail-rope method, had he not known that a rope could be capped to give as great strength in the cap as in the rope itself. The weakness of the ordinary methods of capping had often been recognized, and some years ago specimens of ropes capped by makers in different manners were tested in the Engineering Department of the University of Leeds. Table I. contained the results, as recorded by Mr. Arnold Lupton.* The efficiencies of these cappings are 49.46, 28.3, 35, and 89 per cent, respectively.

* Mining, 1899, page 424.
The method of capping, by filling the socket with white metal, advocated by Mr. John Gerrard and Mr. W. Walker was quite satisfactory: it gave efficiencies exceeding 90 per cent., and the rope broke instead of the capping failing. One would, however, have hardly expected that the strength of the rope was equal to the sum of the strengths of the wires tested; since, in the rope, the wires were not subject to direct tension but to a combined stress. In capping a wire-rope, it was important that each strand and each wire should take its due proportion of the load: and to secure this, in a short test-piece, when testing in the Engineering Laboratory of the University of Leeds, the rope was carefully wrapped, the ends were opened out for a length of about 5 inches and the wires were separately cleaned and dipped in hydrochloric acid: the ends being folded in for about an inch in length.* The white metal, consisting of lead hardened with about 10 per cent. of antimony, was melted and run into the conical cap in which the coned rope-end had been previously placed: the cap having been previously heated to prevent chilling of the metal. The internal dimensions of the cap used in testing were \( \frac{3}{2} \) inches in diameter at the base, tapering to \( 1\frac{1}{2} \) inches at the top in a height of \( 3\frac{1}{2} \) inches: the cap being \( 4\frac{1}{2} \) inches in height, and the uppermost inch had parallel sides. In the case of the rope referred to by Mr. I. Hodges, which was tested by Prof. Goodman, he (Mr. Thompson) found that the adhesion between the white metal and the wires had amounted to 10 cwts. per square inch of contact-surface, without the wires drawing, and if friction were

* *Mechanics Applied to Engineering,* by Mr. John Goodman, page 305, Fig. 285c,
DISCUSSION—NOTES ON CAPELS FOR WINDING-ROPESS.

neglected, that the normal pressure between the cone-surface and the white metal would have amounted to 8 tons per square inch, though on allowing for friction, this probably was reduced to 3 tons or less per square inch.

His colleague, Prof. John Goodman, had kindly given him access to the records of tests made by engineering students of the University of Leeds for experimental purposes. These tests, recording all work done both good and bad, might be taken as an average for careless and careful workers and for unskilled workmen. The wires were usually only cleaned with emery-cloth and frequently not hooked over in the cap, while the quantity of antimony in the alloy was estimated and not weighed. Taking the last 50 tests made on ropes breaking with loads varying from 4 to 47 tons, the average efficiency of the ropes (and capping included) was 94.2 per cent., the lowest result being 68.4 per cent. Following this, no rope broke at less than 80 per cent.; one broke at 83.4 per cent.; one at 86 per cent.; one at 87 per cent.; one at 89 per cent.; and one at 89.8 per cent.; the remaining 44 breaking at over 90 per cent. Eight ropes, among these 50, broke with loads over 40 tons, the average efficiency being 96.5 per cent.; the lowest being 86 per cent. In the 25 tests, next preceding the 50 abovementioned, only 3 results were less than 90 per cent., namely, 83 per cent., 84 per cent., and 86.5 per cent. These figures show that the results are higher than those got with ordinary cappings, that they are more uniform and reliable, even when made by unskilled workmen, and that the fear of weakening the rope by annealing the wires by the hot white metal may be regarded as groundless.

In connection with his previous remarks about the pressure between the surface of the white-metal plug and the cone of the capping, he desired to point out that the length of the cap could be kept short, in fact, practically to the length requisite to give sufficient adhesion, according to the diameter and tensile strength of the wires constituting the rope; and the normal pressure from the sides of the cone could be kept low, without unduly increasing its basal diameter, by turning grooves in the interior of the cap.

He would like to direct attention to the great differences of length between the white-metal capping and some of the specimens, which exceeded 3½ feet in length,
Mr. W. Talbot Cheesman wrote that his son, Mr. Herbert Cheesman, had dealt exhaustively with the strength of rope-cappings in a paper* that he had read at the Yorkshire College, some 10 or 12 years ago, but there were one or two features which might be further discussed.

In every case, where a wire-rope required socketing, the utmost care must be taken to preserve the regular tension of the individual wires, and, as may be readily imagined, the more wires there are the greater must be the precautionary measures, particularly so in these days, when practically all ropes of this kind are manufactured from steel of high tensile strength. This steel is not only difficult and stubborn to handle, but it is particularly springy in nature, and consequently most liable to deformation. Therefore, when a rope is being prepared for socketing, it is essential that the workmen should start and serve down to the cut end of the rope, possibly a distance of 10 to 50 feet, depending upon the construction and size of the rope. A wire-rope, made of six strands each containing seven wires of, say, 110 tons quality steel, will not be so liable to disturbance as, say, a wire-rope, $1\frac{1}{2}$ inches in diameter, compound laid, say, containing six strands of nineteen wires. It must be clearly understood that the serving must travel down to the cut-end: there is a specific object in doing this, namely, to force any slack in the strands or wires out at the cut-end.

There are various patterns of sockets or capels, each claiming some respective merit, and in the North of England, the style most commonly used is the long split socket, attached by means of rivets, and taper-rings, driven on to the wedge-shaped section of the socket, and held in position there. He (Mr. Cheesman) particularly desired to point out that, although this was the pattern generally adopted, it appeared to be full of dangerous drawbacks. He had had several cases, which revealed a terrible and treacherous condition, when the rope had been taken out of the sockets. For instance, in one case, a rope suddenly broke close to the socket, and, upon making an examination, it was found that in attaching the socket to the rope five out of the six strands had actually been severed during the process of forcing the punch through the rope to make the holes for the rivets. In another case, where an important ordinary compound-laid best plough-steel winding-rope, 5½

* The Various Forms, Uses and Developments of Wire-ropes, 1893,
inches in diameter, was used, a similar occurrence took place: and, on examination, it was found that three strands, each containing nineteen wires, had been so damaged during the process of socketing that only two or three wires were left intact in each, whilst of the other three strands, two were similarly mutilated, but not to the same extent. From his (Mr. Cheesman's) experience, which had been fairly extensive, he thought he could safely say that many colliery managers would be absolutely shocked and horrified if they were to make a close examination of their winding-ropes in this particular direction; at the same time, whilst not condemning this method of socketing as always bad, he would point out that as a rule sockets were made and drilled for the rivets quite irrespective of the length of the lay of the rope to which they were to be attached; and moreover, as ropemakers' views, as to the most desirable lay at which the respective ropes should be spiralled, varied, it was highly improbable that the rivets would come exactly between the strands, which was the only proper way to attach this style of socket with the minimum amount of depreciation to the rope. In any case, it would be readily recognized that this method necessarily must cause a displacement and general disturbance of the wires, and must materially lessen the actual breaking-strength of the rope.

The taper-socket, made out of solid drawn steel, had the advantage of being attached to the rope, without recourse to any means such as the forcing of rivets and the like between the strands. The usual method employed in making this attachment is to serve the rope in the manner already described, after which the individual strands are prepared in a suitable way by being cut to an exact measurement and carefully marked for bending back and spread in such a manner as to fill into the space due to the taper of the socket; and finally a copper or steel tapered pin is driven firmly down into the centre of the rope, and further spreads and increases the general grip of the rope in the socket. If this system were carried out with great care and precision, he (Mr. Cheesman) considered that it was the best method yet employed for the socketing of wire-ropes. Another system of attaching the rope to the same type of socket, after the strands have been drawn back in the manner before explained, is to fill the interstices with white metal, which forms a solid and homogeneous tapered end to the rope.
There are many other patterns of sockets, all of which are more or less modifications of the foregoing.

In conclusion, he (Mr. Cheesman) would like to lay special emphasis on the absolute necessity of resocketing all winding-ropes at fixed periods, dependent on the conditions under which the rope was working. This resocketing enabled one to ascertain the actual internal condition of the strands and wires, so as to see whether the rope was still safe. In his experience, he had seen ropes which, from their outward appearance, were apparently sound and in good condition; but a closer examination of the internal parts revealed exactly the opposite condition. In one case, a compound laid rope, 1½ inches in diameter, looked like a veritable bar of steel, without the sign of a fractured wire: on being opened at the socket-end, the wires, forming the inner strand, which originally measured 0.084 inch in diameter, were less than 0.020 inch in diameter; in some places the wires were practically eaten away; and a similar pitting and corrosion had severely attacked the internal side of the outer wires.

Mr. G. Blake Walker and Mr. L. T. O'Shea's paper on "The Utilization of Surplus-gases from Bye-product Coke-ovens" was read as follows:
THE UTILIZATION OF SURPLUS-GASES FROM BYE-PRODUCT COKE-OVENS.

By G. BLAKE WALKER and L. T. O'SHEA.

Introduction.

During the last ten years, the bye-product coke-oven has been steadily winning its way in this country, and at the present time more plants are in course of erection than at any previous period. Should the coal-trade improve, it is probable that many firms which are now considering the question will proceed to the erection of ovens of this type. Hitherto, the bye-products chiefly considered have been sulphate of ammonia and tar products; but in addition to these there is a third residual which has, only within recent years, been recognized as valuable. That residual comprises the gases which are not required for distilling the coal in the ovens. These gases can be utilized with most valuable results for the generation of power in gas-engines; and, under favourable conditions, are sufficient in quantity to furnish an amount of power equal to supplying the greater part of the colliery-consumption of fuel, assuming that 20 to 25 per cent. of the output is coked. Colliery-consumption costs a large sum, probably from 1½d. to 3d. per ton on all the coal raised, and the amount which can be saved by the utilization of waste-gases is, therefore, very considerable.

The value of the surplus-gases was not much thought of by the earlier inventors of bye-product ovens, and naturally so, because the development of the gas-engine is of comparatively recent date. Latterly, however, attention has been directed to the production of surplus-gas for power-purposes, with the result that ovens have been modified to achieve this object. Economy in the use of gas is sought, by applying the most intense heat as uniformly as possible throughout the length of the oven-walls.

In the earlier types of ovens, the method of burning the gas and air was wasteful and unsatisfactory, and accurate
adjustment was almost impossible. The amount of surplus-gas was, therefore, relatively small. Now, it may be asserted that where a coal contains 28 per cent. of volatile constituents, nearly one half of the gases returning from the scrubbers is available for power-purposes, when the best types of ovens are used.

It is not the writers' object to specify the ovens of any particular type, or to enter into the merits or demerits of any particular design. It is sufficient to indicate the essential principle which should influence the selection of a type of oven, namely, the possibility of accurately regulating the heating of the side-walls with the maximum of efficiency and with the minimum of waste of gas. The writers may, however, remark that the burning time for ordinary coal should be limited, say, to from 25 to 30 hours, as in this case the oven maintains a higher temperature and less heat is lost. The charging of ovens by the compressor occupies the minimum time and exposes the hot walls for the shortest time to the chilling effect of the outer air. The proportion of moisture can be better regulated in this way, and should be kept down to 9 per cent, if possible. Lastly, the more uniform the temperature, the less the wear and tear of the ovens.

With these introductory remarks the writers propose to deal with the subject under the following heads: (1) The composition and properties of the gases from retort coke-ovens; (2) their explosive and heat-values; (3) the cleansing and filtering of power-gas from coke-ovens; and (4) internal combustion motors or gas-engines.

The Composition and Properties of the Gases from Retort Coke-ovens.

From the manner in which the coking process is conducted in retort-ovens, namely, by heating the coal in a closed chamber from which the air is excluded, the gas obtained has a composition similar to that of illuminating or town gas.

It is a complex mixture of several gases, which may be classified as (a) heat-producing gases: hydrogen, marsh-gas, and carbon monoxide; (b) illuminants: heavy hydrocarbons; and (c) diluents: carbon dioxide and nitrogen.

The chief differences in the composition of coke-oven and
THE UTILIZATION OF SURPLUS-GASES.

Town gas, are, firstly, the former is deprived of the benzol in the bye-product recovery-plant, whereas that substance is retained in town gas on account of its high illuminating power. Secondly, the proportion of nitrogen is usually greater in coke-oven gases, owing to the difficulty of keeping the joints in the oven-walls gas-tight: hence air often finds its way from the combustion-flues into the oven, and the nitrogen in the air goes to dilute the gases from the coal. Thirdly, the quantity of carbon dioxide is greater in coke-oven gases than in illuminating gas, because no means are taken to remove it from coke-oven gases, as is the case with illuminating gas.

These points are clearly illustrated by the results of the writers' analyses of gas from a battery of 35 Simon-Carvès ovens at the Wharncliffe Silkstone colliery. The coal used is a mixture of washed slack from the Silkstone, Parkgate and Whinmoor seams, and yields, on an average, 33 per cent. of volatile products by the crucible-test.

The composition of the gas is detailed in Table I., to which are added, for comparison, average analyses of illuminating gas and of the gas obtained by coking Silkstone coal in Otto-Hilgenstock ovens at the Yorkshire Coal and Iron Company's Tingley collieries. The first analysis is representative of a number made by the writers. The quantity of nitrogen is high, and it is due to leakage of air into the ovens, caused by faulty joints in the oven-flues: but not to any special superiority of one type of oven over the other, as may seem by comparing the writers'
results with many of those quoted by Bergassessor Baum,* containing as much as from 34 to 45 per cent. of nitrogen. The tightness of the joints in the oven-walls has a most important bearing on the quality of the gas produced, inasmuch as the nitrogen acts as a diluent, and reduces the heating power of the gases. Consequently, to obtain the greatest economy from the gases, it is essential to reduce the leakage from the oven-flues to the lowest feasible limit. It is hardly possible to obtain the same freedom from nitrogen in coke-oven gases as in gas made in a gas-retort. The latter is small and without joints, whereas the former is of large capacity, and built of comparatively small bricks, with numerous joints, which tend to open by continual expansion and contraction. However, by maintaining a uniform temperature in the flues, and discharging and charging the ovens as regularly and rapidly as possible, the cooling influences are greatly reduced, and, thereby, the dangers arising from excessive contraction are minimized.

The results quoted in Table I. represent the average composition of the gas produced during the whole coking time, but from Dr. Bunte's† experiments on the gases from the coking-plant at the Consolidation colliery in Westphalia, it appears that the composition of the gases varies at different stages of the coking time. If the coking time be divided into five equal periods, it is clearly shewn that during the first and second periods, when the temperature is lowest, the gases, marsh-gas, heavy hydrocarbons, and carbon monoxide, are formed in greatest quantity; but, as the process continues and the temperature rises, the quantity of these gases gradually diminishes whilst that of hydrogen gradually increases, until in the last period as much as 60 per cent. of that gas is present.

Dr. F. Schniewind has obtained similar results, which are recorded in his paper on "The Production of Illuminating Gas from Coke-ovens"‡ to which the writers would refer the members.

If the object is to supply illuminating gas, as in Dr. F. Schniewind’s case, it is very important to be able to separate the gas produced in the early stages of coking from that pro-

* Die Verwerthung des Koksofengases (The Utilization of Coke-oven Gas), page 10.
† Stahl und Eisen, 1899, page 615.
duced later, on account of its higher illuminating power; but, when the gas is required for power-generation, this would appear to be a doubtful policy, for the illuminants possess a very high calorific power; and in fact Dr. Schniewind shows that the gas produced during the first half of the coking time has a higher calorific power than that produced in the second half.*

The Calorific Power or Heating Value of Coke-oven Gases.

The heating value of coke-oven gas is naturally high, in comparison with that of producer-gas or blast-furnace gases, owing to the large proportion of combustible gases of high calorific power which it contains. Illuminating gas has the highest value of all power-gases, retort coke-oven gas comes next; and its value, expressed in heat-units, more closely approaches that of illuminating gas in proportion to its freedom from nitrogen.

The heating value of a gas depends upon whether the steam produced by the combustion is condensed or not; and, when expressed in heat-units per cubic foot, upon the temperature and pressure at which the volume of the gas is measured. If the steam is condensed, the heating value is higher than when it is uncondensed; and in the gas-engine it is probable that the lower value is obtained.

Determinations of the calorific power of the gases from the Simon-Carvès ovens already referred to were made on three different days, in a Simmance-and-Abady gas-calorimeter. The results calculated in British thermal units per cubic foot, measured at 32° Fahr. and 30 inches of pressure and at 60° Fahr. and 30 inches pressure, are given in Table II.

<table>
<thead>
<tr>
<th>Experiments</th>
<th>British Thermal Units per Cubic Foot at 32° Fahr. and a Pressure of 30 Inches of Mercury</th>
<th>British Thermal Units per Cubic Foot at 60° Fahr. and a Pressure of 30 Inches of Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Steam condensed</td>
<td>438</td>
<td>403</td>
</tr>
<tr>
<td>Steam uncondensed</td>
<td>...</td>
<td>402</td>
</tr>
<tr>
<td>Theoretical calorific power, calculated from analysis</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

* * *
The results are low, for the reasons already given; but, on comparing them with the calorific power of other power-gases given in Table III., it is evident, in spite of the dilution, that a very valuable power-gas is obtained.

<table>
<thead>
<tr>
<th>Description of Gas</th>
<th>British Thermal Units per Cubic Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illuminating gas, London</td>
<td>641</td>
</tr>
<tr>
<td>&quot;&quot; Birkenhead</td>
<td>746</td>
</tr>
<tr>
<td>Carburetted water-gas ...</td>
<td>677</td>
</tr>
<tr>
<td>Producer-gas:</td>
<td></td>
</tr>
<tr>
<td>Dowson</td>
<td>146</td>
</tr>
<tr>
<td>Mond</td>
<td>145</td>
</tr>
<tr>
<td>Dynamic</td>
<td>150</td>
</tr>
<tr>
<td>Wilson</td>
<td>150</td>
</tr>
<tr>
<td>Blast-furnace gas</td>
<td>135</td>
</tr>
</tbody>
</table>

*Horsepower to be obtained from Retort-oven Gas.*—The actual horsepower to be obtained from the gas depends on the quantity as well as on the calorific power.

The primary use of the gas is to heat the ovens, and only the surplus is available for power-generation. It is necessary, therefore, to consider the conditions under which the maximum surplus of gas can be obtained. From the experience of recent years this would appear to depend on (1) the quality of the coal coked, (2) the suitability of the oven, and (3) whether the air going to the combustion-flues is heated before meeting the gas.

(1) *The Quality of the Coal.*—Lean coals, yielding comparatively small volumes of gas, and requiring the highest possible temperatures to be reached during the coking process, produce very little more gas than is required for burning in the flues, and sometimes the whole quantity has to be used for this purpose. But with good fat coal, which can be coked at somewhat lower temperatures, often from 20 to 40 per cent. of the gas produced remains, over and above that required for heating the ovens. According to Dr. Baum, however, it does not necessarily follow that those coals giving the highest proportion of gaseous products, such as the gas-coals, will yield a larger percentage of surplus than those less rich in volatile products. Often, the former require to be coked at a higher temperature than the latter, which entails a larger consumption of gas in the oven-flues and a corresponding reduction in the quantity of
the surplus. It may be, therefore, that in the former case there is, not a greater, but perhaps a smaller, quantity of surplus-gas available for power-generation than in the latter.

There is a minimum yield of volatile products below which it is impossible to obtain sufficient surplus for the profitable generation of power, and this limit is fixed by Mr. E. Reumaux at coals yielding 20 per cent. of volatile products.

(2) The Suitability of the Oven,—In this respect, the main point is to obtain a uniformly high temperature in the coking mass. For this purpose, the regulation of the width of the oven to suit the class of coal that is to be coked, and the thickness of the walls separating the oven from the heating flues, are of importance. The width of the oven is solely determined by the character of the coal, the ovens being narrower for lean coals than for fat ones; and the walls of the ovens should be as thin as possible, consistent with durability of structure, in order that the heat may rapidly pass through the somewhat badly-conducting material of which the oven is built.

A third point of supreme importance is the even combustion of the gas in the heating flues. This can only be obtained by a proper distribution of the gas and air. In the early types of oven, the gas was admitted at one, or, at the most, at two or three points, where it met with air for its combustion, producing local overheating at these points; whilst it was a matter of great difficulty to obtain a sufficiently high temperature in other parts of the heating flues. The desirability of a greater distribution of gas and air has been fully recognized and the tendency in the more modern types of ovens is in this direction. Messrs. Otto & Company, have replaced the Otto-Hoffmann oven, in which the gas entered at a single jet under the sole-flue, by the Otto-Hilgenstock: in the earliest designs of the latter, gas was delivered at eight burners of Bunsen-type placed directly under the side-flues; but in the latest designs, the number of burners has been increased to twelve. The same principle was applied by Mr. Collin to ovens with horizontal flues, by dividing the flues in the middle by a mid-rib so as to form a front and back set of heating flues. Gas was admitted into the front and the back of each of these sets of flues simultaneously, whilst a similar admission of air at various points took place.

These pioneers in the subdivision of gas and air have been followed by most modern inventors, and in the latest types of ovens, such as the Kopper and Poetter ovens, each heating flue is separately supplied with gas and air. The gas enters each heating flue through a specially constructed nozzle into a combustion-chamber, where it meets with a supply of air for combustion; and the amount of gas entering each flue can be regulated until a uniform temperature is obtained throughout.

It would appear that the vertical heating flue lends itself more readily to this principle of subdivision than the horizontal flue, for in nearly all the more modern types the vertical flue is adopted.

(3) Heating the Air, previously to its Meeting the Gas in the Combustion-flues.—This has considerable influence on the amount of surplus-gas, for it must be remembered that the volume of air required for the combustion is at least ten times as great as that of the gas. The temperature of this volume of air has to be raised to the combustion-temperature in the flue. If cold air is admitted, the whole of the heat necessary to produce this temperature in the air must be generated at the expense of a certain quantity of the burning gas; but, if air previously heated to 1,200° Fahr., is introduced into the flues, a much smaller quantity of gas will suffice to raise the temperature of the air up to that of the flame.

Dr. Gasser points out that this principle was well illustrated when Messrs. Otto & Company abandoned the Otto-Hoffmann oven, with regenerators for heating the air, and adopted the Otto-Hilgenstock oven, in which the regenerators were dispensed with, and the air supplied to the burners was only slightly warmed by coming into contact with the hot walls of the structure carrying the oven. With the latter oven, the amount of surplus-gas was very small, or sometimes none at all; whereas with the former often a large supply was obtained.

In all the more recent types of ovens, the heating of the air is effected in large regenerators through the agency of the waste-heat in the gases that have been used for burning in the oven-flues, and, according to Dr. Baum, in this way, at least 20 per cent. of gas can be saved, if the air for combustion be previously heated to 1,300° Fahr. (700° Cent.).
The actual quantity of gas for power-generation that can reasonably be expected, after taking the above considerations into account, is variously stated by different authorities. Dr. Baum* states that from 20 to 40 per cent. of surplus-gas can be obtained from fat coals yielding from 9,800 to 15,000 cubic feet (280 to 450 cubic metres) per ton: Mr. E. Reumaux† considers that 25 per cent. of the total volume of gas may be obtained as surplus from Westphalian coal, whilst Mr. J. H. Darby‡ estimates that from 30 to 40 per cent. is available for power-generation, and Dr. P. P. Bedson§ quotes 30 per cent. as being obtained with Durham coal in Otto-Hilgenstock ovens. With the special arrangements adopted in America and Canada by the United Coke and Gas Company, for the supply of illuminating gas, from 44 to 50 per cent. of the gas is surplus.||

The writers made direct measurements of the available surplus-gas in the case of the ovens already mentioned. Two series of measurements were made under different conditions, extending over periods of 146 to 150 hours respectively. In the first series, the rate of supply was subject to considerable fluctuation; but it was much more regular in the second series. The average quantity per hour, however, was remarkably constant, as shown in Table IV. These results are lower than those previously quoted, but they may be considered highly satisfactory, when one takes into consideration, firstly, that in addition to the gas used in the oven-flues, a portion is burnt directly under the boilers to assist in raising steam for working the plant, and this

<table>
<thead>
<tr>
<th>Experiments</th>
<th>A.</th>
<th>B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surplus-gas per hour at 32° Fahr. and a pressure of 30 inches</td>
<td>14,728</td>
<td>14,996</td>
</tr>
<tr>
<td>Duration of period of measurements</td>
<td>146</td>
<td>150</td>
</tr>
<tr>
<td>Dry coal coked</td>
<td>934</td>
<td>964</td>
</tr>
<tr>
<td>Surplus-gas per ton of coal coked</td>
<td>2,300</td>
<td>2,334</td>
</tr>
<tr>
<td>Estimated yield of gas per ton of coal</td>
<td>10,500</td>
<td>10,500</td>
</tr>
<tr>
<td>Surplus-gas available for power generation per cent.</td>
<td>21.9</td>
<td>22.2</td>
</tr>
</tbody>
</table>

quantity is not included in the above figures; and secondly, that no special means were taken to heat the air used for combustion.

Taking the average supply at 15,000 cubic feet per hour, and the heating value to be 365 British thermal units, the lowest estimate given in Table II., the theoretical horsepower is about 2,200; and assuming that only 20 to 25 per cent. of this can be directly used in the gas-engine, between 400 and 500 horsepower is available. It would, therefore, require about 30 to 37 cubic feet per hour to give 1 brake-horsepower, or from 13 to 17 horsepower per oven. Mr. E. Reumaux* gives for 120 ovens, with an available surplus of 18 per cent. of gas, 15 horsepower per oven.

Mr. Richard Pearson, in his evidence before the Royal Commission on Coal-supplies,† gives an estimate (Table V.) of the volume of different gases required to produce 1 brake-horsepower in any wellknown make of gas-engine.

<table>
<thead>
<tr>
<th>Description of Gas</th>
<th>Consumption of Gas per Hour per Brake-horsepower.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heathfield natural gas</td>
<td>Cubic Feet.</td>
</tr>
<tr>
<td>Illuminating gas</td>
<td>12-15</td>
</tr>
<tr>
<td>Water-gas</td>
<td>20-25</td>
</tr>
<tr>
<td>Producer-gas</td>
<td>60-80</td>
</tr>
<tr>
<td></td>
<td>100-120</td>
</tr>
</tbody>
</table>

The gas requires theoretically 3 to 3.5 times its volume of air for complete combustion, and probably 6 or 7 volumes of air would have to be used for explosion in the gas-engine; for, with the theoretical quantity of air, a maximum temperature of about 5,000° Fahr. would be produced, which, with double the quantity of air, would be reduced to about 3,000° Fahr. These

<table>
<thead>
<tr>
<th>Experiments</th>
<th>I. When burnt with the Theoretical Volume of Air.</th>
<th>II. When burnt with twice the Theoretical Volume of Air.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mond gas</td>
<td>3,100</td>
<td>2,000</td>
</tr>
<tr>
<td>Dowson gas</td>
<td>3,500</td>
<td>2,150</td>
</tr>
<tr>
<td></td>
<td>3,600</td>
<td>2,300</td>
</tr>
</tbody>
</table>

* * *

temperatures are much higher than those obtained with producer- and blast-furnace gases, and are comparable with those obtained with town gas; hence the gases are suitable for use in the type of engine used with town or illuminating gas, and not in the types used with producer-gas or blast-furnace gases.

**Purification of Coke-oven Gases.**

When the gases leave the coke-oven they are conveyed to the bye-product plant, where they are cooled and freed from tar, ammonia and benzol, but whether they are sufficiently clean for use in a gas-engine after passing through that plant depends on its efficiency.

Usually, tarry matter in the form of fine spray is carried along with the gases: and whereas this is of no consequence when the gases are used for burning in the flues, or under the boilers, it constitutes a considerable detriment if they are passed in such a state directly to the gas-engine. For the tar adheres to the spindles of the valves, and prevents them from closing properly, which gives rise to back-firing; Mr. E. Reumaux* also states that it causes sooting in the cylinder. Apparently, the amount of this spray depends to a large extent on the efficiency of the cooling that takes place in the bye-product plant. If the temperature of the gases is reduced to 15° Cent. (60° Fahr.) before being scrubbed for ammonia and benzol recovery, then what spray is carried away in the gases is easily dealt with, but with inefficient cooling it is liable to cause trouble.

Under favourable circumstances, very simple appliances can be used, such as sawdust or coke scrubbers, through which the gas is passed on its way to the engine; but in some plants (as, for instance, the Otto-Hilgenstock plant), the spray is removed by means of a Pelouze-Audouin tar-separator before the gases pass to the ammonia-scrubber. In this separator, the gas is made to impinge in fine streams against baffle-plates, to which the tar adheres. A more recent invention for removing tar and dirt from the gases is the Theisen gas-washer, in which a very thin layer of gas is made to impinge against a thin film of water, which is carried round a spiral channel on a rapidly revolving drum, the gas travelling in the opposite direction to the water.†

* Loc. cit.
† *Engineering,* 1904, vol. lxxviii., pages 78 and 383.
### Table VII.

**Results obtained with the Theisen Gas-washer, when used to clean Blast-furnace Gases.**

<table>
<thead>
<tr>
<th>Name of Works</th>
<th>Volume of Gas per Hour</th>
<th>Particulars of Gas</th>
<th>Water used</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hochdahl</td>
<td>602,000</td>
<td>260</td>
<td>291</td>
<td>760</td>
</tr>
<tr>
<td>Do.</td>
<td>420,000</td>
<td>260</td>
<td>316</td>
<td>103</td>
</tr>
<tr>
<td>Schalke</td>
<td>357,000</td>
<td>130 to 170</td>
<td>291</td>
<td>75 percent.</td>
</tr>
<tr>
<td><strong>Hot Gases direct from the Furnace.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horde...</td>
<td>420,000 to 525,000</td>
<td>107</td>
<td>115</td>
<td>1,090</td>
</tr>
<tr>
<td>Do.</td>
<td>216,000</td>
<td>103</td>
<td>113</td>
<td>1,465</td>
</tr>
<tr>
<td>Rombach</td>
<td>315,000</td>
<td>85</td>
<td>109</td>
<td>1,800</td>
</tr>
<tr>
<td><strong>Cooled Gases with the Heavy Dust Separated.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The efficiency of these washers is shewn by the results recorded in Table VII.

There is no doubt that many difficulties will be avoided, if, at the outset, efficient means are taken to cool and cleanse the gas.

On the question of the removal of the sulphur and cyanogen, experts appear to hold different opinions. The quantity of sulphur in the gas is high, amounting to from 300 to 600 grains per 100 cubic feet. In the opinion of some authorities, it is essential that these should be removed, so as to prevent corrosion in the cylinder and valves by the sulphur dioxide produced during the explosion; whereas others hold that the gases, after the explosion, are so quickly scavenged out of the cylinder that there is little to fear from corrosion. This would appear to be justified by the experience of the Yorkshire Coal and Iron Company, Limited, who have had a 250 horsepower engine, fed with gas from an Otto-Hilgenstock retort-oven plant without special treatment for removal of sulphur, running for 18 months without any difficulty arising from corrosion. The writers hope that at some future date the members may be favoured with an account of the company's experience.

If it is deemed advisable to purify the gas from sulphuretted hydrogen, there are three processes available: — (1) Passing the gas over slaked lime; (2) passing the gas over oxide of iron; and (3) combining the two processes, and using both lime and oxide of iron.

The last is the most effective, as it removes sulphuretted hydrogen, carbon disulphide, and, to a certain extent, cyanogen. It entails, however, a somewhat extensive plant, which requires considerable attention and involves a good deal of labour in renewing the purifying material. The first method removes the sulphuretted hydrogen only, and is open to the objection that considerable nuisance attends the recharging of the purifiers, whilst there is much difficulty in disposing of the waste-lime, which, if allowed to accumulate, is a source of annoyance, owing to the evolution of sulphuretted hydrogen.

The second process would appear to be the best to adopt, for although the purification from sulphur would not be so complete as in the third, still it would probably be sufficient for practical purposes, and in it a portion of the cyanogen would be removed;
whilst the spent oxide, when completely saturated with sulphur, is a marketable commodity, and can be sold to the sulphuric-acid maker to be used in the manufacture of sulphuric acid, or to German manufacturers for the recovery of the cyanogen.

With regard to the economy to be attained in using these gases for the generation of power, it must always be remembered that the gases are there in excess of what is required for working the bye-product plant, consequently, if not used for power-purposes, a portion of the heat-value of the fuel is wasted.

The distribution of the heat-value of the coal in the different products of the bye-product oven is given by Prof. P. P. Bedson* in his evidence before the Royal Commission on Coal-supplies, as follows:

<table>
<thead>
<tr>
<th>Product</th>
<th>Heat Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke</td>
<td>70</td>
</tr>
<tr>
<td>Waste-heat utilized</td>
<td>8</td>
</tr>
<tr>
<td>Heat used in coking, including loss by chimney</td>
<td>10</td>
</tr>
<tr>
<td>Surplus, as gas</td>
<td>4.4</td>
</tr>
<tr>
<td>Tar and ammonia</td>
<td>7.6</td>
</tr>
</tbody>
</table>

And according to Dr. Schniewind,† the distribution of the calorific power of the dry coal is as follows:

<table>
<thead>
<tr>
<th>Product</th>
<th>Calorific Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke</td>
<td>72.2</td>
</tr>
<tr>
<td>Tar</td>
<td>4.1</td>
</tr>
<tr>
<td>Surplus-gas</td>
<td>12.7</td>
</tr>
<tr>
<td>Heating gas</td>
<td>10.7</td>
</tr>
<tr>
<td>Ammonia liquor</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Assuming that 23 per cent. of the heating-value of the coal is represented by the gases, then in the case of the gases referred to in the early part of this paper, 5 per cent. of the heating value of the coal is wasted, which is represented by about 450 horsepower on the assumption that only 20 per cent. of the theoretical heat-value of these gases can be used.

Now, the fuel-consumption per horsepower per hour depends on the efficiency of the engine; and in colliery-engines of non-condensing type it is probably about 6 to 7 pounds. To develop 450 horsepower, therefore, entails a consumption of 2,700 pounds, or say 1 ton of coal saved per hour, which is equal to 7,200 tons

† Loc. cit.
saved in a year of 300 working days. Taking the output at 500,000 tons per annum and the colliery-consumption equal to 6 per cent. of the output, this amounts to 24 per cent. of the total coal-consumption; and at 4s. 6d. per ton it amounts to £1,600 per annum; but with more efficient engines consuming only 3 pounds of coal per brake-horsepower, this amount would be reduced to one-half.

Use of Producer-gas.

Though not falling strictly within the scope of this paper, a few words may be acceptable with regard to the third alternative source of power, namely, producer-gas for use in the case of non-coking coals. Many manufacturers have adopted gas-producers as being more economical than the steam-boiler, probably to the extent of 7 per cent., all things being equal.

It is necessary, however, to distinguish between producers suitable for non-bituminous coal, and those suitable for bituminous coal.

The former class, including the Dowson and similar producers, are worked with anthracite-slack, the value of which at a great distance from the base of supply (say 22s. per ton in Yorkshire) has to be compared with the value of a cheaper fuel on the spot (say 4s. 6d. per ton) which can be worked in the second class of producers, such as the Mond, Mason, and others.

The inducement would be, therefore, to erect a Mason or Dynamic producer at a Yorkshire colliery, whereas at a South Wales colliery, with anthracite, say, at 8s. per ton, the Dowson type would be selected.

Besides the economy in the heating value of the gas-plant as compared with the steam-plant, there is a notable saving in the cost of working the two plants to the extent of about 16 per cent., and this is still further increased when the quantity of power required allows of the recovery of ammonium sulphate which is so strongly advocated in the Mond, Duff, and other producers. It is found, however, that 1,000 horsepower, or perhaps a still larger unit, is the minimum for which it will pay to erect one of these costly plants.

Assuming that the quantity is sufficiently large, which undoubtedly it is at many collieries, it is possible to get as much for ammonium sulphate, at present prices (£12 per ton), as
represents 4s. 6d. per ton on the coal carbonized. This would be an important economy at collieries where the coal cannot be coked, but is suitable for use in this kind of producer.

The range of such coals is limited, for with the improvements for obtaining very high temperatures in retort-ovens, and the use of the compressor for charging, it is possible to coke much leaner and poorer coals than heretofore; and the value of the coal coked with recovery of bye-products being about 12s. 6d. per ton, would yield about 8s. per ton on the coal put into the oven as compared with 4s. 6d. per ton on the coal carbonized in the Mond or Duff producer. As a set-off to this, it must not be forgotten that, probably with coal yielding less than 20 per cent. of volatile products, there will be no surplus-gas, and that a much larger volume of gas per ton of coal carbonized is available from the producer than from the coke-oven.

Gas-engines.

Gas-engines, or, as they are more correctly termed, internal combustion-motors, are very much more efficient in the generation of power from a given number of heat-units than any steam-engine. The principal cause of this is, that in the gas-engine the power created by the explosion of gas and air takes place in the cylinder itself, and the force is applied directly to the piston. In a steam-engine, however well designed, the loss from a variety of causes is so great that if 10 per cent. of the power in the coal is converted into work, it is considered a very good result indeed. Mr. Henry McLaren, of Leeds, stated in his evidence before the Royal Commission on Coal-supplies that "All engineers are aware that the steam-engine, at its best, is a very crude arrangement for converting heat into power."* He gives the statement of heat-losses shewn in Table VIII.

Mr. McLaren states that "8·87 per cent. of the heat in the coal converted into power at the engine appears to be a very poor result; but if all condensing engines throughout the country did equally well, and non-condensing engines in the same proportion, considerably over 50 per cent. of the engine-fuel now used would be saved." He thinks that all engines not capable of working on 3·2 pounds of coal per brake-horsepower should be "scrapped." Colliery-engines probably, on the average, con-

surne 8 pounds of coal per horsepower, or twice as much as Mr. McLaren says should be the maximum.

<table>
<thead>
<tr>
<th>Table VIII.—Heat losses of Steam-engines.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat losses of Steam-engines.*</td>
</tr>
<tr>
<td>British Thermal Units.</td>
</tr>
<tr>
<td>Loss through bars ...</td>
</tr>
<tr>
<td>, by radiation from the boiler ...</td>
</tr>
<tr>
<td>, in chimney-gases ...</td>
</tr>
<tr>
<td>, radiation from the main steam-pipes ...</td>
</tr>
<tr>
<td>, radiation from the auxiliary pipes ...</td>
</tr>
<tr>
<td>, in auxiliary engines exhaust ...</td>
</tr>
<tr>
<td>, in radiation from the engine ...</td>
</tr>
<tr>
<td>, in engine-exhaust ...</td>
</tr>
<tr>
<td>, engine-friction ...</td>
</tr>
<tr>
<td>Total losses ...</td>
</tr>
<tr>
<td>Heat converted into brake-horsepower ...</td>
</tr>
<tr>
<td>Total heat in the coal ...</td>
</tr>
<tr>
<td>Percentage of Total Heat in Coal.</td>
</tr>
<tr>
<td>1.00</td>
</tr>
<tr>
<td>5.00</td>
</tr>
<tr>
<td>22.00</td>
</tr>
<tr>
<td>1.56</td>
</tr>
<tr>
<td>0.22</td>
</tr>
<tr>
<td>1.40</td>
</tr>
<tr>
<td>2.08</td>
</tr>
<tr>
<td>57.31</td>
</tr>
<tr>
<td>0.36</td>
</tr>
<tr>
<td>91.13</td>
</tr>
<tr>
<td>8.87</td>
</tr>
<tr>
<td>100.00</td>
</tr>
</tbody>
</table>

One must guard against taking comparisons of the relative efficiency of gas-engines and condensing steam-engines of the highest type, such as are used in electric-lighting stations, as such engines are about three times as efficient as the average colliery-engine. No doubt there is at every colliery a considerable quantity of unsaleable fuel, such as screen-pickings and inferior coal, which can be burnt to raise steam by forced draught or other special appliances; but this is not, as a rule, enough to furnish half the colliery-consumption, and consequently good merchantable coal or slack is used in large quantities. Nor is the value of the fuel the only consideration in the raising of steam, for the labour of stokers is a very expensive item; and the worse the fuel, the greater the expense in labour, because the fires require cleaning so much oftener. With gas-engines there is a minimum of labour. There is, consequently, every inducement, in laying out a new colliery, to provide for the generation of all the secondary power required, especially where it is proposed to use electricity underground, and to consider the provision of a plant in which gas would be the motive power.

Assuming, then, that gas-power is adopted, a few general remarks on the subject of gas-engines may be acceptable. It has been pointed out, in the earlier part of this paper, that there

* Power,
is a very wide difference between the explosion-temperatures of various power-gases. Thus, blast-furnace gases have a maximum theoretical temperature of about 3,100° Fahr.; Dowson producer-gas, 3,600° Fahr.; Mond producer-gas, 3,500° Fahr.; and coke-oven gases from Silkstone coal, 5,000° Fahr. It is clear, therefore, that engines which work well on blast-furnace gas may be quite unsuitable for coke-oven gas.

The great difficulty in the working of large gas-engines is the high temperature produced in the cylinder. The bigger the cylinder, the larger the volume of mixture to be exploded, and the greater the total amount of heat generated. There is a limit to the permissible temperature, namely, about 3,300° Fahr. (1,800° Cent.), as above this point pre-ignition is likely to take place. This is one of the worst things that can happen to a gas-engine, as it throws a prodigious strain on all the parts. Besides this, cylinders and pistons are liable to crack, for they are working at almost red heat; and, to meet this, the cylinders and pistons, and even the valve-boxes, are water-cooled by elaborate jacketting. One must not, therefore, conclude that because one hears of very large gas-engines being at work, say, from 1,000 to 3,000 horsepower, that such engines are available for use with coke-oven gases. As a matter of fact, engines of about 250 horsepower, and cylinders, 24 inches in diameter, may be regarded as the maximum for use with coke-oven gases.

There are two principal classes of gas-engines. The Otto or four-cycle type, and the Clerk or two-cycle type. The former is by far the commoner, but the latter is employed in many of the larger engines recently designed. By using two cylinders, either side by side, opposite, or in tandem, the effect of a two-cycle engine may be secured: that is to say an impetus is given to the crank-shaft every revolution, instead of every second revolution. In this way, an engine of 500 horsepower may be arranged.

The Otto or four-cycle consists of four operations: (1) Forward stroke (suction), during which the gas-mixture is sucked into the mixing-chamber, and the back-end of the cylinder; (2) back stroke (compression), during which the mixture is compressed by the returning piston; (3) forward stroke (work), when the explosion of the gas-mixture gives impetus to the
piston; and (4) back stroke (exhaust), during which the exhaust-valve opens, and the cylinder is cleared of the products of combustion. It thus takes four strokes or two revolutions to go through the Otto cycle, the cylinder being used alternately as a pump and a motor. The valves are of the conical-seated lift type, and are four in number: charge inlet-valve, gas inlet-valve, igniting-valve, and exhaust-valve. The valves are actuated by cams and levers from a horizontal shaft, which rotates parallel to the cylinder, and is geared to the crank-shaft.

The following well-known gas-engines operate on the Otto cycle, with various modifications in detail:—Crossley, Deutz, National, Premier, Westinghouse, and many others. They are, however, usually associated with the double-acting engine or Clerk cycle. Of the Clerk-cycle type, there are the Cockerill, Körting, Oechelhauser, and others, all of which have been made in very large sizes, but all intended for use with blast-furnace or producer-gases. There does not appear to be any very great advantage, so far as collieries are concerned, in using very large engines. A pair of 250 horsepower engines developing 500 horsepower are quite large enough, and, having regard to the serious consequences of an interruption of work, it seems distinctly advisable to reduce the size of the units and increase their number.

The subject of gas-engines is too large to be further treated here, but within the present year, Mr. Dugald Clerk has delivered a series of four Cantor lectures before the Society of Arts, in which the whole subject is treated in the most up-to-date manner, and to his lectures we would refer those who desire to acquaint themselves with the subject.*

Whilst writing the above paper, an article on the same subject appeared in an American journal, in which it is stated that amongst others, the following large engines (Table IX.) are being fed with coke-oven gases.

The John Cockerill Company, Seraing, Belgium, have installed three engines at their works, to be fed with coke-oven gases. Further, it is contemplated by the Lackawanna Steel Company, Buffalo, New York, to use the gases from the coke-

oven plant which they are now erecting, to drive blowing-engines of 2,000 horsepower.

**Table IX.**—Large Gas-engines worked with Coke-oven Gases.*

<table>
<thead>
<tr>
<th>Where Working.</th>
<th>Type of Engine.</th>
<th>Horse-power</th>
<th>Number of Engines.</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Coke and Gas Company, Camden, New Jersey</td>
<td>Three-cylindered Westinghouse</td>
<td>Not stated</td>
<td>—</td>
</tr>
<tr>
<td>Yorkshire Iron and Coal Company, Ltd., Tingley</td>
<td>Cockerill</td>
<td>250</td>
<td>2</td>
</tr>
<tr>
<td>Graf Larisch-Mönnich’sche Colliery, Karwin, Moravia</td>
<td>Marienfeld</td>
<td>600</td>
<td>1</td>
</tr>
<tr>
<td>Witkowitz Colliery Company, Polnisch-Ostrau</td>
<td>Dessan, single-acting, four-cylindered twin-engine</td>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>Carolinen Schacht</td>
<td>Cockerill, single-acting, four-cylindered twin-engine</td>
<td>250</td>
<td>1</td>
</tr>
<tr>
<td>Neunkirchen, Saar</td>
<td>Not stated</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>Minster Stein Colliery</td>
<td></td>
<td>125</td>
<td>1</td>
</tr>
<tr>
<td>Lohringen Colliery</td>
<td></td>
<td>350</td>
<td>1</td>
</tr>
<tr>
<td>Beuthen, Upper Silesia</td>
<td>Körtig</td>
<td>300</td>
<td>4</td>
</tr>
<tr>
<td>Borsig Works</td>
<td>Not stated</td>
<td>600</td>
<td>1</td>
</tr>
<tr>
<td>Pluto Colliery, Gelsenkirchen</td>
<td>Deutz, single cylinder</td>
<td>Not stated</td>
<td>2</td>
</tr>
</tbody>
</table>


Mr. W. N. Drew wrote that for more than 16 years, at the Thorncliffe collieries, all the steam required had been raised by the surplus gases from modified beehive coke-ovens. This gas resembled that of blast-furnace gas in composition, and contained 75 per cent. of nitrogen. Although a time might come when all coke would be made in bye-product retort-ovens, it should not be forgotten that there was great irregularity in the values of the bye-products, on the sale of which the success of such expensive and delicate plants was largely based. When the carbonizing works with which he (Mr. Drew) was connected were put down, benzol was worth 6s. 6d. per gallon, it is now worth 9d.; similarly, sulphate of ammonia, then worth £14 per ton had since been as low as £6 10s.; and the enormously increasing output made it unlikely that the present high price would be maintained. With benzol at its present price, he (Mr. Drew) suggested that it would be more profitable to scrub the gas only for ammonia, and to leave the benzol in the gas to be used as fuel in the gas-engine.
Dr. G. A. Meyer (Westphalia) wrote that at the Schlägel and Eisen III. and IV. collieries, there were 60 bye-product ovens using 330 tons of coking coal every 24 hours, and producing 75 per cent. of coke. The volume of gas, over and above that required to heat the coke-ovens, was 937,000 cubic feet (26,530 cubic metres) every 24 hours, at a pressure of 2·36 inches. The heat from the coke-oven flues was passed under 7 boilers, with a heating surface of 1,000 square feet each. With the temperature of the feed-water at 61° Fahr., the quantity of water evaporated was 67,760 gallons (306 cubic metres) in 24 hours, equivalent to 4·10 gallons per hour: the steam-pressure being 100 pounds per square inch.

The President (Mr. T. W. H. Mitchell) moved a vote of thanks to Messrs. G. B. Walker and L. T. O'Shea for their interesting paper.

The vote was cordially approved.

Mr. J. Clegg read the following paper on a "Safety-catch for Cages."
SAFETY-CATCH FOR CAGES.*

By JOSEPH CLEGG.

The safety-catch, of which a model is shewn, is applicable to mine and other similar cages, and it is intended to prevent the cage from falling, in the event of the winding-rope breaking or becoming accidentally detached. In either case, the safety-catch would immediately stop the cage, and hold it in position.

Connected with each conductor and bolted to the uprights of the cage is a device, which is worked on the eccentric principle, and takes up no more room than the ordinary slides. There is a short lever, with one end in the shape of the cam on the crank-shaft of an engine. This works on a pin, and presses against a block. When the cage is descending, the conductors are relatively ascending, the cage and the conductors are working against each other. The other end of the lever is attached by means of a small chain to each corner-chain of the cage, so that, when the cages are working in the ordinary way, the catches are out of touch with the conductors. But the instant the rope breaks, the chains slacken, the levers drop and put the catches into such a position that they cause a perfect jam between the cage and the conductors, and the heavier the cage, the more tightly do they grip.

* British Patent, 1904, No. 19,433. Mr. Thomas Moody and Mr. Joseph Clegg.
DISCUSSION—A JOINT COLLIERY RESCUE-STATION.

DISCUSSION OF MR. M. H. HABERSHON'S PAPER ON "THE WORK OF A JOINT COLLIERY RESCUE-STATION."

Mr. M. H. Habershon said that since the paper was read, they had succeeded in producing a smoke-mixture in the experimental station, and were now able to give men practice in a noxious atmosphere. Only a few days ago, some apparatus was received from the makers of the Giersberg pneumatophore, which was found to be superior to the apparatus exhibited when the paper was read. Men who could not use the former apparatus, were able to use the new one for $\frac{1}{2}$ hour, on even the first occasion. He (Mr. Habershon) hoped that shortly an opportunity would be afforded of testing and using the apparatus in a noxious atmosphere underground, where there was no ventilation whatever. All their experience, since the paper was read, had been most encouraging, and confirmed the opinion that it only required practice to wear the pneumatophore for a satisfactory length of time.

Mr. J. Wroe's paper on "The Effect of the Watering of Coal-mines on the Spread of Ankylostomiasis" was read as follows:—

THE EFFECT OF THE WATERING OF COAL-MINES ON THE SPREAD OF ANKYLOSTOMIASIS.

By Jonathan Wroe.

A great deal of interest has been taken by the members in the miners' worm-disease, and as to whether the introduction of a system of damping the working-places, with a view to reducing the liability to the spread of explosions by dry coal-dust, is responsible for the spread of the disease. Various opinions have been held on this point, and some experiments made by Mr. Lüthgen, manager of the Julia and Von der Heydt collieries, Herne, Westphalia, recently published, are worthy of careful attention.*

Mr. Lüthgen obtained the permission of the Government authorities to suspend watering the workings of the Julia colliery for twelve months, from March 9th, 1903, to March 1st, 1904; and the results obtained in that colliery were compared with those of the adjacent Von der Heydt colliery, where the conditions were very similar, but where the watering regulations were in operation.

At both collieries, there has been a marked reduction of the disease, due no doubt to the stringent regulations now in force at all German collieries with regard to the isolation and medical care of infected persons; but, as will be shewn hereafter, the reduction was much greater at the mine, in which the watering was suspended than in that where it was continued. Experiments were also made in the Recklinghausen I. and II. collieries with similar results.

Mr. Lüthgen stated that "there was no water-sprinkling at the Julia colliery from March 9th, 1903, to March 1st, 1904. It was several months before the mine could be said to be perfectly dry, and as small feeders of water were met with in different parts of the mine, they were treated with milk of lime, so as to disinfect them as far as possible."*

Eleven examinations of the workmen employed in the Julia and Von der Heydt collieries (Tables I. and II.) were made at various times throughout the year. At the commencement of the experiments, out of the 1,168 men employed at the Julia colliery 19·52 per cent. were suffering from ankylostomiasis, and

**Table I. — Julia Colliery.**

<table>
<thead>
<tr>
<th>No. of Examination</th>
<th>Period of Examinations</th>
<th>No. of Men Examined</th>
<th>Workmen Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>1</td>
<td>Dec. 17th, 1902, to Feb. 16th, 1903</td>
<td>1,168</td>
<td>228</td>
</tr>
<tr>
<td>2</td>
<td>Feb. 16th, 1903, to March 25th, 1903</td>
<td>1,169</td>
<td>153</td>
</tr>
<tr>
<td>3</td>
<td>March 30th, 1903, to April 18th, 1903</td>
<td>1,079</td>
<td>87</td>
</tr>
<tr>
<td>4</td>
<td>April 20th, 1903, to May 5th, 1903</td>
<td>1,103</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>May 11th, 1903, to June 3rd, 1903</td>
<td>1,098</td>
<td>44</td>
</tr>
<tr>
<td>6</td>
<td>June 4th, 1903, to July 16th, 1903</td>
<td>1,093</td>
<td>51</td>
</tr>
<tr>
<td>7</td>
<td>July 17th, 1903, to July 31st, 1903</td>
<td>267</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>August 10th, 1903, to Sept. 11th, 1903</td>
<td>242</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>Oct. 15th, 1903, to Nov. 30th, 1903</td>
<td>1,105</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>Jany. 25th, 1904, to March 12th, 1904</td>
<td>1,088</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>July 19th, 1904, to Aug. 6th, 1904</td>
<td>1,063</td>
<td>10</td>
</tr>
</tbody>
</table>

17·89 per cent. of the 928 men employed at the Von der Heydt colliery. The examinations show that as the number of men affected by the disease had decreased from 228 men, or 19·52 per cent., to 10 men, or 0·94 per cent., at the Julia colliery, within the same period, the number had decreased from 166 men, or 17·89 per cent., to 13 men, or 1·47 per cent., at the Von der Heydt colliery.

**Table II. — Von der Heydt Colliery.**

<table>
<thead>
<tr>
<th>No. of Examination</th>
<th>Period of Examinations</th>
<th>No. of Men Examined</th>
<th>Workmen Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>1</td>
<td>March 10th, 1903, to April 27th, 1903</td>
<td>928</td>
<td>166</td>
</tr>
<tr>
<td>2</td>
<td>April 28th, 1903, to June 8th, 1903</td>
<td>894</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>June 9th, 1903, to July 15th, 1903</td>
<td>926</td>
<td>63</td>
</tr>
<tr>
<td>4</td>
<td>July 16th, 1903, to August 22nd, 1903</td>
<td>910</td>
<td>48</td>
</tr>
<tr>
<td>5</td>
<td>August 24th, 1903, to Oct. 14th, 1903</td>
<td>930</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>Nov. 11th, 1903, to Dec. 2nd, 1903</td>
<td>890</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>Dec. 14th, 1903, to Jany. 2nd, 1904</td>
<td>221</td>
<td>13</td>
</tr>
<tr>
<td>8</td>
<td>Jany. 5th, 1904, to March 9th, 1904</td>
<td>265</td>
<td>17</td>
</tr>
<tr>
<td>9</td>
<td>March 14th, 1904, to April 20th, 1904</td>
<td>898</td>
<td>31</td>
</tr>
<tr>
<td>10</td>
<td>April 29th, 1904, to June 10th, 1904</td>
<td>928</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>August 22nd, 1904, to Oct. 22nd, 1904</td>
<td>886</td>
<td>13</td>
</tr>
</tbody>
</table>

It is thus clearly shewn that the examinations at the Julia colliery, where the sprinkling had been stopped, yield more favourable results than those at the Von der Heydt colliery; and it is specially indicated when the details of the results of the ninth, tenth and eleventh examinations are com-
pared. In the ninth examination at the Julia colliery, 10 men were found to be affected, and only one was proved to have been infected in that pit. In the tenth examination at the Julia colliery, out of 16 persons affected, one only had previously suffered from ankylostomiasis. This man had returned from his military service in October, 1903, and was employed at the colliery at that time: he had neither produced worm-eggs at the time of his engagement, nor for six weeks afterwards. There was, however, a possibility that the man was already affected by the disease at the time of these two examinations, without the fact being detected by the doctor. At the eleventh examination, 10 persons were found to be affected; it was stated that they had suffered from it several times previously, except a trammer, who had been engaged on July 4th, 1904, and was found to be suffering from the disease on August 2nd, 1904. It

**Table III.—Recklinghausen I. Colliery.**

<table>
<thead>
<tr>
<th>No. of</th>
<th>Period of Examinations</th>
<th>No. of Men Examined</th>
<th>Workmen Infected</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>April 4th, 1903, to May 27th, 1903</td>
<td>1,141</td>
<td>144</td>
<td>12.76</td>
</tr>
<tr>
<td>2</td>
<td>May 29th, 1903, to July 10th, 1903</td>
<td>1,136</td>
<td>123</td>
<td>10.83</td>
</tr>
<tr>
<td>3</td>
<td>July 17th, 1903, to Oct. 29th, 1903</td>
<td>1,163</td>
<td>82</td>
<td>7.03</td>
</tr>
<tr>
<td>4</td>
<td>Sept. 2nd, 1903, to Jan. 9th, 1904</td>
<td>1,146</td>
<td>88</td>
<td>7.56</td>
</tr>
<tr>
<td>5</td>
<td>Jan. 11th, 1904, to March 9th, 1904</td>
<td>1,208</td>
<td>96</td>
<td>8.00</td>
</tr>
<tr>
<td>6</td>
<td>March 10th, 1904, to June 25th, 1904</td>
<td>1,306</td>
<td>102</td>
<td>8.00</td>
</tr>
<tr>
<td>7</td>
<td>June 27th, 1904, to August 25th, 1904</td>
<td>1,239</td>
<td>98</td>
<td>7.98</td>
</tr>
<tr>
<td>8</td>
<td>August 26th, 1904, to Oct. 12th, 1904</td>
<td>1,227</td>
<td>81</td>
<td>6.66</td>
</tr>
<tr>
<td>9</td>
<td>Oct. 13th, 1904, to Nov. 30th, 1904</td>
<td>1,190</td>
<td>81</td>
<td>6.66</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>1,006</td>
<td>29</td>
<td>2.88</td>
</tr>
</tbody>
</table>

was, however, very unlikely that this man was infected at the Julia colliery, for the development of the eggs could hardly have taken place in so short a time; besides, the man said that he had not been working in a pit for some time previously, but he had been employed at the Friedrich der Grosse colliery in 1900.

At the Von der Heydt colliery, in the ninth, tenth and eleventh examinations, 31, 20 and 13 men respectively were found to be suffering from the disease: 11, 7 and 6 men respectively being found to be affected for the first time. It is evident, therefore, that the stopping of the sprinkling had a disinfecting effect, and that the continuation of the sprinkling had largely assisted in the extension of the disease.

This opinion was further confirmed by the results of the examinations (Tables III. and IV.) at the Recklinghausen I. and II. collieries.
At the first examination at Recklinghausen II. colliery, only 37 per cent. of the men were found to be suffering from ankylostomiasis, whilst at the neighbouring Recklinghausen I. colliery not less than 12·76 per cent. of the men were affected. The conditions at Recklinghausen II. colliery are more favourable for the spread of ankylostomiasis, in consequence of the seams being steeper and the temperature being higher than at Recklinghausen I. colliery, and also from the workings being packed at the former colliery. It should, however, be taken into consideration that no watering had taken place in the gas-coal district, and few persons had been found to be affected amongst the men employed therein. Further examinations have confirmed the fact that the liability of infection is less at No. II. than at No. I. colliery. At Recklinghausen II. colliery, after six examinations (the first two being made only once with each man), they succeeded in reducing the number of the affected men from 3·7 to 0·22 per cent. At Recklinghausen I. colliery, after four examinations, the number of affected men was reduced from 12·76 to 3·31 per cent.; but the percentage remained stationary in the six further examinations.

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Mr. J. S. Barnes’ paper on “The Automatic Prevention of Overwinding of Hoisting, Winding and Haulage-engines or Motors” was read as follows:
THE AUTOMATIC PREVENTION OF OVERWINDING OF HOISTING, WINDING AND HAULAGE-ENGINES OR MOTORS.

By J. S. BARNES.

The apparatus described in this paper consists of a combination of mechanical and electrical appliances so arranged as to prevent overwinding.* The electromagnets, MM, must exert sufficient force to attract the armature, A, when the circuit is closed. The armature must be fixed on bearings, having a minimum of friction. This object is attained by using pivot-bearings, PP, which allow the armature to move freely, and respond to the magnetic inductive action of the electromagnets; thus the movement of the armature can be regulated by means of the screws, JJ, and H, (Figs. 1 and 2, Plate VI.). The electromagnets are enclosed in a case, CA, so as to protect them from dust, dirt or injury.

The terminals, TT, are connected by means of wires, W, to the battery or dynamo, BD, and to the finger-pointer, FP, of the indicator-dial, ID. Suitably insulated contacts, CC, secured to the indicator-dial, are connected by wires with the battery, passing through the switch, SW.

The armature, A, is provided with a lever, L₃, projecting out of the box, and working the lever, L, which is supported on the brackets, R and S. The lever, L₅, with a weight, ZZ, is connected to a steam-valve, XX, and suitably supported on a knife-edge, Y, and provided with guides, G.

The lever, L₁, representing either the main stop-valve, or the reversing-lever of the engine (depending upon the lever used by the winding-engineman to stop and to start the engine), is coupled to the switch, SW, by means of a link, L₂.

The valve, XX, independent of the main stop-valve, is fitted with one or more valves and seats, and is connected to the steam-supply pipes in the most convenient position.

* British Patent, 1902, No. 24,390, Mr. John Shaw Barnes.
In the case of electric winding, suitable connections are made to a switch, OO, which breaks the supply-circuit from the motors.

Should the engineman or motorman fail to shut off steam from the engine, or current from the motor, at the proper place, overwinding is prevented by the finger-pointer, or other suitable means closing the circuit, making contact with the insulated studs on the dial, causing a current of electricity to pass from the battery, or other source of electrical supply, and thereby magnetizing the electromagnets, which attract the armature through the distance, X, and move the lever connected with it at the same time. The lever, L, is thus caused to turn on its fulcrum and withdraw the knife-edged support, Y, from the weighted valve-lever. The valve-spindle drops and, at the same time, the valve-seat, XX, is closed, and the valve-seat, NN, is opened. The valve, XX, stops the supply of steam to the winding-engine, and opens the valve admitting steam to the brake.

The electric service is operated in a similar manner: the switch, OO, being opened, the supply of electric energy is cut off.

The switch, SW, is operated every time that the engineman starts and stops the engine, breaking the circuit on stopping, and making the circuit on starting. It is opened just before the finger-pointer makes contact, by pulling the lever, thus breaking the circuit at the switch, SW, at the same time as the circuit is about to be closed on the indicator-dial.

An electric bell can be arranged to warn the engineman, when steam should be shut off, if required.

When the engineman is decking the cage, another set of contacts can be arranged on the indicator, so as to close the circuit electrically should the cage reach a certain position above the decking-landing.

When the finger-pointer is travelling backwards, arrangements can be made to keep the circuit open whilst the finger-pointer is passing over the contacts, by applying the principle of the make-and-break usually adopted in the ordinary mechanical bell-striking arrangement, which is fixed to nearly every indicator. Thus the apparatus is prevented from coming into action.
MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
Held in the Literary and Philosophical Society's Rooms,
Leopold Street, Sheffield, July 25th, 1905.

Mr. J. R. ROBINSON WILSON, Vice-President, in the Chair.

The minutes of the previous General Meeting were read and confirmed.

Messrs. C. Creswick and G. B. Stones were appointed scrutineers of the balloting-papers for the election of officers, and also for representatives on the Council of The Institution of Mining Engineers for 1905-1906.

The following gentlemen were elected, having been previously nominated:

Members
Mr. Richard Raymont Cam, Mining and Metallurgical Engineer, Woodhall Spa, Lincolnshire.
Mr. William Hepburn, Assistant Manager of Engineering Works, 150, Beeston Road, Leeds.
Mr. Mark Rhodes, Mining Engineer, Monkton Main Colliery, Barnsley.
Mr. W. Walker, H.M. Inspector of Mines, Doncaster.

The Annual Report of the Council, and the Statement of Accounts for the past year were read as follows:


The Council has pleasure in presenting to the members of the Institute its annual report.

The number of members for the last two years is as follows:

<table>
<thead>
<tr>
<th></th>
<th>1903-1904</th>
<th>1904-1905</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Member</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Members</td>
<td>...</td>
<td>273</td>
</tr>
<tr>
<td>Associate Members</td>
<td>...</td>
<td>10</td>
</tr>
<tr>
<td>Associates</td>
<td>...</td>
<td>10</td>
</tr>
<tr>
<td>Students</td>
<td>...</td>
<td>12</td>
</tr>
<tr>
<td>Totals</td>
<td>...</td>
<td>305</td>
</tr>
</tbody>
</table>
The table shows an apparent decrease in the number of members of 3 during the year. The above figures, however, do not include 5 members whose subscriptions were received after June 30th, making the total number of subscribing members 307.

At the date of closing the accounts for the year, 19 subscriptions were owing; and deducting 5 since received, there is at present £21 owing from 14 members.

The following arrears of subscriptions have been paid during the year:—1899-1900, £1 10s.; 1900-1901, £1 10s.; 1901-1902, £3; 1902-1903, £3; and 1903-1904, £10 10s.; a total of £19 10s.

The Council regrets to announce that 3 members have died during the year, namely:—Dr. Schultz, Messrs. F. Bagshaw and W. J. S. Batey, and that 9 members have resigned.

The balance in the bank is £243 1s. 4½d., as compared with £240 8s. 1d. at the end of last year. There are, however, outstanding accounts to the value of £17 12s. 1d., making the actual balance £225 9s. 10½d. The Council considers this very satisfactory, in view of the heavy expenditure entailed in removing the head-quarters of the Institute to Sheffield.

The following papers have been read:—

"The Automatic Prevention of Over-winding of Hoisting, Winding and Haulage-engines or Motors." By Mr. J. S. Barnes.

"Systematic Timbering at Emley Moor Collieries." By Mr. H. Baddiley.

"A Safety Catch for Cages." By Mr. J. Clegg.

"Notes and Considerations on Systems having Work of an Intermittent and Irregular Character to Perform: Methods of Load-compensation." By Mr. Maurice Georgi.

"The Work of a Joint Colliery Rescue-station." By Mr. M. H. Habershon.

"Notes on Capels for Winding-ropes." By Mr. T. W. H. Mitchell.

"Presidential Address." By Mr. T. W. H. Mitchell.

"The Dust-danger." By Mr. W. H. Pickering.


"The Effect of Watering of Coal-mines on the Spread of Ankylostomiasis." By Mr. Jonathan Wroe.

This shows a satisfactory increase in the number of papers as compared with last year, but the Council would remind the members that it has only been obtained at the cost of frequent appeals and great labour. The Council feels strongly that this should be unnecessary, and members would relieve it of the anxiety which it experiences in this respect, if they would voluntarily offer papers for discussion.
The Council, being of opinion that the facilities for the discussion of papers read before this and other Institutes are insufficient, has decided that one or two meetings in the year shall be set apart for discussions.

Mr. T. W. H. Mitchell, having been elected to the Presidency of the Institute, resigned the offices of Secretary and Treasurer, which he had held for 14 years. The Council desires to place on record its high appreciation of the valuable and disinterested services which he has rendered to the Institute whilst holding these offices, and in thanking him for those services it wishes him a successful term as President.

Mr. L. T. O'Shea was appointed Secretary and Treasurer in succession to Mr. Mitchell, and in consequence, the headquarters of the Institute have been removed to Sheffield. An agreement has been entered into with the Sheffield Literary and Philosophical Society for the use of one of its rooms in Leopold Street as a Council-room and Library, and for the use of its Lecture-room for the meetings of the Institute.

The Library has been transferred to Sheffield, and the books placed in bookcases. It is open to members daily from 11 to 6 (Saturdays 11 to 1), when books may be consulted or borrowed on applying to Mr. S. Johnson at the Society's Room.

It is with pleasure that the Council records the gift to the Library, by Mr. W. E. Garforth, of 20 bound volumes of the Reports of H.M. Inspectors of Mines, and tenders to him the hearty thanks of the Institute.

Three hundred and fifty copies of An Abstract of the Report of the Prussian Commission on Falls of Stone and Coal have been purchased by the Council and presented to the members free of cost.

In the report for last year, the Council announced its desire to tabulate the various strata that had been proved in the Yorkshire district. The Committee appointed to carry out this work has made considerable progress, and the Council desires to thank those members of the Institute and others, who have contributed records of sections, for their valuable co-operation and assistance. It is further able to announce that The Midland Counties Institution of Engineers has consented to co-operate with your Committee and supply sections of the Nottinghamshire and Derbyshire districts. This will greatly increase the value of the publication, and make it a record of the whole coal-field.
Dr. The Treasurer (Mr. L. T. O'Shea) in Account with the Midland Institute of Mining, Civil and Mechanical Engineers, 1904-1905.

<table>
<thead>
<tr>
<th>July 1st, 1904.</th>
<th>£</th>
<th>s</th>
<th>d</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>To Balance at bankers'</td>
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<td>210</td>
<td>8</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Cash in Treasurer's hands</td>
<td>...</td>
<td>2 11</td>
<td>3½</td>
<td>212</td>
<td>19</td>
<td>4½</td>
</tr>
</tbody>
</table>

June 30th, 1905.

| To Subscriptions for 1904-1905, 298 at £1 10s. | ... | 447 | 0  | 0  |    |    |
| " Arrears, 1903-1904, 7 at £1 10s. | ... | 10 | 10 | 0  |    |    |
| " 1902-1903, 3 at £1 10s. | ... | 3 0 | 0  | 0  |    |    |
| " 1901-1902, 2 at £1 10s. | ... | 3 0 | 0  | 0  |    |    |
| " 1900-1901, 1 at £1 10s. | ... | 1 10 | 0  |    |    |
| " 1899-1900, 1 at £1 10s. | ... | 1 10 | 0  |    |    |
| " Subscriptions paid in advance for 1905-1906, 1 at £1 10s. | ... | 1 10 | 0  |    |    |
| " Life-subscription, 1 at £30 | ... | 30 | 0  | 0  |    |    |
| " Sale of dinner-tickets, 121 at 5s. | ... | 30 | 5  | 0  |    |    |
| " Wine account | ... | 7 1 | 8  |    |    |    |
| " Sale of Transactions, and authors' copies | ... | 37 | 6 | 8  |    |    |
| " Sale of furniture | ... | 1 2 | 0  |    |    |    |
| " Letting of room | ... | 1 0 | 0  |    |    |    |
| " Bank interest | ... | 8 17 | 2  |    |    |    |

Examinated and found correct.

M. H. HABERSHON, Auditors.

THOMAS GILL.

July 15th, 1905.

<table>
<thead>
<tr>
<th>June 30th, 1905.</th>
<th>£</th>
<th>s</th>
<th>d</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>by The Institution of Mining Engineers:—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Call of 19s. per Member on 294 Members</td>
<td>...</td>
<td>279</td>
<td>6</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; 7 at 19s.</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>6 13</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>&quot; Excerpt Transactions, etc.</td>
<td>...</td>
<td>11</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Report of the Prussian Commission on Falls of Stone and Coal</td>
<td>...</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Authors' copies</td>
<td>...</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Binding</td>
<td>...</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Annual dinner</td>
<td>...</td>
<td>44</td>
<td>13</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Printing and stationery</td>
<td>...</td>
<td>37</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Rent of rooms</td>
<td>...</td>
<td>22</td>
<td>12</td>
<td>6</td>
<td></td>
<td></td>
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<tr>
<td>&quot; Reporter</td>
<td>...</td>
<td>6</td>
<td>15</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Insurance</td>
<td>...</td>
<td>1</td>
<td>11</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Cleaning</td>
<td>...</td>
<td>1</td>
<td>19</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Hire of rooms for meetings at Sheffield and Leeds</td>
<td>...</td>
<td>3</td>
<td>8</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Secretary's salary:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T. W. H. Mitchell</td>
<td>...</td>
<td>16</td>
<td>13</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. T. O'Shea</td>
<td>...</td>
<td>33</td>
<td>6</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Secretary's expenses</td>
<td>...</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Stamps, telegrams, carriage, etc.</td>
<td>...</td>
<td>17</td>
<td>7</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Telephone-rent</td>
<td>...</td>
<td>8</td>
<td>10</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Bookcases</td>
<td>...</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Removal and arranging library</td>
<td>...</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Balance at bankers'</td>
<td>...</td>
<td>242</td>
<td>2</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; Cash in Treasurer's hands</td>
<td>...</td>
<td>0</td>
<td>19</td>
<td>0½</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

£791 6 8½

£791 6 8½
## Accounts

**Liabilities.**

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 30th.—To Creditors:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calls</td>
<td>13</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Exchanges</td>
<td>3</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Electric Light</td>
<td>0</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total Liabilities</strong></td>
<td>17</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td><strong>Balance, being capital, as</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at June 30th, 1904</td>
<td>611</td>
<td>11</td>
<td>4½</td>
</tr>
<tr>
<td>Increase since</td>
<td>22</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total Liabilities</strong></td>
<td>634</td>
<td>10</td>
<td>10½</td>
</tr>
</tbody>
</table>

Examined and found correct,

**M. H. HABERSON.**

**THOMAS GILL.**

**Auditors.**

*July 13th, 1905.*

**Assets.**

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 30th.—By Cash at bank</td>
<td>242</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>in Treasurer's hands</td>
<td>0</td>
<td>19</td>
<td>0½</td>
</tr>
<tr>
<td><strong>Total Assets</strong></td>
<td>243</td>
<td>1</td>
<td>11½</td>
</tr>
<tr>
<td>Bookcase (cost)</td>
<td></td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Value of 7,213 parts of Transactions, at 1s.</td>
<td>360</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Value of 115 copies of Narrative of Sudden Outbursts of Gas, at 1s.</td>
<td>5</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Value of 116 copies of Committee's Report on Safety-lamps, at 1s.</td>
<td>5</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Value of 16 copies of Report of French Commission on Use of Explosives, at 3s.</td>
<td>2</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Value of 9 copies of Report of the Prussian Commission on Falls of Stone and Coal, at 1s.</td>
<td>0</td>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total Assets**

£652 2 11½
Mr. M. H. Habershon moved the adoption of the Report and of the Accounts.

Mr. I. Hodges seconded the resolution, which was adopted.

ELECTION OF OFFICERS, 1905-1906.

The Scrutineers reported the result of the ballot, as follows:—

President:
Mr. T. W. H. Mitchell.

Vice-Presidents:
Mr. M. H. Habershon.
Mr. I. Hodges.
Mr. J. L. Marshall.

Councillors:
Mr. Thomas Gill.
Mr. Roslyn Holiday.
Prof. G. R. Thompson.

Mr. P. Greaves.
Mr. Harry Rhodes.
Mr. W. Walker.

Prof. F. W. Hardwick.
Mr. Thomas Stubbs.
Mr. W. Washington.

Mr. Walter Hargreaves.
Mr. E. W. Thirkell.
Mr. J. R. R. Wilson.


Mr. W. H. Chambers.
Mr. W. H. Mitchell.
Mr. J. Nevin.

Mr. W. E. Garforth.
Mr. H. B. Nash.
Mr. G. B. Walker.

Mr. J. R. R. Wilson.

DISCUSSION OF MR. A. HASSAM'S PAPER ON "THE TAXATION OF COLLIERIES."

Mr. H. B. Nash thought that the anomalies in matters of colliery-rating, brought to notice, furnished proof that something might be done by Institutes like their own, to force the hands of rating authorities, and to place the matter on a more satisfactory footing than was the case at present. All who were connected with collieries, if they attempted anything to reduce their costs, knew that they ran the risk of increasing the rates, and this was generally done in cases where the oppression was most severe. Mr. Hassam stated in his paper that in 145 unions there were 2,085 mines, and no less than sixteen different systems of rating; and that in Cheshire the average gross rate-
able value was 7:03d. per ton, and in Derbyshire, 2:09d. per ton.*

He (Mr. Nash) suggested that some more uniform system should be adopted, whereby, at least, different counties might be treated on a common basis, instead of the wide diversity between 7d. and 2d. per ton, and where, probably, there was little difference in the value of the coal. The Denaby colliery rating-appeal case, of a few years ago, was yet in their memory, whereby an effort was made to arrive at the rateable value of the colliery in the same manner as that of gas-works and railways. The costs involved in that case, however, were so great that no other attempts were made to get the rateable value reduced: the feeling being that the costs would exceed any relief likely to be obtained.

Mr. M. H. Habershon thought that the method of rating, of which an example was given,† would provide a means whereby a fair valuation of a colliery could be calculated, as it enabled deductions to be made at certain collieries for expenses which did not exist at other collieries; but it would be difficult to apply in many cases. He thought that the method of valuation based on the royalties was, at any rate, a convenient one, especially in those cases where collieries were working coal in several adjoining townships. It was most important, however, that the surface-plant should not be taken at too high a valuation, and he thought that it was a matter in which a great amount of consideration was required. A colliery with a pumping-plant, was liable to be called upon to face an increased valuation in consequence of having installed this plant, which, as a matter of fact, was an incubus upon the concern instead of a source of profit.

Mr. John Wainwright thought that the rateable value of a colliery should be based upon its output, irrespective of the value of the machinery used in winning the coal. The thickness of the seam and the commercial value of the coal were important factors in assisting rating authorities, if only they would consider them, because for the same output, the area worked of a thin seam was large compared with that of a thick seam, and the working costs were higher in the case of the thin seam. It was

† "Ibid.," pages 103 and 104.
manifestly unfair to take the plant and buildings as a basis for rating, as one colliery might find it necessary to make a large capital-outlay on a pumping-plant, which might drain the surrounding district and so relieve other collieries of that expense. If this were used by the rating authority as a basis for the rateable value, it was very unfair, because that colliery had not only provided the plant, but it had also found the water to be pumped. Further, neighbouring collieries might be situated in parishes where a cheap supply of electricity from some large electrical power-company might be available; in that case it would not be necessary for those collieries to provide so large a plant. All this brought one back to the fact that the output should be the basis for rating, and not the buildings and machinery.

He thought that it would be very much better for both rating authorities and ratepayers if a statutory basis could be fixed, so that all collieries would be rated upon like methods. He suggested that Parliament should be approached upon the matter by both sides, with a view to the establishment of a more uniform system of rating. A board appointed for each mines-inspection district, with power to fix the rateable value of collieries upon some statutory basis, would be a better authority than the present system of Assessment Committees.

The discussion was adjourned.

DISCUSSION OF MR. W. H. PICKERING’S PAPER ON “THE DUST-DANGER.”*

Mr. W. Walker (H.M. Inspector of Mines) referring to his description of the firing of dust by gas-flames at the bottom of a shaft,† said that the shaft was about 1,680 feet deep, and, until some seven or eight years ago, the shaft-bottom was lighted by open gas-lights. The shaking-screens and belts were placed close to the top of the downcast-shaft. The coal-dust was carried down by the air from the screens, and ignited at the open lights to such an extent that the flame was sometimes carried for a considerable distance. The danger of fire and of the ignition of coal-dust in the mine was apparent; and, consequently, the

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open lights were removed and replaced by electric incandescent lamps; and the other measures, which he had described,* were taken to prevent coal-dust from descending the shaft. He believed that several firms in the Yorkshire mines-inspection district were considering the question of removing the dust from the screens. At one colliery it was proposed that the screens and tipplers should be enclosed, and that fans should be employed to draw the coal-dust from the screens and pass it into a cyclone-collector, where it would be damped with steam. Much had been said about the bad effect of water upon certain stones in mines, and, to a certain extent, this was true; but he felt that the ill effects had been overrated. In the discussion upon a paper by Mr. Cresswell Roscamp on an improved apparatus for laying dust in coal-mines, Mr. A. A. Atkinson, chief inspector of coal-mines in New South Wales, suggested that a committee should be appointed to investigate and report upon the best means of dealing with, what Mr. Pickering appropriately called, the dust-danger. He agreed with that suggestion, and he had no doubt as to the necessity of adopting, in many mines, up-to-date methods of dealing with dust.

Mr. M. H. Habershon said that Mr. Pickering pointed out that permitted explosives were only relatively safe. In his recent report, Captain A. P. H. Desborough† stated that the only guarantee which one could take from the fact that an explosive had passed the special test, was that it was safer than gunpowder. The members of the Institute, for some time past, had felt that there should be some means of testing explosives, under the same conditions as when used in pits. The subject was at present in abeyance, but he thought that Mr. Pickering’s remark, coupled with what was stated in the report to which he had referred, should bring the matter strongly forward again; and he hoped that, sooner or later, it would be possible for mining engineers to test, say, 16 ounces of explosive in a manner analogous to the conditions met with in mines. Mr. Pickering also stated that it was not necessary for screening-plant to be placed contiguous to the pit-bank; and in several Continental coal-fields this danger had been recognized for some time past.

† Twenty-ninth Annual Report of H.M. Inspectors of Explosives: being their Annual Report for the Year 1904, 1905, [Cd. 2395], page 142.
He thought that it should be borne in mind that, in addition to guarding against the danger from dust, the screens should be placed as far away as possible from the pit-top, so that, in case of fire, there could be no danger of fumes and smoke being carried down the downcast-shaft.

Mr. L. T. O'Shea said that a Joint Committee appointed by the Midland Counties Institution of Engineers and the Midland Institute of Mining, Civil and Mechanical Engineers, were unanimously of opinion that an explosives testing-station should be erected, and that there was great necessity for it, but it was found difficult to meet the question of expense. There had been a joint meeting of representatives of the Institute, the Leeds University, and the, then, University College of Sheffield, to see what could be done with regard to taking active steps to erect a testing-station. The method by which funds could be raised for the erection of a station was discussed; but the matter went no further, as the opportunity for obtaining the necessary money did not seem a favourable one. The amount required to erect a testing-station, such as would enable them to obtain the information which Mr. Habershon had mentioned, would range from £1,800 to £2,000.

The method of testing explosives at Woolwich placed all explosives that passed the test on the same level as regards their safety in the presence of gas; and the results of the experiments did not indicate to the consumer which were the safest explosives to use.

He had no doubt, however, that if a station, such as had already been described in the Transactions,* were erected, the information obtained would well repay those who had contributed to its erection. If funds were forthcoming, the mining department of the University of Sheffield was prepared to give every assistance in its power.

Mr. H. Rhodes thought that Mr. Pickering had found the key to the situation, when he said that the only radical way of keeping mines free from dust was by cutting off the supply. There were one or two methods by which this could be done to a great extent. One was by placing the screens a sufficient distance away from the pits, so as to prevent the fine dust from

the screening-operations from being taken down into the mine by
the intake-air. Another method, by which a great deal could be
prevented, was by using impervious bottoms and sides to the
tubs. In his opinion, a great deal of dust was produced by
small coal, falling through interstices in the tub-bottoms, being
crushed into impalpable dust by the passing of men and animals.

With respect to the laying of dust, he had been surprised
at the effect of salt-water upon dust in a deep mine, where
the temperature in the return-airways was 84° Fahr. In this
mine, the pit-water was very salt, and although the roads were
very dry, comparatively little dust was found in them, when
distant more than about 1,500 feet from the shaft-bottom. It
had been proved that the addition of salt to the slaking water
had a marked effect at Continental collieries, and he thought
that this was the reason why these workings of this colliery were
also, to a great extent, free from dust. The conditions for mak-
ing dust were very favourable, here, as the difference between
the wet-bulb and dry-bulb thermometers was as much as 5½°
Fahr. The effect of injudicious watering was very marked at
this colliery, and great trouble was experienced from the floor
lifting, whenever a water-pipe burst or a tub of water was over-
turned.

The Chairman (Mr. J. R. R. Wilson) thought that coal
falling through the interstices of the bottom and sides of the
tubs was undoubtedly the chief source of dust, but a certain
amount was also blown from the tops of the tubs. His own
suggestion (frequently reiterated) of preventing the dust from
passing on to the roads was (1) to catch it at both ends before
it came to the roads, and (2) to prevent it from going down the
shaft. Some years ago, Mr. E. W. Thirkell tried the experi-
ment at the Oaks colliery, of spraying the tubs, and it proved
very effective. The question had been raised that, if the tubs
were watered, the tare of the tubs should be altered: but he
thought that a short trial would soon enable them to ascertain
the amount of water to be used, in order that all might be
evaporated by the time that the tubs reached the screens.

The discussion was closed.
THE YORKSHIRE ELECTRIC POWER COMPANY: THORNHILL POWER-STATION.

The Yorkshire Electric Power Company is authorized to supply electrical energy over an area of 1,800 square miles, taking in the whole of South Yorkshire. The Thornhill power-station is one of the four which are to be erected. Current is generated and transmitted at a pressure of 10,000 volts, and transformed to 2,000 and to 400 volts at the consumers' terminals. The switch-board controlling this high-pressure current is of the most modern type, all the switches being operated by motors.

The three-phase generators are coupled direct to Curtis steam-turbines: this type of turbine is notable for the small floor-space occupied, the shaft being vertical. There are, at present installed, three turbines of 2,700 horsepower each.

The boiler-equipment consists of Babcock-and-Wilcox land-type boilers. The coal is elevated by an endless conveyor to overhead bunkers.

The auxiliary machinery is driven by electric motors: the current being obtained from dynamos driven by three high-speed Allen engines.
MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE HARVEY INSTITUTE, BARNSLEY, NOVEMBER 8TH, 1905.

Mr. T. W. H. MITCHELL, President, in the Chair.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:

MEMBERS—
Mr. William Henry Fudge, Under Manager, Hornes Terrace, Durkar, near Wakefield.
Mr. John William Gardner, Mechanical Engineer, Elmfield, Outwood, Wakefield.
Mr. Sam Hopkinson, Under Manager, 17, Ivanhoe Road, Conisborough.
Mr. Frederick Anthony Steart, Geological Survey Department, P.O. Box 978, Pretoria, Transvaal.

ASSOCIATE MEMBER—
Mr. George Steeples, 13, Joannah Street, Sunderland.

STUDENTS—
Mr. Harold Charles Firth Jeffcock, Mining Student, Birley Collieries, Sheffield.
Mr. Sam Swift, Mining Student, Lepton Colliery, near Huddersfield.
Mr. John Wilfrid Talbot, Mining Student, Field Head, Batley, Yorkshire.

The President (Mr. T. W. H. Mitchell) read the following Further Notes on Capels for Winding-ropes"; —
FURTHER NOTES ON CAPELS FOR WINDING-ROPE.

By T. W. H. MITCHELL.

The writer has caused further tests to be made with different capels, in addition to those already reported on in his former note,* and the details of the results are given in Table II.

(1) This capel, supplied by the makers of the rope, was made on the principle of two wedges tightening against the rope as soon as it comes under tension. This capel was successful in breaking the rope (Fig. 1, Plate VIII.) at a load of 64.5 tons. The capel was attached to the rope by the makers, and the rope was tested in the same state as it was received from them. Attention is called to the note in Table II. shewing the extent to which the wedges were drawn out of the capel. This rope was stated to have a breaking-strain of 90 tons.

(2) The writer had a portion of the same rope tested for its breaking-strain only, using a capel which is ordinarily employed by the engineers when testing ropes.

(3) This test was made on a box-capel supplied to the writer. The rope (Fig. 1, Plate VIII.) was a piece cut from the same length as that used in Nos. 1 and 2 experiments.

(4) This test was made on an ordinary capel, 3 feet 6 inches long, described in the writer's former note,† and illustrated in Plate VIII. The only difference being that the rope was pulled right through, bound with soft No. 13 gauge copper-wire for a length of 21$\frac{1}{2}$ inches, and then opened out and cleaned for a length of 16 inches (Fig. 2) at the end, without turning the wires back. When this was done, two iron wedge-shaped pieces (Figs. 5 and 6) were inserted at the sides or joints of the capel (Fig. 3) and the collars driven home. White-metal, consisting of 60 per cent. of lead, 30 per cent. of tin, 9 per cent. of antimony and 1 per cent. of bismuth, as described by Mr. John Gerrard‡, was then

† Ibid., page 174.
‡ Ibid., page 178.
# Table I.—Recording Tests of Capels.*

<table>
<thead>
<tr>
<th>No. of Test</th>
<th>Description of Capel.</th>
<th>Circumference</th>
<th>Details of Ropes.</th>
<th>Stress in Tons.</th>
<th>Maximum Stress</th>
<th>Total Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Layers or Strands</td>
<td>Total Number of Wires</td>
<td>Hanger Gauge</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

**Remarks:**
1. With a load of 28.4 tons, the rope pulled rapidly through the capel; and, with a load of 29.29 tons, the rope broke inside the capel, and finally pulled through.
2. The rope commenced to pull out of the capel with a load of 14.0 tons; and with a load of 46.48 tons, the rope broke inside the capel, and finally pulled through.
3. Seven of the outer layer of wires broke first; then nearly all the remaining wires were broken together, clear of the fastenings. Several of the wires were broken at different places in the length of the rope.
4. The first wire broke with a load of 22 tons, and, on the test being continued, several more wires broke. With a load of 32.1 tons, the rope pulled rapidly out of the capel, and at 42.4 tons, two strands and wires in the remaining strands broke together, clear of the capel. The wires were broken at different places along the length of the rope. The total movement of the rope in the capel was 4.75 inches.
5. With a load of 3.5 tons, the rope was pulled 0.14 inch out of the capel; and the first wire broke with a load of 24.70 tons. The rope pulled rapidly out of the capel with a load of 27.30 tons, and, with a load of 42.69 tons, the rope pulled out of the capel. A slight fracture was found in the capel after the test was finished.
6. Three strands broke together, clear of the fastenings.


*Further Notes on Capels for Winding-rope.*

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<tr>
<th>No. of Test</th>
<th>Description of Capel</th>
<th>CIRCUMFERENCE</th>
<th>WEIGHT PER Fathom.</th>
<th>NUM. OF WIRE</th>
<th>SHAPE OF SECTION OF WIRE</th>
<th>TOTAL NUMBER OF WIRE</th>
<th>STRESS in Tons</th>
<th>Maximum Stress</th>
<th>ELONGATION in Inches.</th>
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<tr>
<td>1.</td>
<td>Locked-coil rope, with a capel-attachment at one end.</td>
<td>3'85</td>
<td>21'46</td>
<td>33 recess</td>
<td>93</td>
<td>inches, inches, inches, 0'00, 0'02, 0'18</td>
<td>0'20, 0'25, 0'40, 0'68</td>
<td>1'38</td>
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<tr>
<td>2.</td>
<td>Another length of locked-coil rope, cut from the same rope as that used in No. 1 test.</td>
<td>3'85</td>
<td>21'46</td>
<td>33 recess</td>
<td>93</td>
<td>inches, inches, inches, 0'00, 0'00, 0'01</td>
<td>0'05, 0'06, 0'11, 0'14</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>3.</td>
<td>Locked-coil rope, with a box-capel fixed at one end.</td>
<td>3'85</td>
<td>21'46</td>
<td>33 recess</td>
<td>93</td>
<td>inches, inches, inches, 0'00, 0'00, 0'00</td>
<td>0'00, 0'10, 0'20, 0'47</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>4.</td>
<td>Locked-coil rope, with a capel-attachment at one end.</td>
<td>3'85</td>
<td>21'46</td>
<td>33 recess</td>
<td>93</td>
<td>inches, inches, inches, 0'01, 0'13</td>
<td>0'20, 0'30, 0'43, 0'63</td>
<td>1'46</td>
<td>64'92</td>
</tr>
</tbody>
</table>

**Remarks**—(1) The first wire of the rope broke at a load of 62'59 tons; and, with a load of 64'5 tons, the rope broke as a whole at a position corresponding to the front edges of the first ring on the sheath, and at a distance of 31 inches from the front of the wedge. The total length of travel of the wedges during the test was 2 inches.
(2) Seventy-seven of the wires broke together, clear of the fastenings. The ratio of the holding-power of the capel to the breaking-load of the rope was 98'8 per cent.
(3) The rope broke clear of the fastenings and of the capel-attachment. The total movement of the rope in the capel was 0'35 inch.
(4) The rope broke clear of the fastenings and of the capel-attachment.
poured in, forming a length of 25 inches. When cooled down properly, the wedge-shaped pieces of iron were taken out and the collars were driven tightly home on the white-metal. Figs. 7 and 8 shew the rope-end with the capel removed. This arrangement was carried out by their engineer, Mr. S. Brittain, and tested with the results shewn in Table II.

In the writer's opinion, the success of this form of capel shews that it does not matter particularly what is the shape of the capel, so long as no wires are turned back, and the white metal is run in carefully. The writer was somewhat astonished to find that a rope, described as having a breaking-strain of 90 tons, should break in two or three cases with a load of about 65 tons, and the experience of other members on this point would be useful. The explanation given is that the cutting of the rope into short lengths imperceptibly disintegrates the wires, so that they do not all take the same stress.

The locked-coil rope (Fig. 1, Plate VIII.) used in the tests was 3'85 inches in circumference, and weighed 21.46 pounds per fathom. There were 33 recess-shaped wires in the outer ring of the rope, 26 wedge-shaped wires in the second ring, 16 round wires in the third ring, 11 round wires in the fourth ring, 6 round wires in the fifth ring, and the central core was a round wire.

The method of calculating the strength of a rope seems to be as follows:—Locked-coil rope, No. 2,254 (Fig. 1, Plate VIII.), a sample of which was sent to the Sheffield Testing Works, made of improved plough-steel, contained 6 round wires in the fifth ring, 11 round wires in the fourth ring and 16 round wires in the third ring, and 33 round wires at 2,270 pounds equals 74,910 pounds; 26 wedge-shaped wires at 2,115 pounds equals 54,990 pounds; and 33 recess-shaped wires at 2,164 pounds equals 71,412 pounds; making a total breaking-strain of 201,312 pounds or 89.87 tons, or, say, 89.87 tons.

Mr. W. Walker (H.M. Inspector of Mines) said that he had taken the opportunity of seeing some of the tests made at Sheffield, and he could not understand why the ropes broke in all of them at about 65 tons. The results of the experiments seemed to be very even, and to give a breaking-strain practically
of 72 per cent., yet in other experiments, with the same description of capel and rope, from 90 to 100 per cent. of the theoretical breaking-strain of the rope was obtained. Messrs. Glaholm and Robson, of Sunderland, had sent him the results of a test of an ordinary stranded rope for the Pekin syndicate. The breaking-strain was guaranteed at 84 tons, and the rope broke at 87·40 tons. The capel was formed in the following manner: (1) Bind the end of the rope securely, and after measuring the length of the chamber of the socket to be fixed, bind the rope again at that distance so as to prevent the strands from unlaying when the wires are opened out. (2) Pass the rings in their proper order on the rope, push the rope through the chamber of the socket; and then drive the rings back into the socket. Fill the apertures at the sides and bottom with clay, so as to keep the metal from running out when poured in. (3) Open out the strands to the second binding, thoroughly clean the wires and place the socket in a vertical position, then draw the rope level with the top of the chamber, and pour in the molten spelter. (4) Allow it to cool, caulk the rings in their position, remove the temporary bindings and dress, with a file, the spelter at the top of the chamber of the socket. That method was practically the same as that used by Mr. Brittain, of Mitchell Main colliery. The metal used for filling the socket was composed of a good quality of spelter, with the addition of 10 per cent. of tin. He thought that this information shewed that such capels did give a maximum breaking-strain. At a colliery, he recently raised the question with the engineer, who said that he preferred the old-fashioned capels, because they gave some notice of when they were about to draw, and the others did not. Personally, he could not agree with that view, holding that the bigger margin of breaking-strain must give a greater degree of safety.

Mr. M. H. Habershion said that a few years ago he felt some doubt as to whether the old-fashioned capel was satisfactory and an improved form had been adopted. After reading Mr. Mitchell's paper, it was thought desirable to make a test, and, accordingly, a length was cut from a rope in work, and it was tested at Sheffield. The rope, 4⅛ inches in diameter, was made of special plough-steel, with six strands, ½ inch in diameter, and a main hemp core. The rope broke under a stress of 83·3 tons, but the capel was not injured: a slight movement was noticed when
the strain first came on, but it did not go any further. A second piece of the same rope broke at 81.9 tons, so that the full percentage was realized. This capel was made in the old-fashioned form, but none of the wires were turned back. The method of capelling was to open out the strands for a length of 3 or 4 feet, and then replace them on the top of an iron plug 3 feet long, which tapered from a diameter of \( \frac{5}{8} \) inch to 1\( \frac{1}{16} \) inches, the original lay of the strands being maintained. After replacing the various strands on this plug, the spaces between them were filled with short lengths of the strands, which were tapered to a point so as to fill in the spaces left, and annealed. This solid end, 3 feet long, was then wrapped with steel-wire and inserted in a capel of the ordinary form, bound together by six iron hoops, 1 inch thick and of varying widths, driven on cold.

Mr. H. Ingold (Sheffield) said that he saw the tests made on Nos. 3 and 4 samples. In the third test, about twelve of the outer wires and a few of the inner ones broke first; and, in the fourth test, only four outer wires broke first, and about the same number of the inner wires. The tests of the four samples only gave 72 per cent. of the aggregate strain of the wires. Testing-machine results with locked-coil ropes could not be taken as accurate, as it was difficult to fasten the ends, without disturbing the twist of the wires, and practically impossible to prevent the slackening of some of the wires. Consequently, the wires could not take their proper share of the load. In the two instances quoted, so small a proportion of the wires broke together, that there could be little doubt that the rope, when in use, would stand a much higher tensile breaking-strain than that obtained on the testing-machine.

Mr. Brittain's adaptation of an ordinary winding-rope capel (Figs. 3 and 4, Plate VIII.) for use with white-metal in the fourth test, was ingenious: he converted it into a solid capel by putting in liners, and, after casting, removed them, enabling the hoops to be driven up. He noticed that the capel was 42 inches long, and, as that was probably his first attempt, the test was highly satisfactory. The capel, about 24 inches long, used in the third test, was made from a mild-steel forging, machined all over in order to make sure that there was no flaw in the material.
He proposed, shortly, to carry out a series of experiments with locked-coil ropes, on a 100 tons wire-rope testing-machine. He hoped that the experiments would enable him to find the percentage of loss of the aggregate strength of the wires due to spinning, and, perhaps, a method of cutting off and preparing the ends of the samples, by which a larger proportion of the wires would carry the load.

Tensile tests of ordinary wire-ropes, made of round wires, twisted into round strands and closed into round ropes, were much more regular and reliable. The tensile breaking-strain of the usual sections of winding-ropes might be taken at 80 to 90 per cent. of the aggregate strain of the wires; but that percentage decreased in very large ropes, probably owing to the untwisting of the short sample tested, owing to the springing of the wires. He agreed, when using white-metal capels, that the wires should not be turned backward, as the cleaning of the wires could be better done: they need not be handled after cleaning; and the white-metal could more easily run round each individual wire. He was so assured of the efficiency of this method of fastening, that, in 1901, he had 280 samples of rope, with 560 ends, tested in that way for the British Admiralty, and not one of them drew out before the rope was broken. These tests gave 85 to 90 per cent. of the aggregate strain of the wires.

A capel of the open-shackle type (Fig. 10), principally used for quarry-crane ropes, was employed on account of convenience in testing. It was fastened to a winding-rope 1\(\frac{1}{4}\) inches in diameter. It was 11\(\frac{3}{8}\) inches long, the barrel was only 5\(\frac{5}{8}\) inches long, and none of the wires were turned backward. The result of 53\(\frac{3}{5}\) tons was remarkably and
DISCUSSION—FURTHER NOTES ON CAPELS FOR WINDING-ropes. 187

unusually good, being 93 per cent. of the aggregate strain of the wires: the estimated breaking-strain being 51.62 tons. The casting proved to be quite sound, when sawn through.

Another capel of the closed weldless type (Fig. 11) was largely used for hauling-ropes (\(\frac{3}{8}\) inch in diameter): for underground work, the wires would be turned backward, and a small iron peg driven in; and, for surface work, white-metal could be used. The size of this capel (6\(\frac{1}{4}\) inches long and barrel 2\(\frac{1}{2}\) inches long) would not, of course, allow of its use on winding-ropes, owing to its diminutive appearance, but it shewed that even a small capel could be stronger than the rope.

White-metal capels were the strongest fastenings known, but great care was necessary in putting them on, the points to be watched being: the use of a proper alloy, the temperature at which it was melted and used, the cleaning of the wires, and the shape of the capel.

Mr. J. R. R. Wilson (H.M. Inspector of Mines) pointed out that there were hundreds of quarries in the Yorkshire mines-inspection district, and he had made special enquiries on the subject of rope-breakages. Almost universally, a small box-capel was used, the attachment being made by running in white-metal as had been described, and it was very rarely indeed that the capel was drawn. Sometimes, a stone which had to be pulled out of the quarry, was not properly dislodged from its bed, and when the crane-rope was applied, it was subjected to a very severe strain. Ropes had broken under such conditions, the drum-axles had been bent, even the drums had been broken, but very rarely was the capel drawn. The box-form of capel had the further advantage that it obviated the use of rings, such as were commonly adopted, especially upon large rope-attachments. He had known instances where rings had become loose and stripped, resulting in serious personal injury and destruction of property.

The tests recorded in Mr. Mitchell's paper, and other instances of weakness shown in locked-coil ropes, raised the question, which he thought ought to be considered, of the advisability of using these ropes for ordinary winding, especially in
upcast-shafts. It would be of interest and value to the members if someone, who was thoroughly conversant with the manufacture of such ropes, would give his opinion.

Mr. H. B. Nash thought that the results of the tests made on locked-coil ropes were an eye-opener to many engineers, who were responsible for the working of such ropes. It was a serious matter to be told, after running a rope for four months with a guaranteed breaking-strain of 90 tons, that they must consider that strain to be reduced to 65 tons, because, owing to its being recapped, such a rearrangement of the internal wires of the rope had taken place, as to bring about this result. In his opinion, the question resolved itself into whether it was not more advantageous to use a rope of ordinary lay, upon which a reasonable amount of reliance could be placed, than to use a locked-coil rope, which, according to the tests made, broke in every instance at about two-thirds of its guaranteed breaking-strain. If the makers of locked-coil ropes could give some assurance that the breaking-strains were reliable, instead of stating that, after a short life or in the case of recapping, they could not be properly tested owing to the rearrangement of the internal wires, it would create a much greater feeling of security in the minds of the users. The frequent recapping of winding and other ropes was for the sole purpose of obtaining increased safety, and, in the case of locked-coil ropes, apparently, it had just the reverse effect and defeated its own object.

Mr. Isaac Hodges pointed out that the rope-makers' guaranteed breaking-strain for winding-ropes of ordinary lay was usually 15 per cent. less than the computed breaking-strain ascertained by multiplying the breaking-strain of one wire by the number of wires in the rope. This allowance was made, as it was obvious that all the wires could not take an equal strain at one time. If this deduction was made from the 89½ tons computed breaking-strain of the locked-coil rope, described by Mr. Mitchell, it would bring the guaranteed real breaking-strain to 76½ tons, which was fairly near the 65 tons at which the rope actually broke under the several tests.

The President (Mr. T. W. H. Mitchell) did not think that the deduction was made.
DISCUSSION OF MR. A. HASSAM’S PAPER ON "THE TAXATION OF COLLIERIES."*

The President (Mr. T. W. H. Mitchell) said that municipal debts had increased in twenty-eight years nearly 300 per cent.; the rateable value had increased about 55 per cent.; the poundage had increased from 3s. 3d. to 5s. 7d. or nearly 70 per cent.; whilst the population had increased by only 39 per cent.†

Attention was directed to the method of assessing the income-tax, the anomaly occurring in the case of a colliery, which, on a yearly basis should pay about £1,333, only paid £416 on the five-years’ basis: whereas, in bad times, when only £95 was due, it had to pay £678.‡ Mr. Hassam did not refer to the fact that to get a reduction of the tax, a three-years’ basis only was allowed. He (Mr. Mitchell) did not think that Mr. Hassam had given sufficient attention to the allowance for depreciation. In his experience, the only allowance granted was 3 per cent., and it did not in any way allow for the proprietors’ capital which was being worn away every year. Mr. Hassam directed special attention to the fact that Assessment Committees in all the unions were virtually a law unto themselves: thus, in Glamorganshire, the gross valuation averaged 8.44d. per ton; and in Derbyshire, it was only 2.09d. per ton. Unfairness existed in each union, where the basis was taken on the tonnage or the acreage, because a colliery that had great difficulties to overcome, say, as to water and faults, was valued on the same basis as one free of all difficulty. Perhaps some member could speak on the typical case given by Sir Edward Boyle, where he proposed a sinking-fund at 2\(\frac{1}{2}\) per cent. to repay the cost of the plant in 30 years; and a sinking-fund at 2\(\frac{1}{2}\) per cent. to replace the shafts in 60 years. He asked whether anyone had been able to obtain such allowances.

The discussion was closed.

† Ibid., vol. xxix., page 91.
‡ Ibid., vol. xxix., page 96.

Mr. G. Blake Walker said that, since the paper was read, he had visited Germany, where this question was being taken up on a large scale, and several important plants had been erected. He had obtained the following particulars of the working of two important installations:

Gas-power Plant at the Constantin der Grosse Colliery.—The gas-power plant at the No. 2 pit of the Constantin der Grosse colliery consists of a twin-cylinder Deutz gas-engine of 600 horsepower, with a flywheel weighing 5 tons, and a generator; and a tandem Nürnberg gas-engine, of 1,200 horsepower, with a flywheel armature arranged for 3,500 volts and capable of working in parallel. The flywheel and dynamo weigh 45 tons.

The gases supplied to these engines comprised:—(1) Producer-gas, obtained from two producers and used in the Deutz gas-engine; and (2) coke-oven gases obtained from 60 Otto-Hoffmann ovens of 7-5 tons capacity. Forty ovens are discharged every 24 hours, the yield of gas is 3,850,000 cubic feet, 2,800,000 to 2,975,000 cubic feet are employed in heating the flues, and 875,000 to 1,050,000 cubic feet are available for boiler-firing and in gas-engines. The gases, after passing through the bye-product plant, are purified in three dry purifiers arranged with five grids, on which wood-shavings and oxide of iron are used. The purified gas is delivered from a gas-holder at a pressure of 5½ inches, and a temperature of 77° Fahr. The average composition of the gases is as follows:—Nitrogen, 16·05 per cent.; carbon dioxide, 0·59 per cent.; oxygen, 0·76 per cent.; heavy hydrocarbons, 0·76 per cent.; marsh-gas, 20·47 per cent.; hydrogen, 55·98 per cent.; and carbon monoxide, 5·13 per cent.: there being 82·34 per cent. of heat-producing gases. The heating value of the gas, estimated from three different tests, was 4,226 calories per cubic metre or about 460 British thermal units per cubic foot.

The gas-consumption of the Nürnberg engine of 1,200 horsepower is 700,000 cubic feet per 24 hours or 24.3 cubic feet per horsepower-hour; and it is hoped that it may be reduced. The water required for cooling the cylinders is about 2,920 cubic feet per hour or about 24 cubic feet per horsepower-hour, and about 7,000 cubic feet of water are lost per day. The water enters the cooling-jacket at a temperature of 77° to 80° Fahr., leaves at a temperature of 113° to 122° Fahr., and is afterwards cooled by the Schwarz chimney-cooling system. The oil-consumption of the Nürnberg engine is 8.8 gallons per day.

The working expenses for the Nürnberg engine of 1,200 horsepower are £1,100 per annum, exclusive of the gas, which is estimated to cost 0.125d. per horsepower-hour.

Gas-power Plant at the Consolidation Colliery.—At the Consolidation colliery, the gas-engine plant comprises two tandem double-acting four-cycle Nürnberg gas-engines, each of 680 horsepower, and one single-cylinder Otto gas-engine of 160 horsepower; a total of 1,520 horsepower. The plant is driving two alternators at a pressure of 5,000 volts, with a frequency of 100 cycles per second. The capacity under an inductive load is 630 kilowatts, at 125 revolutions per minute.

The plant driven by the electric current, thus generated, is as follows:—(1) Pumping: Two Sulzer high-pressure centrifugal pumps, having a capacity of 656 gallons per minute, under a head of 2,109 feet. (2) Air-compressors: One horizontal two-stage compound air-compressor with piston-valves on the Köster system, having a capacity of 140,000 cubic feet of free air per minute at a speed of 121 revolutions per minute: the air being
DISCUSSION—UTILIZATION OF SURPLUS-GASES.

compressed to 6 atmospheres. (3) Coke-pushing machine. (4) Lighting of the No. 6 seam loading-station and the pumping-installations. (5) It is intended eventually to use electricity to drive the machinery in the workshops and the coal-washer. The lighting of the surface-plant is also effected by means of a gas-engine driving a shunt-wound direct-current dynamo of 110 volts, and a capacity of 116 kilowatts, when running at 150 revolutions per minute.

The available gas, obtained from Otto-Hilgenstock ovens, is about 795,000 cubic feet in 24 hours or 22 cubic feet per horsepower-hour, and equal to 23.7 per cent. of the total gas obtained from the coal. The gas is purified before passing to the engines, and its heating value is 4,000 calories per cubic metre or 450 British thermal units per cubic foot.

The water required to cool the cylinders is 1.33 cubic feet per horsepower-hour, or 2,000 cubic feet per hour for 1,520 horsepower. The water is cooled and used again.

The cost of the plant was as follows:—(1) Engines: two gas-engines, each of 680 horsepower, £8,450; one gas-engine of 160 horsepower, £1,880; travelling-crane, £413; pipe-connections, etc., £1,522; a total of £12,265. (2) Electric plant: two alternators and one direct-current dynamo, £3,607; air-compressor for starting the motors, £187; switchboard, cables and transformers, £1,087; lighting of central station, £150; a total of £5,031. (3) Accessory plant: purifying-plant and buildings, £1,625; cooling-plant, £927; gas-regulator, £150; a total of £2,702. The total cost of £19,998 is equivalent to £13 15s. per horsepower.

The working expenses are only estimated, as the plant has only been working for about three months: they are per day as follows:—Cleaning engines, £2 2s. 9d.; oil, £1 5s.; purifying the gas, 5d.; a total of £3 8s. 2d. or approximately £1,240 per annum. Only a few small stoppages have occurred through the fusion of sparking-plugs, since the plant was started.

Mr. H. B. Nash wrote that, at Messrs. Bell Brothers’ Port Clarence works, there was a battery of sixty Huessener coke-ovens and six Lancashire boilers, each 30 feet long and 8 feet in diameter, attached to the waste-heat flue. Five boilers were in use at one time, and the steam from them was used in driving
an electrical installation of 1,000 kilowatts. This power was derived from the waste-heat alone, no gas being used, and as Messrs. Bell Brothers have, at present, all the power that they require, the surplus-gas is burnt away in large torches.

Dr. Roelofsen, of the Coal-distillation Company, who is in charge of this plant, made the following tests during the first week in September, 1905, to determine the actual work being done by the waste-heat, and also what further work could be done in steam-raising with the surplus-gases. The results of the tests are as follows:—(1) 297 tons 10 cwts. of dry coal, charged with 10 per cent. of moisture, were carbonized per 24 hours or 27,800 pounds of coal per hour. (2) The water evaporated by the waste-heat only was 23,750 pounds per hour or 0.855 pound of water evaporated per pound of coal carbonized: the boilers working at a pressure of 120 pounds per square inch. (3) The water evaporated by the surplus-gases was 14,500 pounds per hour, or a further evaporation of 0.521 pound of water per pound of coal carbonized: the boilers working at a pressure of 120 pounds per square inch. (4) The total evaporation was, therefore, 1.376 pounds of water per pound of coal carbonized, at a boiler-pressure of 120 pounds per square inch. The feed-water was heated by the exhaust-steam from the dynamo-engines, and was fed into the boilers at a temperature of 170° Fahr.

Mr. H. Rhodes, referring to Mr. Tonge's paper on "A Colliery-plant: its Economy and Waste," said they wanted to obtain now the actual cost of coal used for colliery consumption, and the percentage of coal consumed to coal used afforded no real information. The boiler-fires might burn 5 per cent. of unsaleable slack, which might cost less than 1 per cent. of smudge, suitable for coking and the recovery of the bye-products.
MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, LEEDS, JANUARY 23RD, 1906.

MR. T. W. H. MITCHELL, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—
Mr. Henry Barton, Mining Engineer, Central Bank Chambers, Leeds.
Mr. Henry Vernon Haigh, Mining Engineer, Lewisham House, Morley, near Leeds.
Mr. George Houghton, Mechanical Engineer, Old Silkstone Collieries, Dodworth, near Barnsley.
Mr. Richard Purdy, Colliery Manager, Tingle Collieries, Wakefield.
Mr. Francis Brown Sinclair, Electrical Engineer, 31, Broomhall Place, Sheffield.

ASSOCIATE MEMBER—
Mr. Sinclair Wilfrid H. Chambers, Surveyor and Assistant to Colliery Manager, Aldwarke Main Colliery, near Rotherham.

STUDENTS—
Mr. John Charlesworth Crawshaw, Mining Student, Dinnington Main Colliery, near Rotherham.
Mr. Norman Wilkinson Routledge, Mining Student, Colliery House, Garforth, near Leeds.
DISCUSSION OF MR. H. BADDELEY'S PAPER ON "SYSTEMATIC TIMBERING AT EMLEY MOOR COLLIERIES;"* MR. J. T. BEARD'S PAPER ON "THE ACTION, INFLUENCE AND CONTROL OF THE ROOF IN LONGWALL WORKING;"† AND MR. E. W. ROBERTON'S PAPER ON "THE ACTION, INFLUENCE AND CONTROL OF THE ROOF IN LONGWALL WORKING."‡

Mr. W. E. Garforth said that, before proceeding to open the discussion of the papers, he wished to explain that some months ago, the Secretary reported that there was a scarcity of papers, whereupon he (Mr. Garforth) suggested that, if each Past-President and member of Council would select one or more papers, which had been read at previous meetings of this and other institutes, with the view of criticizing the opinions of the various writers and at the same time supplementing the original paper by additional experience, it might increase the usefulness of this Institute. This proposal was approved by other members of Council, and hence the present remarks. It was to be expected that the idea would be carried out whenever there was a scarcity of papers which it was hoped would rarely occur. The Council sincerely desired members, especially the younger ones, to make every effort to introduce papers for discussion, for in their preparation useful information had to be collected, ideas had often to be exchanged with older and practical men, and more numerous visits and closer observations had to be undertaken. Theory and practice may, in this way, be combined, and thus tend to give the best judgment.

He (Mr. Garforth) had selected Mr. Baddeley's paper, entitled "Systematic Timbering at Emley Moor Collieries." At the same time, he proposed, at the suggestion of the Secretary, to offer a few remarks, based on practical experience, on the two other papers, read before The North of England Institute of Mining and Mechanical Engineers by Mr. Beard and Mr. Roberton.

Members would recollect that Mr. Baddeley's paper, read in January, 1905, described the straight-line or systematic timber-

Discussing Systematic Timbering.

The previous work carried out under his direction at Emley Moor collieries, during the previous three years, had been attended with highly satisfactory results. With respect to the Wheatley Lime coal-seam, Mr. Baddeley said that "previous to introducing this systematic [straight-line] method of timbering, the props were set in a rather irregular manner: the roof, being composed of strong bind, came on in heavy weights, breaking the straggling props one by one, and finally came in along the face. Wood chocks were tried with better results: but, as they proved rather expensive, the system of setting two rows of props close together in a straight line was tried. With double the number of props in the row, the roof now breaks off in a straight line, close behind the back row of props, and there is not half the trouble with the face falling in, in fact it is almost a thing of the past, and very few chocks are now set."

As regards the New Hards or Silkstone coal-seam, Mr. Baddeley stated that the seam was worked by coal-cutters, but "the roof, being composed of a softer bind, is broken off much more easily: and the seam, being thin, . . . . is packed solid in the goaf . . . . only one set of props is left to support the roof . . . . but another row is set, as the holing is done." In the Blocking coal-seam, the straight line of face is carried out as in the New Hard seam, with special arrangements made for setting lids, 12 to 18 inches long, above each prop, with the view of allowing the props to be more easily withdrawn. In conclusion, Mr. Baddeley stated that he "feels sure, if the workmen are taught to set timber in a systematic way, and a strict supervision is kept over them by the officials, that the number of accidents from falls of roof can be most materially reduced." With the opinions expressed by Mr. Baddeley, he (Mr. Garforth) entirely concurred and by way of confirmation he believed that a description of another seam worked on the straight-line system of coal-face would be the best means of opening a discussion on this important question. The drawing (Fig. 1, Plate IV.)* accompanying Mr. Baddeley's paper, shewed the straight line of cut made by the coal-cutter and the straight line of props. In 1902, he (Mr. Garforth) read a paper,† in which the straight line of under-cut was strongly advocated, on the principle

†Ibid., 1902, vol. xxiii., page 312.
that the teaching of Nature, as shewn in the cleatage-lines (running through coal-seams, rocks underlying the surface, and the intervening strata) were in straight lines, and he had repeatedly proved that the straight under-cut in the holing produced a straight line of break in the roof, which was most efficiently supported by a straight line of timber. This opinion was based upon many years of experience, and still continued to be confirmed year after year at the collieries with which he was directly connected, and at many others from which he had opportunities of getting reliable information.

He (Mr. Garforth) ventured to think that, in a communication of this character, it was necessary to place before the members the facts, or a description of the details, connected with the natural conditions, artificial means adopted, and results obtained in working a particular seam. If a statement of actual facts was followed by an invitation to any member who wished personally to inspect the seam on the principle that the eye would, under certain conditions, take in more than the ear, it was to be expected that such information would assist those members who were now required, or might in the future be called upon, to work seams of coal lying at great depths. In his (Mr. Garforth's) opinion, one of the principle subjects for discussion, next in importance to that of providing for the greatest safety of the workmen, was one which should treat of the best means to be adopted to minimize the crushing effect of the strata on seams of coal lying at depths of 1,500 feet, 3,000 feet, or more, below the surface, in order to reduce the large percentage of small or low-priced coal, from which disadvantage every colliery working deep mines now suffered.

Holding this opinion, he therefore gave the following statement of the results obtained in working the Diamond seam at the West Riding collieries, together with a few particulars of under-cutting, timbering, and effects produced on the strata immediately overlying the seam:

Name and Situation of Seam.—Diamond or Upper Beeston: worked at Normanton, Yorkshire.
Thickness of Coal.—3½ feet.
Inclination.—Level.
Depth below Surface.—1,500 feet.
Description of Strata.—Principally argillaceous binds, shales, thin seams of coal, fire-clay and a few strong rocks.
**DISCUSSION—SYSTEMATIC TIMBERING.**

*Temperature.*—74° Fahr. at the coal-face, rising to 76° in the return-airways.

*Method of Working.*—Longwall packgate, with a straight line of face cut by machine, end on or at right angles to the cleatage-lines.

*Output.*—1,200 tons drawn per day in a single shift, 13 tons per stall, or 6½ tons per man per shift.

*Accidents.*—No fatal or serious accident has taken place at the coal-face since this seam was opened out 7½ years ago, during which time 1,200,000 tons of coal have been got.

One fatal accident had occurred at the coal-face in the Silkstone seam belonging to the same collieries since 1897, during which time 1,697,929 tons have been got from coal-faces worked by coal-cutters on the straight-line principle.

From Fig. 1 (Plate XIV.), it will be noticed that the main face, in the Diamond seam, is nearly 2,000 feet long, and the two adjoining right and left-hand, or rear faces, are 1,450 feet and 700 feet long respectively. Fig. 2 (Plate XIV.) is a section of the strata immediately overlying the coal. The gateways, 90 to 99 feet apart and 9 feet wide, are usually carried forward for a distance of 600 feet, and they are then cut off by cross-gates. The coal-face advances by successive end-on machine-cuts, 5 to 5½ feet deep. The main face is 3,600 feet distant from the shaft-pillar.

The break in the coal and roof follows the 5½ feet under-cut, and the subsequent and regular breaks are traceable in each gateway and waste as shown in the section (Fig. 2, Plate XIV.) which has been prepared from actual measurements. The roof-breaks are almost vertical (at an angle of 85 degrees), and extend up to the "four-feet stone" in certain districts, and to the "seven-feet stone" in other parts of the mine. They occur with interesting regularity, from the coal-face down the gateways, where they are seen at intervals of 5 to 5½ feet, corresponding to the under-cuts made by the machines. On reference to Fig. 2 (Plate XIV.), it will be noticed that in addition to the vertical breaks, called for the purpose of distinction "minor breaks," there are other or "major breaks," inclined at an angle of 45 degrees and separated one from the other by distances of 35 to 40 feet. These latter breaks extend up to the seven-feet ironstone-parting or to the "ten-feet stone." They are independent of the machine-breaks, and are found to occur in the strata or ripping of the gateways, and sometimes between the vertical or minor breaks as the width of the span increases. The major breaks, occurring at the distances mentioned, may be said to be
formed on the principle proved in beams and girders, say, that the strength is in direct proportion to the depth or thickness of strata in question, and inversely as the span or distance between the supports, in this case, say, the coal-face and the consolidated dirt-pack. To ascertain whether the line of break continued, and in order to measure the extent of the settlement and the cavities between each stratum, a pit, ABDC, was driven to the ten-feet stone, at the side of the major break, AB (Fig. 2, Plate XIV.). The measurement of the vertical depth of the strata, after the break and cavities had appeared, was 4 feet 3 inches instead of 4 feet, 7 feet 5 inches instead of 7 feet, and 10 feet 6 inches instead of 10 feet.

With respect to the method of timbering (Fig. 3, Plate XIV.), the props measure 3½ feet to 4 feet 4 inches in length (according to the undulating nature of the floor) and are 5½ inches in diameter. They are set in accordance with the Home Office and Special Rules, which specify that the distance between props shall not exceed 4½ feet: and they are set 4 feet from the face. A bank-bar is set on every alternate prop, and the face-end is let into a pocket-hole made in the upper part of the coal. These bars are made by cutting props (4 feet 8 inches long by 6 inches diameter) in half, and flattening the ends so as to facilitate the setting.

After the machine has undercut the coal to a depth of 5½ feet, the machine-men set straggling props under the face-end of the bank-bars and sprag the coal with wedges placed 4½ feet apart, in the undercut. Two rows of face-props are left standing, the third row being drawn by the stallman as the work of filling the coal proceeds. Chocks, formed of pieces of oak, 22 inches long and 6 inches square, are set, 24 feet apart, along the face in duplicate, and are moved forward alternately; and one chock is also maintained in each pack-hole, these latter being moved forward by the rippers. All timber is withdrawn, except those props which the deputy decides are unsafe to draw. As the work of filling the coal proceeds from the end of the buttock, a temporary prop is fixed until the permanent timber can be set in accordance with the Special Rules. The coal-face has never "fallen in," consequently there has been no necessity to "bord out," due to the weighting or breaking-down of the roof during the 7½ years that the Diamond seam has been
worked by machine with a straight line of timbering. The cost of the face-timber amounts to only 1½d. per ton, due to the special method of working described.

Four feet of space is left, on each side of the gateway, for the ripping-dirt, 3 to 4 feet thick; and the miners make up 11 feet additional on each side, or together equal to 15 feet of gate-pack. Two middle packs, not less than 9 feet wide, are made with the machine-cuttings and bottom-dirt, leaving wastes 24 feet wide. Measurements have been taken to shew the extent of the gradual settlement of the roof on the dirt-packs, as follows:—At the coal-face, the height of the roof is 4 feet 2 inches; at 1 chain from the face, the height of the roof is 3 feet; at 2 chains, 2 feet 8 inches; at 3 chains, 2 feet 3 inches; at 4 chains, 2 feet 2 inches; and at 14 chains, 1 foot 9 inches. A photograph, taken to illustrate the subsidence, shews six distinct settlements or steps in the roof.

No timber is required in the gateways leading from the crossgate to the coal-face, owing to the artificial breaks crossing the lines of cleatage, thus reducing the number of breaks, and allowing the strata to settle much more quickly and in more solid blocks. The two lines of props, which are left standing until after the ripping is finished, and the packs built are generally broken by the settlement of the roof. Telescopic props have been used with advantage.

In the south and east side districts, an inspection has been made in twenty-nine gateways (9 feet wide and 7 feet high, when first ripped) or, say, a total length of 1½ miles, in which there is neither prop, nor bar, nor stretcher to support the roof. But in the crossgates (10 feet wide and 7 feet high), which are carried forward at an angle of 45 degrees from the main haulage-road, a considerable quantity of timber and steel bars is required. This extra quantity is required, owing to the crossgate-breaks being crossed at an angle by the coal-face breaks.

The plan (Fig. 1, Plate XIV.) shews that the two rear faces are a considerable distance behind the 2,000 feet or main face. Where the south-east face has been worked alongside the old goaf, breaks have been produced of greater or less magnitude according to the distance from the old goaf. These breaks are shewn in Fig. 4 (Plate XIV.) by straight lines, which run parallel with the gateway and extend over a distance of 50 to
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60 feet; they may be looked upon as crushed coal, especially as the strata have been further affected by the induced straight-line fractures, which give this small area a kind of chess-board pattern, the size of the squares gradually increasing as the distances from the goaf increase. After the distance mentioned, the effect arising from the goaf does not detrimentally affect the remaining portion of the coal-face.

Having described some of the natural conditions of the coal-seam and strata and the effects and details connected with the under-cutting, the induced fractures in coal and roof, the timbering and packing, he (Mr. Garforth) would briefly summarize some of the advantages obtained in working the coal by the method described.

With respect to the under-cut, the experience of the past 7½ years in this seam and 12 years and 8 years respectively in two other seams (the latter having an unstratified rotten clod-roof), had proved that the straight under-cut could be maintained. The setting of timber must, however, be only looked upon as dealing with the effect, the cause of the timber being placed in a straight or in an irregular line is due to the direction and character of the under-cutting. A straight cut produced a straight break, and a sinuous or irregular cut an irregular break. The placing of timber in crooked lines with no two settings alike, even under normal conditions, could not be called systematic, and perhaps a better name would be "the regular spacing of timber." Having regard to improved methods for winning coal, he (Mr. Garforth) thought that "systematic timbering" should be understood to mean doing the same work day by day and month by month in almost exactly the same way. The foregoing facts shewed that the system, being carried out in straight lines with props placed according to a prescribed distance, had resulted in greater safety to workmen, better quality of coal, quicker and more regular settlement of the surface, with consequent less injury to property, intervening coal-seams, etc. The use of mechanical conveyors, the use of sledges on coal-cutters to dispense with wheels and rails and other contemplated improvements, all point to the coal-face being worked and to the timber being placed in straight lines.

He (Mr. Garforth) formerly considered that the so-called straight face in the Old Silkstone seam, at the same collieries,
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holed by the hand-pick and gauged by an instrument, was straight; but, with the experience gained by machine under-cutting, during the past 13 years, the difference and defects between the two systems are most noticeable. Amongst other reasons, and to shew the effect of superincumbent weight, it may be mentioned that in 1881 a narrow or straight road was driven in advance of the coal-face and numerous breaks were noticed; and their character shewed that the strata, above the advancing irregular line of coal-face, had broken over the solid. A similar narrow road had lately been driven in advance of the straight-line coal-face without such breaks being perceived. From these facts it is argued that, whilst in the former case the overlying strata broke irregularly, in the latter instance the straight line of face produced a straight line of weak resistance, which allowed the strata regularly or systematically to fall back in the direction of the goaf. In the case of flat seams, the action may be compared to something like the leaves of a book falling back on each other when the binding overhangs.

He (Mr. Garforth) might remark that what occurred in the overlying strata after the excavation in the coal-seam had been made, when a certain area of goaf had been exposed, and the settlement of the roof and other strata had taken place, had been a constant source of speculation to the mining engineer. But now that the coal was being got in such a manner that the settlement of the roof occurred with regularity and parallelism there seemed to be a better prospect of satisfying this curiosity, as it was possible in many cases to define the rock-movement. With the knowledge of what had already been done by producing a straight break by means of a straight under-cut, or an irregular or sinuous break by an irregular cut, the mining engineer would now be able to induce a more regular settlement of the strata on the goaf, and thereby relieve the coal-face from an overhanging weight in a way that had only been realized within the last few years. This would be another important step in the direction of reducing the percentage of small or low-priced coal in working deep mines.

Although there were many interesting details which might be mentioned in connection with the effects produced on the roof, etc., yet as these remarks on Mr. Baddeley’s paper were much longer than intended, he (Mr. Garforth) could only briefly refer to
the two papers read by Mr. Beard and Mr. Roberton. From the
drawings accompanying Mr. Beard's paper,* it would be noticed
that he suggested that the coal-face should be worked in curved
lines. This system of work was directly opposed to the method
referred to in the foregoing remarks, and to Mr. Baddeley's suggest-
sions, both advocating the straight line of cut. He (Mr. Garforth)
made the following remarks in a previous communica-
tion, from which he ventured to quote now, as the experience
of many years had since confirmed the opinion then expressed,
namely:—If the coal-face be worked on a curved line "there
are serious disadvantages, including amongst others:—(1)
Under-cutting the back of the holing in an irregular line; and,
when an extra depth of holing is necessary to ensure the
excavated coal breaking from the solid portion, cutting or
slabbing part of the solid face into small pieces to permit of
shoulder-room for the workman. The projections at the back
of the holing act as struts almost as effectively as the sprags in
front of the coal-face, especially when assisted by the under-
mined coal adhering to the roof and the back of the solid coal.
The projecting portions are consequently exposed to an excess
of crushing-weight, . . . . and the coal (being usually softer
than the roof and floor) suffers by such association. (2) Under-
mining one part of the coal-face at a period of time different
from the adjoining portion, consequently an additional weight
is thrown on the remaining portion of the holing dirt; . . . a
greater percentage of low-priced coal is produced."† "If it
be correct to work coal by following straight lines, either on
the principle of (a) plumb end, (b) bord, or (c) half end and half
bord, then the coal-face cannot, for the reasons given, be advan-
tageously worked at constantly varying curves and angles. When
the coal is worked end on, it may be said to have its maximum
strength to resist pressure, and allows the deepest excavation
to be made before the coal falls, usually in large pieces and with
a cubical fracture, even in the smaller pieces. On the other
hand, the coal most readily falls when worked bord-way, or
when the lines of cleavage run parallel with the cutting, in
which case friable, slabby, and an increased percentage of
fine-coal results."‡

† Ibid., 1902, vol. xxviii., page 324.‡ Ibid., page 326.
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As Mr. Beard was not present to explain certain matters not mentioned in his paper respecting the depth of the seam from the surface, the nature of the strata, how the getting price was regulated with the men working alternately end on or bord on; how the coal-face was maintained in curved lines, especially when men did not regularly attend work; and whether the roof was broken at the loose ends, besides other matters, he (Mr. Garforth) thought it undesirable to criticize the paper further. There might be special circumstances, and the profitable working of the colliery might not be dependent on obtaining a high percentage of large or high-priced coal, such as was required at the collieries of the Yorkshire district.

Some of the foregoing remarks equally applied to Mr. Roberton's paper, but it might be further pointed out that, about 1870, the Silkstone face, to which reference had been made, was driven with a step face as shewn in Mr. Roberton's drawing.*

Owing to the corners of the steps being crushed by the superincumbent weight and the consequent loss by the larger percentage of small coal, the method was abandoned more than 30 years ago. He (Mr. Garforth) preferred not to criticize further, but he would be guided by the subsequent discussion, as there were certain remarks which might be construed to mean that Mr. Robertson preferred a straight line of face.

In conclusion, he (Mr. Garforth) wished to explain that recently he had carried out further experiments, commenced many years ago, with the view of seeing, on a large-sized model, how lines of fracture might be produced or induced by removing supports in straight and also in irregular lines, similar to those herein described, but they were not yet completed.
Mr. H. Baddeley said that it was now more than twelve months since he read his remarks on "Systematic Timbering at Emley Moor Collieries," which were intended to be a supplement to a paper that had previously been read on this subject, rather than a separate paper. Seeing that there was so little in it to discuss, he thought that a few remarks on the system of timbering in a conveyor-face might interest members who had not already seen a conveyor at work, and more especially as several members had remarked that they could not see how the roof could be kept up, as there was too great a width of roof on the timbering. This might be so, but the rate at which the face travelled must not be forgotten, say, 20 to 27 feet per week. In his (Mr. Baddeley's) opinion, this, along with the quick changing of the timber, and the straight line of face, was to a great extent the secret of this particular kind of work. He did not wish to inter that conveyors could be worked with almost any kind of roof, but
he did think that with a roof of moderate strength they could be worked to great advantage in thin seams. Fig. 1 shewed the face clear: the face of coal having been filled away since last the conveyor was shunted or moved forward. The face of the coal had again been under-cut, two fresh rows of props set, and the Sylvester prop-drawer got ready for moving the conveyor forward. The row of props in front of the conveyor was drawn out, and the conveyor pulled over to the next row: the props in this particular row were only set to maintain the roof, while the con-

Fig. 4.—Main Gateway, with Coal-Cutter.

veyor was being moved forward. The props were set about 5 feet apart from prop to prop along the row, and another line of props was set behind the conveyor which was now moved half the distance: this row was only set where the roof was not good. The line of props in front of the conveyor was now taken out, and the conveyor was moved forward to the face-row of props, which were in this case set 3 feet apart from prop to prop.
Another similar row was set behind the conveyor, so that these two rows of props were only 2 feet apart. Wood chocks, 2 feet square and 15 feet apart, were set close behind the conveyor. All back props and chocks were then drawn out. As stated above, the distance between each row of props was 2 feet, but the distance between the coal-face and the front row of props was 4 feet, leaving room for the coal-cutter to travel along the face. When, however, the machine had made its under-cut, two rows of props were set, one close to the coal-face and another was set between that and the one in front of the conveyor (Fig. 1), so that the rows of props, as stated above, were only 2 feet apart, except during the time when the machine was cutting along the face. The main gateway (Fig. 2), into which the conveyor delivered the coal, was 9 feet wide and 6 feet high, and set with steel girders, 3 feet apart (Figs. 3 and 4). No ripping was done in the top stone, but the bottom stone was taken up, 3½ feet thick. The main gate-road was driven in advance of the coal-face by a Champion heading-machine. Two conveyors (Fig. 5) were now delivering coal into this main gate-
road; and one face was from 25 to 30 feet in advance of the other. This was a great improvement on the method of working with one conveyor, in which case the main gate-road had one pack-wall and one post side, causing the roof to cut off along one side; whereas, with two conveyors, the whole of the coal was taken out, and the main gate-road settled in a body on to the pack-walls, and, there being only one main gate-road to make for both conveyors, a considerable saving was effected.

In conclusion, he wished to thank Mr. A. Crowther for showing the views on the screen and Prof. G. R. Thompson for taking the photographs that had been shewn.

The President (Mr. T. W. H. Mitchell) observed that the members were greatly indebted to Mr. Garforth for the excellent manner in which he had opened the discussion; and he had set a heavy task before the other members of the Council. A few years ago, he (Mr. Mitchell) had occasion to take particulars of the cracks in the goaf-road and level-road, together with the effect on the surface; and he found, owing to the regular way in which the face was kept going, that an even and very regular subsidence was produced.

Mr. P. C. Greaves said that recently one feature had come before his notice, and had given trouble. One particular face was being worked slowly, and caused constant trouble from falls. They now worked better time, worked the face faster, and the result was that the breaks became more regular, and they had fewer falls; but when they worked five days per week, weeks elapsed without a fall in a gate-way or at the face. After each holiday, trouble was sure to ensue within about a fortnight, and it seemed to him that one of the most important features was that the pit must be kept working full time, which, in the present state of trade, was impossible. A number of chocks were set on that particular face; but they found that they were not so good as props, and now nothing but props were set. Wherever systematic timbering was used, it must be carried out to the fullest extent, and no small point must be missed. As an example, in another pit, chocks were set 15 feet apart: owing to someone’s neglect, there was a shortage of chocks and they had to be set 24 feet apart, and in consequence a heavy break took place.
Mr. J. R. R. Wilson said that it was to be inferred from previous remarks that the breaks always took place in a direction towards the goaf. If the breaks continued in that direction to the surface, how was it that they often heard of claims for damages in respect of property on the solid side of coal-faces? There was always what they called "draw," and evidence of a certain pull and subsidence beyond the line of face. This line of subsidence, and perhaps of fracture, was very regular. He had frequently noticed breaks in a machine-cut face as regular as those that Mr. Garforth had described, leaning, not into the goaf, but over the face. They were sometimes described to him as slips: they were slips in appearance, both sides being perfectly smooth. He had only seen them where the faces were moving very slowly, and so the roof had plenty of time to subside in its normal way, that was, with the line of fracture leaning over the solid. The usual break that they got with faces moving quickly, as Mr. Garforth had described, was, of course, simply an ordinary fracture of the roof, which, unable to support itself, fell into the cavity. Following this, they had the whole pressure of the strata sliding down, which would produce the effect of breaks leaning over the solid.

Mr. C. C. Ellison said that it would be interesting to know why the men wanted extra pay for using iron girders, and what had been the effect of not adopting steel props.

Mr. H. Boxser said that in Derbyshire, 20 years ago, in working the Deep soft seam, a system, such as that advocated in Mr. Beard's paper, was adopted with a view of getting round coal; and he asked whether the writers of the papers had not more the idea of producing round coal than anything else, in their minds, as was the case in Derbyshire, where the long horn system was worked with good results as regards the production of round coal.

Mr. S. Field wrote that he had read Mr. Beard's paper with considerable interest, and whilst he was unable to agree with it entirely, he could endorse many of the opinions expressed. The division of the superincumbent strata into two separate masses was substantially correct, although in all probability the cantilever-action of the overweight played a more important part in determining the breakage of the underweight and of the coal
than Mr. Beard thought. He (Mr. Field) understood by under-weight, the strata upwards from the coal to a stratum of such physical character as to be able to bridge over a considerable area. Mr. Beard's remarks on the influence of the roof's action were clear and to the point, and he (Mr. Field) entirely agreed with them. He did not agree with Mr. Beard's idea of the control of roof-pressure in longwall-workings. He had thought, until reading these papers on the control of roof-pressure in long-wall-workings, that the fallacy of step-working, or modifications of step-working, as aids to roof-control, had been exposed many years ago, and that true longwall-work consisted in having as long a length of straight-line face open as circumstances would permit. It was true that few collieries had great lengths of face in a straight line, but the irregularities were not associated with any idea of controlling the roof-pressure. Mr. Beard evidently thought that, by an eccentricity of the face-line, the roof-pressure could be controlled. Now when it was considered that the general line of face determined the induced break in the overlying-strata, the fallacy of this idea was easily appreciated. Any obstruction or deviation from the straight line imposed on that portion an excessive weight and produced what he (Mr. Field) might term a "gobbing-weight break," that was, an induced break, which ought, in the proper order of procedure, to have been made on the back gobbing some time before. In speaking of the influence of the roof-action, Mr. Beard stated that "the influence of the action of the roof may be disastrous when, owing to a lack of uniformity in the line of the working-face, a secondary movement is set up in the roof, or the travelling weight is started off in a wrong direction, throwing an irresistible weight or pressure on the road-packs, or on some portion of the coal-face:"* and then he proposed to control the roof-pressure by the lack of uniformity which he had previously condemned. The only way in which the roof of a coal-seam could be controlled by natural means was by leaving pillars of coal, as in pillar-and-stall work, where the size of the pillars was regulated by the strength of the roof, floor and coal, and in this way no induced breaks were produced. In longwall work, the control must be effected by artificial means, by pack-walls and timber, and the interposition of an irregularity in the face-line to control the roof-pressure acted on that portion in a

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similar manner to what would occur if the pillars of pillar-and-stall work were left far too small: the roof would be badly broken, and the coal crushed. The error of this system of roof-control was obvious, when it was considered that a length of roof, which had been badly broken in the attempt to control the roof-pressure, had to be controlled by the very same means that would have been used had it been preserved in its best state under straight-line conditions: that was, by packs and timber. The combination of straight-line face, systematic timbering and packing and the withdrawal of all back timber, was productive of the best results in longwall work, so far as the condition of the roof, the coal, the coal-getting, and the maintenance of the roadways were concerned. He (Mr. Field) thought that any colliery working on these lines would experience no difficulty in keeping the cost down to the lowest level.

Mr. W. Walker, in proposing a vote of thanks to Mr. Garforth for what was practically another paper, said that he was convinced from the facts and figures given, of the advantages of working on a straight-face system such as that described. He felt this very forcibly when he looked over the number (71) of fatal accidents from falls that had occurred during the last year in the Yorkshire mines-inspection district, whereas Mr. Garforth had worked over 1½ million tons without a fatal accident from this cause.

The vote was agreed to.

Mr. W. E. Garforth said that, for many years at the colliery with which he was connected, levels had been taken before and after the coal-face advanced, so that it might be known from half-year to half-year what subsidence was taking place, and he could confirm what Mr. Wilson had said. Sometimes, owing to local circumstances, the weight had broken over and affected property 300 feet away. An instance occurred some time ago, where the effect was noticed 500 feet away, but there were attendant circumstances which he could not there describe.

The discussion was adjourned.

Mr. Ellis Barraclough's "Practical Notes on Winding-ropes and Capels" were read as follows:
PRACTICAL NOTES ON WINDING-ROPEs AND CAPELS.

By ELLIS BARRACLOUGH.

As the subject of winding-ropes and capels has been recently brought very prominently to the notice of the members in the Transactions, and as a Commission has been appointed by the Government of the Transvaal to enquire into the subject of "the safety of persons lowered or raised in shafts" for which evidence is being collected in his mines-inspection district by Mr. W. Walker, H.M. inspector of mines, the writer has thought that a few notes on the subject relative to the treatment and care of ropes, etc., at the colliery with which he is connected would not be out of place, and might be of some interest to his fellow-members. He does not, however, anticipate being able to bring to their notice any novel or special features, the methods followed being those used in general practice. His object in writing this paper is to lay before the members his own personal experience, and to elicit the opinions and experiences of his fellow-members for their mutual benefit.

Winding-ropes.—The only varieties of ropes in use at Ackton Hall colliery are (a) Lang lay and (b) locked coil. The former had been, until recently, the only ones used; they had been generally satisfactory, and had done their work well, being taken off at the end of periods averaging about three years. The performances of several winding-ropes, typical of the whole, are recorded in Table I.

<table>
<thead>
<tr>
<th>No. of Rope</th>
<th>Description of Rope</th>
<th>Dimensions of Rope</th>
<th>Top-side</th>
<th>Time in Use</th>
<th>Cost of Rope per Ton of Coal raised</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Length.</td>
<td>Diameter.</td>
<td>Circumference</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>Best plough-steel...</td>
<td>1,275 Feet.</td>
<td>4 Inches.</td>
<td>4 Feet.</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Improved special steel</td>
<td>1,530 Feet.</td>
<td>1 1/2 Inches.</td>
<td>4 1/2 Feet.</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Best plough-steel...</td>
<td>2,160 Feet.</td>
<td>5 1/2 Inches.</td>
<td>5 Feet.</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Treatment.—When sent from the makers, the ropes are usually already well covered with oil, and this should be sufficient for some time. At the end of six or nine months, more oil is applied to all visible portions, and a quantity allowed to run into and through the coils; and this is found to keep them in good order until required for use. When received from the makers, the ropes are stored in a dry place, being placed on a platform 3 or 4 feet above the ground, covered with tarpaulin, and inspected from time to time.

When put into use, the ropes are examined in the ordinary way each day, being wound at a slow speed up or down the shaft, while the examiner carefully looks for any broken wires or other defects. Once a week, the ropes are well oiled, and passed carefully through the hands of the examiner: any broken wires being at once detected by the hand or the eye.

A length of 30 or 40 feet of the rope nearest to the capel is periodically cleaned, scraped, and again carefully examined, as this portion is found to be the most difficult to keep well lubricated owing to the dust, etc., absorbing the oil and rendering it dry; and a good dressing of oil is afterwards applied.

The daily examination of the ropes is usually made at luncheon-time, the normal working-load being on the cage for the purpose. The lubricant used is either Russian or vacuum oil, of about the same consistency as treacle. This dressing is found to be still efficient at the end of a week's time, and materially assists in preventing corrosion of the wires, and in reducing the friction between the ropes and the pulleys or drums. The dressing used does not prevent the examination of the rope. The shafts being dry, no metallic covering is used on the ropes.

The internal examination of a rope is not easily possible, but some estimate of the state of the interior may be formed when recapping takes place. This is done at the end of the first twelve months in the life of the rope, at the end of each six months in the second year, and of each three months in the third year. Thus the internal state of the rope may be seen at least six times during its working life, at the point which is generally looked upon as being most susceptible to corrosion, namely, near the capel. At each recapping, a portion of the rope is cut off, varying in length from 6 to 30 feet according to circumstances, and very little corrosion is found as a rule.
No springs or other automatic contrivances are used, but the ropes are adjusted carefully to their proper length, so as to avoid or to reduce to a minimum the sudden jerks, which are ruinous to the "temper" of a rope and considerably shorten its life.

It is generally the writer's custom when a new rope is put on, to order another into stock to replace it, although this is not always done until some time, perhaps twelve months, has elapsed. A rope will, therefore, be stored for, say, two years before being used: but, if well looked after, it does not suffer any evil effects during that period, and is always available in case of necessity or urgency.

Much of the foregoing may be considered as insignificant detail; but, in the writer's opinion, it is the perfection of such detail that makes the difference between good and bad results.

Cores.—Ropes are generally made with either wire-cores or hemp-cores, the former being most commonly used for deep mines with heavy loads: this class of rope having less liability to internal corrosion. As there is little or no difference of cost between wire-cores and hemp-cores in winding-ropes, nothing can be gained financially by the use of ropes with either class of core. When, however, the wire-core of a winding-rope breaks at one or more places (which, in the writer's opinion, occurs far more frequently than is generally imagined), it at once ceases to do any useful work in the way of lifting the load, and becomes, instead, a dead weight upon the rope. In the writer's opinion, it is also a considerable factor in reducing the strength of the outer strands, as the rope in passing over the pulley loses its symmetry at the points where the core is broken, and receives a series of shocks due to variations in its rigidity. The writer is, therefore, inclined to think that, where this class of rope is used, success or otherwise is dependent largely upon the amount of twist given to the core in the making of the rope. The twist should be sufficient to allow the core to stretch in the same ratio as the outer strands, otherwise it will either break or draw itself up the interior of the rope. The stretching of a rope will also vary somewhat with local conditions, which, in many instances, are unknown to the makers.

The writer, therefore, has come to the conclusion that, all
things considered, the use of wire-cores is not advantageous. The following is a brief record of experiences with this class of rope, which has led to the abovementioned conclusions.

The first experiences were with winding-ropes. In several instances, it had been noticed, when new ropes were put to work, that the core, not stretching with the outer strands, took the weight for the time being; and, the strands being slack, they bulged out at some point shewing the interior of the rope and forming an enlarged place upon it (Fig. 1, Plate XV.). More than one bulge had formed, on some ropes, at various points between the drum and the capel, and in one instance a bulge actually occurred inside the drum, between the laggings and the drum-shaft. In few instances were bulges interfered with, as they appeared to right themselves, and consequently the ropes were allowed to run their normal course. A special examination, made after a rope had been finally taken off, revealed a broken core where a bulge had formed in the first instance: but, so far as could be detected by the eye, no difference in the wear of the rope had taken place at the point where a fracture of the core had occurred. What might have been the result had the rope been sent to be tested to its breaking-limit the writer does not care to suggest, but he believes that the margin of safety would have been much smaller than he would have liked.

In another case, the core broke at a point 35 feet from the capel, and drew apart for a distance of 6 or 8 inches, gradually decreasing in thickness towards the point of fracture (Fig. 2, Plate XV.). This defect was discovered by the rope-examiner about 10:30 a.m. while making his usual examination. The pit ceased winding at 12 noon on that day, and the men were drawn out on the other rope. It was decided to cut off the portion of rope beyond the point abovementioned, and recapel it: this was done, and the rope ran its normal course without any further occurrences of a similar character.

The second experiences were in the tail or balance-ropes, suspended from the cages in a shaft, 1,740 feet deep. When the first of these ropes was being prepared for use, it was found to be 16 feet too short to connect to the cages, and 30 feet shorter than the length ordered. This difficulty was overcome by attaching a chain at each end under the cages: and, after a time, one of the chains was removed, as the rope had stretched. The
fact of the rope being 30 feet shorter than the ordered length, occasioned some surprise to the makers when that fact was pointed out to them. The remarkable feature in regard to this rope was that the core at the point of the rope, which at the end of each second wind came into contact with the sump-pulley, commenced to push through the strands, thus forming enlarged portions, which had to be cut out, and in the course of time this operation became a weekly necessity. The rope was taken off and the ends attached to the reverse cages, in the hope that by running it in the opposite direction this defect might be remedied. However, the core pushed itself out at the other end of the rope in the same position, in just the same way as before, 120 and 180 feet respectively being taken out. [The two pieces of core shown at the meeting were taken out of this rope, and illustrate how the core-wires cluster together and work through the outer strands.]

The second balance-rope, and that now in use, was capeled in the ordinary way, and after two days' work had stretched to some extent, so that it became necessary to shorten and recapel it. The end of the rope was cut off and examined, and it was then found that the wire-core had been withdrawn, up the centre of the capel, for a length of $9\frac{3}{4}$ inches (Fig. 3, Plate XV.). It is possible, and to be presumed, that this process would have continued; and, if so, the result might have been serious, as, the heart of the rope being drawn out, there would have been nothing to prevent the swell upon it from collapsing to a greater or less extent, and the rope from being drawn out of the capel.

The writer ventures the suggestion that the foregoing remarks may offer some explanation of the, hitherto, inexplicable failure of winding-ropes in times past.

_Capels._—The variety of capel in use at Ackton Hall colliery is that commonly adopted, namely, two halves, securely connected by four collars, tightly driven on by hammers. The capels are made at the colliery of best cold-blast Farnley iron, and shaped on the anvil to the required size. The four edges are then planed, in a machine, in order to ensure their parallelism, and the pin-holes are drilled. A spare capel, for each of the pits, is kept in stock. A sketch of the capel is appended (Figs.
4 and 5, Plate XV.). The pin attaching the capel to the cage is 2 inches in diameter.

The method of capping is somewhat as follows:—The rope being cut to the required length, the hoops or collars are passed on to it in their proper order. A binding of soft-drawn iron-wire (No. 15 Birmingham wire-gauge) is then put on for a length of 7\(\frac{1}{2}\) inches, commencing at a point about 2 feet 6 inches from the end of the rope. A second binding is then wound over the former one, but it is only carried up a length of 5 inches, and a third wrapping, on the top of the second one, is carried up a length of 3\(\frac{1}{2}\) inches. These lappings form a more or less conical plug, over which the outermost of the rope-wires are turned backward for a length of 2 feet 6 inches, and hammered or pressed into position. The other layers of wires are treated in the same way, each successive layer being cut off somewhat shorter than the preceding one, so as to gradually increase the size of the plug from the top to the bottom. The whole end is then again carefully wrapped with wire as before and as tightly as possible. During this final wrapping, a screw-clamp is used, which is first put on about 3 inches from the end, and the wires pressed together as tightly as possible (Figs. 7 and 8, Plate XV.). The wrapping is carried up to the clamp, which is then released, tightened again about 3 or 4 inches further on, and the process repeated up to the top. The wire-wrapping machine is shown in Figs. 9 and 10 (Plate XV.). The nut, A, is used to regulate the tension of the binding-wire.

The rope is now ready for insertion in the capel; the two halves being laid together, a pin, fitting the holes, is inserted so as to maintain them in their proper relative positions. This is a most important point, as failure in this respect will probably result in the rope drawing from the capel: for, the strain coming upon one half, B, only of the capel to commence with, will cause the hoops, G, to become dislocated (to some extent) before the other half, A, takes up its load. A somewhat exaggerated view of this dislocation is shown in Fig. 6 (Plate XV.) in order to illustrate the effect more clearly; and the obvious way to prevent this from happening is to have the pin-holes carefully drilled, and the pin made a dead fit. During the process of capeling, a spare pin is used for insertion in the pin-holes, as the permanent pin, if used for the purpose, might sustain some damage.
due to the hammering necessary to force on the collars. The collars are now driven tightly down upon the capel, firmly gripping it; and it has been found that, except in two instances, no movement of the rope had taken place. The first of these was caused by neglect of the precaution described to ensure an equal strain being taken by both halves of the capel: the rope ran three weeks and then drew $1\frac{1}{2}$ inches; it was then recapeled, and ran without further trouble for the remainder of the normal term. In the second instance, the rope drew about $1\frac{1}{2}$ inches on the day after the capel had been put on. This was found to be due to the swell on the rope not being large enough; the rope was recapeled, more wire being used to increase the size of the swell, and it ran without further trouble until recapeled in the ordinary course.

Another important point is the tendency of the wrapping wires to squeeze in between the two halves of the capel, when the collars are driven home, as shown on Fig. 11 (Plate XV.); this may be avoided to a great extent by wrapping the rope very tightly, and rounding off the edges of the half-capels so as to give them a lead. If, however, it occurs, the wrapping should be undone, any projecting strand-wires cut out, and the whole rewrapped.

When a rope is recapeled, the capel taken off is carefully examined by the smith, and if any defects are discovered, it is discarded. If quite sound it is annealed, dressed up, and put into stock for further use.

Locked-coil Ropes.—Two locked-coil ropes have been in use for the past twelve months, and have so far given every satisfaction. They were put on in place of the ordinary type of rope, because the drum was not sufficiently wide to take the ropes without overlapping. The locked-coil ropes being smaller in diameter for the same strength, this objectionable feature of overlapping was obviated. They run very steadily in the shaft, and, once they have been adjusted, do not stretch further, giving little trouble afterwards. They are capeled in a manner similar to the ordinary type of rope, a method which has been found so far satisfactory, and the capels have not shown any signs of drawing.
A plate (Figs. 12 and 13, Plate XV.) is used to connect the safety-hook to the bull-chains. This plate, 13 inches square and 2 inches thick, was made at the colliery of best cold-blast Farnley iron. The holes, 1\(\frac{3}{4}\) inches in diameter, are drilled to an accurate fit with the shackle-pins. These plates wear for a considerable time; but, eventually, owing to the constant lifting of the cages, the holes become slotted to some extent. A new plate is then substituted, and the one taken off is carefully examined for any possible flaw. If still quite sound it is annealed, and the holes redrilled of a slightly larger diameter so as to include the slotted portion; new pins of slightly larger diameter are fitted, and the whole put into stock for further use. A good margin of metal is provided for in the first instance, so that the strength of the plate is always ample for the work which it has to do.

Tests.—Table II. contains the result of a test made with a winding-rope capeled in the manner previously described. The rope was laid with Lang lay and a hemp-core, and is now in use for winding from a shaft 1,740 feet deep. The result of the test was on the whole unsatisfactory, and, although the margin between the working-load and the maximum stress was 42 tons, a much higher percentage of efficiency had been expected. The ratio of the holding-power of the capel to the breaking-load of the rope was 61\(\frac{1}{2}\) per cent. The writer intends to make further tests of ropes capeled in a manner somewhat similar to that described above, with various modifications and improvements which have suggested themselves to him; and he has every reason to think that a much improved capel will be the result, and that a much higher percentage will be attained.

Conclusion.—In conclusion, the writer would say that it is not within the bounds of human possibility to ensure absolute immunity from accident, but all means at one's disposal may be used to reduce the risk to a minimum. The best materials obtainable should be employed, and every care should be taken in the construction of the various appliances. All that then remains to be done is to exercise the utmost vigilance and care in the periodical examinations which are made, and at once to condemn and remove any part of the tackle which shows signs of defect or failure.
**DISCUSSION—NOTES ON WINDING-ROPEs AND CAPELS.**

**Table II.—Tests of a Capel and of a Winding-rope, with a Main Hemp-core.**

<table>
<thead>
<tr>
<th>No. of test</th>
<th>Description of rope</th>
<th>Circumference of rope, inches</th>
<th>Weight per fathom, pounds</th>
<th>Strands:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lang- lay wire-rope, after being in use, with a capel attached at one end.</td>
<td>5.35</td>
<td>25.76</td>
<td></td>
</tr>
</tbody>
</table>

| Weight per fathom, pounds | 25.76 |

<table>
<thead>
<tr>
<th>No. of test</th>
<th>Description of rope</th>
<th>Circumference of rope, inches</th>
<th>Weight per fathom, pounds</th>
<th>Strands:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lang- lay wire-rope, cut from the same length of rope as that used in the first experiment.</td>
<td>5.40</td>
<td>25.76</td>
<td>6</td>
</tr>
</tbody>
</table>

| Weight per fathom, pounds | 25.76 |

<table>
<thead>
<tr>
<th>Strands:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of strands</td>
</tr>
<tr>
<td>Number of wires</td>
</tr>
<tr>
<td>Diameter of wires, inches</td>
</tr>
<tr>
<td>Total number of wires</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stress</th>
<th>Elongation of the rope on a length of 25 inches.</th>
<th>Movement of the rope in the capel.</th>
<th>Closing of the shackle, EF.</th>
<th>Elongation of the rope on a length of 25 inches.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ton</td>
<td>0.02</td>
<td>0.08</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>5 tons</td>
<td>0.15</td>
<td>0.19</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>10 tons</td>
<td>0.25</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>15 tons</td>
<td>0.35</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>20 tons</td>
<td>0.45</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>25 tons</td>
<td>0.55</td>
<td>0.60</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>30 tons</td>
<td>0.65</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>35 tons</td>
<td>0.75</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>Maximum stress</td>
<td>57.40</td>
<td>93.72</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

**Remarks.—(1) The rope rapidly pulled out of the socket with a load of 39.20 tons: the shackle, EF (Fig. 5, Plate XV.), began to close in with a load of 45 tons; and the pin, P, began to bend with a load of 50 tons. With a load of 57.40 tons, the rope broke inside the capel, at the place where the wires were bent over. There was no movement at AB or CD (Fig. 5, Plate XV.) during the test, but there was a permanent set of 0.20 inch on the shackle, EF, after the rope had been broken. (2) One strand and some of the wires in one of the remaining strands broke together, clear of the fastenings.**

Mr. R. Holiday instanced a case that had come before his notice where, on examination of a rope, it was found that 50 feet of the core had disappeared. It was a balance- rope which had no great amount of weight on it, and absolutely no change was noticed on the outside of the rope.

Mr. Barracough stated that the diameter of the drum, referred to in his paper, was 23 feet: that of the pulley on the stocks, 19 feet; and that of the pulley in the sump, about 6 feet.
Mr. I. Hodges said that he had found the same difficulties as Mr. Barraclough with wire-core winding-ropes. He had used them with the object of reducing the stretching with full loads, as compared with the empty cage: the difference was as much as 2 feet in a length of 1,200 feet and it was somewhat disconcerting to the winding engineman, particularly if his view of the cage was obstructed. The wire-core had the effect of keeping a more average length, but the reason for which he discarded the use of wire-cores was not because of any actual difficulty in the working, so much as in the making. A wire-core rope, 5½ inches in circumference, on being put to work, was found to be bulged so wide as to be unable to pass the groove of the winding-pulley. This bulging occurred at intervals, say, 150 to 300 feet apart. The manufacturer of the rope took it back and re-spun it; but, when it was returned the following week, it was just as bad. The manufacturer then spun it with a hemp core, and there was no further trouble. Previous winding-ropes, with wire-cores of the same quality of material and the same construction, had given no trouble, and they had certainly the advantage that the elongation of the rope due to heavy loads was nothing like so marked as with a hemp core. Of course, wire-core haulage-ropes were well-known: in fact, the bulk of the ropes that he used had wire-cores (so as to give less stretching on long lengths of haulage), and the fact that they retained their diameter on steep gradients was advantageous when using screw-clips.
THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS AND THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
Held in the Lecture Hall of the Literary and Philosophical Society, Sheffield, April 10th, 1906.

Mr. W. G. PHILLIPS, in the Chair.

The Secretary announced the election of the following gentlemen to The Midland Counties Institution of Engineers:—

MEMBERS—
Mr. René Faery, Civil Engineer, 24, Rue des Minimes, Brussels, Belgium.
Mr. Laurence Holland, Mining Engineer, Hamstead Colliery, near Birmingham.
Mr. Fitz Severn, Director and General Manager, Claye's, Limited, Long Eaton, Derby.

ASSOCIATES—
Mr. Herbert Danby, Surveyor, Shirebrook Colliery, near Mansfield.
Mr. John Wesley Harvey, Deputy Manager, Whaley Bridge, Stockport.

STUDENTS—
Mr. John Charlesworth Crawshaw, Mining Student, Dinnington Main Colliery, near Rotherham.
Mr. Frank Stephen Hanson, Mining Student, Cloverlands, Kimberley, near Nottingham.
Mr. Clement Heathcote, Mining Student, Newstead Colliery, near Nottingham.

The following gentlemen were elected to the Midland Institute of Mining, Civil and Mechanical Engineers, having been previously nominated:—
DISCUSSION—BYE-PRODUCT COKE-OVENS.

MEMBERS—

Mr. John Brass, Colliery Manager, Houghton Main Colliery, near Barnsley.
Mr. Joseph Eston, Colliery Manager, 31, Ferrybridge Road, Castleford.
Mr. Horace John Jones, Consulting Engineer, 72, Victoria Street, London, S.W.
Mr. Henry Parker Laws, Engineer, Mountain View, Thornhill, Dewsbury.
Mr. Walter Machen, Colliery Manager, Thorncliffe Collieries, near Sheffield.
Mr. Hugo Presser, Mining Engineer, Bettina Schacht, Dombrau, Silesia, Austria.
Mr. Fred Robinson, Under Manager, Wood Pit, New Mill, Huddersfield.
Mr. Fred Singleton, Colliery Surveyor and Manager's Assistant, Manvers Main Collieries, Wath-upon-Dearne, near Rotherham.
Mr. Lawford Sidney Joseph Thomson, Surveyor and Manager's Assistant, Manvers Main Collieries, Wath-upon-Dearne, near Rotherham.

Students—

Mr. Basil Henry Pickering, Mining Student, Lawn House, Doncaster.
Mr. Edgar Schofield, Mining Apprentice, 20, Nowell View, Harehills Lane, Leeds.
Mr. Gilbert Kirk Smith, Mining Student, Barnes Hall, Grenoside, Sheffield.

DISCUSSION OF MESSRS. G. BLAKE WALKER AND L. T. O'SHEA'S PAPER ON "THE UTILIZATION OF SURPLUS-GASES FROM BYE-PRODUCT COKE-OVENS."

Dr. R. Herzfeld wrote that Mr. Blake Walker and Prof. O'Shea have shewn that an enormous amount of energy is stored in those gases which can be collected in coke-ovens, and what means have been developed by engineers to put this energy into mechanical effect. The question presenting itself for consideration in this connection is, how this mechanical effect may be applied to the best advantage, and there are two solutions which must be considered:—(1) Gas-engines can either be applied to the machinery direct within a reasonable radius; or (2) they can be used for the generation of electrical energy: the latter method having been found to be by far the most effective. Gas-engines, although developed to a very high standard, are not suited for very rough usage and should not be left to the unskilled hands of men employed at collieries and

DISCUSSION—BYE-PRODUCT COKE-Ovens.

iron-works. There are special and complicated details which demand particular treatment; their proper place, therefore, is in a suitable engine-house, away from dust and unforeseen occurrences associated with works; and the best use, to which they can be put, is in connection with electrical distribution. This also has the great advantage of allowing the individual units of gas-engines to run at their best efficiency, and to produce exactly the number of units which the time of day and the works may require. The electrical drive overcomes all the difficulties which would have to be met when applying gas-engines direct to the machinery in the way of variation of load, and particularly in connection with reversing and speed-control. Electricity affords very efficient means of balancing the variable loads of the driven machinery, achieving a very steady load on the generating station. These electrical balancing devices have been developed to so high a state of efficiency that, on a rolling-mill recently installed of 500 to 600 horsepower, the ammeter connected to the electrical motor did not vary more than 1 per cent., in spite of the great peaks with which the driving of this mill had to contend. Even those heavy jerks, which are encountered when accelerating reversing-mills or winding-engines, have been successfully overcome by electrical balancing devices, so that the load on the generating station comes out nearly constant, even with a reversing mill of 10,000 horsepower, reversing ten times a minute.

The generation of electricity by means of powerful gas-engines is not so easy a problem as is generally believed. It is necessary for the gearing of the gas-engine to be particularly sensitive in order to allow for the parallel running of alternators, which (for the sake of economical running) is required in large power-stations. A good deal can be done to further this purpose by heavy flywheel masses, and he (Dr. Herzfeld) would like to draw the attention of the members to a design for an alternator, which had lately been introduced and allowed of a heavy flywheel-effect, without the use of unduly large masses of metal and without complicated shafting. In this alternator, the inductor rotates outside the stator-windings, and gives a heavy flywheel-effect in a very effective manner. Two of these alternators, one of 1,200 horsepower and one of 900 horsepower, will shortly be running at the Bargoed colliery of the Powell
Duffryn Steam Coal Company, Limited, and at the Brymbo steel and iron-works. In his (Dr. Herzfeld's) opinion the advantages to be derived from the use of coke-oven gas will be materially increased by the adoption of electrical drives throughout collieries and adjacent works; and it is hardly possible to turn coke-oven gas to profitable account by any other means. Electrical drives have proved themselves to be eminently satisfactory for every kind of mining or iron-work operation, and the conversion of huge reversing rolling-mills from steam to electricity, which has been adopted in order to increase the output of mills by way of quicker acceleration and retardation, represents the latest and most improved example of the application of electricity. It would appear that the facilities for the employment of electrical energy on a large scale, afforded by the use of waste-gases, should be regarded as their chief merit.

Mr. W. Price Abell read the following paper on "The Reavell Air-compressor at Work":—
THE REAVELL AIR-COMPRESSOR AT WORK.

By W. PRICE ABELL.

Following the author's previous paper dealing with the details and types of the high-speed air-compressor developed by Mr. W. Reavell for colliery and mining work, it will be interesting now to consider briefly a few of the advantages which attend the working of some of these machines.

Coal-cutting Machines.—Last year, over 6,744,000 tons of coal were cut by machinery; and, in doing this, 485 machines were driven by compressed air and 270 by electricity. It has become almost an axiom that many of the thinner seams must, in future, be undercut by mechanical means, if they are to be worked economically; but, unfortunately, the data available by the author to place before the members are not complete. He has been surprised at the demand made by all makers of coal-cutting machines for a supply of air at a pressure of 50 to 60 pounds per square inch; and it was only after going very carefully into the working details, and taking indicator-diagrams, that he arrived at the fact that this high pressure was necessary or, in other words, that the large cylinders on the coal-cutters were necessary, owing to the loss of efficiency in the pipe-lines, as dealt with in his aforementioned paper.

The following typical case illustrates, perhaps, the average working, from which it will be seen that, although the bank-pressure was 60 pounds per square inch, a pressure of only 20 pounds was usually available and necessary for working the coal-cutter. This fully bears out the recognized practice that for 100 horsepower at the air-compressor at bank not more than 20 horsepower is delivered at the coal-face. The piston-speed was 450 feet per minute. The crank made 300 revolutions, and the cutting-wheel 14 revolutions per minute. The average air-pressures per square inch were as follow: On piston, 15 pounds;
on stop-valve, 30 pounds; below stop-valve, 20 pounds; at bank, 60 pounds. The cutting-wheel was 5½ feet in diameter, and a length of 1,500 feet was cut in 16 hours.

In another case, the piston-speed was 360 feet per minute, and the air-pressure on the piston was 18 pounds per square inch. The crank-shaft made 240 revolutions per minute, and the cutting-wheel, 1½ feet in diameter, made 11⅔ to 14 revolutions per minute.

In another case, a Diamond coal-cutter, having two cylinders, 9½ inches in diameter and of 8 inches stroke, was undercutting to a depth of 4½ feet in a very stiff fire-clay, at the rate of 36 feet per hour. A pressure-gauge, screwed on to the machine-side of the stop-cock, and therefore approximately in a position to show the pressure of the air supplied to the coal-cutter, showed an air-pressure of 11 pounds per square inch; and under these conditions the crank-shaft made 250 revolutions per minute.

It is an obvious conclusion that the enormous loss, entailed by the conveyance of air from an air-compressor at bank to coal-cutters in the mine, could be avoided by "in-bye" compression; the air would then be delivered from the air-compressor to the coal-cutting machine through a short length of pipe, with consequent low friction and leakage-losses, giving a combined efficiency of 64 per cent., as detailed in the author's previous paper.

**Heading Machines.**—A rotary type Stanley header driven by air supplied from an air-compressor at bank practically suffers the high losses shown in the preceding paragraph. This machine working in a seam 21 feet thick, in the Nuneaton district, in actual practice works with an air-pressure of 20 pounds per square inch, while the pipes-lines are supplied from the pit-head compressor-system with air at a pressure of 60 pounds per square inch. The pressure-gauge, screwed right on the inlet-pipe to the heading-machine at the face, shewed that the actual air-pressure in the cylinder of the heading machine never exceeded 25 pounds per square inch when the machine was running; and it fluctuated from 18 to 20 pounds. This showed that a very large frictional loss was taking place in the "in-bye" pipes between the bank-compressor and the Stanley header. Of course, the writer is aware of the arguments fre-
quently raised, that this is not really a loss: one argument being based on the ground that, although the air is falling in pressure it is correspondingly increasing in volume. This is true, so far as it goes, but one must not overlook the fact that if all that is required is to deliver air at a lower pressure to modern heading and coal-cutting machines; then, if the air can be compressed to only the pressure required (this work being readily done close to the face by an electrically-driven air-compressor), it is obvious that a very much smaller power would be required to compress the air to this lower pressure than is actually used at bank to compress the air to a higher pressure, and afterwards have it wire-drawn and reduced in pressure.

Electrically-driven Air-compressors.—At the same colliery, in the Nuneaton district, in another part of the mine, an electrically-driven Reavell air-compressor is supplying air at a pressure of 29 pounds per square inch to a Stanley header similar to that from which the aforementioned data were supplied. This compressor was fixed within a few feet of the point where the header started. It was driven by continuous current at 500 volts, and arranged to cut out automatically whenever the air-pressure exceeded 29 pounds per square inch. The header worked easily when supplied with air at an average pressure of 20 pounds per square inch; but this was exceeded when the machine was choked or passed into harder material. Rapid work was effected with a maximum occasional pressure of 29 pounds per square inch.

The author saw this Stanley header working, a few weeks ago, about 900 feet distant from the Reavell compressor. The air was carried to it through a pipe, 4 inches in diameter. It was then working at an average air-pressure varying from 20 to 24 pounds per square inch, as the machine seldom required more. The automatic cut-off worked regularly and quite automatically without trouble, at an air-pressure of 29 pounds per square inch.

The author discussed the work with Mr. J. H. W. Laverick, who expressed the opinion that it would be an advantage to have a maximum cut-out, working at a pressure of 40 pounds per square inch, available in cases of emergency: not that it was necessary regularly, but for use in hard places, when the
machine could work at a slower speed. The motor would be sufficiently powerful to supply a less quantity of air, in cases of emergency, at a pressure of 40 pounds per square inch. Of course, where the coal is soft, the average pressure of 20 pounds is more than ample. It would only be in cases of emergency, such as a block, that the higher pressure of 40 pounds and the less quantity would be of advantage.

The air-filter on the side of this compressor practically prevents any trouble that might arise through dust getting into the machine, and admirably serves the purpose for which it was designed.

Another important point, in connection with the working of this compressor and the Stanley header, was observed: namely, that the heading machine only runs 2 to 2½ minutes at a time, and that for 90 per cent. of its time it is standing, while the men are clearing away the spoil, shifting machinery, etc. This, of course, gives rise to very marked economy, the automatic cut-off bringing the air-compressor to a stand, while for 90 per cent. of the time the bank air-compressor, under similar conditions, would be obliged to run.

As a matter of fact, in this particular instance, the average input into the motor was between 35 and 40 kilowatts: and, taking the cost of current at 1d. per kilowatt-hour, the cost per hour for cutting 1 foot of heading would be (35 kilowatts \times 9 minutes ÷ 60 minutes = ) 5d.

Percussive Machines.—In the case of percussive machines, such as the Little Hardy, the Champion, etc., the same conditions apply, except that when a pressure of 60 pounds per square inch is required, for holing in soft material, a Reavell single stage air-compressor may be employed: and, when a pressure of 90 pounds per square inch is required, for holing in hard material, an economy will accrue from the use of a Reavell two-stage air-compressor.

Percussive Drills.—Closely allied to heading with percussive drills comes quarry work, also requiring the use of percussive drills. In this case, in the past, it has been the practice to use steam-drills, with heavy condensation pipe-losses, especially in cold weather, accompanied by great waste of steam, preventing
the drills from getting the high initial pressure necessary for economical work, whilst the drill is not so handy as when fed with compressed air.

The differences in this respect alone will more than pay for the unavoidable losses due to the double conversion of energy involved by using electricity; and the saving in labour by having the enginewomen looking after the generators would be a clear gain. Further, the electric generator would use much less steam per horsepower than would be required for feeding the drills directly with steam, and consequently there would also be a saving in fuel.

Another very important advantage possessed by the Reavell air-compressor is its portability. Consequently, it can be placed near to the drills in the quarry; and the efficiency, by the avoidance of consequent leaks and friction, may be raised from 20 to 70 per cent. For this class of work, it is advisable to use a Reavell two-stage air-compressor.

The author has to thank members, who have so kindly given assistance and data, which make this subject particularly attractive to those who attach importance to economy, not only of coal but also of the steam-producing plant. The capital outlay saved in boilers alone for an economical air-compressing plant, shows up and opens out a field for enormous saving.

Mr. W. Reavell said he wished to refer specially to that part of Mr. Abell's paper in which he mentioned the losses inseparable from pit-head compression at a pressure of 60 pounds per square inch, when the air was to be used in coal-cutters. He thought that a false analogy was too often drawn between the use of steam and air under pressure and the effect of latent heat was overlooked. The fact, of course, was that when latent heat was overcome and steam was once generated in a boiler, very little additional heat-energy was required to raise the pressure considerably and to increase its capacity for work in the same proportion. With compressed air, on the other hand, whatever pressure was used beyond that absolutely required, meant an additional and correspondingly equal amount of wasted energy expended in the air-compressor.

He (Mr. Reavell) thought that it should be taken as an
DISCUSSION—THE REAVELL AIR-COMPRESSOR AT WORK. 233

axiom that, other things being equal and within common-sense limits, the lower the pressure the better the efficiency. Applying this to the question of coal-cutting machines, he had prepared Figs. 1 and 2 to illustrate the difference between pit-head and in-byre compression, and also to indicate another source of considerable saving. The full black lines (Fig. 1) represented a theoretical diagram taken from a coal-cutter cylinder, with an initial pressure of 20 pounds per square inch and cutting off at 90 per cent. of the stroke. He had collected information as

Fig. 1.—A: Pressure of 20 Pounds per Square Inch; Free Air, 635 Cubic Feet; Compressed Air, 315 Cubic Feet; Cut-off, 90 per Cent.; and Mean Effective Pressure, 19-6 Pounds per Square Inch. B: Pressure of 22\(\frac{1}{2}\) Pounds per Square Inch; Free Air, 425 Cubic Feet; Compressed Air, 220 Cubic Feet; Cut-off, 62\(\frac{1}{2}\) per Cent.; and Mean Effective Pressure, 19-6 Pounds per Square Inch.

to the cylinder-capacities of coal-cutters and found that a machine with two cylinders, 9\(\frac{1}{2}\) inches in diameter and 9 inches stroke, might be taken as an average. At a speed of 230 to 250 revolutions per minute, the cylinder-volume would be, say, 350 cubic feet; and, allowing for cutting-off at 90 per cent. of the stroke, the quantity of air required at a pressure of 20 pounds per square inch would be 315 cubic feet per minute.

The members would probably agree that indicator-diagrams taken from coal-cutters showed actually a lower pressure than
 DISCUSSION—THE REAVELL AIR-COMPRESSOR AT WORK.

20 pounds per square inch, and that this figure was ample. An indicator-diagram taken under these conditions would show 30 horsepower, which would be ample; and, as further corroboration, it might be mentioned that electrically-driven compressors of this type were only fitted with one motor of 20 horsepower, or two motors of 10 horsepower each. Seeing, therefore, that a pressure of 20 pounds per square inch was ample for working a coal-cutter and that a pressure of 60 pounds per square inch, and, in more recent times, 70 and 80 pounds per square inch, was common at bank, he would leave the members to decide how the loss came about, and would merely point out that serious waste was taking place.

![Diagram](Fig. 2.—C: Pressure of 20 Pounds per Square Inch; Free Air, 635 Cubic Feet; Compressed Air, 315 Cubic Feet; and Mean Effective Pressure, 14.47 Pounds per Square Inch. D: Pressure of 60 Pounds per Square Inch; Free Air, 735 Cubic Feet; and Mean Effective Pressure, 31.17 Pounds per Square Inch.)

With pit-head compression of 60 pounds and in-byre compression of 20 pounds per square inch, he would, now, show what this loss amounted to. Assuming that an in-byre electrically-driven air-compressor was used, and that it could be placed relatively close to the coal-cutter, and connected thereto by a pipe, 4 inches in diameter, the drop in pressure would be negligible; and the full lines (Fig. 2) shew the indicator-diagram that would be obtained from the air-compressor. With ordinary
water-jacketing and, say, 40 per cent. absorption of the heat of compression, the mean effective pressure would be 14.47 pounds per square inch, the equivalent free air would be 635 cubic feet, and 40 horsepower would be required for compression. The dotted lines (Fig. 2) show the energy required to compress up to a pressure of 60 pounds per square inch and the mean effective pressure under the same conditions would be 31.17 pounds per square inch. A larger equivalent quantity of free air would be required, because the air compressed at bank and delivered at a fairly high temperature from the compressor would be rapidly cooled down to the temperature of the mine before it had travelled far along the air-mains; consequently, the air-compressor capacity at bank, to supply 315 cubic feet to the coal-cutter cylinders at a pressure of 20 pounds per square inch, would be 735 cubic feet; and the horsepower indicated in the air-compressor cylinder at bank would be 100, as compared with 40 in the in-bye compressor.

It was common knowledge that no attempt was made to use the air expansively in coal-cutter cylinders, for the equally well-known reason that the result was the production of fog and even of ice in the exhaust parts. The dotted lines (Fig. 1) shewed an indicator-card equal in area and power to the full-line card. It was obtained by raising the air-pressure to 22.5 pounds (an increase of 2 1/2 pounds) per square inch and cutting off at 62 1/2 per cent. of the stroke. When using air expansively under these conditions, the resultant temperature of the exhaust-air would be considerably below freezing point: the actual figure being 0° Fahr., if the air reached the coal-cutter cylinders at, say, the mine-temperature of 70° Fahr. If, however, the air reached the coal-cutter at a temperature of, say, 150° Fahr., it would then be possible to cut off at 62 1/2 per cent. of the stroke, to save one-third of the air, and to exhaust the air at about the temperature of the mine. He (Mr. Reavell) proposed to do this by still further simplifying and cheapening the in-bye compressor, removing the water-jacket, and thus avoiding the necessity of providing a supply of jacket-water. Instead, he would lag the cylinders of the compressor with non-conducting composition and cover the pipes from the air-compressor to the coal-cutter with asbestos rope. Under these conditions, if the air was compressed to 22 1/2 pounds instead of 20 pounds per square
inch, the temperature would be about 200° Fahr., and the air would reach the coal-cutter hot enough for the expansion referred to. The volume of air required (Fig. 1) by the coal-cutter would now be 220 cubic feet instead of 315 cubic feet, and the free-air capacity of the compressor would now be 425 cubic feet instead of 635 cubic feet. Owing to the air being compressed adiabatically, the mean effective pressure would naturally rise, the value becoming 17.2 pounds per square inch; but, owing to the great saving in the size of the compressor, the horsepower required would only be 32 instead of 40.

The results may be epitomized as follows:—(1) Pit-head compression of air to a pressure of 60 pounds per square inch requires a compressor-capacity of 735 cubic feet and 100 horsepower. (2) In-bye compression of air to a pressure of 20 pounds per square inch, with a jacketed compressor, requires a compressor-capacity of 635 cubic feet and 40 horsepower; while, for the new method proposed, a compressor with a capacity of 425 cubic feet, at a pressure of 22.4 pounds per square inch, will suffice and 32 horsepower will be required. He would not advance these figures as being correct for all conditions, but they were certainly proportionally correct and he considered, where pneumatic coal-cutters were used, that the plan suggested merited the serious consideration of mining engineers.

Mr. M. Deacon said that he had used the Reavell air-compressor in more than one pit and for more than one purpose, and he was bound to say that he had formed a favourable impression of it; but, although there was little doubt as to the advantage of having the air-compressor near to the face if it were necessary to use compressed air, he was satisfied that most work could be done more economically by electricity. With regard to Mr. Reavell's proposal to use the air in the cylinders expansively, to be effective, this would necessitate a moderately high pressure of air, say, 60 to 80 pounds per square inch at the air-compressor. He (Mr. Deacon) thought that, in single compression, there would be a greater loss of power by radiation of heat due to this somewhat high pressure than the economy gained in expansion. He would like to know whether Mr. Reavell had made any experiments in this direction, confirming the advantage that he claimed.
DISCUSSION—THE REAVELL AIR-COMPRESSOR AT WORK.

The Chairman (Mr. W. G. Phillips) proposed a vote of thanks to Mr. W. Price Abell for his paper.

Mr. Isaac Hodges seconded the resolution, which was cordially approved.

The discussion was adjourned.

Mr. T. Beach's paper on "'Black Ends': Their Cause, Cost and Cure" was read as follows:—
"Black Ends."—Rather more than a year ago, Mr. George B. Walker, in the course of a lecture given at Chesterfield, made use of the following words:—"The coal at the end of the oven resting against the door is only slightly carbonized."* This led the writer, who had been previously much annoyed at the evident waste taking place at the ovens under his charge, to enquire more minutely into the cause, to ascertain from experiment the actual cost, and if possible to find a cure, for such waste.

**Cause.**—The cause of the so-called "black ends" is obvious, and may be summed up in two words, namely, "insufficient heat," which may arise from a variety of conditions, such as:—

1. A cold wind blowing on to the oven-ends.
2. The first flues in the side-walls (where vertical flues are in use) not attaining the temperature of the second and subsequent flues, owing to the cooling action of the atmosphere.
3. The doors not being sufficiently recessed, between the side-walls of the oven. And (4) the chilling action produced by the solid door, which is in contact with the only part of the charge of coal that is not resting against incandescent walls.

**Cost.**—The cost of the "black ends" is a somewhat difficult matter to ascertain. Under different circumstances, it will undoubtedly vary very considerably; and the writer would wish it to be borne in mind that the figures which are hereafter given must only be taken as applying to those particular ovens upon which the experiments have been made.

These were carried out last autumn, and in February of this year, by having the unburnt slack and seconds coke carefully weighed from three successive drawings of each individual oven.

and the latter again taken over a week's work of the whole battery. The figures referring to February, 1906, are about 10 per cent, less than those taken last autumn, and the writer, wishing to avoid any exaggeration, has adopted the lower ones. It will be noticed that the effect of cold winds is shewn by the results, as in every case the quantity of waste slack is greater at the bench-end, which is exposed to the north and east, than at the ram-end, which is sheltered by the recovery-plant buildings and a high dirt-stack.

As regards seconds coke, it may be argued that, at many (and possibly the majority of) coking plants, no coke whatever is sold as seconds; but it is submitted with a considerable amount of confidence that wherever a "black end" exists, a piece of coke of an inferior quality is produced, and although a small percentage of this may be of no very great moment when used for blast-furnace purposes, in the case of malting coke it is imperative that it should be most carefully excluded, as the presence of even a very small quantity of imperfectly burnt smudge will inevitably result in smoked barley, complaints, and, if repeated, loss of trade.

_Collins Coke-ovens._—The Snydale battery consists of 45 Collins ovens, with vertical flues. These are all connected and worked as one installation, although the last 15 ovens were built at a later date, and are in reality an extension of the original 30 ovens. Each oven is 33½ feet long, 6½ feet high to the spring of the arch, and 18½ and 16½ inches wide at the bench-end and ram-end respectively. The first 30 ovens were built with neither of the doors recessed (Fig. 1, Plate XVI.); and last summer, when a number of these were being repaired, it was decided to recess the doors to the extent of 5 inches, so as to bring the charge of coal into line with the first flues in the side-walls (Fig. 2, Plate XVI.); but time and circumstances only allowed of this being done at the ram-end, and so there are now a certain number of ovens with one door recessed. The last 15 ovens have both doors recessed (Fig. 2, Plate XVI.).

The actual amount of seconds coke produced from the ovens referred to in Tables I., II. and III., amounted to 3,124 pounds, or an average of 173 pounds per oven. The accuracy of this result is corroborated by the weekly return of seconds coke,
namely, two wagons of about 8 tons each from 210 ovens drawn, or an average of 170 pounds per oven, and, with 36 hours charges, this equals 18.4 tons per oven per annum.

**Table I.—Waste Slack Produced from Coke-ovens with Neither of the Doors Recessed.**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>23</td>
<td>1906, Feb. 15</td>
<td>38</td>
<td>64</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>,</td>
<td>21</td>
<td>28</td>
<td>78</td>
<td>106</td>
<td></td>
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<tr>
<td>,</td>
<td>27</td>
<td>27</td>
<td>50</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>20</td>
<td>29</td>
<td>62</td>
<td>91</td>
<td></td>
</tr>
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<td>29</td>
<td>42</td>
<td>71</td>
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</tr>
<tr>
<td>,</td>
<td>26</td>
<td>40</td>
<td>53</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>Totals ...</td>
<td>...</td>
<td>191</td>
<td>349</td>
<td>540</td>
<td></td>
</tr>
<tr>
<td>Averages ...</td>
<td>82</td>
<td>58</td>
<td>90</td>
<td>9-77</td>
<td></td>
</tr>
</tbody>
</table>

**Table II.—Waste Slack Produced from Coke-ovens with One Door Recessed.**

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>5</td>
<td>1906, Feb. 17</td>
<td>24</td>
<td>51</td>
<td>75</td>
<td></td>
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<tr>
<td>,</td>
<td>20</td>
<td>18</td>
<td>50</td>
<td>68</td>
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<td>23</td>
<td>19</td>
<td>54</td>
<td>73</td>
<td></td>
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<td>10</td>
<td>20</td>
<td>16</td>
<td>44</td>
<td>60</td>
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<td>,</td>
<td>23</td>
<td>12</td>
<td>44</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>,</td>
<td>26</td>
<td>14</td>
<td>59</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Totals ...</td>
<td>...</td>
<td>103</td>
<td>302</td>
<td>405</td>
<td></td>
</tr>
<tr>
<td>Averages ...</td>
<td>17</td>
<td>50</td>
<td>67</td>
<td>7-27</td>
<td></td>
</tr>
</tbody>
</table>

**Table III.—Waste Slack Produced from Coke-ovens with Both Doors Recessed.**

<table>
<thead>
<tr>
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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>35</td>
<td>1906, Feb. 16</td>
<td>12</td>
<td>31</td>
<td>43</td>
<td></td>
</tr>
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<td>19</td>
<td>14</td>
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<td>,</td>
<td>22</td>
<td>17</td>
<td>26</td>
<td>43</td>
<td></td>
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<tr>
<td>40</td>
<td>15</td>
<td>17</td>
<td>57</td>
<td>74</td>
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</tr>
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<td>,</td>
<td>21</td>
<td>19</td>
<td>33</td>
<td>52</td>
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<td>27</td>
<td>nil</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Totals ...</td>
<td>...</td>
<td>79</td>
<td>185</td>
<td>264</td>
<td></td>
</tr>
<tr>
<td>Averages ...</td>
<td>13</td>
<td>31</td>
<td>44</td>
<td>4-78</td>
<td></td>
</tr>
</tbody>
</table>

Putting the above results into money, and taking the value of coke at an average price of 12s. per ton, the difference in
value between seconds and best coke at 5s. per ton, and the value of the bye-products at 3s. 3d. per ton of coal, the wastage is recorded in Tables IV., V. and VI.

**Table IV.—Value of the Wastage at Coke-ovens with neither of the Doors Recessed.**

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.77 tons of slack, yielding 70 per cent. of coke, 6s. 83d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tons at 12s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.4 tons of seconds coke converted into best coke, at 5s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bye-products on 9.77 tons, at 3s. 3d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total wastage per oven per annum</td>
<td>£10</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

**Table V.—Value of the Wastage at Coke-ovens with one Door Recessed.**

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.27 tons of slack, yielding 70 per cent. of coke, 5s. 9d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tons at 12s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.4 tons of seconds coke converted into best coke, at 5s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bye-products on 7.27 tons, at 3s. 3d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total wastage per oven per annum</td>
<td>£8</td>
<td>16</td>
<td>7</td>
</tr>
</tbody>
</table>

**Table VI.—Value of the Wastage at Coke-ovens with both Doors Recessed.**

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.78 tons of slack, yielding 70 per cent. of coke, 3s. 34d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tons at 12s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.4 tons of seconds coke converted into best coke, at 5s.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bye-products on 4.78 tons, at 3s. 3d.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total wastage per oven per annum</td>
<td>£7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

The recessing of the doors, however satisfactory it may be as regards the minimizing of the "black ends," has the great disadvantage of materially reducing the oven-capacity; and, if done to the extent of only 5 inches at each end, means, in an oven 18 inches wide and 5 feet high, a loss of 6.25 cubic feet. On charges burning for 36 hours, taking the weight of a cubic foot of coke at 39 pounds, the loss is nearly 26.25 tons of coke per oven per annum; a loss of output surely worthy of consideration.

**Flued Doors.**—With a view to overcoming the before-mentioned disadvantages and losses, and at the same time avoiding the reduction of oven-capacity and consequent loss of output, a flued door (Figs. 3 to 8, Plate XVI.) has been designed. It may briefly be described as a door having an internal vertical
flue of sinuous or zig-zag formation, with an external gas-admission aperture at the base and an external escape-port at the upper extremity, for the purpose of burning purified or other gas in the said flue, so as to heat that portion of the door in contact with the charge of coal within the oven to a state of incandescence, thus driving off all gases contained in the said charge of coal, which may not come under the influence of the heated flues in the side-walls of the oven, and thereby ensuring the complete and perfect carbonization of the entire charge of coal within the oven. The external admission and escape-ports are provided with sliding shutters, which should be closed whenever the gas is not burning in the flue in order to exclude cold air, thus retaining, as far as possible, the heat of the door and preventing extreme changes of temperature.

The flue is formed by specially-designed fire-clay blocks which fit the door, and which can be built in by any ordinary bricklayer in less time than it takes to line the door in the usual way. The
blocks cost from 2s. 6d. to 3s. per door more than the bricks that they replace, but an advantage is gained in the shorter time occupied in setting them in the door frame.

It will be seen that there is no internal communication with the oven, so that an increase in the bye-products, in proportion to the extra amount of slack carbonized (which was previously wasted), is ensured.

The general arrangements of the doors and the pipe-connections for supplying gas are shewn in Fig. 9.

In designing and laying out gas-plant to be used in connection with retort coke-ovens, it should be remembered that the quantity of surplus gas over and above that required for heating the ovens, and available for power-generation, will necessarily be a very variable quantity owing to:—(1) Different qualities of coal being used, yielding different amounts of gas; (2) the condition of the side-walls as regards leakage; (3) the number of ovens at work; etc. It will, therefore, always be necessary to allow an ample margin, or, in other words, it would be highly imprudent to equip the works with costly gas-engines relying upon the maximum quantity of gas to be always available. In the chain, the strength is only that of its weakest link, and in a like manner the minimum surplus supply can only safely be reckoned upon as available for power-generation. Again, assuming the maximum quantity to be available, there are many times, such as nights, holidays and week-ends, when the total engine-power will not be required; and, the storage of gas except in very considerable units being prohibited by capital expenditure, it is the surplus over and above the engine-power requirements, that is, the difference between the minimum and maximum surplus supplies, that can beneficially be used for burning off the “black ends,” and so increasing, possibly by only a small extent, the gas-supply.

Messrs. G. B. Walker and L. T. O'Shea state that “the primary use of the gas is to heat the ovens, and only the surplus is available for power-generation”* and the writer contends that the gas burnt in the door is equally well used, and used for exactly the same purpose as that burnt in the flue-walls, namely, for the heating of the oven and the carbonizing of the coal contained therein.

As regards the quantity of gas consumed, it is surprizing how little is necessary, and it is only requisite that a tongue of flame be occasionally seen at the upper or escape-aperture, for sufficient heat to be generated to cause the inside lining adjoining the coal to glow. A tap, $\frac{1}{4}$ inch in diameter, would give an ample supply, but the writer has adopted a tap, $\frac{1}{2}$ inch in diameter, as easier to keep clean; this has to be kept turned half or three-quarters off to regulate the supply.

![Fig. 10.—“Black Ends” burnt off and converted into Best Coke by means of the Fluid Door.](image)

Another advantage derived from the use of the above-described door is that a hard clean face of coke (Fig. 10) is formed for the ram to push against; and it must be admitted that this is preferable to several inches of soft spongy material (Fig. 11) which is liable to squeeze out sideways, and may easily cause the coke to stick, particularly if the sides of the oven are rough and irregular from long and continual use.

In conclusion, it may be said that several of these doors have
been used experimentally at Snydale colliery since August, 1905, and have proved their efficiency (and are little, if any, the worse after 8 months' wear) by producing coke at the extreme ends of the oven, equal in quality to that which is to be found in any other portion of the oven, thus entirely eliminating all loss from unburnt slack and seconds coke from those ovens to which they have been fitted.

Mr. J. McCutcheon exhibited and described his apparatus for the detection of minute quantities of fire-damp.*

Mr. Arthur Hall's paper on "The Stanley Double-heading Machine" was read as follows:

THE STANLEY DOUBLE-HEADING MACHINE.

By ARTHUR HALL.

Some time ago, Mr. Reginald Stanley read a paper on his heading machine at a meeting of the members of this Institute held in this city (Sheffield). That paper gave the history, and also a plenary description, of the machines (which were all of the single type) as worked up to that time, together with the various methods adopted for the driving of the same, namely, by hand-power, by water-power, and by means of compressed air. A full account of the results obtained was also given.*

Since then, however, although the fundamental principle remains the same, the machines have undergone considerable alterations and additions, and greatly increased efficiency as well as other advantages have resulted. Rope-driven and electrically-driven machines have also since been designed. The latter is a single, 5 feet in diameter, annular groove machine, to which, some 14 years ago, a continuous-current electric motor was fitted. This machine was put to work by Mr. King Harrison, of Stourbridge, and did some good cutting, but sometimes, when the coal fell in such a way as to cause an obstruction to the cutting arms, the fuses would blow. This was not, however, so great a disadvantage to the progress made with the heading as the size of the motor, which proved to be too unwieldy, taking up too much room; but motors to give the same power are, nowadays, made much smaller and more compact, and this difficulty would therefore not occur.

At first, single machines only were used, that is, machines cutting a circular head in diameters varying from 4 feet to 7½ feet. Some of these were designed to cut an annular groove, leaving a core of coal. Other machines were constructed to take out the full cut of the particular diameter of the machine. A machine of this description was fitted with a worm-conveyor

to facilitate the removal of the coal in heading, which in this case is mostly slack. These machines will cut an average distance of 15 feet in a shift of 8 hours.

As the majority of the members of this Institute are no doubt familiar with these single heading machines, the writer does not deem it necessary to give any further detailed description here. It may, however, be stated that no less than 123 single machines, to cut up to 7 feet in diameter, have been made up to the present time, and have proved highly successful in every case where they have been worked under the suitable and normal conditions for which they were intended.

Subsequently, Mr. Stanley brought out the double- or duplex-heading machine. This was designed to cut a wider or double-road, so as to admit of two lines of rails being laid, for endless haulage, etc.: the largest size yet constructed will cut a road, 12 feet wide and 6 feet high. This machine practically consists of two single machines joined and working together, with the cutting arms placed at right angles to each other, and overlapping in the cut: but, in this case, the cylinders, instead of being vertical as in the single machine, are placed horizontally, leaving a space in the central upper portion, which is fitted with a smooth plate, over which the coal and slack made in the heading can be thrown back. The coal and slack can also be thrown past each side of the machine, if found desirable, and smooth hinged plates can also be attached for this purpose as in the single heading machine. The three spaces, therefore, greatly facilitate the removal of the coal and slack, an operation which has in the past been found to take up far more time than the actual cutting. The different parts of the machine (Figs. 1 and 2, Plate XVII.) are as follows: A, framework of machine, made of steel angle-irons, 6 inches by 4 inches; B, cylinders; C, connecting-rod; D, compressed-air feed; E, first-motion shaft from engine; F, double-carriage to carry front end of first-motion shaft; G, bevel-wheels on crank-shaft and shaft, E; H and H', first and second gear-wheels for driving, J and J', third and fourth gear-wheels driving on the centre shaft, K; L, L', L_2 and L_3, back and forward propelling gear; V, cutter-arm; W and W', cutting wings and cutting knives; X, side stays for spragging the machine; and Y, wheels carrying the machine.
The cutting arms of the double machine work in opposite directions, that is, one clockwise, and the other counter-clockwise: and they can be arranged, either to tend to bring the coal and slack towards the sides of the head (Fig. 3, Plate XVII.), or towards the centre of the head (Fig. 4). The small triangular-shaped pieces left on at the points A (Figs. 3 and 4), are readily trimmed off by hand, either at the front or at the back of the machine, after cutting, thus making an even roof and floor, and the side corners at the points A₁ (Figs. 3 and 4) can be made square, in like manner, if desired or should circumstances require it.

Five double machines, cutting a heading, 8 feet 6 inches wide and 5 feet 4 inches high, were put to work at the Rylands Main colliery, Barnsley, in 1891. They worked very successfully until the closing of the colliery, the rate of cutting being 7 lineal feet per shift of 8 hours. The writer regrets that no figures are now available showing the costs, as compared with hand-heading. Fig. 5 (Plate XVII.), is a section of the cutting. The fire-clay, 1 foot 8 inches thick, was very tough, having to be picked off in small pieces, and, even blasting had to be resorted to, when possible. The machines worked on the level, and both uphill and downhill, at a gradient of 1 in 12.

In the summer of 1905, Mr. Stanley designed a much improved form of the double machine (Figs. 6 and 7, Plate XVII.). It may be noticed that in general principle it is practically the same as the double machine, previously described, except that, in this case, the cylinders and driving gears are placed at the top instead of at the bottom of the machine, thus leaving a good clear space at the floor-level, between the feeding screws for the coal to be passed through, an operation which is performed much more quickly and easily than in the other machine, where the cylinders are placed at the base, and the coal has to be lifted up to, and passed over, the centre plate, or past the sides, as previously mentioned. The lettering and description of the double machine (Figs. 1 and 2) apply also to this machine (Figs. 6 and 7, Plate XVII.) so far as they go.

In the autumn of 1905, two double machines were put to work at the Charity colliery, Bedworth, to drive main hills
in the Ryder coal-seam: the headings dipping at the rate of 1 in 6. One of these machines had its cylinders and gear placed at the base, as previously described; and in the other they were placed uppermost, as last described. Each machine made a cut 9 feet wide and 5 feet 4 inches high (Fig. 8, Plate XVII.). The following results were obtained:—The machine with the cylinders at the base averaged a cut of 75 feet per week; and the machine, with the cylinders uppermost, averaged a cut of 93 feet per week. These lengths (cut when the machines were in full and constant work) fully demonstrated the extra speed of the latter machine, by reason of the easier removal of the coal from the front to the back of the machine. The cost, including everything, is a little above 3s. 4d. per foot. The contract price, paid to the men, was 1s. 8d. per foot, and the charter on the coal produced (a little over 2 tons per foot) was 1s. 8d. per ton. The district-price for driving this size of heading by hand is 7s. per foot, and the charter on the coal produced as before. The coal need not be taken into account in this comparison, being common to both machine and hand-heading. The distance cut by hand per week averages 45 feet. It is therefore apparent that the cost of the heading by these machines was less than half that of heading by hand, and (in the case of the machine with the overhead cylinders) the length cut was double that of hand-heading, in the same time.

The section (Fig. 8, Plate XVII.) of this heading shews that a band of very hard stone (Ryder stone) of an average thickness of 4 inches had to be cut. This retarded the cutting to a great extent, and the writer expresses his firm belief that, had it not been present, an average of 150 feet, or even more, would have been cut per week.

The experience with this latter machine (with overhead cylinders and drive) demonstrated more than ever the fact that, in order to increase the distance cut, it was necessary to improve further the facilities for removing the coal from the cutting. This has now been done to a much greater extent than before by the application of either a band-conveyor, or a trough-conveyor with scrapers (whichever best suits the special circumstances of any particular cutting), either of which practically performs this work automatically, and reduces hand-labour to a
minimum. The band-conveyor (Figs. 6 and 7, Plate XVII.) consists of a composition-belt, R, about 1 foot 9 inches wide, running on rollers or drums, placed about 7 feet apart, the front one being 6 inches in diameter and the back one 10 inches in diameter. The belt is kept tight by means of screw-carriages, O, operating on the back-end drum. It is driven by two sprocket-wheels, N, and N, on the shaft N, and a chain, N, these in turn being driven from the side-shaft of the machine by worm-and-bevel gearing: M is the worm; M, the clutch; M, the worm-wheel; M, the shaft; M, the bevel driving wheels; P and P, the shafts carrying the conveyor-belt drums; Q, bearings to carry the front drum-shaft; S, side-plates to retain the coal on the conveyor; and T, side-plates to pass the coal over, if desired. By varying the sizes of the gear and chain-wheels, the speed of the conveyor can be regulated to suit practically all circumstances. The inclination of the belt can also be varied by means of the sliding bracket, and the conveyor can be extended some distance further back from the machine, and at a greater inclination, so as to deliver the coal directly into a tub, thus saving it from having to be handled at all at the back of the machine. In cutting downhill, at a steep angle, the conveyor-band can be fitted at intervals with angle-iron ribs, so as to prevent the coal from rolling back to the face of the heading. This conveyor has not been practically tested in the mine; but, when this takes place, the writer will furnish a supplementary account of the results obtained.

The double machines, for a cut 9 feet wide and 5 feet 4 inches high, are fitted with cylinders, 10 inches in diameter and of 9 inches stroke. The speed of the engine varies from 160 to 200 revolutions per minute, the horsepower varying from 20 to 23. The gearing ratio is 24½ to 1, that is, the engine makes 24½ revolutions to 1 of the cutting arm. The piston-speed is usually about 240 feet per minute, and there are three threads to the inch on the main centre-shaft or feeding screw.

The length of the machine from the back gear to the front wings is 8 feet 4 inches; the width of the machine is 5 feet; the length of the centre screw-shaft is 10 feet 9 inches; and the total weight of the machine, including the conveyor, is a little over 6 tons. The different parts are easily detachable for removal, and the machine can be readily rebuilt in a new position.
The gear-wheels are made of crucible cast-steel; and the cranks, shafts, and main centre-shaft are made of best mild steel: the feed-nut for the last-named being of gun-metal.

The width of the groove cut by the double machine is about 4 inches, and the depth is 2 feet. The coal, however, generally begins to fall off when the groove is cut into a depth of about 9 inches. For use in tough seams, the wings have been made to cut to a depth of 3 feet. There are three cutters (each chisel-shaped) on each wing; and, when working in coal only, a length of 30 feet is often cut without having to change the cutters.

An air-pressure varying from 30 to 50 pounds per square inch is required at the machine for successful working, varying, of course, with the hardness of the material to be cut; and in soft coal, a pressure of 25 pounds at the machine will suffice.

The following diameters of pipes are recommended for carrying the compressed air to the double machines:—300 feet from the air-compressor, 2$\frac{1}{2}$ inches; 1,000 feet, 3 inches; 1,500 feet, 3$\frac{1}{2}$ inches; and 3,000 feet, 4 inches.

In all, eleven double machines have been constructed, all driven by compressed air; and, as regards electric driving, the double machine is much more convenient for its application than the single one. About a year ago, a double machine was made for a cut 8 feet wide and 4 feet high, and fitted with a three-phase motor of 30 horsepower, but it has not yet been tried in actual work. It must, however, be borne in mind that, in driving electrically, single headings would require to be ventilated, or two headings driven with slits between them, as in heading by hand.

The advantages gained by the use of these machines are as follows:—The heading is done in much less time than by hand, and at a much less cost. The workings are opened out quickly, in one-fourth of the time entailed by the use of hand-labour. No explosive is required in most cases. A much larger proportion of round coal, 70 to 80 per cent., is produced, than in hand-heading. There is a great saving in timber. The machine ventilates its own heading for long distances. The roads stand well, being unshaken by explosives, and are driven straight and smooth, thus offering little resistance to the ventilating current. The motive power, compressed air, makes the heading cool and
fresh. The driving of counter-headings and thirls is avoided to a great extent. No rails are required for the machine. The roads are easily turned in any direction, and the machines will work either to the rise or to the dip. The machines combine economy, efficiency and safety, and, in suitable seams, give great satisfaction: the better the seam the greater is the satisfaction given over hand-heading, and the machines will quickly pay for themselves. For special work, they can be constructed of any required strength, and capable of cutting through any material through which it is possible for steel to cut. Skilled labour is not necessary.
LONGITUDINAL-SECTION OF A GATEWAY.

Fig. 3.

Scale, 24 Feet to 1 Inch.

Fig. 4.

Scale, 24 Feet to 1 Inch.
FIG. 1.—Plan of Longwall Workings in Diamond Coal-seam

Scale: 660 Feet to 1 Inch.

FIG. 2—Longitudinal Section of a Gateway.

Scale, 24 Feet to 1 Inch.

FIG. 3.

FIG. 4.

Scale, 24 Feet to 1 Inch.
Fig. 1.—*Insti*

Fig. 7.—Side View

Fig. 13.—Side View

Plate for Attachment of Bull-chains.

Screw Clamp.

Scale, 6 Inches to 1 Inch.

Bulge in Winding-Row.

Scale, 6

12.—End View.

Midland Line
To illustrate M. E. Barracough's "Practical Notes on Winding-rope and Capels."

Fig. 1. - Side View.

Fig. 2. - Front View.

Fig. 3. - Cross-section of Capel.

Fig. 4. - End View.

Fig. 5. - Side View.

Fig. 6. - Plate for Attachment of Bull-chains.

Fig. 7. - Side View.

Fig. 8. - Front View.

Fig. 9. - Side View.

Fig. 10. - Front View.

Fig. 11. - Cross-section of Capel.

Fig. 12. - Side View.

Fig. 13. - Side View.
Fig. 4.—Cross-section of Heading.

Scale, 5 Feet to 1 Inch.

Fig. 5.—Cross-section of Heading.

Feet. Inches.

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<tr>
<th>Material</th>
<th>Foot.</th>
<th>Inch.</th>
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<td>Hard Fire-clay</td>
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<td>Coal, Soft</td>
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<tr>
<td>Dirt</td>
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Fig. 8.—Cross-section of Heading.

Scale, 4 Feet to 1 Inch.

Feet. Inches.

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MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT LOW MOOR, JULY 19TH, 1906.

Mr. T. W. H. MITCHELL, Retiring-President, in the Chair.

The minutes of the previous General Meeting were read and confirmed.

Messrs. H. Baddeley and James Gregory were appointed scrutineers of the balloting-lists for the election of Officers and Council, and also for representatives of the Institute on the Council of The Institution of Mining Engineers for 1906-1907.

The following gentlemen and colliery firms, having been duly nominated, were elected:

Members—
Mr. Dietrich Benthais, Mechanical and Consulting Engineer, Telephone Buildings, Commercial Street, Sheffield.
Mr. Robert Clive, Colliery Manager, Bentley Colliery, Doncaster.
Mr. Thomas Hanson Cockin, Mining Engineer, 120, Harcourt Road, Sheffield.
Mr. Joshua Lister Ingham, Director of Ingham Thornhill Collieries, Blake Hall, Mirfield, S.O., Yorkshire.
Mr. James Thomas Watson, Inspector of Collieries, Wollongong, New South Wales.
Mr. Willie Woodhead, Colliery Manager, Beeston Colliery, Leeds.

Associate Member—
Mr. William Petrie, Mechanical Engineer, Hickleton Main Colliery, Thurnscoe, near Rotherham.

Subscribers—
The Carlton Main Colliery Company, Limited, Colliery Proprietors, Barnsley.
The Mitchell Main Colliery Company, Limited, Colliery Proprietors, Barnsley.
The Annual Report of the Council and the Accounts were read and adopted, as follows:


The Council has pleasure in presenting its Annual Report for the past year to the members of the Institute.

The number of members who have paid their subscriptions for the year is 308. A comparison with the numbers for the year 1904-1905 is shewn in the following table:

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At the date of closing the accounts, subscriptions were due from 13 members.

26 members were elected during the year, namely: 15 members, 2 associate members and 9 students. 18 members have resigned since July 1st, 1905.

The Council regret to have to record the death of four members during the year, namely: Mr. E. Brown, Mr. E. F. D. Mosby, Mr. G. Spooner, and Mr. Hargreaves Walters.

Thirteen subscriptions in arrear for the year 1904-1905 have been paid during the year.

The following table shews the balance of members for the year:

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<tr>
<td>Resignations during 1905-1906</td>
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<td>Total number of subscribing members at June 30th, 1906</td>
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<tr>
<td>Total</td>
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<td>315</td>
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The Council has had the question of increased membership under its consideration. It strongly feels that the usefulness of the Institute might be extended if the number of its members were larger, and urges members to use their influence to secure new members. Steps have also been taken to secure the support of colliery companies, and the Council have pleasure in announcing that five companies have signified their intention of subscribing to the funds of the Institute.

The balance at the bank on July 1st, 1905, was £243 1s. 11½d., of which £160 has been invested in Great Northern Railway 4 per cent. guaranteed stock at a cost of £196 2s. 10d. The balance at the bank for the year just passed is £46 7s. 5d., and the cash in the Treasurer's hands, £2 12s. 9d.

The Annual Dinner was held at Barnsley on November 8th, 1905, at which 110 members and guests were present. After dinner, the members were entertained at an "At Home" at the invitation of the President (Mr. T. W. H. Mitchell).

Four meetings were held during the year, including a joint meeting with the Midland Counties Institution of Mining Engineers. At these meetings the following papers have been read:

"The Reavel Air-compressor at Work." By Mr. W. Price Abell.
"Supplementary Remarks on Systematic Timbering at Emley Moor Collieries." By Mr. H. Baddeley.
"Practical Notes on Ropes and Capels." By Mr. E. Barraclough.
"'Black Ends,' their Cause, Cost and Cure." By Mr. T. Beach.
"The Stanley Double Heading Machine." By Mr. Arthur Hall.
"An Account of Sinking and Tubbing at the Methley Junction Colliery, with a description of a Cast-iron Dam to resist Outbursts of Water." By Mr. I. Hodges.
"Further Notes on Capels for Winding-ropes." By Mr. T. W. H. Mitchell.

The papers read were of a thoroughly practical character, and dealt with subjects of great importance and interest. The number of papers is smaller than last year, when ten papers were read. This is partly due to the fact that one meeting was given over to the discussion of papers only, at which, in accordance with the resolution of the Council of May 23rd, 1905, Mr. W. E. Garforth introduced a discussion on systematic timbering and methods of controlling the roof in longwall working. The joint meeting was largely attended, and papers of considerable interest were read and discussed.
Dr. The Treasurer (Mr. L. T. O'Shea) in Account with the Midland Institute of Mining, Civil and Mechanical Engineers, 1905-1906.

<table>
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<td>M. H. HABERSON</td>
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<td>THOMAS GILL</td>
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June 30th, 1906.

By The Institution of Mining Engineers:—

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**ACCOUNTS.**

**June 30th, 1906.**

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  1 Narrative of Gas Outbursts ... 0 1 0 |
  28 copies of North of England Institute Report on Mechanical Coal-cutting ... 4 4 0 |
  Less Life Members' Subscriptions at that date ... 28 10 0 |
  Less Transferred from Income account ... 1 2 10 1/2 |
| £680 19 0 | | | |

By Cash at bank ... ... ... ... 46 7 5 |
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Less depreciation written off ... 3 8 0 |
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Value of 116 copies of Committee's Report on Safety-lamps, at 1s. ... ... ... ... 5 16 0 |
Value of 16 copies of Report of French Commission on Use of Explosives, at 3s. ... ... ... 2 8 0 |
Value of 9 copies of Report of the Prussian Commission on Falls of Stone, at 1s. ... ... ... 0 9 0 |
Value of 28 copies of North of England Institute Report on Mechanical Coal-cutting, at 3s. ... ... ... 4 4 0 |
Outstanding Subscriptions (1901-1905) received since June 30th, 1905 ... ... ... 19 10 0 |

Examined and found correct,

M. H. HABERSHON,

THOMAS GILL,

AUDITORS.

£680 19 0
The question of the delay that exists in the publication of
the reports of Institute meetings has engaged the attention of
the Council during the past year. To avoid postponing the dis-
cussion of papers until they have appeared in the Transactions,
advance-copies of the papers to be read at the meetings have
been sent to every member whenever possible. This has entailed
considerable expense in postage and extra printing; the expense
in postage would be avoided, if members contributing papers
would send the manuscript to the Secretary at least one month
before the meeting. With the object of preventing the delay in
the future the Council has given its hearty support to the Council
of the Midland Counties Institution of Mining Engineers in its
action in bringing this matter before the Council of The Insti-
tution of Mining Engineers.

The Report of the Committee of the North of England Insti-
tute of Mining and Mechanical Engineers on Mechanical Coal-
cutting was published during the year. As 67 applications for
copies were made by members, the Council purchased 100 copies
and distributed the 67 copies at cost price.

The Sections Committee is proceeding with the work of edit-
ing the sections supplied by the members, and the Council is
pleased to report that the Director of the Geological Survey and
Museum has consented to publish the sections of the Notting-
hamshire and Derbyshire coal-fields in the same volume with
the Yorkshire sections. As mentioned in last year's report, the
Council of the Midland Counties Institution of Mining Engineers
has consented to assist in this matter.

A complete catalogue of the books in the Library has been
made, but the Council regret that the funds of the Institute do
not permit of its being published.

A number of books have been presented to the Library during
the year, and the Council tenders its hearty thanks to the donors.

During the year, £10 10s. was offered anonymously to the
Council for prizes for the best essay on "The Most Suitable
Form of Guides for Cages for winding Coal from Deep Shafts
(1,500 feet and deeper)." The following prizes were offered:—
(1) £4 4s. for members of class a (members), (2) £3 3s. for
members of class d (associates), and (3) £3 3s. for members of
class c (students). The number of essays received were: class
a, 1; class d, 0; and class c, 6. Messrs. W. E. Garforth, W. H.
Chambers and J. R. R. Wilson were appointed assessors to make the awards. They reported that two of the essays contributed by students were worthy of prizes, and recommended that the associate's prize for which there was no candidate should be awarded to the student candidate whose essay was placed second in order of merit. The following prizes were awarded:—First prize for essay by "Vernier," Mr. Norman W. Routledge; and second prize for essay by "Scotsman," Mr. Augustus John Kennedy. The Council, in thanking the donor for his generous offer, begs to assure him that by his action he has rendered a valuable service to the Institute, in encouraging study and research among its members.

A vote of thanks was passed to the examining committee, consisting of Mr. W. E. Garforth, Mr. J. R. R. Wilson, and Mr. W. H. Chambers.

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ELECTION OF OFFICERS AND COUNCIL, 1906-1907.

The Scrutineers reported the result of the ballot, as follows:—

President: 
Mr. J. R. Robinson Wilson.

Vice-Presidents:  
Mr. I. Hodges.  |  Mr. J. L. Marshall.  |  Mr. W. Walker.

Councillors:
Mr. J. E. Chambers.  |  Mr. M. H. Habershon.  |  Mr. E. W. Thirkell.
Mr. H. St. J. Durnford.  |  Mr. Walter Hardreaves.  |  Mr. G. R. Thompson.
Mr. J. J. Eley.  |  Mr. R. Rowand.  |  Mr. W. Washington.
Mr. Thomas Gill.  |  Mr. T. Stubbs.  |  Mr. A. Woodhead.

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Mr. W. E. Garforth.  |  Mr. H. B. Nash.  |  Mr. J. R. R. Wilson.
Mr. I. Hodges.  |  Mr. J. Nevin.

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Mr. J. R. Robinson Wilson, in returning thanks for his election, said that he took it as the greatest honour that the members could confer upon him. He could also accept it as an indication
that one of H.M. inspector of mines, in spite of the trammels of his office, had the same interests as themselves; the chief of them being the progress of scientific mining. He ventured to hope, and thought it was a laudable ambition, that his term of office might be a record one; and he would like to feel at its close that some progress had been made, that the membership had increased, and that they had done good work. There was no question that in that district they had some of the finest types of collieries, and he need hardly say before that meeting, that they had also some of the most skilled engineers. If they, as individuals, would take upon themselves the responsibility of looking after the welfare of the Institute, they were bound to succeed and become second to none.

The President (Mr. J. R. Robinson Wilson) moved a vote of thanks to Mr. T. W. H. Mitchell for his services as president during the past two years. The name of Mitchell had been honourably associated with the Institute for a great number of years. Father and son had always had its interests at heart, and the very least they could do on that occasion was to place on record their feeling of hearty thanks.

Mr. W. E. Garforth seconded the resolution, which was carried.

Mr. T. W. H. Mitchell said that whatever he had done in connexion with the Institute had been a labour of pleasure. He felt confident that it would go on and prosper, if the members would only do as the President had suggested. He heartily appreciated all that had been said in regard to what he had tried to do, and was thankful that the members were satisfied.

Mr. R. Cremer then read the following paper on "The Pneumatogen: the Self-generating Rescue-apparatus, compared with Other Types":—
THE PNEUMATOGEN: THE SELF-GENERATING RESCUE-APPARATUS, COMPARED WITH OTHER TYPES.

By R. CREMER.

The principle on which modern rescue-apparatus are constructed, consists in purifying the exhaled air of the user by means of suitable chemicals for absorbing the carbonic acid and moisture, and by restoring the consumed oxygen from receptacles containing the gas in a compressed state.

For storing the gas, more or less heavy and cumbersome steel cylinders are required, and in order to obtain satisfactory results it has been found necessary to add numerous mechanical appliances, which not only considerably increase the weight, but also add more or less to the complication of the apparatus, as is seen in the better known types, such as the Shamrock, Giersberg and Draeger apparatus.

Ever since the invention of forms of apparatus in which compressed oxygen is used and especially since they took their present form, efforts have been made to find a substitute for compressed oxygen, by using chemical compounds which would absorb the carbonic acid of the breath and simultaneously generate oxygen.

As described in the early literature on the subject, and as also mentioned by Mr. G. A. Meyer in his paper on "Rescue-apparatus"* read before The Institution of Mining Engineers last month, Prof. Théodore Schwann, of Liège, many years ago endeavoured to construct an apparatus in which hydrated barium peroxide acted as the oxygen-generator and air-filtering material; but he failed to obtain any satisfactory results by this method, and had to adopt the use of compressed oxygen, according to the principle introduced by Messrs. V. Regnault and J. Reiset.† This apparatus was the forerunner of the various forms of breath-

ing apparatus of the present day, in which compressed oxygen is used, and it led later to the construction of the Fleuss apparatus. After the explosion at the Karwin collieries ten years ago, the question of life-saving apparatus was revived by Mr. Walcher von Uysdal and from that time rescue-apparatus had become more or less an indispensable part of the equipment of collieries and other mines. By the exertions of Mr. Uysdal, together with those of Prof. G. Gärtner, of Vienna, and Mr. H. Rössner, the manager of the Karwin collieries, the pneumatophore* was presented to the mining world, and in a short time was adopted by many collieries: subsequently, by an order of the Austrian Mining Department, all collieries in the Ostrau-Karwin coal-district were compelled to provide the apparatus. Soon endeavours were made to improve the original form of the pneumatophore, and by the energetic action of Mr. J. Mayer and Mr. F. Wanz in Austria, Mr. G. A. Meyer, of Berlin, Mr. B. Draeger, of Lubeck, and others, various types of apparatus were devised.

The unavoidable disadvantages arising from the use of compressed oxygen, however, revived the idea of supplying this gas by generating it by chemical means brought about by the respiration of the wearer.

In the apparatus of Messrs. A. Desgrez and V. Balthazard,† alkaline peroxides were periodically projected into water by means of clock-work or an electric accumulator, the solution produced serving to absorb the carbonic acid. This apparatus was heavy, of very complicated construction, expensive, and of low efficiency. The apparatus of Mr. G. F. Jaubert,‡ in which also peroxide tabloids were used, did not give satisfactory results, as the necessary reactions only lasted for a short period.

However, with the primary object of constructing an apparatus which could be used by the miner for self-rescue purposes, Prof. Dr. Max Bamberger and Dr. Friedrich Böck, of Vienna, succeeded, after four years' extensive and energetic experimental work, in producing the pneumatogen, which is based on a new and exceedingly simple principle, regarding which the

following extract is given from their paper on "Apparatus for Self-rescue from Irrespirable Gases":—

The first considerations that we had in mind were the following: lightness, compactness, simplicity in handling, absolute guarantee of security in use, durability, and low cost. To avoid the disadvantages of compressed oxygen we endeavoured to produce the oxygen in such quantities as are required for breathing by chemical means; and at the same time avoid the use of heavy and complicated valves and pressure-regulators.” Like Messrs. Balthazard and Desgrez, these inventors first used sodium peroxide in the form of sticks or balls, which were thrown, by mechanical appliances, into water at certain intervals. The exhaled air was made to pass over the sodium peroxide, which absorbed the carbonic acid, by means of mica-valves in a manner similar to that adopted in the pneumatophore.

One great disadvantage of this method of generating the oxygen was the high temperature produced by the chemical reaction, in consequence of which the air was returned to the user at rather a high temperature. Whilst Messrs. Desgrez and Balthazard met this drawback by using low boiling methyl chloride to cool the air, the inventors of the pneumatogen considered this method unsuitable to the conditions laid down by them. Another disadvantage was that, at the commencement of breathing, the absorption of the carbonic acid was far from satisfactory, because the caustic-soda solution was dilute and less active.

In order to absorb the large amount of moisture and the last traces of carbonic acid in the regenerated air, the inventors adopted, instead of the solution, solid sodium peroxide as the absorbing material and the oxygen-generator simultaneously. Thus great simplicity was attained, but the result was hardly practical: because, in the first instance, it was not easy to obtain the chemicals in a proper size and porous state, and, in the second, it was necessary to divide the apparatus into two parts, namely, the absorption and air-regenerating chamber, and the oxygen-generating chamber.

Later the inventors found that the production of oxygen was considerably greater, and the construction of the appar-
The reactions which take place may be expressed as follows:

I. \[ \text{KNaO}_3 + \text{H}_2\text{O} = \text{KHO} + \text{NaHO} + \text{O}_2. \]
II. \[ \text{CO}_2 + \text{KHO} + \text{NaHO} = \text{KNaCO}_3 + \text{H}_2\text{O}. \]
III. \[ \text{CO}_2 + \text{KNaO}_3 = \text{KNaCO}_3 + \text{O}_2. \]

From which it is seen that the oxygen set free is not only equal to the carbonic acid absorbed, but a further quantity is liberated by the absorption of the water, and the exhaled air becomes richer in oxygen, a result which, with reference to small leakages or diffusion-processes, is well worthy of consideration.

A vertical section of the generator of the rescue-apparatus constructed after this principle is shown in Fig. 1 (Plate II.), whilst in Figs. 13 to 15, the pneumatogen I. type, and in Figs. 16 to 19, the pneumatogen II. type are reproduced.

The essential part of the apparatus, the generating cartridge, shown in Fig. 1 (Plate II.), is constructed as follows:—The potassium-sodium peroxide is placed in a cylindrical metal box, about 3 inches in diameter and 4 inches high, having a neck at either end. These are hermetically sealed by means of thin lead plates, so that no air can come into contact with the chemicals. In the chief space of the tin, \( \frac{1}{2} \) pound of potassium-sodium peroxide, B, is held between two wire-gauzes, C; between B and the upper cover of the box a filter and distributing device, F, is provided, consisting of a series of perforated asbestos-plates, which are so arranged that not only is the air-current uniformly distributed over the whole layer of peroxide, B, but also any particles of the latter that might be carried away by the air are retained with almost absolute certainty.

A light framework, C, of perforated sheet-metal, within the layer of peroxide, prevents the latter from clinkering, and ensures the easy passage of the air for as long as possible a period during the time that the apparatus is in use.
By breaking the lead seals, and at the same time making a tight connection with the respiratory organs of the user on the one hand, and the breathing-bag on the other, communication is established with the contents of the cartridge and thus the apparatus is ready for use.

In the first type of the pneumatogen, intended and constructed for self-rescue, as shown in Figs. 13 to 15, the cartridge (as described) is held by a frame consisting of two movable parts: each of these parts carries perforating crowns, which are so placed that they enter into the necks of the cartridges and break the lead seals, whilst tight connections between the upper and lower parts are established by means of indiarubber washers. The upper crown is provided with a hose, S, fitted with mouth-piece and saliva-catcher; and the lower crown with a bag, H. The frame and cartridge are covered with a mantle, I, of non-conducting material. Cartridges containing \( \frac{1}{2} \) pound of peroxide will permit of the apparatus being used in irrespirable atmospheres for at least 45 minutes when the user walks quickly or works; and for 90 minutes or more, when the user keeps quiet or walks slowly.

The whole apparatus is kept folded together in a tin protecting case ready for use. The weight of the apparatus is 2 pounds, and that of the tin 1 pound 4 ounces. The apparatus can be kept inside the tin for many years: an occasional examin-
ation of the indiarubber parts and the lead seals only being necessary.

To use the apparatus, the two parts of the frame are pushed vigorously together as shown in Fig. 14, whereby the cartridge is opened, the two joints made perfectly tight and the connection with the mouthpiece and the bag established. The apparatus is then hung over the neck, and, after putting the mouthpiece and nose-clamp into position, breathing can commence.

The exhaled air, entering through the hose, S, distributes itself in the asbestos-filter, becomes regenerated by passing through the layer of peroxide, and leaves the cartridge through the lower perforated crown, underneath which a small dust-collecting box is attached, in which any peroxide dust is re-

Fig. 14.—Pneumatogen : I. Type.
tained. From this box the air enters the bag, H, which is made of best Para indiarubber, and the air returns in the same way when exhalation takes place.

Cleaning and recharging of the apparatus is equally simple. As shown in Fig. 15, the insulating covering and frame is taken into two parts, and the exhausted cartridge is changed for a newly charged one.

The excellent results obtained with the first type of this apparatus encouraged the inventors to design the second type. To enable the wearer to use the apparatus for longer periods when heavy work had to be carried out, it was found, for various reasons, that a simple increase of the dimensions of the first type of the pneumatogen did not give satisfactory results. Dr. Bamberger and Dr. Böck, therefore, designed the second type of their pneu-
matogen, in which three cartridges of the same dimensions and contents as in the first type are placed together side by side in a protecting case made of aluminium, together with a frame consisting substantially of two transverse tubes connected by a yoke. Both transverse tubes carry three perforating crowns for the three cartridges, Fig. 16. To the upper transverse tube are attached two flexible hoses carrying the mouthpiece, the saliva-catcher, and the nose-clamp, whilst the lower transverse tube is connected by an aluminium-tube with the breathing-bag, which is made in the form of a jacket as shown in Fig. 16. When using the apparatus the lead seals of the cartridges are perforated by turning the screw, R, whereby all the joints are hermetically closed in the same way as in the first type. The wearer then puts on the jacket, AR, and the apparatus is hung on the neck and fastened in position by waistbands. In order to test the apparatus as to its tightness, it is advisable to blow through the same by closing the outlet-opening with one hand as shown in Fig. 17. The breathing-bag is made of a special strong and reliable material, and lined inside with indiarubber. The mouthpiece and the nose-clamp are the same as those of the first type of the pneumatogen.

The cleaning and recharging of this apparatus is carried out in the same simple manner as that already described.

The apparatus is constructed in such a way that, during work, the breathing takes place simultaneously through the two outer boxes, whilst the third box is kept in reserve for retreat. When the first two cartridges have been exhausted,
of which the user is warned by the high resistance offered to breathing, the third box is put into action by pulling outward the handle G (Fig. 18), whereby a sliding tube inside the upper transverse tube effects a connection with the third cartridge.

The apparatus containing three cartridges, each filled with $\frac{1}{2}$ pound of potassium-sodium peroxide, permits the user to remain in irrespirable gases for 120 minutes when heavy work is done by the wearer; 80 minutes are counted for work, and 40 for the retreat. With less work, the time of using increases to 3 or 4 hours.

The same apparatus, provided with cartridges containing 10½ ounces (330 grammes), permits a comparatively longer breathing time, whilst the dimensions of the apparatus are only increased 1 inch in length. The weight of the complete apparatus provided with three cartridges, each containing $\frac{1}{2}$ pound of peroxide, amounts to 8½ pounds, which is distributed over the breast and back.

It is evident that when the pneumatogen is brought into use the breathing-bags of both types are almost empty. It is therefore necessary to fill them with a quantity of air equal to that contained in the lungs before the apparatus is brought into action. In the first type this is effected by providing a spring frame inside the bag, so that when the latter is taken out of the tin, the bag inflates and fills itself with the necessary volume of air automatically.
The first tests made with the pneumatogen showed that at first the generation of oxygen from the peroxide is rather slow, as the reaction does not properly commence until a certain temperature is reached. During the first few minutes, therefore, the user must avoid any great exertion, but should breathe quietly, whilst sitting, standing or slowly walking.

With the second type of working apparatus, naturally the time, before the reaction of the peroxide becomes prompt and energetic, is comparatively longer. To avoid any waiting, and to enable the user to quickly begin to walk or carry out heavy work, it is advisable to fill the bag previously with a small quantity of oxygen (500 to 800 cubic inches). This is most simply done by the use of the apparatus shown in Fig. 19, which consists of a large receptacle, St, containing oxygen under high pressure, to which is attached a smaller empty cylinder, St, holding 500 to 800 cubic inches of oxygen at low pressure. By opening the valve, V1, the oxygen enters the cylinder, St, under a pressure of 7 atmospheres, which is indicated on the manometer, M1 (at a pressure of 8 atmospheres, the safety-valve, S, will come into action). After closing the valve, V1, and opening the valve, V2, which is connected by means of a flexible pipe, FR, with the breathing-bag, 500 to 800 cubic inches of oxygen enter at ordinary atmospheric pressure.
A number of apparatus can be filled simultaneously by connecting them at the same time with the oxygen-cylinder.

If compressed oxygen is not available, a specially rapid oxygen-producer may be used, as shown in Fig. 20, in which oxygen is generated from potassium-sodium peroxide by the action of water. The oxygen enters through the tube, F, into the breathing-bag. The oxygen can also be introduced through the mouthpiece.

Fig. 19.—Pneumatogen : II. Type : charging the Breathing-bag.

Although the temperature of the inhaled air in the pneumatogen is found by measurements to be fairly high, due to the heat generated by the chemical action, this does not interfere with the comfort of the user, owing to the almost completely dry state of the regenerated air. Consequently, in the pneumatogen the special cooling appliances found necessary in other forms of apparatus are dispensed with.
In the types of apparatus in which compressed oxygen is used, it is necessary to regulate the supply of oxygen so that it escapes in a constant and regular stream during the whole time that the apparatus is in use, whether the user is carrying out heavy work or whether he remains quiet. In the pneumatogen, the regulation of the oxygen-supply is automatic, so that the quantity of oxygen produced is proportional to the wearer’s requirements. An increase in the quantity of oxygen required is always preceded by an increased development of carbonic acid and steam, which, reacting on the peroxide, generates a larger quantity of oxygen. This accounts for the difference in the time during which the pneumatogen can be worn, according as the wearer is at rest or actively working.

An important advantage possessed by the pneumatogen is the abolition of all valves, especially pressure-reducing valves,
injector-valves, etc., which form an unavoidable supplement to an apparatus using compressed oxygen. If one considers the exceedingly great differences in pressure prevailing in the latter apparatus, it is evident that as the pressure of oxygen, amounting to over 1,700 pounds, has to be reduced to a few pounds by means of a finely made valve with minute holes, there is risk of danger even to the skilled and experienced user, and it is difficult to imagine how the auxiliary valves provided can decrease such danger, if by accident the supply of oxygen is cut off; as for instance, small particles of dust may be carried over by the oxygen, block the pressure-reducing valve, and so cut off the oxygen-supply. In such cases, the user, overcome by excitement through the increasing want of oxygen, may not be able to manipulate such auxiliary valves. Amongst others, Messrs. J. Mayer and Köhler,* of Austria, both mining engineers of great experience in the development of rescue-apparatus, have repeatedly referred to the danger entailed by the use of such valves. Of the various cases known to the writer, in which most serious consequences resulted from the failure of the valves, he would only refer to the sad case at Courrières, where, during the rescue-work, a member of the rescue-party using a Draeger apparatus lost his life. The man was found suffocated, with the helmet detached lying beside him: and, considering the whole circumstances of the accident, it seems probable that his death was caused through some failure of the valves.

Referring to the use of nose-clips, the writer, without discussing the relative merits of helmets, masks or nose-clips, would state that the objection raised against nose-clips, that they fall off when the wearer perspires, has been overcome in the case

of the new pneumatogen nose-clip. This nose-clip (Fig. 21) is so constructed that it can be regulated to any form of nose, and by means of sticking plaster inside the clip, can be prevented from slipping off.

In order to give the members an idea of the most important results that Dr. Bamberger and Dr. Böck have attained by the construction of their pneumatogen, the writer will refer to the construction and development of those forms of modern rescue-apparatus which have been approved and adopted by the mining world.

The latest type of rescue-apparatus which Mr. W. E. Garforth described before The Institution of Mining Engineers last month is not included, as the writer has been unable to obtain the necessary information during the short time that he had to prepare this paper. He has also omitted the Fleuss apparatus as he has failed to ascertain whether in its present form it has been tested or adopted.

Figs. 2 to 10 (Plate II.) represent diagrammatic sketches of the principal forms of apparatus, all of which are based on the use of compressed oxygen and of various alkanes for absorbing carbonic acid. The illustrations show how the apparatus, from the plain and simple form of the pneumatophore, become more and more complex through the endeavour to bring them to a more perfect working state.

Fig. 2 (Plate II.) shows the original form of the pneumatophore, with its essential parts, consisting of a breathing-bag, containing one oxygen-cylinder, carried on the chest. The absorbing material, consisting of a solution of caustic soda, contained in the lower part of the bag, is poured from time to time by the user over a net made of cotton-wool, distributed over the inner side of the bag. There is only one valve for regulating the oxygen-supply, which is opened and closed by the user as occasion requires.

Fig. 3 (Plate II.) represents the Shamrock type of the pneumatophore, with two oxygen-cylinders carried on the back, one provided for actual work, and the other for the retreat. The cotton-wool net is replaced by loofa-pillows. There are two valves for the opening and closing of the steel cylinders containing the oxygen.
In Fig. 4 (Plate II.), the J. Mayer helmet-apparatus is represented. In this type, the solution of caustic soda is replaced by solid material in the breathing-bag, covering the neck of the bearer; and the direction of the air is regulated by two mica-valves.

In the Giersberg apparatus, shown in Fig. 5 (Plate II.), the valves of the Mayer apparatus have been abolished; and the air is forced to circulate, by dividing the bag into two halves. The absorbing material is soda-lime, stored in a drum which is carried on the back.

In the Giersberg apparatus, 1901 model, Fig. 6 (Plate II.), an injector-valve for the automatic circulation of the oxygen and regenerated air, and a pressure-reducing valve for obtaining a constant and equal supply of oxygen automatically, are used for the first time; while a manometer indicates the pressure in the cylinders at any time. The absorbing material is soda-lime. Two oxygen-cylinders are carried in the same way as with the pneumatophore type (Fig. 3).

In the Shamrock-Giersberg apparatus, 1903 model (Fig. 7, Plate II.), the absorbing material is placed inside the breathing-bag instead of being carried on the back, so that the exhaled air has a shorter distance to traverse before being regenerated. Underneath this, material for absorbing the alkaline solution is fixed. As the oxygen-supply is regulated to continuously supply the maximum quantity required by the user when working hard, frequently more oxygen than necessary is supplied. To avoid the danger and inconvenience caused by this excess of oxygen a discharge-valve became necessary.* Three oxygen-cylinders are used instead of two;† whilst the reducing valve is provided with a safety-discharge valve. Behind the discharge-valve, an auxiliary valve is inserted, to enable the oxygen-supply to be shut off without operating the valves of the oxygen-cylinders, and the suction-pipe for the exhaled and regenerated air is carried to the bottom of the breathing-bag.

Fig. 8 (Plate II.) represents the Shamrock-Giersberg apparatus, 1904 type, in which the 1903 type is further modi-

† Ibid.
fied by connecting the oxygen-supply pipe close to the mouthpiece, in order to supply fresh air to the user more readily, and by introducing a tube by which the exhaled air is more effectually conducted to the absorbing material. The carbonic-acid absorbing regenerator is considerably enlarged and an arrangement for cooling the exhaled air after regeneration, consisting of a metal pipe about 15 feet long, and placed round the oxygen-cylinders, is added.

The latest model of the Shamrock-Giersberg apparatus, the 1906 type, is shown in Fig. 9 (Plate II.), and differs from the previous type mainly in the addition of a special device for the absorption of moisture and caustic-soda dust, which was found necessary, because in many cases the cooling pipes and injector became choked by the moisture and dust carried over from the breathing-bag. This device consists of a pipe filled with kieselguhr (infusorial earth) and connected longitudinally with the lower horizontal pipe of the cooling arrangement. Two oxygen-cylinders of larger dimensions have been adopted. A device for warning the wearer when the oxygen-supply is running out has been added.

Regarding the Draeger apparatus, which more or less resembles the Giersberg and Shamrock-Giersberg types, the writer will only refer to the latest type, as shown in Fig. 10 (Plate II.). In this type, a special regenerator, in the shape of cartridges, charged with caustic potash in a granulated form instead of sticks, is carried on the back: whilst a surface-cooler, and two breathing-bags, one for the air to be inhaled, and the other for the exhaled air, are added. Mica-valves are fixed inside the tubes connecting the helmet with the breathing-bags. The two breathing-bags are connected together by a small tube in order to enable the user, in cases of emergency, to inhale the contents of both bags. There are two oxygen-cylinders of large dimensions, one of which is used as a reserve; and an automatic alarm, which comes into operation at certain intervals, is provided. A discharge-valve is fitted on a specially constructed mouthpiece, or to the helmet, if that form is used.

Fig. 11 (Plate II.) represents the first type, and Fig. 12, the second type of the pneumatogen.
The writer has compared the various types of modern rescue-apparatus in the accompanying table, in which the figures quoted are taken from data and results obtained in practice. The results of the comparisons made in the table are briefly as follows:—

The types of apparatus using compressed oxygen are not absolutely reliable, being complicated in construction and fitted with numerous valves and joints, some of which are subject to high pressure; the pneumatogen, however, is free from such drawbacks. The oxygen is generated in the pneumatogen, according to requirements, and the supply is reliable. The pneumatogen of the second type weighs about one fourth, and of the first type about one-eighteenth of the other forms of apparatus. The warning device is simple and effective. The price of the pneumatogen of the first type is considerably less than half that of the second type, and only one-ninth of that of the Shamrock apparatus. The cost of using the pneumatogen is slightly higher than that of other forms. This, however, will be reduced so soon as the potassium-sodium peroxide is manufactured on a large scale, and this can be looked for at an early date. It should also be taken into consideration that with the Giersberg, Shamrock and Draeger apparatus, considerable wear-and-tear, entailing costly repairs, are unavoidable, as the valves and sensitive metal parts are much affected by oxidation, caustic potash and oxygen.

None of the parts of the pneumatogen are subjected to high pressure, and the length of connecting piping is reduced to 6 inches. The whole distance travelled by the generated oxygen and the exhaled air in process of regeneration, is only 18 to 20 inches.

It has been stated that the use of alkaline peroxides in the pneumatogen might give rise to the ignition of combustible materials, but such a danger is avoided by keeping the peroxide in hermetically sealed cases, when stored ready for use in the apparatus. It may be pointed out on the other hand that the danger attending the handling of oxygen, compressed under the enormous pressure of more than 1,700 pounds per square inch, has often been referred to by various writers.*

### Table I.—Summary of the Details of Construction of the Various Types Station of the Westphalian Mine.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Apparatus</th>
<th>Draeger Helmet</th>
<th>Giersberg Helmet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Time during which the apparatus can be used.</td>
<td>2 hours, including heavy working.</td>
<td>Apparatus in present form unsuitable for long work in irrespirable gases.*</td>
</tr>
<tr>
<td>2</td>
<td>Reliability.</td>
<td>Not reliable, owing to reducing valves.</td>
<td>Not reliable, owing to reducing valves.</td>
</tr>
<tr>
<td>3</td>
<td>Valves.</td>
<td>1 reducing, 1 injector, 2 discharge, 2 oxygen admission and shut-off valves, 2 mica valves in breathing tubes and 1 manometer.</td>
<td>1 reducing, 1 injector, 2 discharge, 2 oxygen admission and shut-off valves and manometer.</td>
</tr>
<tr>
<td>4</td>
<td>Oxygen-cylinders.</td>
<td>2 cylinders.</td>
<td>2 cylinders.</td>
</tr>
<tr>
<td>5</td>
<td>Cooling of exhaled air.</td>
<td>Surface-cooler.</td>
<td>Tube-cooler.</td>
</tr>
<tr>
<td>6</td>
<td>Regulation of oxygen-supply.</td>
<td>Constant supply; for regulating, reducing, and discharge, valve used.</td>
<td>Constant supply; for regulating, reducing and discharge, valve used.</td>
</tr>
<tr>
<td>7</td>
<td>Device for warning, when the apparatus is becoming exhausted.</td>
<td>Automatic acoustic signals at certain intervals.</td>
<td>User has to work to his watch, or manometer placed on his back has to be observed by his companions.</td>
</tr>
<tr>
<td>9</td>
<td>Weight of apparatus.</td>
<td>36 lbs.</td>
<td>38 lbs.</td>
</tr>
<tr>
<td>10</td>
<td>Method of carrying the apparatus.</td>
<td>The whole apparatus, with numerous joints, carried on the back, and two breathing-bags on the breast.</td>
<td>Like the Draeger.</td>
</tr>
<tr>
<td>11</td>
<td>Price of the apparatus.</td>
<td>£16 16s. Od.</td>
<td>£13 15s. Od.</td>
</tr>
<tr>
<td>12</td>
<td>Working cost for 2 hours.</td>
<td>6s. 10d.</td>
<td>.....</td>
</tr>
</tbody>
</table>

## THE PNEUMATOGEN.

### OF RESCUE-APPARATUS TESTED AT THE RESCUE-APPARATUS TESTING AND TRAINING OWNERS' ASSOCIATION AT BOCHUM.

<table>
<thead>
<tr>
<th>No.</th>
<th>Shamrock-Giersberg.</th>
<th>Pneumato­gen II.</th>
<th>Pneumato­gen I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 hours, including heavy working under the same conditions as the Draeger.</td>
<td>2 hours, including heavy working under the same conditions as the two previous apparatus.</td>
<td>80 minutes, including almost constant work (fixing pipes, etc.)</td>
</tr>
<tr>
<td>2</td>
<td>Not reliable, owing to reducing valves.</td>
<td>Absolutely reliable, because the working does not depend on mechanical appliances. Smallest diameter of inlets and outlets, 1/4 inch.</td>
<td>Same as pneumato­gen II.</td>
</tr>
<tr>
<td>3</td>
<td>1 reducing, 1 injector, 2 discharge, 1 auxiliary, 2 oxygen admission and shut-off valves and 1 manometer.</td>
<td>No valves.</td>
<td>No valves.</td>
</tr>
<tr>
<td>4</td>
<td>2 cylinders.</td>
<td>No cylinders.</td>
<td>No cylinders.</td>
</tr>
<tr>
<td>5</td>
<td>Tube-cooler with moisture and caustic soda-dust absorber.</td>
<td>No cooler required.</td>
<td>No cooler required.</td>
</tr>
<tr>
<td>6</td>
<td>Constant supply; for regulating, reducing and discharge, valve used.</td>
<td>Oxygen generated automatically, according to consumption. No valves required.</td>
<td>Same as pneumato­gen II. (For self-rescue purposes.)</td>
</tr>
<tr>
<td>7</td>
<td>Same as the Draeger.</td>
<td>One cartridge reserved for retreat.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Injector and tube.</td>
<td>No air-circulation device required.</td>
<td>No air-circulation device required.</td>
</tr>
<tr>
<td>9</td>
<td>35 lbs.</td>
<td>8½ lbs.</td>
<td>2 lbs.</td>
</tr>
<tr>
<td>10</td>
<td>On the back, the whole oxygen-apparatus with numerous valve-joints, and one large breathing bag in front.</td>
<td>On the back, perfectly smooth as a jacket. Regenerator in front, to hand and in sight. Weight divided equally between the chest and the back.</td>
<td>The whole apparatus with the breathing bag is carried on the chest.</td>
</tr>
<tr>
<td>11</td>
<td>£19 17s. 6d.</td>
<td>£7 10s. 0d.</td>
<td>£2 5s. 0d.</td>
</tr>
<tr>
<td>12</td>
<td>5s. 0d.</td>
<td>6s. 10d. *</td>
<td>3s. 4d.</td>
</tr>
</tbody>
</table>

* Cartridges for retreat are not required for training purposes.
The writer would especially mention that the pneumatogen has long since passed out of the experimental stage, and has been adopted extensively in the mines of Austria and other countries. It was used at the Courrières mines, although, unfortunately, this was only possible after the German rescue-party had left.

The practical value of the first type of the pneumatogen, which is essentially for self-rescue, has yet to be proved. It affords, however, a most valuable apparatus, enabling men to pass through noxious gases in mines as well as in other industrial establishments; whilst, owing to its exceedingly small weight (2 pounds), it may be carried by rescue-parties, using the larger working-apparatus, and also used by the rescued persons to pass through those parts and roadways of the mine that are filled with irrespirable gases.

In conclusion, the writer would draw the attention of the members to the recent valuable and interesting report by Prof. H. Grahn, who is in charge of the rescue-training and testing station of the Westphalian Mine-owners' Association, of the Mining School at Bochum, on "Tests with Rescue-apparatus and its Improvements." Prof. Grahn summarizes the results of the tests as follows:

Regarding the forms of oxygen-apparatus, the two types of the Draeger apparatus, and the altered form of apparatus of the Oxygen Works at Berlin (Shamrock type) fitted with reducing valves and easily accessible purifying tubes, have proved quite practicable. The Giersberg helmet-apparatus, in its present form, is unsuitable for use, the tests having shown clearly and distinctly, that, although the helmet is made to fit better, the apparatus cannot be worn for any length of time in an irrespirable atmosphere when physical exertion is necessary. Special interest is attached to the pneumatogen, particularly to the type fitted with three cartridges. It is now evident that the two cartridges, of 12½ ounces (330 grammes) each, are sufficient to allow of the apparatus being used for 2 hours, in a similar manner to other forms of oxygen-apparatus, and after bringing the third (reserve) cartridge into action, for an additional hour (about 80 minutes) when performing light work or walking. Cooling the air is unnecessary, because the high temperature of the air, owing to its dryness, causes no inconvenience to the wearer. The apparatus is completely without valves. The apparatus is of the greatest interest to government and mining officials.

The writer may mention that courses on rescue-work for organizers and trainers of rescue-corps, will be given during the

summer at the Bochum Mining School, and that the collieries in Westphalia, almost without exception, have agreed to take part in them.

The great interest that is being taken in this country in rescue-installations is due in no small degree to the members of this Institute, amongst whom the writer would mention Mr. W. E. Garforth, Mr. W. Blake Walker and Mr. M. H. Habershon; and he hopes that by calling attention to the pneumatogen to have been of some service in the noble work of rescue.

Mr. T. W. H. Mitchell said that the pneumatogen was light, but he was not sure that it was lighter than the apparatus which Mr. Garforth shewed them in London. He felt, however, that it had some small advantage over the other apparatus inasmuch as it had the third cylinder, and a man always knew that, when the two others were done, it was time that he stopped work and returned to fresh air again. He moved a vote of thanks to Mr. Cremer for his paper.

Mr. W. Walker (H.M. Inspector of Mines), in seconding the resolution, said that such papers helped the object that they had in view of discovering the best apparatus for rescue-work. He had had the opportunity of seeing both types of pneumatogen in use at the rescue-station at Tankersley. A man wore the self-rescue type, for 26 minutes, doing light work, such as building a stopping with bricks, and at the end of that time came out of the gallery because the apparatus had become so hot that he thought something was wrong with it. On examination, it was found that the paper round the tin containing the potassium-sodium peroxide was singed and that there was a smell of burning from the apparatus itself. The second type was worn by a man for 42 minutes doing work which required some energy, such as putting up a brattice and sawing hard wood, and he was asked to come out because they could not wait any longer. The apparatus was hot, and the wearer complained of a dry and hot feeling in his throat. Mr. J. McMahon had had it on, and he felt the same thing. The nose-clip, which Mr. Cremer advised, was very efficacious, it could only be got off at the expense of the skin on the man's nose. The great value of this apparatus was its lightness.
If it could be made absolutely reliable, and the defects as to heat remedied, it would be a very useful apparatus.

Mr. J. McMahon said that he had worn the pneumatogen, and had had a good deal of experience with the Giersberg apparatus, and the only defect that he could detect in the former apparatus was the excessive heating. Breathing was simple and easy, and he could do laborious work when using it. If the heat-defect were remedied, the apparatus would be a very practicable one. There was no feeling of fatigue in wearing it, as the weight was only 8 pounds; and this was a great advantage when compared with the weight of the other apparatus, 32 to 37 pounds.

Mr. M. H. Habershon asked Mr. Cremer whether any information had been obtained as to the purity of the oxygen generated by the chemical reaction that he had described.

Prof. G. R. Thompson said that he had estimated the cost of oxygen prepared by Mr. Cremer’s process; and it was 1s. 6d. per cubic foot, as compared with 3d. per cubic foot, the price of the oxygen ordinarily supplied, but the system provided at the same time the absorbent for the carbon dioxide generated in breathing. He agreed that the expense of generating this oxygen was chiefly due to the small demand for potassium-sodium peroxide and that would seem to be the case, for sodium peroxide, a somewhat similar compound used extensively in dyeing, was only a third or a quarter of the cost. If the cost of potassium-sodium peroxide could be proportionally reduced, they would be able to obtain oxygen at a very cheap rate, and the apparatus could be always ready for use. He urged the necessity for cheapening the oxygen-supply from the point of view that a man going to use the apparatus efficiently must use it in practice, and the use in practice must be made as cheap as possible.

Mr. W. E. Garforth supported the resolution of thanks to Mr. Cremer for bringing the paper, and the interesting experiments made by the two German doctors of science, before their notice. He thought that such information helped them very considerably in the solution of a difficult problem which had attracted so much attention, especially since the dreadful accident at the Courrières collieries. He hoped that within the next few
months they would have, from one source or another, a better form of apparatus than those they had been using.

The resolution was carried.

Mr. Cremer said that oxygen produced from these chemicals was absolutely pure, whilst the compressed oxygen supplied by various manufacturers was not always absolutely pure. There was no doubt that the temperature, raised by the oxygen generation, was higher than in other apparatus; but, at the same time, the air was considerably drier, and, therefore, the heat should not be felt so much as in other apparatus, with which it was always necessary to use a special cooling arrangement. The temperature was easily reduced by adopting an arrangement which would cause the air to circulate through an additional pipe attached to the breathing-bag. By introducing two mica-valves, the air could be forced to circulate in the pipe, and this would decrease the temperature enormously. One of the great claims, however, for the pneumatogen was its simplicity, and as soon as the mica-valves were adopted, that simplicity would, to a certain extent, be destroyed. The advantage gained by the lower temperature was not, in the opinion of the inventors, worth the addition of two mica-valves; and in his (Mr. Cremer's) opinion the wearer would, with experience, get accustomed to the slightly higher temperature. Table I. showed the exact costs of using the various apparatus. Prof. Thompson had not considered the cost of the alkalis used in the other apparatus.

The discussion was adjourned.

LOW MOOR IRON-WORKS.

Low Moor iron is made from ironstone, worked in conjunction with the Black Bed coal-seam, which lies just below it; and the coke used for smelting the ironstone is made from the Better Bed coal-seam, which is found 120 feet below the Black Bed seam.

The blast-furnace plant consists of two furnaces of the following dimensions:—(1) Height, 70 feet; bosh, 18 feet; hearth, 8 feet; and throat, 15 feet. (2) Height, 70 feet; bosh, 14 feet;
LOW MOOR IRON-WORKS.

hearth, 7 feet; and throat, 11\(\frac{1}{2}\) feet. These furnaces are capable of producing about 600 tons of cold-blast pig-iron per week. The vertical direct acting blowing-engine has a steam-cylinder, 40 inches in diameter; an air-cylinder, 84 inches in diameter, and a stroke of 5 feet; the steam-pressure is 80 pounds per square inch; and the pressure of the blast, up to 6 pounds per square inch. This engine has been duplicated to meet emergencies.

*Electrical Installation.*—This installation comprises one combined unit consisting of a cross-compound horizontal condensing engine, with double-beat drop-valves for the high-pressure cylinder and Corliss valves on the low-pressure cylinder. When running at 96 revolutions per minute with a boiler-pressure of 160 pounds per square inch, it will develop 550 indicated horsepower. The engine is coupled to a three-phase alternator of 350 kilowatts normal capacity. The power is transmitted to a distance of \(\frac{3}{4}\) mile at a pressure of 1,000 to 1,050 volts. The current drives thirty motors ranging from \(3\frac{1}{2}\) to 50 brake-horsepower, and a total of 479 brake-horsepower.

The motors, with the exception of one of \(3\frac{1}{2}\) brake-horsepower and the crane-motors, are placed direct on the 1,000 volts system. A suitable static transformer-plant gives a 250 volts system for the above exception and also for lighting.

The lighting installation consists of approximately 550 incandescent lights and 80 arc lights.

*Iron-works.*—The iron-works consist of refining, puddling and reheating furnaces; steam-hammers; and plate and bar rolling-mills.

The vertical high-pressure compound blowing-engine, in connection with the refinery, is fitted with valves, so arranged that it can be worked at high or low pressure or as a condensing or compound condensing engine. The high-pressure cylinder is 17 inches in diameter; low-pressure cylinder, 28\(\frac{1}{2}\) inches in diameter; the air-cylinder, 77 inches in diameter; the stroke, 4 feet; and the steam-pressure is 100 pounds per square inch. This engine is capable of delivering 720,000 cubic feet of air per hour at a pressure of 2\(\frac{1}{2}\) pounds per square inch.

The refining furnaces are 4 feet long, 3 feet 4 inches wide, and 18 inches deep. They are supplied with blast from two
tuyères and are capable of being worked with a charge of 30 cwts. of pig-iron. In the puddling furnaces, a weight of about 3 cwts. of refined iron is charged per heat.

The steam-hammers, which have replaced the old tilt-hammers and helves, consist of 3 tons, 4 tons, 7 tons and 8 tons hammers. The plate rolling-mills consist of (1) a 24 inches plate-mill with 7½ feet rolls, driven by two 60 horsepower low-pressure beam condensing engines having two cylinders 41 inches in diameter and 7 feet stroke, attached to the mill and fitted with reversing gear; and (2) a large plate-mill driven by a horizontal high-pressure reversing engine with two cylinders, 50 inches in diameter and 5 feet stroke, working at 50 revolutions per minute, under a steam-pressure of 60 pounds per square inch. The plate rolls are 32 inches in diameter and 11 feet long.

The testing-house contains a 50 tons single-lever testing-machine, fitted with a hydraulic straining cylinder, 10½ inches in diameter and 6 inches stroke, working at a pressure of 1,500 pounds per square inch.

The following paper was read and discussed at the General Meeting held in Sheffield on April 10th, 1906:—
AN ACCOUNT OF SINKING AND TUBBING AT METHLEY JUNCTION COLLIERY, WITH A DESCRIPTION OF A CAST-IRON DAM TO RESIST AN OUTBURST OF WATER.

BY ISAAC HODGES.

I. SINKING AND TUBBING.

The Methley Junction colliery is situate near the river Calder, about 8 miles south-east of Leeds. About the year 1850, a downcast shaft, 11 feet in diameter and an upcast shaft, 10 feet 8 inches in diameter, was sunk to the Haigh Moor seam. Great difficulties were encountered in the sinking, owing to bad ground and large quantities of water, due to the fact that the shafts passed through the Methley fault, having a very wide fracture. This fault crossed the river Calder, some 1,800 feet away, and conveyed a feeder from the river to the pits (Fig. 1, Plate III.).

Five lifts, 12 inches in diameter and of 3½ feet stroke, were used during the sinkings, dealing with a feeder of upwards of 100,000 gallons per hour, which was considered a large quantity of water for those days. Each shaft was tubbed from 60 feet to a little over 200 feet deep; but, a further quantity of water being found below the tubing-crib of the downcast shaft, an additional length of 75 feet was put in that shaft, making a total length of tubing of 218 feet, the bottom crib being 278 feet below the surface (Figs. 2 and 3, Plate III.).

On the Haigh Moor coal-seam being reached at a depth of 442 feet, the then proprietors were anxious to obtain quickly an output such as to recoup them for their heavy capital-expenditure, and commenced working almost from the pit-bottom, leaving a much smaller shaft-pillar than was really necessary under the circumstances. This is the more surprising, as the distance from the bottom crib of the tubing to the coal-seam was only about 160 feet. The shaft-pillar was further weakened by furnace-
and dumb-drifts, stables and roadways, with the result that the crush on the weakened pillar caused difficulties with the tubbing in the upcast shaft (Fig. 4, Plate III).

An attempt was made to strengthen the shaft-pillar by building strong stone packs of dressed-stone blocks at great expense, but this was not very successful. The ventilation being produced by a furnace, the leaky tubbing of the upcast shaft was much deteriorated by sulphur-fumes in conjunction with the water, the sheathing and plugs being also partly burned out: so much so, that about 1872 it was decided that the tubbing in the upcast shaft had become unsafe. That shaft was then re-lined with tubbing, the new crib being attached to the bottom-crib of the old tubbing by projections into the pigeon-holes of the old crib (Figs. 5 and 6, Plate IV.). This reduced the diameter of the pit from 10 feet 8 inches to 9 feet 6 inches, and 10 feet lengths of bell-mouthed extensions were built at the top and bottom of the lining to get back to the original diameter. The re-lining was done by damping-down the furnace at week-ends, the old tubbing being scraped, re-wedged and re-plugged, and the new tubbing built. The heat and fumes, however, largely destroyed the sheathing of the new tubbing before the next weekend came round to build another length; and, when the new tubbing was completed and the furnace finally put out, the contraction, together with the defective sheathing and plugs, caused considerable quantities of water to escape. The foundation cribbed of this re-lining was also not a good one, and some water escaped therefrom; and, gradually increasing in quantity, it became a serious matter about 1897, when the author of this paper came to the colliery.

The decision having been taken to work the Silkstone and Beeston coal-seams in that district from Whitwood, by rise drifts through the Methley fault, it was resolved to sink one of the Methley Junction pits to those seams for ventilation and power purposes, and for winding men. Before coming to a decision as to which pit should be sunk, the writer made a careful examination of the tubbing of each shaft. He found that the tubbing of the upcast shaft was sound, but the foundation-crib was leaky, with a gradually increasing quantity of water then reaching about 6,000 gallons per hour; the tubbing in the downcast shaft was
quite dry, the foundation-crib was tight, and a few test-holes made in that tubbing shewed strengths and pressures as recorded in Table I.

**Table I.—Thicknesses of Tubbing and Pressures of Water in the Downcast Shaft.**

<table>
<thead>
<tr>
<th>Depths from Top of Tubbing.</th>
<th>Thicknesses of Tubbing.</th>
<th>Actual Pressures of Water per Square Inch.</th>
<th>Calculated Pressures of Water per Square Inch.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet. Inches.</td>
<td>Inches.</td>
<td>Pounds</td>
<td>Pounds</td>
</tr>
<tr>
<td><strong>Upper Section—</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>$1\frac{1}{4}$</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>60</td>
<td>$1\frac{1}{4}$</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>91</td>
<td>$1\frac{1}{2}$</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>122</td>
<td>$\frac{7}{8}$</td>
<td>55</td>
<td>53</td>
</tr>
<tr>
<td><strong>Lower Section—</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>$1\frac{1}{4}$</td>
<td>20</td>
<td>66</td>
</tr>
<tr>
<td>183</td>
<td>$1\frac{3}{16}$</td>
<td>323</td>
<td>80</td>
</tr>
<tr>
<td>214</td>
<td>$1\frac{1}{2}$</td>
<td>45</td>
<td>92</td>
</tr>
</tbody>
</table>

The test-holes were made by a fine ratchet-drill boring a hole, $\frac{3}{16}$ inch in diameter, and carrying a graduated scale, which could be read off the instant that water was reached. The tests were considered fairly satisfactory, and it was resolved to sink the downcast shaft to the lower seams. Some months afterwards, the writer, pondering over the differences of the test-thicknesses of the tubbing, decided to try every segment of a few of the rings at the base of the upper section, in order to see how far they corroborated the general tests taken. The results are detailed in Table II.

**Table II.—Thicknesses of Tubbing in the Downcast Shaft.**

<table>
<thead>
<tr>
<th>No. of Ring above the Crib of the Upper Section of Tubbing.</th>
<th>Thicknesses of Metal in each Segment of Tubbing in each Ring.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ...</td>
<td>Inch. Inch. Inch. Inch.</td>
</tr>
<tr>
<td>2 ...</td>
<td>$2\frac{7}{16}$ $2\frac{3}{8}$ $2\frac{1}{8}$ $2\frac{1}{8}$</td>
</tr>
<tr>
<td>3 ...</td>
<td>$1\frac{1}{2}$ $1\frac{3}{16}$ $1\frac{3}{16}$ $1\frac{3}{16}$</td>
</tr>
<tr>
<td>4 ...</td>
<td>$1\frac{1}{2}$ $1\frac{3}{16}$ $1\frac{3}{16}$ $1\frac{3}{16}$</td>
</tr>
<tr>
<td>5 ...</td>
<td>$1\frac{1}{2}$ $1\frac{3}{16}$ $1\frac{3}{16}$ $1\frac{3}{16}$</td>
</tr>
<tr>
<td>6 ...</td>
<td>$1\frac{1}{2}$ $1\frac{3}{16}$ $1\frac{3}{16}$ $1\frac{3}{16}$</td>
</tr>
</tbody>
</table>

The tests were then stopped, as segments $\frac{7}{16}$ inch thick with a pressure of water of 60 pounds per square inch were decidedly
unsafe, and particularly so as the metal was very much deteriorated in quality. From the section of the shaft, it will be seen that the first ring, J, above the crib of the upper section of tubbing was inside-flanged; and this was found to be backed with cement, forming a barrier between the two sections of water, which explains the different series of pressures (Fig. 2, Plate III.). The second ring was outside-flanged, and carried a pipe, I, 6 inches in diameter, having a blank flange, 12 inches in diameter, secured by four studs, 3/4 inch in diameter, which had been used to let out the water behind the tubbing, so as to ease the pressure during the tubbing-operations and to aid in fixing the segments. This flanged pipe caused considerable anxiety, as the studs had been badly eaten away by water trickling down the shaft, in the earlier days: the threads had quite disappeared, and the nuts were much reduced in size and strength.

An attempt was now made to ascertain the quantity of water that had to be dealt with. The water in the lower section of the tubbing was quickly run off, and was found to be only a pocket of water, with a very small feeder. In the upper section, the tubbing segments were unplugged, until the water-level was reached, and this level was found to be about that of the river Calder: the water rising and falling approximately with that in the river. To ascertain the quantity of water passing from the river, a house was made in the side of the shaft, at the top of the tubbing, in which a Tangye pump was fixed, pumping from a semicircular cistern, slung in the shaft between the back of the conductors and the tubbing (Fig. 29, Plate VI.). This cistern was fed by twenty-five indiarubber pipes passing round the shaft, out of reach of the winding cages, and coupled to the plug-holes in the segments of tubbing. Continuous pumping of about 10,000 gallons per hour for eight weeks had little effect on the water-level: the pumping only reducing the pressure by about 3 pounds per square inch. These experiments proving that the volume of water was a large one, it was decided not to attempt further to pump the feeder, but to line the shaft with stronger tubbing.

Before deciding upon the internal diameter of this re-lining, careful measurements were taken of each ring of the old tubbing
from a centre-line, and particularly of the position of the flanged pipe; and, from the plotting-plan of these rings, a new centre-line was determined. Allowing for tubbing with flanges $3\frac{3}{8}$ inches wide and lips $\frac{3}{8}$ inch wide, it was found that an internal diameter of 9 feet 11 inches could be obtained. To reach this reduced diameter, the writer decided to adopt three tapered foundation-cribs, the bottom one, 24 inches wide, tapering from 10 feet 11 inches to 10 feet 7 inches; the second one, 20 inches wide, tapering from 10 feet 7 inches to 10 feet 3 inches; and the third one, 20 inches wide, tapering from 10 feet 3 inches to 9 feet 11 inches; with a special base ring, 20 inches wide on the bottom flange, diminishing to $3\frac{3}{8}$ inches on the top flange to carry the tubbing (Figs. 7, 8, 9, 10 and 11, Plate IV.). The cribs were made of metal $1\frac{1}{2}$ inches thick, and were each 5 inches deep, the base ring of metal $1\frac{1}{2}$ inches thick and 2 feet 6 inches deep, and the tubbing was 2 feet 6 inches deep and $1\frac{3}{8}$ inches thick, reducing by steps of $\frac{1}{4}$ inch to $\frac{3}{8}$ inch. The number of segments used were as follow: 128, $1\frac{3}{8}$ inches thick; 128, $1\frac{1}{4}$ inches thick; 128, $1\frac{1}{2}$ inches thick; 128, 1 inch thick; 128, $\frac{3}{8}$ inch thick; and 176, $\frac{3}{4}$ inch thick (Fig. 2, Plate III.). The cribs, base ring and tubbing plates had eight segments to a ring, and all of them were coated with Dr. Angus Smith's composition. The tubbing plates were strongly bracketed, and had three bolt-holes in each flange, so as to be bolted together at the surface and sent down the pit in rings. Each segment had the thickness cast on the inside face in relief figures, for future reference and testing in coming years. Each segment was tested at the works by a skilled foreman striking a blow with a pointed hammer on each square inch of surface both back and front; and the three foundation-cribs, base ring, and one ring of tubbing were erected in position on the surface, so as to see that all was in order before they were sent down the pit.

Before commencing to put in the tubbing, coal-winding was discontinued, and arrangements were made for the miners to work at the other collieries belonging to the company. The shaft was stripped, the buntons and wood conductors removed, and the steam-pipe and two rising-mains were transferred to the upcast shaft.

Trials made below the bottom crib of the old tubbing did
not find a good foundation until a depth of 318 feet, necessitating
the laying of the new crib-bed within 120 feet of the coal-seam.
A sound bed was made there by running in granite-concrete,
composed of three parts of 1 inch granite-chippings to one of
cement, floated to a level surface, and allowed to stand for
12 hours. The foundation-crib was placed in position, dowelled
and securely wedged, and the two tapered cribs and the special
base ring were placed thereon. The cribs and ring were further
strengthened by eight oak struts, 12 inches square, tightly
wedged to strong ledges on the shaft-sides, and the whole was
run in solid with rough granite-concrete (5 to 1); a block of
about 50 tons being thus made.

The tubbing segments were then built in position, the
annular space between the old and the new tubbing being filled
with concrete so long as there was space. On reaching the
middle crib of the old tubbing, and opposite to the inside flanged
ring, J, that had been found to be backed with concrete, the new
tubbing was tightly wedged and made solid to form a bed; and
a 10 feet length of concrete was formed to act as a diaphragm
between the two sections of water, so as to keep the full pressure
of water from the lower length of tubbing, whenever the upper
section of the old tubbing should burst (Fig. 2, Plate III.).

Up to this point, the tubbing had been sent down the pit
in segments, owing to the risk of conveying complete rings past
the dangerous flanged pipe; but, from that point upwards, the
segments were built into rings at the surface and sent down by
a special tool. A double drawbridge was arranged at the surface,
one drawbridge being placed on each side of the pit (Figs. 12 and
13, Plate IV.). The upper bridge had a turntable built in the
centre; the segments being carried by blocks running on overhead
girders to the turntable, the sheathing was attached, the turntable
was revolved, and the segments were bolted together until a com-
plete ring was formed. The rings weighed 3 1/2 to 2 1/2 tons each. The
lower bridge on the opposite side of the shaft carried two projecting
girders to span the shaft, the girders sliding into cast-iron tests
to hold them secure. This bridge was weighted to counter-
balance the weight of the overhanging girders, and was pulled
into position by a barrel-winch, fixed on the bridge, hauling on
a stationary chain anchored at both ends. The lower bridge was
hauled with the girders over the shaft, the upper bridge was then run on so as to be in position for the crab-rope to take up the ring, and when this was lifted the upper bridge was drawn away on one side of the pit and the lower bridge, with the girders attached, on the other side, leaving the shaft clear. The tool for lowering the tubbing was a cross, hung on chains, made of two bands of wrought iron, 3½ inches wide and ⅞ inch thick, riveted together and having four sliding projections, 1 inch in diameter, to fit into the plug-holes of the tubbing (Figs. 14, 15, 16 and 17, Plates IV. and V.). These projections could slide about 5 inches, and, whilst carrying the rings, were held securely in position by cotter-bolts. On the projections being withdrawn, they swivelled on a carrying bolt and hung vertically, whilst re-ascending the shaft. For safety, the workmen were withdrawn from the shaft for each ring, the crab-rope lowered the ring of tubbing, which guided itself down the shaft, and the workmen followed on the winding-rod in a kibble and guided the ring into position. On the workmen reaching the scaffold, the crab-rope was slackened, the cotter-bolts in the special tool were taken out, the projections slid back, and the tool was sent back to the surface on the crab-rope. The workmen then sent the empty kibble to the surface, and, on receiving the empty winding-rod, attached it to the scaffold and lifted it the height of a ring, secured the scaffold by pushing the bolts into the plug-holes of the tubbing, then disconnected the winding-rod, sent it to the surface for the kibble again, and, after laying the sheathing for the next ring of tubbing, the workmen returned to the surface. Meanwhile, another ring of tubbing was being built at the surface so as to be ready when the empty crab-rope came up, and by this means a ring could be built and put into position in 40 minutes, and, on an average, 80 to 90 feet of tubbing was built per day of 24 hours. The 140 feet of the upper section of tubbing was completed in less than two days, the total time taken in putting in the three cribs, the special base ring, the filling-in of the concrete, and the building of 260 feet of tubbing, with the intermediate concrete dam, was seven days, of which three days were taken up in fixing and wedging the foundation-crib. The total weight on the foundation was as follows:—Foundation-crib, 4 tons 14 cwt.; second crib, 3 tons 18 cwt.; third crib, 3 tons 17 cwt.; the three cribs together, 12 tons 9 cwt.; the special base ring, 5 tons 9 cwt.; tubbing plates, 268 tons 3 cwt.; making a total of 286 tons 1 cwt.
On the top of the tubbing, a walling crib was fixed, and new walling, 10 feet in diameter, was built to the surface: the old pump-house being filled with earth.

The wedging of the tubbing was then commenced from the bottom, and was carried lightly throughout the whole length: to be more tightly wedged afterwards, as occasion required.

The decreased diameter of the shaft prevented the winding cages from being used again; and, in place of single-decked cages, carrying tubs side by side, two-decked cages having a single tub on each deck were designed, each cage running on three wire-rope conductors (Figs. 18 and 19, Plate V.). As conductor-weights, hanging in the sump, would have been a possible danger to the sinkers below, it was decided to anchor the conductors to the safety-scaffold, described hereafter, and weight the conductors in the head-gear. To this end, levers carrying quadrants, to which the conductors were attached, were provided, and the levers were weighted sufficiently to take up the slack rope (Figs. 20, 21, 22, 23, 24 and 25, Plate V.). Very little time was required to take a fresh purchase, whenever the levers had descended so much as to give too little margin for expansion during warmer days. The steam and rising-main pipes were re-changed from the upcast to the downcast shaft, and an additional exhaust-steam main was put in to keep the free steam out of the upcast shaft.

Whilst designs were being prepared, the tubbing manufactured, and arrangements made for putting it into position, the sinking of the shaft was commenced. The sump was widened from 10 feet to 11 feet in diameter, by means of a kibble slung under the winding cages, the brickwork being built in cement to hold back the water from the old culverts. A staple-pit was sunk, 81 feet distant from the shaft, for a depth of 48 feet until favourable strata were reached: and then an under-level drift, on a slightly rising gradient and made sufficiently wide for empty and full roads, was driven to meet the shaft, which by that time had been deepened to that depth.

* The references to Figs. 18 and 19 are as follows: A, rising main, 6 inches in diameter; B, rising main, 6 inches in diameter; C, steam-pipe, 6 inches in diameter; D, rising main, 7 inches in diameter; E, exhaust-steam main, 5 inches in diameter; F, gas-pipe, 2 inches in diameter; G, single-decked cage; H, two-decked cage; a, wood conductors; and b, wire-rope conductors.
(Fig. 4, Plate III.). The staple-pit was fitted with a steam-winch and cage to fit the ordinary pit-tub. In the main shaft, in addition to the balks carrying the keps and the sump-balks carrying the cages, a safety-scaffold made of close fitting memel, 12 inches square, was built, and covered with a thickness of 3 feet of clay, E (Figs. 26, 27 and 28, Plate VI.).

As the sinking-rope could not run in the centre of the shaft, owing to the winding-cages running in wood conductors having only 2 or 3 inches of margin at the meeting, the sinking rope was run down the side of the shaft and brought into the centre again below the safety-scaffold (Figs 26 and 27, Plate VI.). The angle of deflection of the rope was 130 degrees, running on pulleys, 2 feet in diameter, having flanges sufficiently wide to pass the winding-rope capel, set at centres about 5 feet apart; and, below the bottom pulley, a frame was fixed, and a detaching hook-plate was provided. The sinking-rope was boxed down the side of the shaft and through the safety-scaffold, and the boxes were made large enough to allow of the rope-capel passing through in case of overwinding and detaching. Although, with a geared sinking-engine, overwinding appeared very improbable, this actually occurred during the sinking: the winding-engineman, forgetting himself, over-wound at full speed, the kibble was detached, and the rope and capel passed through the boxes. The rope was lowered, replaced on the pulleys, and the capel re-connected to the kibble with a stoppage of only 2 hours.

The sinking was continued in the usual way, the kibble being wound to the under-drift and tipped into a pit-tub on the draw-bridge (Figs. 26 and 27, Plate VI.). The tubs were stored on the double line in the under-drift and wound at the staple-pit at the convenience of the workmen at the coal-winding shaft. The extra cost of labour caused by the under-drift and staple-pit as compared with sinking from an open pit was 1s. 8d. per foot on the sinking.

The total cost of the staple-pit and the under-drift was £125, which, on the sinking of 540 feet to the Silkstone seam, equalled a further cost of, say, 5s. per foot, making a total extra cost of 6s. 8d. per foot.

The ventilation of the shaft was provided by a high-speed vertical steam-engine of 10 horsepower, built in the Haigh Moor
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seam, driving a fan, 2½ feet in diameter, running at about 1,400 revolutions per minute, and forcing the air down ventilation-boxes, 14 inches square, passing through the safety-scaffold (Figs. 27 and 28, Plate VI.).

When the sinking had reached a depth of about 480 feet, and was within about 60 feet of the Silkstone seam, the working was discontinued, owing to the danger that, should an outburst occur in the defective tubbing and the shaft be connected with the Silkstone seam, the whole of the Whitwood pits would be flooded (Fig. 29, Plate VI.). When the re-lining had been completed, and the shaft thus made secure, sinking was again commenced; and, on the Silkstone seam being reached, a connection was made to the rise drift, which had meantime been driven through the Methley fault.

To provide ventilation for the opening-out of the Silkstone seam it was necessary that the new shaft should be an upcast; and, to allow of this, the under-drift below the Haigh Moor seam was continued beyond the shaft to a point beneath the main return-airway of that seam (Fig. 4, Plate III.). Another staple pit was then sunk to connect the under-drift with this return-airway, by which the ventilation proceeded, and forward through the dumb-drift to the upcast shaft. Doors were placed in that portion of the under-drift which connected with the winding staple, and the safety-scaffold formed a seal between the downcast portion of the shaft from the surface and the upcast portion from the Silkstone seam. The further depth of sinking of about 240 feet to the Beeston seam was banked at the level of the Silkstone seam, and the greater portion of the sinking dirt was stowed in the opening-out workings of that seam, the remainder passing down the drift and out to the surface at the Whitwood Silkstone pit.

II.—CAST-IRON DAM IN THE UPCASt SHAFT.

Tests made of the tubbing in the upcast shaft proved that the segments were safe. In ninety-two rings of eight segments each, 736 tests were made, giving a minimum thickness of 1 inch with a maximum thickness of 1½ inches. A scheme was then considered for underpinning the leaky foundation-crib, with a view to stopping the flow of water, which had now increased
to about 10,000 gallons per hour. Whilst those concerned were thinking of this, a sudden outburst of four or five times the volume of water occurred, bringing a large quantity of dirt, which filled the sump at the bottom of the upcast shaft, clogged the pump suction-pipes at the level of the Haigh Moor seam, and, running down the other shaft, flooded the Beeston seam. Inspection shewed that the rock, H, immediately underlying the foundation-crib, and for about one-third of the circumference of the shaft, had been pushed into the pit for about 18 inches, reducing the diameter of the shaft from 10 feet 8 inches to 9 feet (Fig. 3, Plate III.). This released some of the segments of the foundation-crib, and the tubbing shewed signs of giving way. Temporary steel skeleton-cribs were at once got into position so as to prevent the side of the shaft from being completely pushed in and thus set the tubbing free to fall; and seven stout oak cribs, of varying diameters to suit the reduced sizes of the pit, were afterwards placed in position, and tight wedges were driven between the crib and the shaft-sides to make it quite secure. The rushes of water came intermittently, the dirt dammed the water-course temporarily, until the head increased sufficiently to bring dirt and water together in large volumes. A third pump was rapidly installed, coupled to the existing steam-pipe, and fitted with a new suction-pipe to a temporary sump, and with a new rising-main, 7 inches in diameter and 450 feet long, to the surface: this work being completed within 36 hours. During the same period, the suction-pipes of the other two pumps were disconnected under considerable difficulties, owing to the dirt and water coming down the shaft, and were coupled to temporary water-lodges; and, after that time, no additional water ran down the Beeston shaft.

When sufficient backing deals had been put in behind the oak cribs so as to prevent the dirt from coming away, and the plug-holes of the bottom rings of tubbing had been released sufficiently to give the average flow of water of the feeder and thus prevent the intermittent rushes, the feeder gradually slackened off until the fourth day, when it settled down to a steady volume of 20,000 gallons per hour, which quantity continued, varying a little under and over, until the permanent dam was completed. The bottom crib securing the broken sides of the shaft was made into a wide garland to catch all the water, which was conveyed by two water-boxes to a cistern at the shaft-bottom. It is worthy
of note that the 20,000 gallons of water per hour was pumped from this cistern, having only a capacity of 1,500 gallons, for twelve months without any overflowing.

The quantity of water, with an ever-present fear of further increase should the channel from the river become enlarged, coupled with the very bad state of the shaft, which prevented an attempt to tub off a further section, decided the company to close the shaft with a permanent dam. In designing the dam, two ideas presented themselves, a cast-iron dam in the shape of a dome with a horizontal base, or a wood dam built of vertical logs tapered to form a circular wedge. The wood dam, with, say, a thickness of 8 or 10 feet, gave a largely increased surface with which to make a water-tight joint, but it had the disadvantage of being perishable and somewhat difficult to build. The difficulty of using this kind of dam was further increased, as the writer knew that the sides of the shaft must be weak and tender; consequently it would be difficult to form an accurate taper in the broken horizontal strata, and it was impossible to say beforehand what area of ground must be extracted before solid ground would be reached. It was also of considerable importance that no further time than was absolutely necessary should be taken up in doing the work, not only on account of the risk of the mining operations increasing the outburst and flooding the collieries, but also on account of the safety of the workmen necessarily engaged in a dangerous kind of work. On the other hand, a cast-iron dam was rigid and unyielding, and a slight subsidence of one side, more than the other, might cause the horizontal base to become leaky.

After weighing the respective merits, the writer decided that a cast-iron dome with a horizontal base gave the best chance of success; but he designed the crib with an inclined taper of 40 degrees from the horizontal, so as to allow of some latitude in casting, as also in the fixing, and to keep the dam watertight, even should considerable subsidence occur, as the inclined surfaces might slide on each other. The shaft was 10 feet 8 inches in diameter, but the crib was made 12 feet in internal diameter, and 36 inches wide on the base, giving an external diameter of 18 feet (Figs. 30, 31, 32, 33 and 34, Plate VI.). On the internal
diameter of the crib was cast a lip, 6 inches wide and 1 inch thick, upon which wooden centres were built so as to hold up the dam during erection. The crib was made in ten segments, 2 inches thick, each segment containing two internal ribs, 2 inches thick, with a core-hole, 8 inches by 4 inches, in each division. The dome was formed of ten segments, owing to the reduced diameter of the shaft at the point of the outburst, each 2 inches thick with ribs 2 inches thick; and two of the segments had flanged holes, 9 inches in diameter. The flanges were provided with six holes for bolts, 1½ inches in diameter, to secure pipes, 12 inches in diameter, that would be built through the concrete to allow of the 20,000 gallons of water per hour passing through them whilst fixing. The segments when jointed together left a hole, 9 inches in diameter, in the centre; and this was closed by a cast-iron plug having a heavy flange. All the segments were arranged for sheathing, ¼ inch thick, and the dome-segments had holes 1½ inches in diameter, to bolt them together and to hold them steady whilst being covered with concrete. All the segments of the crib and of the dome were coated with Dr. Angus Smith's composition. The dam was erected in position and carefully fitted together on the surface, before being sent down the pit. The weight of the dam was as follows:—Crib, 12 tons 13½ cwts.; dome, 12 tons 9½ cwts.; a total of 25 tons 3½ cwts.

The proposed closing of the upcast shaft compelled the downcast shaft to be changed into an upcast shaft throughout to the surface, so as to ventilate the Haigh Moor, Silkstone and Beeston seams (Fig. 29, Plate VI.); and on that account it was decided to cease winding coal at the Methley Junction pit and to haul that output underground to the Savile pit, about 1½ miles away. The necessary haulage-roads were at once commenced, and a main- and-tail-rop e haulage was installed (Fig. 4, Plate III.); and at Easter, 1904, the Methley Junction pit ceased to wind coal. The top of the shaft was enclosed with a brick-chamber, and a new fan was built, which commenced running in August, 1904.

The old upcast shaft, in which the outburst of water occurred, being thus rendered unnecessary, the old fan was removed, and a commencement was made to fix on the position of the dam. Below the outburst, the shaft was found to be in a very bad
condition; the furnace, extinguished 35 years before, having destroyed most of the cribs, and allowed the unmortared walling, 4½ inches thick, to sag. The dam could not be placed at the bottom of the upcast pit, as the coal round the pit had been taken out. The porch had four openings, the pillars at the corners being made of dressed stone, and these pillars had long since split to pieces. A commencement was made 100 feet below the bottom of the foundation-crib of the bell-mouthed tubbing, where an old iron-crib formed some support for the walling; but, on the walling being taken away, it was found that the strata had perished so considerably by the heat and water that the sides commenced to run in (Fig. 3, Plate III.). The old crib was supported by driving in twelve iron plugs, 2 inches in diameter and 5½ feet long, and the running ground was held back by oak cribs, 12 inches by 4 inches, each carried on twelve wrought-iron plugs, 2 inches in diameter and 5 to 7 feet long, each crib being stepped back, about the width of itself, until stronger ground was reached. The diameter of the shaft, 10 feet 8 inches, was found to be widened to upwards of 15 feet before any solid ground was reached.

As the state of the walling and the tender nature of the ground caused some alarm to the workmen, the writer decided to line the length, JJ, of 100 feet of dangerous walling with cribs and backing deals (Fig. 3, Plate III.). Forty-seven cribs, 5 inches square, made of elm, larch and poplar, having butt joints and wrought-iron straps, 4 inches wide and ⅜ inch thick, each crib supported on eight punch-props, 18 inches long and 4 inches square, fastened with iron dogs, and close backed by 7,500 lineal feet of boards, 6 inches wide and 1½ inches thick, in 4 feet lengths, were rapidly built and jointed up to the oak cribs, 5 inches square, supporting the ground at the point of the outburst. This made the shaft entirely dry and perfectly safe, and the workmen were much comforted.

The shaft-wall was then stripped downwards in an endeavour to find a firm foundation. Nothing likely shewed itself, until at a depth of 370 feet, a width of 14 feet, with some strong ground, was found (Fig. 3, Plate III., and Fig. 29, Plate VI.). This had the disadvantage of being within 12 feet of a horizontal stone-drift from the Stanley Main seam into the pit. This drift
crossed the fault, and gave a chance to the water, after being dammed back in the shaft, to pass down the hade of the fault into the workings. About 3 feet lower was the mouth of the dumb-drift from the old furnace. An inspection of the dumb-drift shewed that the barrel arch was built of sound brickwork and in good condition; and it was decided to take the risk of the dumb-drift, to fill the stone-drift with concrete so as to prevent any chance of the strata giving way and releasing the fault-hade, and from the level of that drift to carry up the concrete solid in the shaft, so as to assist in making an artificial bed for carrying the dam. A wall, 3 feet thick, was built in the coal-heading just beyond the line of the fault, at a distance of about 72 feet from the shaft side, and the drift was filled back to the shaft with rough concrete, mixed with large blocks of Haigh Moor rock, and well rammed in layers: about 200 tons of concrete, mixed about 9 to 1, being used.

A light scaffold was built in the shaft, between the level of the stone-drift and the mouth of the dumb-drift, made of tramway-rails, 7 inches by 7 inches, side by side, with two pipes, 7 inches in diameter, built through it, to convey the water. The shaft was then filled to the level of the dam-bed, about 200 tons of concrete, made 7 to 1, being used, including an opening, 20 feet in diameter and 3 feet high, cut into the sides of the shaft so as to dovetail the block of concrete into the natural strata and to support the dam when the tramway-rails should have perished (Fig. 3, Plate III.).

The temporary connection, between the two wood boxes coming from the outburst and the pipes leading through the concrete, was effected by tapered indiarubber bags, made of sheeting, ½ inch thick, having a square end to attach to the water-boxes and a circular end to pass into the pipes. These rubber bags were made in 9 feet lengths, fastened together with straps and buckles, and proved very satisfactory, conveying the water past the workmen without inconvenience.

The pipes, 7 inches in diameter, were carried up to the point at which it had been decided to build the dam, and a level bed was there floated up with granite-chippings. This was given time to set, and the dam-crib was then built in segments, dowelled and wedged. A wood-centre was then built on the lip, 6 inches
wide, cast inside the crib, and the segments were built in detail and bolted together. An electric light was kept at the water-garland, at the contracted area of the shaft, and during the passage of the segments a man rode closely behind them to fend off the segments and to prevent damage to the cribs. When the dome was completed, the indiarubber pipes from the water-boxes were passed through the pipes, 9 inches in diameter, in the dome, the water running below the dome and finding an outlet through the pipes, 7 inches in diameter, built in the lower section of concrete. The dome was then cemented solid with granite-concrete, 3 to 1, to a height of 10 feet, pipes, 12 inches in diameter and 4½ feet long, being attached to the dome and built through the concrete. Slag-and-rubble concrete, mixed 5 to 1, to 7 to 1, was carried up a further height of 20 feet, making 30 feet in all, and a total weight of 350 tons of concrete above the dam, until the wood cribs supporting the old walling were reached. This large block had the advantage of taking off a great deal of the pressure from the dam, and of providing such a strength that should the cast-iron dam perish, at some future time, it may be expected to withstand the pressure of the strata and remain watertight (Fig. 3, Plate III.).

On the concrete reaching the inside of the cribs and the backing deals, the writer decided that no further object would be gained by its extension, the main object of the concrete being to seal up any cracks above the dome that might lead downwards into the workings, and with the cribs and backing deals lining the shaft this object could no longer be attained. The total weight of concrete used in the shaft and drift was about 750 tons.

One of the pipes, 12 inches in diameter, was carried a length of 4½ feet higher than the other, and both of the water-boxes were jointed to this longer pipe, the shorter pipe being sealed by a heavy cast-iron plug, dropped down 26 feet to the bed on the dome, the pipe filled up with concrete, and a plug-flange bolted on the top. The concrete was then left to set for three days. It was calculated that the water would take 7 or 8 minutes to rise the 4½ feet extra length of pipe, and give that time for sealing up. A rope-ladder was fixed to the cribs, so that, should the winding arrangements fail at the critical time, a means of keeping pace with the water would be at hand. Five persons,
consisting of two workmen, the enginewright, the manager and
the writer, went down the pit, and, on the indiarubber pipe being
removed, the water commenced to fill the shaft rapidly. The
heavy cast-iron plug to make the seal, suspended on a light
chain, was then dropped down the pipe, but by some unfortunate
circumstance it became wedged. and it was not until the water
had reached the top of the pipe and some of the party were breast
deep that a desperate pull loosened the plug and it was hauled
out and taken back to the shops to be turned slightly less in
diameter. The upper length of the pipe was then unbolted and
canted on one side, and the water was cleared. At the second
atmpt, 8 hours later, the plug passed down the pipe easily (to
effect a more secure joint, an indiarubber pad was fixed on the
plug, and yarn and tallow were thrown on the top), and three
kibbles of cement were rapidly emptied in the pipe: the water,
however, rose rather more quickly than had been anticipated, and
the blank flange could only be put on under water, and four out of
six bolts secured, before the party were beaten out of the shaft.
The water rose 33 feet per hour, reached to the bottom of the
tubbing in 3 hours, and to the top of the tubbing at the river-water
level in 8 hours later. The kibble brought out the men and tools,
and all the cribs and deals were left in the pit (Fig. 3, Plate III.).

An inspection below the dam made immediately afterwards
shewed that the plug and flange of the second pipe had not held
quite securely, and that about 100 gallons of water per hour
were passing. This quantity decreased slightly, but, as the
writer had arranged for about 500 tons of clay to be thrown
in the shaft on the top of the concrete, the quantity gradually
slackened, until within a fortnight it was reduced to 25 gallons
per hour: this was further reduced, until the quantity at the
present time is only 9 gallons per hour. No sign of water in any
of the workings has shewn itself, although the dam-bed is within
75 feet of the seam: and the concrete in the Stanley Main drift
has supported the fault and held it quite tight. The water
has returned to several dry wells, over a radius of 2 miles, and the
water-level of the district has been restored.

The total weight on the dam-crib may be taken as:—Crib,
dam and pipes, 28 tons; concrete, 350 tons; clay and earth to
the surface, 1,335 tons; a total of 1,713 tons. The area of the crib is upwards of 140 square feet, giving a total weight of only 12 tons per square foot of area. The cost of the dam is shewn in detail in Table III.

From the day of entering the shaft to leaving it was exactly 5 weeks. In explanation of this time, it may be pleaded that considerably more work was encountered than had been estimated; and the time required for the setting of the large mass of concrete somewhat hindered operations.

**Table III.—The Cost of the Dam.**

<table>
<thead>
<tr>
<th>Materials:</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-iron dam, sheathing and bolts</td>
<td>222</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cast-iron pipes and bolts, above the dam</td>
<td>27</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Cast-iron pipes and bolts, below the dam</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tramway-rails at Stanley Main drift</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Concrete: Cement</td>
<td>£168</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dross</td>
<td>21</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Granite</td>
<td>26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sand</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rough stones and bricks</td>
<td>50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bricks for the stopping in the drift</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Clay</td>
<td>70</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Cribs and backing-deals</td>
<td>102</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sundries</td>
<td>8</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>300</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labour:</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Including surface-work; removing upcast head-gear and buildings; fixing new head-gear and drawbridge; erecting dam in position on the surface; fixing electric-light engine and cables; emptying cement, slag, bricks, etc.; preparing concrete; making and fixing cribs; making and sharpening tools; drying clothes; winding engine-man and banksmen; underground labour taking out old brickwork; fixing cribs and backing-deals; building scaffolds; and laying concrete and dam</td>
<td>840</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,590</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The charges incurred in pumping during the preceding twelve months are recorded in Table IV.; and this yearly charge was entirely obviated by the expenditure of £1,590 on the dam, with the additional advantage of extra security and safety. The wages are taken from the pay-sheets, and the fuel is calculated on the average monthly consumption of
500 tons burned at the boilers for the twelve months between the outburst and the damming of the water, less the average monthly tonnage burned during the twelve months afterwards.

Table IV.—Charges of Pumping for 12 Months.

<table>
<thead>
<tr>
<th>Labour:</th>
<th>£ s. d.</th>
<th>£ s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumping-enginemen</td>
<td></td>
<td>214 0 0</td>
</tr>
<tr>
<td>Extra winding-enginemen and firemen at weekends</td>
<td></td>
<td>91 0 0</td>
</tr>
<tr>
<td>Additional firemen on week-days</td>
<td></td>
<td>130 0 0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>435 0 0</td>
</tr>
</tbody>
</table>

| Fuel: 6,000 tons at 3s. per ton | 900 0 0 |
| Stores: say                    | 40 0 0  |
| **Total**                      | 1,375 0 0 |

The pumping-plant was, in some respects, extravagant of steam, but the most modern systems of pumping, with electricity charged at ½d. per Board of Trade unit, would not have reduced the charge below £1,000 per annum, as shewn by the estimate detailed in Table V.

Table V.—Estimate of the Cost of Pumping 20,000 Gallons per Hour to a Height of 450 Feet, by Electricity.

| 60 horsepower, including slip and friction, at ½d. per Board of Trade unit | £ 612 |
| Redemption of capital at 5 per cent., and interest at 5 per cent. on the cost of pump, motor, cables and accessories | £ 85 |
| Labour, including winding engineman, banksmen and pumping enginemen             | 300  |
| Stores, say                                                                        | 28   |
| **Total**                                                                          | 1,025 |

It is satisfactory to state that, during the whole of the sinkings and tubbings, and the fixing of the dam, no serious accidents occurred; and less than £20 was paid as compensation. This is largely accounted for by the excellent assistance given by the electric light. A cluster of lamps of 160 candlepower, the flexible cable being supported by a wire-rope on a reel at the surface, by which it could be rapidly raised or lowered, and supplemented by single lights fixed in advantageous positions round the shaft, shewed up the dangers of the walling and tender strata and enabled the men to take care of themselves, and also, very considerably, assisted the speed of the work. At a cost, which
was almost negligible, a small high-speed engine and dynamo were fixed in the course of one afternoon, and they ran without trouble or definite attention during the whole of the period.

The writer has climbed up the shaft under the dam to inspect the general conditions, from time to time, and has noticed that large stalagmites of a calcareous deposit are being formed. Analyses shew that the trickle of water coming through the dam contains 113 grains of solid matter per gallon and that the stalagmites consist of calcium carbonate.

III.—Additional Tubbing in the Upcast Shaft: the Late Downcast Shaft.

As the writer expected that considerable quantities of water would have to be dealt with during the later life of the Haigh Moor seam, owing to the adjoining mines being abandoned, he decided to put the under-drift and the return-airway, used in sinking the shaft and to ventilate the lower seams, to the useful purpose of making a water-standage (Fig. 29, Plate VI.). The under-drift was lengthened by an addition of 375 feet, the whole water-standage being then equal to a capacity of 250,000 gallons. This stone-drift was driven by Champion and Hardy reciprocating drills at a cheap cost, a black oily shale, about 5 inches thick, allowing the drift to be kivered or holed. A pumping-enginehouse, formed in a thin coal-seam about half way up the winding staple, contained pumps driven by electricity and compressed air respectively.

The shaft-tubbing was designed sufficiently strong to carry tubbing at some future date to join up to the taper cribs, 135 feet above, put in the same shaft during 1901, when the Haigh Moor seam is worked out; the whole of the water in the Haigh Moor seam is thus expected to be kept from the lower seams without the expense of pumping.

In calculating the thicknesses of tubbing required, the writer investigated the formulae stated by various experts; and he was much struck with their disparity, and with the small margin allowed for corrosion and general deterioration. For the Methley Junction shaft, the thicknesses of tubbing calculated according to formulae approved by Messrs. J. J. Atkinson, G. C. Greenwell, W. Galloway and W. Tate are recorded in Table VI.;
and the writer has appended the thicknesses of tubbing that he
used in the Methley Junction shaft for purposes of comparison.
The experience with the earlier tubbing at this colliery had shewn
that a considerable factor should be allowed for deterioration,
both in thickness by active corrosion, internal and external, and
for deterioration of the quality of the metal; and, particularly so,
as a diminution of strength had serious consequences, quite out
of proportion to the extra expense incurred in the first instance.

### Table VI. Thicknesses of Tubbing calculated by Various Formulae.

<table>
<thead>
<tr>
<th>Height of Tubbing</th>
<th>Name of Expert</th>
<th>Tubbing in Methley Junction Shaft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet.</td>
<td>Inches.</td>
<td>Inches.</td>
</tr>
<tr>
<td>J. J. Atkinson.</td>
<td>60 0.22</td>
<td>0.50</td>
</tr>
<tr>
<td>W. Galloway.</td>
<td>100 0.30</td>
<td>0.60</td>
</tr>
<tr>
<td>G. C. Greenwell.</td>
<td>140 0.37</td>
<td>0.69</td>
</tr>
<tr>
<td>W. Tate.</td>
<td>180 0.44</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>220 0.51</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>260 0.58</td>
<td>0.98</td>
</tr>
<tr>
<td></td>
<td>300 0.70</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>340 0.80</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>380 0.90</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td>420 1.00</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>460 1.10</td>
<td>1.56</td>
</tr>
<tr>
<td></td>
<td>500 1.20</td>
<td>1.66</td>
</tr>
<tr>
<td></td>
<td>540 1.30</td>
<td>1.76</td>
</tr>
<tr>
<td></td>
<td>580 1.40</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td>620 1.50</td>
<td>1.96</td>
</tr>
</tbody>
</table>

1 Course of Lectures on Mining, by Mr. W. Galloway, 1900. "Shaft Sinking," page 38.

As a crib-bed, of sufficient strength to carry the whole weight
of the tubbing in the future, could not readily be found, an
artificial bed was made, formed by increasing the shaft, 11 feet
in diameter, to a diameter of 21 feet in a seam of dirty coal, 2
feet thick with fire-clay below, 3 feet thick, making a total
height of 5 feet (Fig. 2, Plate III. and Figs. 35 and 36, Plate
VII.). A large corbel was made of reinforced concrete,
consisting of six layers of tramway-rails, 4½ feet long, thirty-
seven to a layer, cross-jointed by five rows of pit-rails, and filled
in with cement-slag-concrete: the shaft-side being formed of
walls, 4½ inches thick, built in cement, with occasional headers
to tooth into the concrete. Above this reinforced concrete-block,
rings formed of steel railway-rails, 85 pounds to the yard, strongly fish-plated together, 12½ feet in diameter, were built in concrete for a further height of 15 feet.

The foundation-crib, weighing 10 tons, was 11 feet in inside diameter, 30 inches wide, 6 inches high. It was made of metal, 2 inches thick, and was built in eight segments, each containing two internal ribs, 2 inches thick with core-holes, 5 inches in diameter, the segments being arranged for dowel-pins, 1½ inches in diameter and 12 inches deep. On this was built a special base ring, weighing 8 tons, made in eight segments, 24 inches wide on the bottom flange and reducing to 4½ inches wide on the top flange, 2 feet 6 inches deep, and made of metal 2 inches thick. The tubbing segments, eight to a ring, strongly bracketted, 1½ inches thick, 2 feet 6 inches deep, were backed with concrete to the sides of the shaft.

At the level of the water-standage, a bye-pass was made to connect the two drifts, a strong wall being built to carry the concrete behind the tubbing. A 40 feet length of tubbing was built, and it reached to the level of the new pumping-engine-house.

As 100,000 cubic feet of air per minute were required to pass up the shaft, during the tubbing operations, to ventilate the Silkstone workings, the scaffold had an opening, 6 feet in diameter, fenced off with a circular boiler-plate, 4 feet high. This opening also allowed of the kibble passing through the scaffold for the purposes of shaft-examination (Figs. 37 and 38, Plate VII.).

The writer trusts that this record of work done may be of interest to the members of this Institute, who may have similar work to carry out. He desires to express his thanks for the interest and enthusiasm shewn by the managers and officials of the company, without which the work could not have been so satisfactorily completed, and also to the friends who assisted with advice during the progress of the operations.
Mr. T. W. H. Mitchell, in proposing a vote of thanks to Mr. Hodges, for his paper, expressed the appreciation of the members for the great trouble that he had taken in preparing the accompanying illustrations.

Mr. W. G. Phillips, in seconding the vote of thanks, commented upon the comparatively small amount that Mr. Hodges had spent, in order to effect a saving of about £1,400 a year.

Mr. E. W. Thirkell, in congratulating Mr. Hodges upon his excellent paper, said that in matters of that kind it was not always a question of saving expense, but it might be a question of saving a pit, and Mr. Hodges had shewn an amount of pluck and grit which the members were bound to admire.

Mr. M. Deacon said that if members would take the time and trouble to write papers of that practical character, the value of the Transactions would be greater, and the Institutes would shew to much better advantage. He was glad to find that Mr. Hodges had departed from the old-fashioned rules regarding the strength of the tubbing. Everybody would agree that if he had taken one of the formulae quoted in his paper, he would not have had to wait very long before the whole thing came in. The question of the strength of the tubbing required unfettered consideration, from the point of view of the greater diameter of the shafts now than in the past. He thought that Mr. Hodges had not put too great a thickness of metal, considering the serious nature of the work that he was performing.

The vote was carried unanimously.

Mr. J. S. Barnes wrote that he would like to know the number of cribs fixed in the shaft, so as to ascertain the number of rings of tubbing fixed between crib and crib. He had known cases in which the lengths of tubbing between the cribs exceeded 120 feet, and this, in his opinion, was courting disaster. In bad ground, it was often difficult to obtain satisfactory crib-beds, which should be put in wherever possible, and certainly at no greater distances apart than 60 feet.

Referring to Mr. Hodges' remarks about commencing to work near the pit-bottom and weakening the shaft-pillars; he
(Mr. Barnes) was not much surprised at this, as even at modern collieries, workings were sometimes commenced too near the shaft, and destroyed its stability.

The idea of having the thicknesses of the tubbing cast on in relief figures for future reference was not usual, but it was an improvement. It was also unusual to coat tubbing and cribs with protective composition, but it should have the effect of preventing corrosion, although it might be doubted whether the coating did not hide flaws, sand-holes and honeycombing. The sending down of complete bolted-rings of tubbing appeared to have been a success; but, of course, this could not be done with tubbing that required wedging. It would be interesting to know how the horizontal and vertical sheathing was inserted. The time taken to complete the 140 feet length of tubbing, in less than two days, probably established a record.
Fig. 5.—GIERSBERG APPARATUS: 1900 Type.

Fig. 6.—GIERSBERG APPARATUS: 1901 Type.

Fig. 7.—SHAMATUS: APPARATUS

Fig. 11.—PNEUMATOCEN: I Type.

Fig. 12.—PNEUMATOCEN: II Type.
Fig 1. Pneumatogen Generator.

Fig 2. Pneumatophore: 1896 Type

Fig 3. Pneumatophore: Shamrock 1898 Type

Fig 4. Mayer Helmet Apparatus: 1898 Type

Fig 5. Giersberg Apparatus: 1900 Type

Fig 6. Giersberg Apparatus: 1901 Type

Fig 7. Shamrock-Giersberg Apparatus: 1903 Type

Fig 8. Shamrock-Giersberg Apparatus: 1904 Type

Fig 9. Shamrock-Giersberg Apparatus: 1906 Type

Fig 10. Draeger Apparatus: 1906 Type

Fig 11. Pneumatogen I Type

Fig 12. Pneumatogen II Type

Scale, 2 Feet to 1 Inch.
Fig. 1.—Ground pillars in Haigh Moor coal-seam.

Fig. 2.—Section shewing position and dam in old upcast shaft.

<table>
<thead>
<tr>
<th>Depth from surface</th>
<th>Thicknesses of new tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet</td>
<td>Ins.</td>
</tr>
<tr>
<td>231</td>
<td>10</td>
</tr>
<tr>
<td>240</td>
<td>3</td>
</tr>
<tr>
<td>261</td>
<td>7</td>
</tr>
</tbody>
</table>
To illustrate Mr. Isaac Hodges' Paper on "An Account of Sinking and Tubbing" etc.

Fig. 1.—Ground Plan of Methley Junction Colliery

Scale, 3,440 feet to 1 inch.

Fig. 2.—Section Shewing Position of Tubbing in Old Downcast Shaft

[Diagram with measurements and annotations]

Fig. 3.—Section Shewing Position of Tubbing and Dam in Old Upcast Shaft

[Diagram with measurements and annotations]

Fig. 4.—Plan of Shaft-pillars in Haigh Moor Coal-seam

Scale, 20 feet to 1 inch.

Vol. XXXII. Plate III.

W. J. Reid & Co., Printers, Newcastle upon Tyne.
FIG. 8. PLAN OF TAPERED CRIBS
AND BASE RING OF TUBBING.

FIG. 11. SECTION TUBBING.

FIG. 14. ELEVATION

FIG. 15.—PLAN.

TOOL USED FOR LOWERING RINGS
OF TUBBING IN OLD DOWNCAST SHAFT

Scale. 6 feet to 1 inch.
ARRANGEMENT ON HEAD-GEAR.

**Fig. 25.** Section through Line YZ of Fig. 23.

Scale, 2 Feet to 1 Inch.

WIRE-ROPE CONDUCTOR FASTENING AT PIT-BOTTOM.

**Fig. 21.** Side Elevation. **Fig. 22.** End Elevation.

Scale, 2 Feet to 1 Inch.
METHOD OF SINKING, WITH UNDER-LEVEL DRIFTS.

26 - SIDE ELEVATION.

Scale, 12 Feet to 1 Inch
VENTILATION SCAFFOLD USED WHEN PUTTING IN TUBBING.

FIG. 37. - ELEVATION.

FIG. 38. - PLAN.

Scale, 6 Feet to 1 Inch.
TRANSACTIONS.  311

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE PHILOSOPHICAL HALL, PARK ROW, LEEDS,
NOVEMBER 6TH, 1906.

MR. J. R. ROBINSON WILSON, PRESIDENT, IN THE CHAIR.

The minutes of the Annual General Meeting were read and confirmed.

The following gentlemen were elected, having previously been nominated—

MEMBERS—
Mr. Christopher William Taylor Fincken, Assistant Undermanager, Bramley, near Rotherham.
Mr. Edward Lloyd, Civil Engineer, 38, Southgrove Road, Sheffield.
Mr. Charles Augustus Midgley, Electrical Engineer, Standard Buildings, Leeds.
Mr. Percy Muschamp, Mining Engineer, Spitsbergen Coal and Trading Company, Corn Exchange, Sheffield.
Mr. Herbert Peake, Managing Director of Strafford Collieries, Bawtry Hall, Yorkshire.
Mr. James Richardson, Mechanical Engineer, St. John's Colliery, Normanton.
Mr. Roland D. Sheard, Engineer, Messrs. Spurr, Inman & Company, Limited, Wakefield.
Mr. Charles Straw, Colliery Manager, Emley Moor Collieries, near Wakefield.
Mr. George Edward Stringer, Mining Engineer and Colliery Manager, Park Mill Collieries, Clayton West, Huddersfield.

ASSOCIATE MEMBERS—
Mr. Norman Savile Walker, 2, Dale View, Conisbro', near Rotherham.

STUDENT—
Mr. John F. Middlebrook, Mining Student, 11, Hereford Road, Harrogate.

SUBSCRIBING FIRMS—
Messrs. Skinner & Holford, Limited, Wadswood Collieries, near Sheffield.
DISCUSSION—BLACK ENDS: THEIR CAUSE, COST AND CURE.

DISCUSSION OF MR. T. BEACH’S PAPER ON "BLACK ENDS": THEIR CAUSE, COST AND CURE.*

Mr. W. McD. Mackey asked whether Mr. Beach could give information with regard to the amount of gas used, and how long the doors would last.

Mr. T. Beach said that, when he had the privilege of bringing the flued door before the members, it was to some extent in an experimental stage, and he now offered further particulars as to what had since been done. The flued doors, which had been used experimentally since August, 1905, were still in use. They had never been repaired, and, to all intents and purposes, were still in a good and sound condition, and would probably last a good deal longer. At the present time, 78 flued doors were in use out of a total of 90, and they quite fulfilled his anticipations in respect to the complete prevention of the formation of seconds coke and waste of slack at the oven-ends. Regarding the economies effected by the door, he had taken a few figures from the colliery-books, and, in giving them, he desired to acknowledge the consideration that he had received from his firm in being allowed to publish them. Table I. shows that the actual quantity

Table I.—Comparative Statement of Seconds Coke made at Snydale Coke-ovens in 1905 and 1906.

<table>
<thead>
<tr>
<th>Week ending</th>
<th>Seconds Coke.</th>
<th>Week ending</th>
<th>Seconds Coke.</th>
<th>Number of Flued Doors in Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1905, Sept. 6</td>
<td>Tons. cwt.</td>
<td>1906, Sept. 5</td>
<td>Tons. cwt.</td>
<td>52</td>
</tr>
<tr>
<td>'' 13</td>
<td>24 9</td>
<td>'' 12</td>
<td>8 19</td>
<td>54</td>
</tr>
<tr>
<td>'' 20</td>
<td>16 10</td>
<td>'' 19</td>
<td>5 4</td>
<td>54</td>
</tr>
<tr>
<td>'' 27</td>
<td>24 16</td>
<td>'' 26</td>
<td>4 6</td>
<td>56</td>
</tr>
<tr>
<td>Oct. 4</td>
<td>22 0</td>
<td>Oct. 3</td>
<td>5 4</td>
<td>56</td>
</tr>
<tr>
<td>'' 11</td>
<td>18 17</td>
<td>'' 10</td>
<td>3 10</td>
<td>58</td>
</tr>
<tr>
<td>'' 18</td>
<td>16 1</td>
<td>'' 17</td>
<td>1 4</td>
<td>60</td>
</tr>
<tr>
<td>'' 25</td>
<td>22 5</td>
<td>'' 24</td>
<td>2 15</td>
<td>64</td>
</tr>
<tr>
<td>Totals ...</td>
<td>169 11</td>
<td>--</td>
<td>36 14</td>
<td>--</td>
</tr>
<tr>
<td>Average per week ...</td>
<td>21 4</td>
<td>--</td>
<td>4 12</td>
<td>--</td>
</tr>
</tbody>
</table>

of seconds coke made in the year 1905 was higher than the estimated figure given in his paper. Absolutely no unburnt slack or seconds coke was produced in the ovens which were fitted with the flued doors, so that the loss arising from these sources would disappear when the fitting of the whole battery with them was

completed. Assuming coke to be worth 12s. per ton, the difference in value between seconds and best coke at 5s. per ton, and bye-products at 3s. 3d. per ton of coal put into the ovens, the value of the saving effected might be taken as shewn in Table II.

It had been found essential to set the flued blocks in a stiff, rigid and strongly constructed door-frame. The light steel door was unsuitable, as it allowed the blocks to expand and crack when some of the crude gas from the oven escaped into the flue. He (Mr. Beach) was unable to give the exact number of cubic feet of gas used to heat the doors; but, whatever it might be, it had no appreciable effect upon the volume of gas returned to the ovens from the recovery-plant. There had always been sufficient surplus gas, after feeding the ovens and doors, to supply two gas-engines for driving the recovery-plant, exhausters, pumps, etc.; and another gas-engine for electric lighting, etc., was now on the works ready for installation.

Table II. — Value of Savings per Week at Coke-ovens.

<table>
<thead>
<tr>
<th>Description</th>
<th>£</th>
<th>s.</th>
<th>d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6·56 tons* of unburnt slack, yielding 70 per cent. of coke, 4·59 tons at 12s.</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 tons of seconds coke, converted into best coke at 5s. per ton</td>
<td>2 15</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bye-products on 6·56 tons at 3s. 3d. per ton</td>
<td>1 1 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total saving per week</strong></td>
<td><strong>£9</strong></td>
<td><strong>1</strong></td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

* The tonnage of unburnt slack is estimated from the average waste per charge, which was experimentally determined to be 70 pounds per charge, the number of charges per week being 210.

The President (Mr. J. R. R. Wilson) delivered the following address:—
PRESIDENTIAL ADDRESS.

By J. R. R. WILSON.

In addressing you as President of this Institute, I would at once acknowledge the great honour that you have conferred upon me, and confess that I may come far short of your opinions of what the occupant of this chair should be able to perform. Of all the great names which have gone before me, I yield to none at all events in the desire to do you service.

You may very naturally expect me to treat you to copious statistics showing how mining in this country, especially in regard to safety, has improved. This has been done so frequently and so well by others, that I wish to avoid it as far as possible, and I propose to glance through mining history from early times, and then to offer a few suggestions as to what the future may have in store.

I will prefaced my remarks with a new feature in presidential addresses, by quoting part of an eighteenth century sermon:—

Every science is the foundation of some art beneficial to men, and while the study of it leads us to see the beneficence of the Laws of Nature, it calls upon us also to follow the great end of the Father of Nature in their employment and application. I need not say my brethren what a field is thus opened to the benevolence of knowledge: I need not tell you, that in every department of learning there is good to be done to mankind: I need not remind you, that the age in which we live has given us the noblest examples of this kind, and that science now finds its highest glory in improving the condition, or in allaying the miseries of humanity. But there is one thing of which it is proper ever to remind you, because the modesty of knowledge often leads us to forget it,—and that is, that the power of scientific benevolence is far greater than that of all others to the welfare of society. The benevolence of the great, or the opulent, however eminent it may be, perishes with themselves. The benevolence even of Sovereigns is limited to the narrow boundary of human life; and not unfrequently is succeeded by different and discordant counsels. But the benevolence of knowledge is of a kind as extensive as the race of man, and as permanent as the existence of society. He, in whatever situation he may be, who, in the study of science, has discovered a new means of alleviating pain, or of remedying disease; who has described a wiser method of preventing poverty, or of shielding misfortune; who has suggested additional means of increasing or improving the beneficent productions of nature, has left a memorial of himself, which can never be forgotten; which will communicate happiness to ages yet unborn.*

Cannot mining engineers rightfully claim by some of their labours and research, that they also have described wiser methods of preventing poverty, and suggested additional means of increasing the beneficial productions of nature?

John Whitaker* mentions a grant of lands made by the Abbey of Peterborough, dated 853, which seems to prove that coal was known and used in Saxon times. By this grant, certain payments in kind were reserved to the monastery, as one night's entertainment: "Ten vessels of Welch ale, . . . . two casks of common ale, sixty cart-loads of wood, and twelve of . fossil or pit-coal."

The first Act of the Scotch Parliament relating to mines is dated May 26th, 1424, and applies to gold and silver, ordaining that if "thre halfpennys of siluer may be fynit out of the punde of leide The lordis of parliament consentis that sik myne be the kingis as is vsuale in vthir realmyes."+

Yorkshire seems to have been a very early coal-producer. In 1308, a licence was granted by the lord of the manor to dig for coals in the greaveship of Hipperholme: and in 1515, in records of the court leets connected with the manor of Wakefield, coal is mentioned as being wrought at Flockton.

In 1590, John Thornborough, Dean of York, took out a patent "to purify pit-coal and free it from its offensive smell": doubtless, one of the early attempts to manufacture coke.

It also smelt in the mine, for Dr. Kaye, or Keys, writing in 1555, mentions, probably for the first time, the appearance of noxious gases in mines:—

We also have in the northern parts of Britain certain coalpits, the unwholesome vapour whereof is so pernicious to the hired labourers, that it would immediately destroy them, if they did not get out of the way as soon as the flame of their lamps becomes blue, and is consumed. These mines are of a bituminous nature: and the proof of the presence of bitumen, is a certain stone, black, hard, scaly, and bituminous, which we thence derive for the service and fuel of our fires. Pliny calls it Obsidian: we term it Sen-coal, or Newcastle, or Smithy coal, names borrowed either from the mode of its carriage, from the situation in which it is found, or from the use to which it is applied: for it is dug up in places near to New Castle, a famous city of England; it is carried thence by ships to the other parts of the kingdom; and it is used by smiths to soften their iron.‡

* The History of Manchester, 1771, vol. i., page 304.
The position of those employed in mines was, no doubt, originally that of slavery. Though serfdom died out in Scotland in the fourteenth century, the last claims proved being in 1364, compulsory service was known long afterwards. Vagrants and sturdy beggars were obliged to find a master, or be liable to pains and penalties. In 1606, it was enacted by the Scottish Parliament that no person should fee or engage any colliers, coal-bearers, or salters, without a testimonial from their last master, showing a reasonable cause for their removal; and if anyone engaged them without such certificate, the master from whom they had deserted could claim them within a year and a day, and they had to be given back within 24 hours, under pain of a fine of £100 Scots. The deserters were also to be punished. By the same Act, commission was given to the owners of coal-heughs and salt-panes to apprehend and put to labour all vagabonds and sturdy beggars.* I am inclined to think that this Act has been repealed.

About the same time, an Act was passed in Scotland confirming former Acts against the export of coal as "the haill coill within this kingdome sall in a verie schorte tyme be waisted and consumed"; † and in 1625 it was proposed to impose a duty of 48 shillings Scots on every ton of coal exported in strange ships.‡ This proposal was rigorously opposed by the coal-owners, who urged that unless foreign vessels were employed, as there was not enough shipping in the country to transport nearly all the coal worked, the coal-trade would be ruined, the pits stopped, and many hundreds of families reduced to beggary. There is a familiar sound about this. The opposition on this occasion was successful.

Apparently, coal-owners were not always successful, even in those days, for an eye-witness, about the year 1650, describes what he saw and heard in the northern counties:—

Many thousand people are employed in this trade of coales; many live by working of them in the pits; many live by conveying them in waggons and waines to the river Tine; many men are employed in conveying the coales in keels from the stathes aboard the ships: One coale merchant employed 500 or 1,000 in his works of coale; yet for all his labour, care and cost, can scarce live of his trade; nay, many of them hath consumed and spent great estates and dyed beggars. I can remember one, of many, that raysed his estate by coale-trade; many I remember that hath wasted great

† Ibid., vol. iv., page 408.
‡ Ibid., vol. v. pages 176, 181 and 186.
estates. . . . Some south gentlemen hath, upon great hope of benefit, come into this country to hazard their monies in coale-pits. Master Beaumont, a gentleman of great ingenuity and rare parts, adventured into our mines with his £30,000; who brought with him many rare engines, not known then in these parts; as the art to boore with iron rodds to try the deepnesse and thicknesse of the coale; rare engines to draw water out of the pits; waggons with one horse to carry down coales from the pits, to the stathes, to the river, etc. Within few yeares, he consumed all his money, and rode home upon his light horse.*

A little later, about 1676, Roger North describes coal-mining in his day as follows:—

Coal lies under the stone; and they are twelve months in sinking a pit. Damps, or foul air, kill insensibly; sinking another pit, that the air may not stagnate, is an infallible remedy. They are most in very hot weather. An infallible trial is by a dog; and the candles shew it. They seem to be heavy sulphurous air not fit for breath; and I have heard some say that they would sometimes lie in the midst of a shaft, and the bottom be clear. The flame of a candle will not kindle them so soon as the snuff; but they have been kindled by the striking fire with a tool. The blast is mighty violent; but men have been saved by lying flat on their bellies.†

In 1812, an explosion occurred at Felling colliery, by which 92 lives were lost. This accident created an impression in the neighbourhood, and, together with the writings of Dr. William Reid Clanny, a local medical man, and others, it was the means of a society being formed in Sunderland for enquiring into the causes of explosions and devising means for their prevention. This society had a very important bearing upon the future of mining. At their invitation, Sir Humphrey Davy visited the North of England in the autumn of 1815, and the result of his visit was undoubtedly the invention of the safety-lamp. The society had previously issued its first report, in which it quoted from a letter written to the society by Mr. John Buddle, who was then the leading viewer in the north. His opinion as to the prevention of explosions was by efficient ventilation, which had a different meaning in those days; and he described the methods adopted. Of the steel-mill invented by Mr. Carlisle Spedding in 1760, he says:—

On approaching the firing point with steel mills, they [the sparks] grow still more luminous, and assume a kind of liquid appearance, nearly resembling

* Chorographia: or, a Survey of Newcastle upon Tyne, by Mr. William Gray, 1649, pages 24 and 25; reprint, 1813, pages 30 and 31; and reprint, 1884, pages 84 and 86.
the sparks arising under the hammer from iron at the welding heat. . . .

When the inflammable gas predominates in the circulating current, the sparks from the steel mill are of a blood red colour; and as the mixture increases, the mill totally ceases to elicit sparks.*

One could imagine that statement provoking a lively discussion, had The Institution of Mining Engineers existed at that day. Explosions are recorded, however, as being due to the steel-mill.

They believed, 100 years ago, as we do now, that the greatest safeguard in working is to get rid of the gas; the means adopted, however, were somewhat different. A scientist, writing in 1816, says:—

When the gas escapes only in regular and moderate quantities, the miner may explode it as he goes on, without producing any other effect than a pleasing phosphoric phenomena in the working, or a flash like the flash of a musket. But this, after being practised for years, unfortunately strengthens the idea of security, and the mind is incapable of informing itself what hidden reservoirs may be broken into in the future progress of a mine. A fact so simple, and yet so incontrovertible as this, can but impress everyone with conviction, and produce the natural inference, that the most desirable and most valuable improvement in a colliery would be afforded by an invention to counteract this operation of nature.+ 

In May, 1813, Dr. William Reid Clanny exhibited a lamp and read a paper before the Royal Society on "The Means of Procuring a Steady Light in Coal-mines, without the Danger of Explosion." The lamp was also exhibited in Newcastle-upon-Tyne in October of the same year; and on another occasion several gentlemen tried the lamp in a room filled with an explosive mixture, and the light was extinguished. It was first tried in a mine on November 20th, 1815, at Harrington Mill pit on the river Wear (a description of this lamp will be found in the Appendix). Dr. Clanny said of it:—

This lamp may be managed with the greatest ease by any boy of common understanding. . . . The combustion of the candle, within the lamp, is supported by the ordinary atmospheric air of the coal mine, which is supplied by a pair of common bellows through a stratum of water below the candle; at the same time a portion of the air, already in the lamp, is driven through another stratum of water above the candle, and thus the air supplied may explode within the body of the lamp, without communicating the effect to the air in the mine. . . .‡

‡ Philosophical Transactions of the Royal Society of London, 1813, part ii., page 203.
George Stephenson also invented a lamp which was tested in October, 1815, in Killingworth colliery. There was no difficulty, I believe, in finding an explosive mixture; and it is reported that the light at once went out. Mr. J. H. H. Holmes, who gave much time to the question of improving the ventilation of mines, wrote as follows: —

Mr. Stephenson is an engineer employed at the Killingworth Main colliery, so that whatever from local or practical information is required for the construction of a safe lamp he was possessed of, and undoubtedly claims great merit, if the invention produced was from his own genius. As I was present at a general meeting of the Society at Newcastle, when this lamp was presented, and made some experiments myself upon it, I am enabled correctly to describe the apparatus. . . . In regard to this lantern having been tried in a mine six weeks previous to its appearance at the meeting, I must express some doubts, as it certainly did not wear the appearance of so old a practitioner; and as Mr. Stephenson appeared totally ignorant of the manner in which the air and gases operated upon the light.*

This statement does not sound very flattering to Mr. Stephenson. Sir Humphrey Davy, after experimenting with very small tubes, undoubtedly discovered the principle of the wire-gauze. Mr. J. H. H. Holmes was very jealous of Dr. Clanny's pre-eminence. He stated that: —

Dr. Clanny had experimented with a tube, having a small perforation to convey the air from a pair of double blast bellows. After this it was not difficult to find out that small air apertures would answer the same purpose: from hence the safety concentric canals, etc., follow in regular succession of ideas; and ultimately the gauze wire apertures are the extremity of refinement, upon a principle clearly originating with Dr. Clanny.†

This gentleman had made experiments with Dr. Clanny, and is very proud of the advantages to be obtained by the use of this lamp. He mentions one instance where the downcast-shaft at a colliery was under repair, and the only entrance for the horsekeeper was by the upcast-shaft, and so inbye, where "he would be compelled to pass through a region or tornado of inflammable air": and he explains how a bore-hole had been put down from one seam to another which was worked out, in order to drain off the gas which was coming up staples and fissures in the strata; and it was this part of the mine which the horsekeeper had to pass. "When the wind is north, north-north-east or north-west," he says, "the gas is going down; but

† Ibid., page 204.
when south-east or east-by-north, the gas is given up and rushes through this aperture in the most violent manner.” The lamp was used here, “and by this means the man was enabled regularly to attend to his cattle.”* This enthusiast was quite aware that improvements cost money, for he says, in 1816, “I am aware that the coal-owner has at all times but a speculative property, and frequently sinks an immense capital without knowing how far the deposit of coals may answer his expectations; and sometimes, owing to the working of too great a number of pits at one time, and consequent depreciation in the market, is rendered a great loser by his trade.”†

Dr. Clanny was not long in improving his lamp and adopting wire-gauze above the glass. Mr. Matthias Dunn, one of the first inspectors of mines, says, “to Dr. Clanny, beyond all doubt, belongs the honour of first conceiving the idea, and of executing a lamp to burn safely in an explosive atmosphere. . . . In the year 1815, however, the safety-lamp of Sir H. Davy was discovered; and . . . has been the means of recovering millions of value in coal, otherwise irrecoverably lost. It was on the first of January, 1816, that the lamp was first tried by me at Hebburn colliery.”‡

The feeling of the coal-owners in the matter can be gauged by a speech made in September, 1817, when the colliery-proprietors of the north of England entertained Sir Humphrey Davy at dinner in Newcastle-upon-Tyne. Mr. J. G. Lambton, in presenting a service of plate, said:—

Your brilliant genius, which has been so long employed in an unparalleled manner, in extending the boundaries of chemical knowledge, never accomplished a higher object, nor obtained a nobler triumph. You had to contend with an element of destruction which seemed uncontrollable by human power; which not only rendered the property of the coal-owner insecure, but kept him in perpetual alarm for the safety of the intrepid miner in his service, and often exhibited to him the most appalling scenes of death and heart sickening misery. You have increased the value of an important branch of productive industry; and, what is of infinitely greater importance, you have contributed to the preservation of the lives and persons of multitudes of your fellow creatures. It is now nearly two years that your safety-lamp has been used by hundreds of miners in the most dangerous recesses of the earth, and under the most trying circum-

† Ibid., page 222.
‡ An Historical, Geological and Descriptive View of the Coal Trade, by Mr. Matthias Dunn, 1844, pages 58 and 59.
stanes. Not a single failure has occurred—its absolute security is demonstrated. I have, indeed, deeply to lament more than one catastrophe, produced by foolhardiness and ignorance, in neglecting to use the safeguard you have supplied; but these dreadful accidents even, if possible, exalt its importance. If your fame had needed anything to make it immortal, this discovery alone would have carried it down to future ages, and connected it with benefits and blessings.*

In 1833, Mr. Carleton Tufnell, a commissioner appointed to carry out the provisions of the Factory Act, made enquiries into the condition of the miners in Lancashire. His report disclosed a state of affairs which, to-day, seems to us to be well nigh impossible. The cruelty to children, the revolting condition of women and girls, and the barbarous methods of mining generally, make one ashamed that those responsible could call themselves Englishmen. There were doubtless exaggerations made and also some misconceptions, for it is stated that after Mr. Cobbett † had been lecturing at Newcastle and adjacent towns in the autumn of 1832; in the interval of a week or two, the inhabitants of the neighbourhood were not a little surprised to read, in the Political Register, the following paragraph:—

'Here is the most surprizing thing in the whole world; thousands of men and thousands of horses continually living underground; children born there, and who, sometimes, never see the surface at all, though they live to a considerable age.'‡

For children, in this outburst, perhaps one should read horses.

In March, 1834, a petition was presented to the House of Commons on behalf of the coal-masters and miners of Staffordshire, praying for a scientific board to examine all lamps intended to be offered for sale to the public as safety-lamps to be used in collieries, and to direct the stamping of all such as they shall approve, and to prohibit the sale of any as safety-lamps, which shall not be so approved. This was really the outcome of experiments by interested persons to show how unsafe the Davy lamp might become in fire-damp. That petition had not yet been granted. Perhaps, even after this lapse of time, the present House of Commons may consider the matter.

In August, 1839, a number of South Shields gentlemen, appalled by the great loss of life in collieries, formed themselves into a committee to investigate mining accidents. They took

* The History and Description of Fossil Fuel, by Mr. John Holland, 1835, page 277.
† Ibid., page 211.
a great mass of evidence, and made a report. They made several suggestions, amongst them being one for a proper inspection of the mines by Government officials; and they pointed out that the practice had been adopted on the Continent for a long time with the best of results.

In 1842, the report of a Royal Commission appointed to enquire into the employment of children in mines was published; and a woeful state of affairs was revealed. Children of three or four years of age were taken into the pits. I can well remember one or two old men telling me that they were carried into one of the north country pits, when they wore petticoats, at the age of four.

Women were largely employed underground in Scotland, Lancashire, Yorkshire and South Wales. Some twenty years ago, an old underviewer remarked to me after we had visited the working place of an old collier, "Bill's a good chap, but he's not as good a man as his wife; she used to tram for me." But all colliers were not satisfied with the condition of things. It is reported that a meeting of some 300 of them was held in Barnsley, and they passed a resolution that "the employment of girls is highly injurious to their morals; that it is not proper work for females; and that it is a scandalous practice." After stormy debates in both Houses of Parliament, chiefly in the Upper one, the Royal assent was given on August 10th, 1842, to the Act which provided that no women and girls were to be employed underground, nor boys under the age of ten years; and that the Secretary of State should be empowered to appoint proper persons to visit and inspect the mines and collieries. In introducing this measure, Lord Ashley said,—"as for subterranean inspection, it is altogether impossible, and indeed, if it were possible it would not be safe, etc."

What was known as the "Midland Commission" was appointed in 1842, to enquire into the condition of the mining population of Worcester, Warwick, Staffordshire and Shropshire. There had been great agitation in the coal-trade at this time, and many strikes and riots took place which were doubtless fomented at the outset by the Chartist movement. The report disclosed an astonishing state of affairs: the chief culprits being

*The Report of the South Shields Committee appointed to investigate the Causes of Accidents in Coal-mines, by Mr. James Mather, 1842.*
not so much the coal-owners as the butties, who were generally also
the landlords of the adjacent public-houses; while the colliery-
owners were the proprietors of the "tommy-shops." Between
them the poor colliers seem to have been betwixt the upper and
nether millstones, and no wonder they created disturbances and
organized strikes. Their meetings, amongst other things, seem
to have been productive of the formation of co-operative societies
and trades unions; and in these days certainly, they were born
of oppression by despotic employers against weak and ignorant
workmen. In July, 1844, Mr. S. Tremendereere, the inspector
who was appointed under Lord Ashley's Act to make enquiries,
but not to enter the mines, made his first report after examining
the Scottish coal-districts. He mentioned that the proprietors
had been compelled to use ponies for haulage, instead of female
labour; and that the change had actually proved economical.

At this time a meeting was held in Newcastle-upon-Tyne
which resulted in a Bill getting so far as to be printed and cir-
culated. It provided for the country being divided into districts,
each under a registrar; to obtain returns from the mines; correct
plans of the workings; names of owners and lessees; sections of
strata; number of seams and their inclination; direction of
faults, etc., and the system of working adopted. Rather a fore-
cast of much more recent legislation.

Serious explosions were terribly frequent: the public generally
were startled, and the miners in various parts of the country met
from time to time, discussed the dangers of their calling, and
sent petitions to Parliament.

In August, 1845, the Government appointed Sir Henry T. De
la Beche and Dr. Lyon Playfair to enquire into the cause of
colliery-explosions, and, if possible, to advise as to the measures
for their prevention. Many of the large collieries, one ought to
bear in mind, had only one shaft, divided by a wooden brattice.
The commissioners travelled about and obtained information,
and made their report in June, 1846. Briefly, they condemned
a large number of mines, classing them as wretched, and the
officials who managed them as very ignorant. They suggested
"Careful and judicious inspection by competent persons," and
anticipated very good results from it.

There were several explosions in different parts of the country
during this year. The colliers continued to hold meetings and
send petitions to Parliament. In May, 1847, the Miners' Association of Great Britain sent a petition asking for legislation; they also asked for the appointment of inspectors to visit all the mines; and suggested that the inspectors should have very large powers. Earl Fitzwilliam brought some of these petitions before the notice of the House of Lords.

In January, 1849, an explosion occurred at Darley Main colliery, near Barnsley, by which 75 lives were lost, caused, as most of such disasters were, by the use of naked lights and great laxity in the management. The Government were again pressed to do something, and Lord Wharncliffe was successful in moving for the appointment of a select committee to enquire into this subject. The commission reported not only upon the general condition of British mines, but upon that of foreign mines also; and agreed that the latter were better, and the officials and workmen employed there superior in education to those employed in Great Britain. Evidence was given pointing out the necessity for two independent shafts, and for better systems of ventilation; and, of course, Government inspection of the mines.

In 1850, the Act was passed which first provided for Government inspectors entering any mine, as well as examining all the works and machinery upon the surface, and enquiring into all matters relating to the safety of those employed: really the first Parliamentary interference with the actual management of mines. The mines of the country were now producing some 50,000,000 tons of coal per annum, and giving employment to over 200,000 workpeople.

We now begin to hear a little more about education. The Royal School of Mines was inaugurated on November 6th, 1851. Another commission was appointed devoting considerable attention to the question of ventilation. They actually reported "Your committee are unanimously of opinion that the steam-jet is the most powerful, and at the same time least expensive, method for the ventilation of mines."* I need hardly say that colliery-viewers of that day by no means agreed with this opinion. On September 3rd, 1852, the North of England Institute of Mining and Mechanical Engineers was inaugurated with Mr. Nicholas Wood as the first President. In his address to the members he very naturally refers to the recent report of the Commission, and offers

* Report from the Select Committee on Coal-mines, 1852 [569], page v.
some criticism upon many of their suggestions. He points out—and how often comparisons of this nature have been made—that since the safety-lamp came into use the number of deaths by explosion had increased; and since inspectors were appointed, that the deaths had multiplied alarmingly.

The inspectors compiled a list of fatal accidents for the years 1851 and 1852, and the total was 2,040, so another select committee was appointed to make enquiries. This committee reported in June, 1854. Every side of mining was touched upon; coal-owners, viewers, workmen, and inspectors were all drawn upon for opinions. Great stress was laid upon the provision of better ventilation; and this committee reported in favour of the furnace; they also suggested some rules to be enforced by legislation. Of course, the number of inspectors was to be increased, and this time it was suggested that their salaries be augmented.

On August 14th, 1855, the Royal assent was given to an Act which embodied the principal feature of the committee's report, and provided for General Rules and Special Rules. And on August 28th, 1860, another Act was passed which increased the number of General Rules to fifteen; the age of prohibition of boys was raised, and education of some kind secured to them.

About the middle of the last century, the system of ventilation, that is, where there was any system at all, was almost entirely by furnace, usually fed by return-air. It is recorded that one of the hottest shafts at this period (1850) was at Marley Hill colliery, in Durham, where the average temperature was 168° Fahr., and at Hetton colliery it was 145° Fahr. The volume of air per minute obtained at a few of the largest collieries was as follows:—Hetton, 190,000 cubic feet; South Hetton and Murton, 132,805 cubic feet; Wallsend, 121,360 cubic feet; and Haswell, 100,000 cubic feet; this result being obtained by splitting the air-currents, a system which was now beginning to be understood (it was introduced about 1840).

At Hetton colliery, we learn that the air was divided into sixteen different currents. Prof. J. Phillips stated that the average length of the air-courses in the larger collieries did not now amount to 3 miles. Mr. Dunn mentions in his *Historical, Geological and Descriptive View of the Coal Trade* that, at the beginning of the nineteenth century, the air-current at Hebburn
colliery traversed at least 30 miles. In Yorkshire, the introduction of large volumes of air into the mines may be said to have only commenced at the middle of the century. Until 1845, the Oaks colliery, Barnsley, then the deepest in Yorkshire (848 feet), was ventilated by means of a fire-lamp placed in a recess in the upcast-shaft—though furnaces had long been in use in other parts of the country.

About 1850, the best ventilated mines in Yorkshire were Honeywell colliery, Barnsley, with 39,666 cubic feet; Oaks colliery, 31,000 cubic feet; and Darley Main colliery, 30,000 cubic feet; and the furnaces in many cases were supplied with fresh air.

As far back as 1811, Mr. John Buddle applied a steam-jet at Hebburn colliery, as a temporary expedient for getting rid of some gas, when the furnace was considered dangerous. He placed the jet nearer the top than the bottom of the shaft.

In 1828, a steam-jet was used in a more permanent fashion at a colliery in Wales, but it was not until 1840 that the question was considered seriously. Opinions apparently differed very greatly as to the useful effect of this system. Numerous experiments were made, jets were tried at the top, part way down, and at the bottom of the shafts: with furnaces, with boilers in the pit, and without either; but generally, when any reasonable amount of air was obtained, the results could be attributed largely to the heat of the shaft. I cannot find any correct account of a steam-jet being used where the shaft was previously cold.

One of the earliest instances in which mechanical ventilation was adopted was at Johnstone Castle colliery in Scotland, in 1827. This was a small exhausting fan, and is described as having "vanes, like those of a winnowing-machine, working horizontally within a circular case fixed air-tight into the mouth of the pit. Though only worked by hand, the effect of it was felt in a few minutes at a distance of nearly a mile."

In 1837, Mr. William Fourness, of Leeds, introduced an exhausting fan. An account of it is given in The Mining Journal as follows:—

Ventilation of Coal-pits.—An ingenious townsman of ours, Mr. W. Fourness, painter, has invented an apparatus for ventilating coal-pits, or other places where inflammable vapours may exist. A gentleman well acquainted with such matters, has formed a very decided opinion in its favour,

as being admirably adapted for the purpose for which it is intended. The construction, we understand, is of a very simple description; but such is its power and capacity, that it is calculated to extract between eight [thousand] and nine thousand gallons of gas or air per minute, which is driven at the rate of 65 miles per hour. With this apparatus in operation, the inventor expresses his fullest confidence that the pit may be entered at all times with lighted lamps, and with the most perfect safety. At the top of the shaft, a small gas-cock is fixed, by the means of which the state of any pit may be at any time ascertained with the greatest precision. The great advantage of the principle on which this apparatus is constructed is, that instead of forcing the atmospheric air into the pit, as by the old plan, it first extracts the hydrogen gas, and the atmospheric air then follows down the shaft, thereby rendering an explosion impossible.—Leeds Times.* By this machine the ventilation can be multiplied to an incredible extent, making the draft of air through the mines 31 times greater than at present.—Wigan Gazette.†

In 1837, one of these machines, 5 feet in diameter and 2 feet wide, was applied at the Osmondthorpe colliery, Leeds, to get rid of the products of a fire, which had originated from an explosion. Mr. Fourness was really the first in this country to make mechanical ventilation an actual success.

In 1842, Mr. Benjamin Biram, viewer at Earl Fitzwilliam's collieries, patented several rotary machines on the screw principle. In the same year, he applied a fan at Elsecar colliery. It was placed at the bottom of the shaft, and driven by a jet of water impinging upon small buckets on its periphery. It was used a few years and then replaced by a horizonta l fan at the surface. A few years later, this gave place to another Biram fan, 23 feet in diameter and 4½ feet wide, with a single inlet; this fan is still at work and exhausting a large quantity of air. In 1841, we first hear of the water-gauge, and a few years later its use became common in the mines. And now great interest was taken in the question of ventilation, as the Proceedings of the Institution of Civil Engineers and the Mining Journal of that period show; and the various controversies were of great benefit to the mining community.

In Yorkshire, we are familiar with the fact that it was in 1811 that John Blenkinsop, of Middleton collieries, Leeds, took out a patent and ran a locomotive engine from the colliery to the town—using toothed wheels and rails. Two years later, William Hedley, of Wylam colliery, after many experiments, took out

† Ibid., 1837, vol. iv., page 166.
a patent for a locomotive which would draw a train of loaded wagons by the friction of the wheels upon the rails. Speaking of a second engine, constructed with two cylinders, Mr. Matthias Dunn says, "This engine succeeded so well that it drew eight loaded waggons at the rate of 4 or 5 miles per hour, and completely superseded the use of horses, which at that time was a ruinous expense to the colliery. . . . . In justice, therefore, to Mr. [William] Hedley, he is entitled to the honour of being the inventor of the present principle of locomotion."* In 1814, George Stephenson fitted up an engine at Killingworth colliery, the motion of which was communicated to the wheels of the engine-carriage by means of an endless chain instead of cog-wheels; and its action depended upon the friction of the wheels upon the rails. Every schoolboy has learned what an influence this invention had upon the trade of the country, and the coal-trade in particular.

Wire-ropes appear to have been first used in mines in the Harz mountains, in 1834, and two or three years later they were introduced to the notice of British coal-owners. Mr. M. Dunn seems to have been a pioneer in this as in many other matters, and used the first iron-wire winding-rope for a staple pit in St. Lawrence colliery, Newcastle-upon-Tyne, in 1840.†

About 1830, conductors of wood were patented by Mr. John Curr, who had charge of the Duke of Norfolk's collieries, at Sheffield. They soon became common in the Leeds and Barnsley districts also, as well as conductors of iron-rods. Mr. Curr also introduced chairs or cages, and corves with wheels. Mr. M. Dunn said that "In 1776, Mr. Curr invented his underground tramways of cast-iron."‡ Another writer, however, puts the date as near the year 1790. I find also that Mr. Curr was the first in this country to apply the steam-engine for the purpose of haulage, in 1805. He was also the inventor of the flat-rope, in 1798. He was apparently a very valuable man to the coal trade.

Steam-engines, directly applied, were probably first used for winding from shafts about 1790 to 1800. For some considerable

* An Historical, Geological and Descriptive View of the Coal Trade, by Mr. M. Dunn, 1844, page 54.
† The Mining Journal, 1840, vol. x., page 357.
‡ An Historical, Geological and Descriptive View of the Coal Trade, by Mr. M. Dunn, 1844, page 39.
time the winding-engine had been a combination of a drum actuated by a water-wheel, which, in its turn, was supplied with water by the fire-engine. Mr. Currr, writing in 1797, estimated that there were at that date 30 or 40 of these water-wheel gins with their fire-engines in use in the north of England.

In the deep mines of the future, we may revert to a system carried out at the end of the eighteenth century. At one or two collieries in the Whitehaven district, the coal was wound in a succession of lifts. Mr. John Holland states that, "In the Alfred pit, at Jarrow, there is a 30 horse steam-engine erected at a depth of about 130 fathoms below the surface: it is used in raising the coals up a shaft which unites with the workings, carried out 45 fathoms deeper still: there is likewise at the profound depth indicated by these two shafts, another steam-engine, to draw the coals up an inclined plane that lies coincident with the dip of the strata."

The year 1862 will always be memorable for the disaster at Hartley colliery, where the beam of the pumping-engine broke, and, falling down the pit, practically sealed up the mine. There was only one shaft here, divided by a wooden brattice, and 204 poor creatures lost their lives. Their sacrifice gained for their fellow-workmen, that same year, an Act which rendered such mantraps impossible in the future. One wonders why the division-brattice in some of these mines was not often destroyed, for one reads that streams of water were allowed to trickle down the brattice to prevent the furnace from setting fire to the timber. It is interesting to note that the first patent for mechanical coal-cutting dates from this year.

There was still much clamour for improved conditions of underground labour, and each year provided its most eloquent advocate in the way of great loss of life from explosions. More commissions were appointed and reports made. Yorkshire became very prominent with the Oaks colliery-explosion in December, 1866, when 334 men and boys, and an unusually large number of volunteer explorers lost their lives. The death-quota that year was 1,500.

The passing of the 1872 Act, introducing certificates for managers, and a good code of general rules; and the 1887 Act,

* The History and Description of Fossil Fuel, by Mr. John Holland, 1835, page 200.
providing that assistant or under managers shall also be certificate, brings us to fairly modern times to which further reference need not be made, excepting to make a comparison (Table I.) showing the improvement that has taken place in regard to safety, in the last 55 years.

Table I.—Ratio of Mortality from different Causes of Accidents in and about Mines classed under the Coal-mines Regulation Acts, per 1,000 Persons Employed, and per 1,000,000 Tons of Mineral Raised.

<table>
<thead>
<tr>
<th>Year</th>
<th>Death-rate from Accidents per 1,000 Persons Employed.</th>
<th>Death-rate from Accidents Under-ground and Above-ground per 1,000,000 Tons of Mineral raised.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1851</td>
<td>1:86</td>
<td>1:90</td>
</tr>
<tr>
<td>1872</td>
<td>0:40</td>
<td>1:37</td>
</tr>
<tr>
<td>1887</td>
<td>0:35</td>
<td>1:10</td>
</tr>
<tr>
<td>1905</td>
<td>0:26</td>
<td>0:75</td>
</tr>
</tbody>
</table>

And this improvement is not to be attributed entirely to legislation; it is due to the spread of knowledge: to the spirit of the times; to scientific institutes like our own; it is due to the enhanced value placed upon human life; and, now I would say, for no class of labour is there greater solicitude and care, on the part of employers and officials, than for those who toil in our mines.

This imperfect résumé of coal-mining shows perhaps mainly how ignorance on the part of all—proprietors, officials and workmen—was very slowly dispelled; and the legislation, which at all the periods was so much needed, possibly in the minds of some lagged not very far behind the growth of knowledge. Today we can find some of the most alert and intelligent men of the future amongst our pony-drivers; and experience the evidence of high reasoning and debating power, which may one day make itself felt in Parliament, being exercised at the coal-face.

So much for the past; the present is with us, and is a time pulsating with vitality. This is the scientific era, the age of skilfully applied machinery, of the triple-expansion engine, gas-
producers and gas-engines of large power, the dynamo and electric motor, the quick-revolution engine and the water-tube boiler. Those of you who are controlling large modern mines do not need to be told of the progress that is being maintained in all departments of mining; and we all appreciate the necessity for continually taking advantage of every discovery and every practical invention.

From the trend of labour-legislation and the development of true socialistic ideals, we may look in the near future for extensive changes. The environment of a large colliery will be very much in the nature of a self-contained village. We shall see a church, free in the best sense of the word, free to radiate all the good it can, without cramping the honest aspirations and opinions of its adherents; an institute for mental and physical recreation; schools that will endeavour to teach the young how to live, as well as acquire smatterings of pseudo-science. A hospital for the relief of all connected with the mine, which will embrace a staff of nurses, who can devote some time to house-visitation, and, perhaps, instil into the wives of the workmen some of the advantages of common-sense in tending sickness. The girls will have a cookery school, so that when they come to preside over households, they will be equipped with one factor that will make for the increased worth and contentment of the men—the caring more efficiently for their bodies.

At evening classes for the boys they will be allowed the use of the colliery-shops with electrically-driven machinery, where they will probably notice that the larger fly-wheels of engines are smoothly cased at the sides to prevent loss by friction. The best boys will rise most quickly to the best-paid positions. They will discover that knowledge pays. Some of the cleverer boys, after passing certain courses of study in the local school, will be assisted to the universities; and perhaps a few also will get their articles of apprenticeship to the colliery-manager, with the addition of a small salary, so that they may not starve their bodies while they are endeavouring to enlarge their minds. A children's library will be connected with the school, and will be under the charge of the teachers, who, while having a part in the selection of the books, may also, by their influence, guide the reading of their pupils.

Perhaps one of the newest features in the surroundings will
be an isolated building, somewhat akin to an engine-house, in close proximity to the coke-ovens, and known by the name of the crematorium.

A co-operative store will continue to attract custom by the large dividends paid. The workmen's cottages must approach more nearly to those associated with the garden-city movement. They will naturally be erected so that the prevailing direction of the wind will take the little smoke that is made away from them. The houses, while preserving a certain uniformity, will vary in size, and all have gardens. Some of the larger houses will receive lodgers, and a list of them will be kept at the office of the gentleman known as the social secretary. Attempts will be made to allow workmen to become the owners of their dwellings; and these houses will be built apart from the rest, upon land kindly given by the lessor of the minerals, in order to lessen the cost and encourage thrift. These houses, of course, will be paid for through the means of increased weekly rent: one of their distinguishing features will be a good roomy general living apartment, and the elimination of the stiffly furnished and rarely used uncomfortable parlour. It will probably be a rule, in the case of coal-getters, for supplies of coal to be delivered to the houses of those who have wrought them: and one can understand that the wife of the day-wageman will always ask for the number of the "motty" or token.

The refuse will be taken away and consumed by the waste-gases from the coke-ovens, or in some other economical form of destructor. Unsightly heaps of pit-dirt will be planted with trees; though we shall possibly hear of all the sinking débris going back into the mine in lieu of shaft-pillars. Batteries of coke-ovens will produce sufficient power for all colliery-purposes, and for generating electric light, or supplying a purified gas for the village, etc., or, where the coal is non-coking, the inferior part of the seam and highly carbonaceous waste would be ground and used in gas-producers. Large units of power will probably be in the form of coke-ovens or producer gas-engines, and the smaller units in the form of electric motors. No coal will be consumed for the production of power alone. Probably the only steam-engine will be a high-pressure engine for winding at the downcast shaft; the upcast shaft being efficiently served by electric motors. Each winder will have an automatic cut-off and brake-attachment, and an automatic recorder of signals.
In the management of the concern, a committee of workmen chosen by themselves will assist the officials in settling all questions between employer and employed, and take part in controlling the organizations in the village. The manager will find it helpful to meet all his underground officials together, excepting those on duty at the time, every week, and discuss all underground questions with them. All will be invited to come with suggestions previously placed upon the agenda-paper. The workmen's committee will join them once a month: amongst other things they will settle the question of distances at which timber should be set; when the men should travel outbye by the return-air roads, etc. All workmen will be encouraged through their committee to make suggestions, and all having a monetary value to the employer will be paid for. All officials will be provided with suits of blue cloth, someone having discovered that it adds to their dignity and promotes efficiency.

Most of the higher officials in every department will be certificated men of some kind. We shall then probably revert to former methods of selecting officers, not because they have a certificate, and are cheap, but for their capacity and experience.

One of the most capable officials will be the social secretary, a man of many sides. All men applying for work must first interview him; and if the interview is satisfactory, he will pass them on to the official who may employ them. He would also under the committee have charge of the institute, and be the recognized leader in all forms of recreation, whether of a mental or a physical kind. He would look after the letting of the houses, and keep an eye on those which accommodated lodgers.

The chemist, in addition to having charge of the production of pure coke, and the production and use of gas, will also see to the quality of the water used, the purity of all oils and grease, and the general preservation of ropes and colliery-stores.

The under-manager will take care that a deputy has never more than 50 men under his supervision in an ordinary longwall-face. Coal-cutting by machinery, even in the thicker seams, where the gradient is not too excessive, will be the rule; and this will come about not for economical reasons, or because it promotes better timbering and general safety, but because the miner will decline to do this, the most arduous part of all mining operations.
The lighting of pit-bottoms and approaches, already very satisfactory in many places, will be much extended; on the principle that a man is much safer in the light, and, with the recollection that you can have a good light for 1d. an hour, whereas an idle man may cost you 9d. an hour.

It is marvellous to-day to see how the weighmen at some of the large concerns get through a big day's output. I think that they may have a somewhat easier time in the future, when they get all tubs weighed automatically: the motty number being called out, the weighman will depress a key of that number, and the exact weight and number will be recorded upon a travelling tape: the weighmen will copy the records and preserve the tape in cases of dispute.

More managers, I believe, will see the advantage of contouring the plans of the underground workings, like a surface ordnance-map. Some already have the levels carefully marked upon the plans: but the lines of equal altitude, showing the wonderful hills and dales in an apparently regular coal-field, will be of very great service in laying out any system of haulage, and of immense value in designing how an upper or lower seam should be worked.

As a knowledge of ambulance-work is even now almost essential to every man applying for a colliery-manager's certificate, we all expect to see considerable extension in this direction; no official without an ambulance-certificate will obtain employment. Rescue-stations, in groups, will be imperative within half-an-hour's call of every colliery: and the apparatus will at all times be immediately available for use. Should a disaster occur, those responsible will not have the bitter mortification of reflecting that they have left something undone—something unprovided. The few firms who have pioneered this work will probably be remembered with gratitude long after we have all descended our last pit.

Perhaps in connection with the attractive community that I have touched upon, and, as an adjunct to the crematorium, a pension-fund for workers may be inaugurated. It could be run somewhat on these lines:—Members, on reaching the age of 20 years, to contribute 3 per cent of their wages: the colliery company contributing an equal amount. Members must contribute for 10 years, and may cease to contribute when they have paid for 40 years. Pensions to be granted for the rest of
life at the rate of one-sixtieth of the average wages in respect of each year for which the contribution has been paid. On leaving his employment, a contributor would receive his own contribution only: a slight inducement to remain at one place. At death, the contribution with 2½ per cent. interest, together with the company's contribution, would be paid to the relatives. At death, after the pension had been received for a time, the same contribution as above less the amount paid in pension.

One has occasionally to think out the problem of what to do in the case of a surface-fire, when the downcast shaft may be endangered. Some means of readily reversing the ventilating current will naturally be of the greatest assistance. I am indebted to Germany for the idea of a safety-shaft; at the Shamrock collieries, Westphalia, I saw an arrangement like the following:—The downcast and upcast shafts are connected together by a drift, just below the surface on the level of the fan-drift. At some point in this drift, between the two shafts, is a third or safety shaft, or rather an independent entrance to the drift. It is arranged entirely for cases of emergency, so that should, say, a fire break out about the surface of the downcast-shaft, the downcast could be quickly sealed off above the level of the drift, that is at the low landing, by a cover kept in readiness for the purpose; this cover could be in the form of a scaffold with iron leaves, or in several ways which will suggest themselves to you; then the entrance to the emergency-shaft would be opened and allow the air to travel on the drift into the downcast pit. In case of a fire in the downcast-shaft, when it might be necessary to reverse the ventilation and cause this shaft to be an upcast; the doors, A and B, in the fan-drift (Fig. 1), would be closed; and the door, C, would be opened: the top of the upcast being at the same time altered to admit the fresh air.

Many minds are already at work upon that most serious problem—coal-dust. Perhaps some of our new mines will
be laid out so that the travelling roads will be the main-intake airways; the haulage-roads will also be in the intake air, but the currents will be regulated much below the speed of those in the travelling-roads: when I say travelling-roads, it does not imply that the workmen will always walk. Of dust, we may read in some new Act, "it shall not be allowed to accumulate in the roadways"; which can be met by not allowing it to go into the mine; and, by using dust-tight tubs and sprinkling the tops of full ones with water before the tubs come into contact with such a current of air as is likely to carry away the dust. The same Act may probably say that "reasonable precautions shall be taken to prevent dust caused in screening from finding its way into the mine." At some of the large mines this will be interpreted as meaning that the screens must not be erected nearer than 300 feet to the downcast-shaft.

We are continually being reminded of the destructive effects of this agency, and there is some action that as yet we little understand. The results of some dust-explosions seem in no way commensurate with our conception of their propagation. A blown-out shot may or may not originate a disaster; it would seem to depend upon the character of the wave produced; and its violence as to whether or not detonation was set up in the galleries of the mine. I am hoping that one of our professors of mining will, in the future, have something to tell us upon this abstruse subject.

To-day and to-morrow are both times of large outputs and sweeping currents of air. The tendency just now seems to be in the direction of large shafts, up to 23 feet in diameter. I am not quite convinced of the necessity for this large area: and if such shafts are at any considerable depth in waterbearing strata, the tunneling will have to be not only very thick, but very broad on the flange and heavily ribbed, and the cost will be enormous. In this connection I may hazard the opinion that we shall some day get back to the idea of the first iron-tubbing which I mention in the Appendix; that is, to place the ribs inside the pit and bolt the segments together, but in addition planing the joints and grooving them to receive a strip of lead.

I am, after some thought, becoming an advocate for the lining of shafts with concrete. This has not been done to any extent in this country, but on the Continent the method has been
adopted with considerable success. A first-class concrete (matured) will withstand a crushing strain of nearly 5,000 pounds on the square inch. It is easily applied, is about three times the strength of good brickwork of the same thickness, and makes a perfect joint with the strata irrespective of any inequalities. In the case of pressure due to a considerable head of water, the lining can be very much strengthened by a form of ferro-concrete: and a ready and effective way when the shaft needed a temporary lining, would be to leave in the skeleton-rings and hanging rods, some 2 inches from the side, and embed them in the concrete. In an actual case supplied to me from Belgium, the lining was inserted in 3 feet lengths, some 10 inches thick, and a length of 12 feet was completed within 24 hours. The advantages over brickwork were:—Less area and less quantity excavated in the shaft, and consequently greater speed: less thickness and less quantity of lining, and cheaper materials. On the whole, the balance was very much in favour of the use of concrete.

As an example: with a shaft, 20 feet in diameter, having a head of water of 100 feet, the thickness of brickwork to withstand that pressure would be 4 feet 4 inches: that of concrete 1 foot 3 inches, allowing a maximum working stress of 166 pounds per square inch for bricks and 400 pounds per square inch for concrete: and cast-iron tubbing only 1 inch (according to recognized formulae, a thickness of 0·35 inch would suffice for a working stress of 15,000 pounds per square inch, if retention of shape and wedging and corrosion had not to be taken into account).

I think for deep pits where the run is continuous, that there will be no difficulties with rope-guides. Where intermediate landings are necessary they are distinctly objectionable; and then either wood or inverted channel-steel, or the two combined, are to be preferred. For some time I held the opinion that there was considerable risk with rope-guides, for the reason that vibrations set up by the cage might be gradually intensified until collisions occurred. After considerable observation and some experiment I have come to the conclusion that the vibration in a properly-fitted shaft is very small. Prof. G. R. Thompson, of Leeds University, and myself have made a few experiments in deep shafts with a form of pendulum suspended in the cage, free
to oscillate in every direction. At the end of the pendulum was a sliding pen which recorded upon a sheet of paper, upon the cage-decking, all the movements of the cage in ascending and descending; the results were very interesting. It perhaps does not always strike one that in a shaft, say, 2,700 feet deep, the velocity of a wave, in a rope of that length of proper strength and suitably weighted, would only be about 400 feet per second. To minimize any tendency to vibrate in unison, the guides could be weighted unequally, so that the waves in the respective ropes would not be of the same pitch. A further help to smoothness of running would be the adoption of locked-coil rope-guides. Experience would suggest having two rubbing ropes between the cages, and allowing the cages to touch them; the clearance that is required is at the corners. Ten guides in a shaft heavily weighted at the bottom cost a great deal in metal alone; it would not be at all difficult to diminish considerably the quantity of metal by attaching a lever at the end of each guide, and placing the weight upon the lever. German engineers do not agree with us in the use of rope-guides, at any rate for their conditions. Their opinion is unmistakable in the following quotation:—"As a relic of the time when English capital and English engineers had taken foothold in some of the mines of this district, we still find in Westphalia some rope-guides. Even to-day such are in use at the Zollern collieries, whilst in the Erin and Hansa collieries, this kind of conductor, so highly characteristic of English mining, had to give way to wooden guides."

Ventilation-difficulties will not lessen as the mines increase in size and number and length of air-roads. We may some day get an enactment that will allow fans to be installed underground, where any other motor can be placed in a mine. At the same time, a safety fan would be erected at the surface, as now; and while normally the top of the upcast shaft would be an open chamber (a great convenience for working and inspection), in case of emergency, and always at the week-end, this chamber would be closed and the surface fan run. An indicator from each underground fan would be placed in the manager’s office, either in the form of an electric contact-signal.

or a water-gauge, which would at all times tell what the fans were producing.

I think that we may all anticipate further legislation affecting mining. It will be of interest to those working thick coal if, in the future, in moderately thick seams, leaving in a mine more than a certain percentage of good coal, will be punishable by a fine. We should then not have the anomaly of a thickness of coal, which in one part of a district may be considered a good workable seam, in another part being left behind in the goaf.

It would not seem unreasonable if, in unproved coal-areas, where a prospective colliery-owner has spent money in proving the minerals, he should, unless otherwise compensated, be entitled after commencing to work coal, to deduct from the rent the cost incurred in boring. And it would be of advantage to the industry if it were compulsory for royalty-owners to sell or lease their coal to the nearest mine-owner at a fair valuation. And, on the other hand, the nearest mine-owner on receiving notice from the royalty-owner should accept a lease upon equitable terms, to commence from a period when the working-faces should reasonably reach the area in question.

Speculation, however, is rather treacherous ground. Of one thing we are all convinced, that, whatever the future produces, it will require good men; men who can combine a high theoretical training with practice; and I trust and believe that the educative value of this Institute will be one of the factors in providing them.

Appendix A.—Safety-lamps.

[Fig. 2] represents the [Dr. W. R. Clanny early] lamp as it now is ready for use. 

\[ a \] The body of the lamp, constructed of copper or block tin; \[ b \], a conical tube which carries off the air (deprived of its oxygen by combustion) through the water in the cistern. \[ c \]; \[ d \] is a cistern containing water to keep the lamp cool, if necessary; \[ e \], the window of the lamp made of very thick glass; \[ f \], the candle, supported upon a tin stand; \[ g \], a cistern containing water through which the air is forced by the bellows; \[ h \], a tube from the bellows which conveys air for supporting the combustion of the candle. An elastic tube may be fixed to the valve of the bellows in case of necessity, by which to draw atmospheric air from any distance to supply the lamp.*

---

[Fig. 3] represents the lamp upon Dr. Clanny's original principle in a more portable and improved shape; the strata of water being dispensed with, and the air urged in by bellows through the oil which supplies the lamp. ... a, a tube fixed to the lamp, and which conveys the air; b, lamp for oils; c, air apertures under the burner in the oil; d, conducting tube, to which an elastic tube, having the bellows at one end, is fixed; e, a pin passed through the tube to prevent the lamp from falling out; f, bellows; g, the glass.*

[Fig. 4] represents the lamp invented by Dr. Clanny for passing the air necessary for the combustion of the candle through a cistern of steam; a, tube by which air is admitted; b, tube fitted air-tight in the smaller tube a, and which supports the water and steam cistern; c, cistern in which the water is kept boiling by the flame of the lamp; d, d, tubes, through which the air, after passing up the tube b, descends to supply the combustion of the lamp and then passes up the sides of the cistern out of the chimney; e, bottom fitted air-tight; f, the glass.†

[Fig. 5 represents Mr. R. W. Brandling's lamp, depending upon the idea that purer air will always be in a lower stratum.] This lamp was constructed of tin, being about 12 inches by 8 [inches] square, and was supplied with a bellows chamber at the top for the purpose of accelerating the draught of air. ... a, the bellows; b, the perforations for the air to pass out of the lamp, over which lies a small piece of wood hinged on with leather as a valve; c, the glass; d, the oil lamp; e, a belt by which the lamp is carried; f, the elastic tube [for taking in air].‡

[Fig. 6 shows Dr. John Murray's lamp, made on the same principle as Mr. Brandling's]. a, the glass body fixed into a tin or copper stud at b; the elastic tube is fixed to the lamp, which, when lighted, is screwed into the body at c; d, a kind of handle to carry the apparatus.

† Ibid., pages 210-211. ‡ Ibid., page 185. § Ibid., page 186.
[Fig. 7] represents Sir H. Davy's lamp, with the air feeder and chimney, furnished with the concentric metallic canals: . . . the sides are of horn or glass made air-tight; and at the top is a hollow cylinder covered with a cap to prevent dust from getting into the lantern.*

[Fig. 8] represents a lamp upon the same principle as [Fig. 7], with concentric metallic air feeders at the bottom, and a glass chimney with similar canals in the top, and covered with a tin plate.*

[Fig. 9] a metallic gauze lamp, with screens of wire gauze, and so constructed that the wick may be trimmed without inconvenience.*

[Fig. 10] represents this [George Stephenson’s] lamp: a, the lamp made of copper; b, the glass chimney fitted air-tight in the lamp, and . . . . enclosed in a case of tin with holes of about a quarter of an inch in diameter, cut out for the escape of the light; c, the cover or tin case so perforated; d, d, d, d, air holes. The principle of this lamp is its being supplied with air through small perforations at the bottom.†

APPENDIX B.—IMPORTANT DATES CONNECTED WITH THE COAL-TRADE.

853. Grant of lands by the Abbey of Peterborough: and requires twelve cart-loads of fossil or pit-coal.
1239. Henry III. granted to men of Newcastle-upon-Tyne a licence to dig coal outside the walls.
1246. Coal, having become an article of export, obtained the name of sea-coal.
1283. Municipal statutes of Berwick contain regulations for selling pit-coal alongside vessels importing it.
1424. First Act of the Parliament of Scotland relating to mining.
1555. Dr. Kaye mentions appearance of noxious gases in mines.
1590. Dean of York took out a patent to purify pit-coal.

† Ibid., page 188.
1806. Act of the Parliament of Scotland that no one should employ any person without testimonial showing cause of removal from last master.

1710. Explosion at Bensham colliery and 75 lives lost.

1714. The first steam-engine, north of the Tyne, erected at Byker colliery.

1782. Fire-lamps or furnaces first used at Fatfield colliery, Durham.

1736. Act punishing with death all who set fire to pits.

1760. Carlisle Spedding invented the steel-mill.

1769. Malicious Injuries Act, punishing, with transportation, wilful injury to colliery-property.

1784. Act passed that, in case of any number of persons above five, buying and re-selling coals, they shall be deemed guilty of unlawful combination to advance the price of coals and be liable to be punished by indictment.

1790. John Curr invented underground tramways of cast-iron.

1795. Up to this period, pillars in the deep pits had been given up as lost: the robbing of them was now introduced by Mr. Thomas Barnes, and a quarter of what remained was taken away.

1795. Introduction of cast-iron tubbing in rings at Walker colliery on the Tyne.

1796. Mr. John Buddle put in tubbing at Percy Main colliery, in segments bolted together.

1800. An Act for the security of collieries and mines.

1805. Segments of tubbing were put in, without bolts, at Howden pit; and this method usually adopted in this country ever since.

1807-1810. First mention of mechanical ventilation in the form of an air-pump, at Hebburn colliery.

1811. John Blenkinsopp, of Middleton colliery, Leeds, took out a patent for a locomotive engine.

1813. William Hedley of Wylam colliery on Tyne, took out a patent for a locomotive engine which would draw a load by the friction of the wheels upon the rails.

1814. George Stephenson built a locomotive engine at Killingworth colliery.

1814. Dr. W. R. Clanny invented his first safety-lamp.

1815. Sir Humphrey Davy's lamp invented.

1815. George Stephenson's lamp invented.

1817. An Act passed against payment of labour in goods or by truck.

1827. A centrifugal horizontal fan used at Johnstone Castle colliery, Scotland.

1831. Wallsend colliery was exhausted in the High Main coal-seam, the working of which was commenced in 1778.

1831. Truck Act.

1835. Commission appointed to enquire into mining accidents.

1837. First exhaust-fan used in Yorkshire, at Osmondthorpe colliery, Leeds.

1840. Commission appointed to enquire into employment of young children.

1842. Act prohibiting the employment of women and young children underground.

1845. Sir Henry T. De la Beche and Dr. Lyon Playfair appointed to enquire into causes of explosions, etc.
1850. Act providing for the appointment of inspectors of mines.
1851. Royal School of Mines inaugurated.
1855. Act to amend the law relating to the inspection of coal-mines.
1860. Act for the regulation and inspection of mines.
1862. Hartley colliery disaster and Act prohibiting single shafts.
1866. Oaks colliery-explosion, where 334 lives were lost.
1872. Act to consolidate and amend the Coal-mines Acts.
1896. Act to amend the Coal-mines Regulation Act, 1887.
1897. Workmen's Compensation Act.
1900. Workmen's Compensation Act, Amendment.
1903. Act to amend the Coal-mines Regulation Act, 1887 (Granting of Certificates).
1905. Act to amend the Coal-mines Regulation Act, 1887 (Weighing of Minerals).

Mr. J. Nevins, in proposing a vote of thanks to the President, said that he knew from experience the difficulty which there was in finding anything new to say to the members, but Mr. Wilson had surmounted that difficulty with great success.

Mr. H. B. Nash, in seconding the vote of thanks, said that the members had all listened to the address with a great deal of interest and pleasure. It took one back to the days when mining was very different from what it was at the present time, but he thought that they were now only following out the sound principles that were then laid down. As to the future, the President followed almost on the same lines in his address as he (Mr. Nash) had followed when he was president, in expressing the opinion that in a few years, except for winding purposes, nothing but gas and electricity would be used for driving the various engines and machinery about a colliery.

The annual dinner was held subsequently.
MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
Held at Wakefield, December 12th, 1906.

Mr. J. R. R. WILSON, President, in the Chair.

The following gentlemen, having been duly nominated, were elected:—

Members—
Mr. WILLIAM CLARKE, Mining Engineer, Lees Hall, Meersbrook, Sheffield.
Mr. ROBERT GEORGE HIGBY, Mining and Civil Engineer, Baltic House, 27, Leadenhall Street, London, E.C.
Mr. HAROLD C. JENKINS, Electrical Engineer, Bank Chambers, Fargate, Sheffield.
Mr. WILLIAM F. MYLAN, Electrical Engineer, Bank Chambers, Fargate, Sheffield.
Mr. JOE STANCLIFF, Mining Engineer, 183, Hyde Park Road, Leeds.
Mr. HORACE TREMLETT, Manager of the Montrose Gold-mining and Exploration Company, Limited, Johannesburg, Transvaal.

Mr. Percy C. GREAVES read the following paper on the “Cost of an Electrical Unit at a Colliery”:—
COST OF AN ELECTRICAL UNIT AT A COLLIERY.

BY PERCY C. GREAVES.

The writer, in presenting the following notes, simply wishes to place before the members the actual cost of producing electricity at a colliery under normal conditions. It is not contended that it is produced as cheaply as possible. He has found opinions differ greatly as to the actual cost, and as he has made an experiment he thinks that it may be of interest to the members.

The plant used for the experiment consists of two 50 kilowatts generators, working at a pressure of 500 volts, built by Mr. Wilson Hartnell, and coupled directly to two Willans central-valve engines running at 460 revolutions per minute under a steam-pressure of 100 pounds per square inch. The boiler is attached to this plant alone, so that accurate results can be obtained. The period of the trial was one week.

The motors and machinery driven by this generator are as follows:—One 24 kilowatts motor driving a main-and-tail-rope haulage-plant; one 1 horsepower motor driving a centrifugal pump; one 42 horsepower motor driving a ram-pump; one 10 horsepower motor driving a ram-pump; one 15 horsepower motor driving machinery in fitting-shops; and three Diamond coal-cutters driven by motors of 20 horsepower each. In addition, there are 115 lights in the pit-bottom, coupled in series.

The two dynamos are run in parallel, and, at a certain period of the day, one is stopped and the other does the work alone. A self-recording watt-meter was put down to ascertain the number of units used by the plant. In one week, from Saturday night to Saturday night, 4,400 units were consumed; during the same period the boiler used 33 tons 12 cwt. of coal. The following stores were consumed by the plant: 9 gallons of engine-oil, \( \frac{1}{2} \) gallon of cylinder-oil, and 2 pounds of waste. The wages of the attendants, one on each shift, were £2 12s. The quality of the coal used was very inferior, 8 tons being bastard.
cannel, while 17 tons 17 cwts. of coal had been in stock for about two years, and, in the writer's opinion, the full value of this fuel was 3s. 6d. per ton. Consequently, on this basis, the costs were as follows:—Coal, 33 tons 12 cwts. at 3s. 6d. per ton, £5 17s. 7d.; oil, 9½ gallons, 18s. 6d.; wages, £2 12s.; cleaning waste, 2 pounds at 2d., 4d.; and the total cost of £9 8s. 5d. is equivalent to 0·51d. a unit. In addition to this, there is the depreciation of plant and interest on the outlay.

A portion of this plant was bought when prices were high, so that it is hardly a fair criterion; but, taking the cost of the boiler, engine-house, and two plants at £2,000, and allowing 15 per cent. for depreciation of plant and interest on capital, it would amount to £5 15s. 4d. per week, and the cost of insurance of the dynamos is 2s. 6d. per week. The total cost will then become £15 6s. 3d. or 0·83d. per unit.

The trial was continued during the following week, when 4,428 units were used, and the results were as follows:—Coal, 34 tons 4 cwts. at 3s. 6d. per ton, £5 19s. 8d.; oil, 9½ gallons, 18s. 6d.; waste, 1 pound, 2d.; wages, £2 12s.; boiler-cleaning, 4s.; interest, depreciation and insurance, £5 17s. 10d.; making a total cost of £15 12s. 2d. or 0·83d. per unit.

Having made these two tests, the writer thought that he would like to know how many units were used by a coal-cutter in normal working, for which purpose all the lights and other motors were cut off, so that the watt-meter would register the actual energy taken by the Diamond coal-cutter. This machine was cutting in tough fire-clay on the floor-level, to a depth of 4½ feet; and it was running partly on the fourth, and partly on the fifth, notch. The actual time taken was 4 hours, and during that period the machine cut 58 yards or 87 square yards, and used 44 units, or 0·50 unit per square yard of cut, or 0·75 unit per lineal yard of cut.

The actual yardage cut was certainly a record, and this may be attributed to the fact that the coal-cutter men knew that a test was being made and they wished to do their best; but the writer does not consider that this would have any effect upon the cost per square yard in general cutting, because, when the machine is cutting, it will consume about the same amount of power.
DISCUSSION—COST OF AN ELECTRICAL UNIT AT A COLLIERY. 347

The coal-cutting machine was working about 1,700 yards from the switch-board where the test was taken, and thus all losses by transmission were taken into account.

It may be explained that an electrical unit is 1 kilowatt-hour (1,000 watts per working hour) and this is equal to 1.34 horsepower acting for 1 hour. It was defined by Act of Parliament in 1882.

DISCUSSION OF MR. P. C. GREAVES' PAPER ON THE "COST OF AN ELECTRICAL UNIT AT A COLLIERY,* AND MR. A. J. TONGE'S PAPER ON "A COLLIERY-PLANT: ITS ECONOMY AND WASTE.†

Mr. G. Blake Walker (Barnsley) wrote that he had been asked to open the discussion on these very interesting papers but would have preferred this to have been done by someone who could have brought the results of original investigation and experiments, which, unfortunately, he had not recently been able to do. At various times different departments of mining engineering attracted special attention, and the subject which was at the present moment most engrossing was that of the production of economical power, to which question Mr. Tonge had ably addressed himself. There were plenty of reasons for this. The pressure of highly competitive times, the increased requirements for power, and the general low efficiency of colliery-machinery as compared with that employed in other industries, constituted one set of reasons. Another was the knowledge of the marvellous strides recently made in connection with the generation of electricity, the advent of the large gas-engine, and the exhaust-turbine. The low efficiency of the steam-engine as a utilizer of heat had long been the despair of engineers. Losses occurred at every stage, in the fire-box, in the boiler, in the steam-pipes, in the ports and in the cylinders. Hence only about 6 per cent. of the heat produced was converted into work. To quote the evidence of Mr. G. T. Beilby before the Royal Commission on Coal-supplies,‡ "When it becomes generally recog-

nized that the power required in mines and factories can be obtained at one-fourth to one-half of its present cost, the transformation from steam to gas will proceed very rapidly."

Gas, however, was not the only way of increasing the efficiency of fuel, and the whole question of the comparative economy to be derived from steam-engines of the highest type, steam-turbines and gas-engines, had recently been exhaustively treated by Prof. Georg Baum, Berlin, in a paper* which had appeared since Mr. Tonge's paper was written. He (Mr. Walker) did not think that he could contribute more usefully to this discussion than by giving some of Prof. Baum's conclusions. Here are a few useful figures: take the cost of steam with a plant of two Cornish boilers, each with 860 square feet of heating-surface, produce together 3'2 tons of steam in one hour, or 76'8 tons in 24 hours. If fired 12 hours a day and 300 days in the year, standing cold six days in the year, the following figures may be taken: With coals at 9s. per ton, a capital outlay of £1,400, and an efficiency of plant of 70 per cent., the cost of a ton of saturated steam would be about 1s. 7d. If the coal be put at 4s. 6d., the cost of a ton of saturated steam would be about 11d.† At Scharnhorst colliery, near Dortmund, the waste-gases from eighty Otto bye-product ovens are used under ten boilers. The quantity of steam produced is 378 tons per diem. The feed-water temperature was 134° Fahr. from a central condensation-plant.‡

Mr. Tonge gives a comparative table of the relative efficiency of electric and steam driving.§ Table I. contains the particulars of a nett saving of 30 per cent. actually made by changing from steam to electrical power at a Silesian colliery.|| This is not quite so high a ratio of saving as Mr. Tonge estimates, but it is the record of a specific case, and it is advantageous enough.

If it be admitted that there is a very great saving to be effected by the use of electricity as the secondary power in collieries, a comparison of the cost of producing it in large central stations is of interest. Mr. F. Schulte, in a paper read

† Ibid., page 1002.
‡ Ibid., page 1003.
**DISCUSSION—COST OF AN ELECTRICAL UNIT AT A COLLIERY.** 319

**Table I.—Costs of Steam-power and Electrical Power at a Silesian Colliery.**

<table>
<thead>
<tr>
<th>Description of Plant</th>
<th>Power used:</th>
<th>Steam-power</th>
<th>Electrical Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horsepower</td>
<td>Working Time during the Year</td>
<td>Cost per Day</td>
</tr>
<tr>
<td></td>
<td>Days</td>
<td>£</td>
<td>s.</td>
</tr>
<tr>
<td>1. Haulage-winchens</td>
<td>18</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>2. Rope- haulage,</td>
<td>20</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>3. &quot; &quot;</td>
<td>20</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>4. &quot; &quot;</td>
<td>25</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>5. Ventilating fans</td>
<td>60</td>
<td>360</td>
<td>1</td>
</tr>
<tr>
<td>6. &quot; &quot;</td>
<td>65</td>
<td>360</td>
<td>1</td>
</tr>
<tr>
<td>7. &quot; &quot;</td>
<td>65</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>8. Screening</td>
<td>2</td>
<td>360</td>
<td>0</td>
</tr>
<tr>
<td>9. Centrifugal pumps</td>
<td>2</td>
<td>360</td>
<td>0</td>
</tr>
<tr>
<td>10. &quot; &quot;</td>
<td>3</td>
<td>360</td>
<td>0</td>
</tr>
<tr>
<td>11. Belts</td>
<td>25</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>12. &quot; &quot;</td>
<td>25</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>13. &quot; &quot;</td>
<td>25</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>14. &quot; &quot;</td>
<td>25</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>15. Coal- hoists</td>
<td>65</td>
<td>310</td>
<td>0</td>
</tr>
<tr>
<td>16. &quot; &quot;</td>
<td>4</td>
<td>360</td>
<td>0</td>
</tr>
<tr>
<td>17. Ash- hoist</td>
<td>23</td>
<td>350</td>
<td>0</td>
</tr>
<tr>
<td>18. Workshops</td>
<td>100</td>
<td>360</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td>502</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

at the Liége Exhibition, gives some figures with regard to a colliery central-station plant to yield 1,200 electrical horsepower continuously.* The cost, detailed in Table II., may seem large, and is perhaps for a higher class of work than is usual at

**Table II.—Cost of Electrical Plant to Generate 1,200 Horsepower.**

Two gas-motors, each of 600 horsepower, including pipe-mains, erected complete... ... ... £8,000
One gas-motor of 600 horsepower, in reserve, for use during cleaning, stoppages, etc. ... ... 4,000
Three dynamos, including pulleys ... ... ... ... 4,500
Switchboard ... ... ... ... ... ... ... 850
Two exciters ... ... ... ... ... ... ... 500
Foundations ... ... ... ... ... ... 600
Enginehouse ... ... ... ... ... ... 1,250
Travelling crane, 15 tons capacity ... ... ... ... 600
Contingencies, say, 20 per cent. ... ... ... ... ... 4,000

Total ... £24,360

British collieries, but it is just as well to be on the safe side. The establishment or plant cost of this central station is about £20 per horsepower, or £27 per kilowatt. Leaving the cost of reserve-motors out of account, the actual cost of a number of completed plants is detailed in Table III.* With large plants, the establishment-charges vary to the advantage of the cost of production so that a plant with an output of 5,150 horsepower or 3,790 kilowatts, inclusive of purifying plant, should be installed for £14 per kilowatt.

Table III.—Actual Costs of Electrical Plants of 120, 550, 900 and 1,800 Horsepower.

| Engine-output ... horsepower | 120 | 550 | 900 | 1,800 |
| Electric output ... kilowatts | 88  | 404 | 662 | 1,315 |
| Cost of electrical plant: dynamo | £375 | £1,015 | £2,650 | £5,000* |
| Do. switchboard | 100 | 75  |     | 850  |
| Totals | £475 | £1,090 | £2,650 | £5,850 |

| Plant-costs: purifying plant | £1,700 | £1,650 | £2,000 | £3,000 |
| Do. gas-engine plant | 2,145 | 4,889 | 7,225 | 14,450 |
| Do. electrical plant | 475  | 1,090 | 2,650 | 5,850 |
| Totals | £4,320 | £7,629 | £11,875 | £23,300 |

| Plant-costs per kilowatt | £49  | £19  | £18  | £17  |

The cost of working a gas-power plant of 1,200 horsepower is somewhat as follows:—The value of coke-oven gas may be taken at a low figure, because hitherto an equivalent amount of heat obtained from gases has been set against the value of the fuel required to evaporate the same quantity of water. Comparing the value of a cubic foot of gas with bunker-coal worth 4s. 6d. per ton with a heat value of 15,000 units, the value is about 0:0033d., to which 0:0018d. should be added for working costs, interest and depreciation, making together say 0:005d. per cubic foot of gas consumed in the gas-engine. The cost of gas for an engine consuming 10,000 cubic feet per hour will therefore be 4s. 2d. The other costs are attendance, cooling water, oil and cleaning. The interest and sinking fund on a first cost of £20,000 may be reckoned at 7s. per working hour. The details contained in Table IV. show a cost of 18s. per hour or 0:18d. per horsepower-hour.† Mr. F. Schulte, from experience of

various plants, estimates the cost as follows:—Gas-engines and connections, £20,300; purifying plant, £3,000; and reserve-engines, £4,650: a total of £27,950. On account of the heavy wear-and-tear of gas-engines, he reckons interest at 16 per cent, or £4,473 a year, equal to 12s. 5d. per working hour, a considerably higher figure than the 7s. used in the previous estimate.*

Table IV.—Cost of Working a Gas-power Plant of 1,200 Horsepower.

<table>
<thead>
<tr>
<th>Item</th>
<th>£</th>
<th>s</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest and sinking fund</td>
<td></td>
<td></td>
<td>7.0</td>
</tr>
<tr>
<td>Cost of gas</td>
<td></td>
<td></td>
<td>4.2</td>
</tr>
<tr>
<td>Attendance</td>
<td></td>
<td></td>
<td>3.3</td>
</tr>
<tr>
<td>Cooling water</td>
<td></td>
<td></td>
<td>2.4</td>
</tr>
<tr>
<td>Oil</td>
<td></td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td>Cleaning</td>
<td></td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>11.0</td>
</tr>
</tbody>
</table>

Mr. Tonge uses a Parsons turbine to produce electricity, and gives the efficiency of this engine at 19 pounds of steam per indicated horsepower. Table V., detailing experiments on a Melms-Pfenniger turbine of 500 kilowatts, gives an even better result, namely, 17·14 pounds per kilowatt-hour, or 11·88 pounds per horsepower-hour.† This excellent result is in a great measure due to the use of superheated steam.

Table V.—Experiments on a Melms-Pfenniger Turbine of 500 Kilowatts.‡

<table>
<thead>
<tr>
<th>No. of Experiment</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>Empty with exciter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentages of full load</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load in kilowatts</td>
<td>500</td>
<td>400</td>
<td>280</td>
<td>150</td>
<td>2,489</td>
<td>2,516</td>
</tr>
<tr>
<td>Average number of revolutions per minute</td>
<td>2,459</td>
<td>2,469</td>
<td>2,477</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute pressure of steam entering the turbine in pounds per square inch</td>
<td>201</td>
<td>200</td>
<td>202</td>
<td>192</td>
<td>196</td>
<td></td>
</tr>
<tr>
<td>Temperature of steam in degrees Cent.</td>
<td>319.4</td>
<td>312.4</td>
<td>308.2</td>
<td>306.2</td>
<td>289.2</td>
<td></td>
</tr>
<tr>
<td>Weight of condensed steam in pounds per kilowatt-hour</td>
<td>17·14</td>
<td>17·46</td>
<td>18·48</td>
<td>22·44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Turbines possess the great advantage of being suited to the use of highly superheated steam, and an experiment recently carried out in the Technical School at Dresden holds out hopes

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of further advantage from the interposition of a second superheater between the high-pressure and low-pressure portions of the turbine. The experiments were made upon a turbine of the Laval type, with a capacity of 100 kilowatts. Steam is passed into the turbine through a superheater, and the exhaust-steam passes through a tubular regenerator before going to the condenser. The surplus heat is used for heating the feed-water. A second superheater is interposed at the point at which the expanded steam has a pressure of about 15 pounds per square inch and the saving thus effected is very important, as will be seen from the figures detailed in Table VI.* It was found that the regenerator alone raised the calorific value of the steam, with 300° Cent. of superheating, about 1 per cent., and with higher superheating to 600° Cent., about 3 per cent. With two-stage working and the intermediate superheater and regenerator, the calorific value was very greatly increased as compared with the single stage. In the first case, the steam-consumption was 16'5 pounds, the total heat absorbed per electrical horsepower was 15,276 units, taking 2'068 pounds of coal with a calorific value of 16,512 units per electrical horsepower. The result with two-stage superheating gave a reduced consumption of 12'95 pounds of steam, equal to 1'61 pounds of coal, per electrical horsepower. It is evident, therefore, that further great economies in connection with the steam-turbine are possible.

Mr. F. Schulte estimates the cost of a plant, with turbines of 1,200 horsepower, at, say, £20,000 (see Table VII.) as compared with £27,000 for a gas-engine plant.*

Table VII.—Cost of Turbine-Plant of 1,200 Horsepower.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td>£450</td>
</tr>
<tr>
<td>Steam-turbogen, of 1,200 horsepower</td>
<td>£5,250</td>
</tr>
<tr>
<td><strong>reserve, of 600 horsepower</strong></td>
<td>£3,000</td>
</tr>
<tr>
<td>Transformer, switchboard, etc.</td>
<td>£650</td>
</tr>
<tr>
<td>Crane</td>
<td>£150</td>
</tr>
<tr>
<td>Steam-pipes</td>
<td>£300</td>
</tr>
<tr>
<td>Duplicates, 10 per cent.</td>
<td>£900</td>
</tr>
<tr>
<td>Boiler-house</td>
<td>£2,500</td>
</tr>
<tr>
<td>Boilers</td>
<td>£3,200</td>
</tr>
<tr>
<td>Seating, chimney, etc.</td>
<td>£800</td>
</tr>
<tr>
<td>Feed-pumps, steam-separators, etc.</td>
<td>£375</td>
</tr>
<tr>
<td>Contingencies</td>
<td>£2,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>£19,575</td>
</tr>
</tbody>
</table>

Mr. W. Maurice recently described the exhaust-steam turbine on the Rateau system, at the Hucknall Torkard collieries.† There can be no doubt that this remarkable invention forms one of the greatest and simplest means of reducing colliery-consumption at old pits. The primary engine, developing 1,100 horsepower at 0.144d. per horsepower-hour, costs 13s. 3d. per hour; the secondary plant, developing 500 horsepower at 0.096d. per horsepower-hour, costs 4s. per hour, and also 600 horsepower, at nil; and the total of 2,200 horsepower will cost 0.094d. per horsepower-hour, or 17s. 3d. per hour. The value of the coal used to produce the power would, therefore, be reduced from £6,750 to £4,500 per annum. It is to practical savings of this nature that such a paper as Mr. Tonge's should direct us.

Mr. J. F. Lee (Dinnington) wrote that mining engineers were generally content with making comparisons, instead of getting at the actual cost of producing electrical motive power for colliery-work, and the information given by Mr. P. C. Greaves was interesting, as it afforded some idea of the cost of obtaining an electrical unit with a direct-current plant. There was some difficulty in getting at the output of motors with varying loads.

such as those working hauling and other kinds of colliery-plant; and for this purpose it was necessary to have check readings so as to obtain reliable figures, by having a double set of instruments, or to have them tested to ensure accuracy, as from his (Mr. Lee's) own experience, unless the output was checked one was apt to be led astray. He noticed that Mr. P. C. Greaves had made two separate tests, which came out at exactly the same cost per unit. This was satisfactory as a comparative test, but for the accuracy of the actual cost it would be interesting to know how the readings of the self-recording wattmeter were checked. Were there two in use, or was the instrument tested before and after the trials, so as to ensure a correct record of the work? The cost of 0'51d. per unit, without depreciation and interest on capital, seemed rather high, as compared with the results of some tests made by the writer on a three-phase plant. An induction-test was run for 6 hours on a generator of 225 kilowatts, actuated by a Robey cross-compound condensing engine, with a rope-driving connection to the generator. Separate boilers were used so as to arrive at the amount of fuel consumed, and the following results were obtained:—Mean indicated horsepower, 407; mean electric horsepower, 298; loss in friction of engine, ropes and generator-bearing, 27 per cent.; and overall efficiency, 73 per cent. The costs were as follow:—Fuel, 7 tons of ordinary pit-slag, made through holes, 1 inch square, at 4s. per ton, £1 8s.; stores, 9d.; labour, 11s. 9d.; and the total, £2 0s. 6d., was equal to 0'365d. per unit on the output obtained.

Mr. W. H. Chambers (Conisborough) said that the question of the application of electricity for winding had been very much before the members lately, and there was no doubt whatever that electricity was very economical when substituted for steam-engines situated at long distances from the boilers; but the questions of using electricity instead of steam where large motive power was required, or whether coal could be more economically used in gas-engines and in other suggested ways, were large ones, and required, he might almost say, rather more education than the members at present possessed. It was possible to buy economy too dearly. There were other matters to be taken into consideration, besides the saving of a fraction of a penny per ton in the coal consumed. Electrical appliances were very delicate,
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and, in the application of electricity to winding, a failure might not be rapidly localized. Simplicity was worth a great deal, and the steam winding-engine was a very simple machine which rarely went wrong: when it did go wrong, the fault was quickly found. But that was not the case with an electrical machine, and the economy would soon be gone if they had 300 to 400 men in a pit, drawing wages for nothing, while a machine was being examined. When tests were made, the conditions were usually the best for the purpose, and if anything went wrong it was a case of "that is no use, we will start again." but that was not what happened at a colliery. There were many things that interfered with the economy of an irregular-running engine, which was dependent upon normal conditions for the economy that it claimed. He (Mr. Chambers) also asked with what sort of engines the comparisons had been made. He was afraid that they were not made with the most efficient steam-engine, whilst he took it that the electrical installations were of the most modern type. They could find steam-engines that were exceedingly extravagant, but why should such engines be used for these comparisons? A high-class steam-engine, situated close to the boilers, where the steam was condensed and the heat utilized to heat the feed-water, so that it went back into the boilers at boiling point, was a good and economical machine. He did not know that they had had any mechanical expert to take up the case on behalf of the steam-engine: they had had plenty of experts to advocate electricity, some to serve their self interests, but so far as he knew, no mechanical engineer had gone deeply into the question as to how far a steam-engine could be made to give better results than those in the comparisons set before them. At a recent meeting of electrical engineers, Mr. C. P. Markham mentioned a winding-engine which he described as the most economical in the country,* and Mr. W. C. Mountain, although an electrical engineer, at an electrical engineers’ meeting, had made out a very good case for the steam-engine.†

As to coal-consumption, they had the quality of the coal

to consider. The same coal that was burned for steam-boilers might not be suitable for gas-engines. At the colliery to which he referred, the coal used for generating steam passed through meshes, 0·118 inch (3 millimetres) square: it contained 25 per cent. of ash and about 16 per cent. of water. It was of no use for gas-making, and indeed was of no use for anything but the purpose for which it was used. It was produced at coal-washers, and they had been at a great deal of trouble to find what to do with it. They had succeeded in utilizing it for raising steam, it was unsaleable, and if they had not burned it they would probably have had to put it on the refuse-heap. Such circumstances as these had a very important bearing upon the economical investment of capital in machinery and engines.

A colliery manager was supposed to know a good deal: he knew something about mining, he had to be a fairly expert diplomat, and he was supposed to be something of a financier, a civil engineer, a lawyer, a geologist, a horse-dealer, a timber-merchant, an electrical engineer, a metallurgist, a chemist, a doctor, an accountant, and one or two other things; but they could not expect him to be expert in all of them. As a solicitor on a knotty point took counsel's opinion, they wanted some assistance in the intricate problems with which they had to deal.

Another important point was that collieries were not like permanent works; and they only lasted as long as the coal. There was no value in the plant of a worked-out colliery, which would more than cover the cost of pulling it down, and restoring the site to its previous agricultural condition, and in order to economize to the last halfpenny, they could very easily overload an undertaking with too much capital, the economy of the moment being the ultimate loss. There was often more economy in putting down a labour-saving appliance than in saving a ton or two of coal. Theoretically, a man's wage justified an expenditure in capital of £750, upon which 10 per cent. interest could be reckoned. If they could put down some simple machinery that would economize labour, rather than put down intricate machinery that would add to the wages expenditure, he thought that the investment would be more remunerative. It was generally a safe rule for managers to follow, that no additional capital expenditure should be incurred after the plant of a col-
liery was completed, except when a quick and large return on the investment was assured. Before existing steam-engines were discarded as obsolete and extravagant, it was worth while to consider what could be done to improve them and at what cost, by altering the valve-gear and putting on condensers, such as were usually provided for the prime motors of an electric installation: and the probability was that in many cases it would be found to be much less expensive and attain a near proximity to the highest efficiency.

Mr. H. St. J. Durnford (Leeds) thought that Mr. Greaves had put a low price upon his coal, as it should be worth more than 3s 6d. per ton. He asked how the price at which current could be bought from, say, the Yorkshire Power Company, Limited, compared with 0'83d. per unit, quoted in the paper, and also how Mr. Greaves' figures compared with Mr. Walker's.

Mr. M. H. Habershon (Thorncliffe) said that, in Westphalia, a company having several hundred miles of cable collected the electric power generated at the collieries in the district, and paid 3d. per unit for it. At a meeting of the Institution of Electrical Engineers held at Leeds, in 1905,* it was stated that the cost of generating electric current with an engine of 500 indicated horsepower driving a dynamo of 270 kilowatts, working 3,000 hours per annum with an average load of 80 per cent. and coal at 6s. 8d. per ton, amounted to 0'418d. per brake-horsepower-hour; and with a suction gas-plant of similar capacity, on the same average load, but with anthracite-cobbles at 25s. per ton, the total working cost was estimated at 0'35d. per brake-horsepower-hour.

Referring to Mr. Tonge's remark as to the possibility of effecting economies in fully developed mines more easily than in new ones, he thought that it was open to doubt, and things might rather be the other way about. It had been given in evidence before the Royal Commission on Coal-supplies,+ that at one colliery an increase of 1,000 feet in the depth of the workings had increased the coal-consumption from 5 to 10½ per cent.


If Mr. Tonge's conclusion was correct, he (Mr. Habershon) thought that it was a strong argument in favour of electric driving being adopted at new collieries. The steam-consumption of 83 pounds per horsepower-hour in the coal raised, stated to be probably as low as could be obtained with an ordinary non-condensing winding-engine, showed that there was a margin for economy with compound engines and condensing plants, and if some member would give the Institute the results of similar tests of such engines the information would be extremely valuable. With regard to the efficiencies of 0.82 and 0.85 for the electric and steam drives given by Mr. Tonge in Table V.,* he thought that it should be remembered that in the case of the electric drive, 49 horsepower was being used for coal-cutting at a distance of about 3,300 feet, which could not be done with steam, so that the slightly higher efficiency of the steam-drive was more apparent than real.

Mr. Alfred Lucas (Sheffield) said that an explanation of the somewhat low efficiency of the plant described by Mr. Greaves was that on the full week's running, the load-factor was 26 kilowatts per hour whereas the total plant capacity was 100 kilowatts. The figures given by Mr. Lee referred to a generator of 220 kilowatts running at full capacity for six hours, which was a very different condition.

Mr. Isaac Hodges (Normanton) said that he was glad that at last the members had the actual cost of electricity at the coal-face, with all the losses taken into consideration, for he felt that a good deal of the popularity of electricity rested not so much on its economical merits as on the fact that the comparisons of an electrical plant had so frequently been made against an obsolete steam-plant. One often met with incongruous comparisons: in evidence from West Yorkshire, given before the Royal Commission on Mines, a steam and compressed-air plant, compared with electricity working under the same conditions, was using three or four times more steam per horsepower-hour than it should have done.† Such excesses should rather have been debited to the fault of the steam-

engine than credited to the advantage of electricity. He thought that it would be wise on the part of colliery managers to look carefully into the merits of their existing plant, and see how far it could be modernized and made economical before deciding to root it up in favour of large electrical installations, as he was of opinion that steam-plants had been removed for defects that might have been easily remedied, and thus made as efficient as electrical plants at a tithe of the cost of the exchange. At the Whitwood collieries, by bringing the steam-engines nearer to the boilers and fitting them with expansion-gears, by removing steam-mains from pit-shafts, and by coupling underground machinery to existing compressed-air plants, an economy of upwards of £3,000 per annum in fuel alone had been made without resorting to any system of electricity, and this had the great advantage of having involved no particular capital expenditure. It should not be forgotten that the greatest faults of steam-plants were the serious losses caused by condensation in long steam-mains. Three years ago he had occasion to discontinue the use of a main-and-tail-rod hauling-engine, with a single cylinder 18 inches in diameter and 3 feet stroke, running at 70 revolutions per minute, situated underground at a depth of 450 feet; and the steam-main was left in the shaft for the purpose of supplying steam to a pump in the same seam. Greatly to his surprise, scarcely any reduction in fuel resulted from the stoppage of the steam-engine; but, when the pump was driven by compressed air, and the steam-main had been removed from the shaft, two Lancashire boilers, 28 feet long and 8 feet in diameter were dispensed with, although the steam-main had been encased with strips of woven-silicate-cotton yarn and protected by a further covering of canvas and pitch.

From experiments extending over a period of several years at the Whitwood collieries, he (Mr. Hodges) had ascertained that the cost of steam raised by means of Haigh-moor smudge (containing 22\% per cent. of ash, screened through holes 3/16 inch in diameter, 8 pounds of fuel being burnt per indicated horsepower-hour and priced at 3s. 6d. per ton), when used in first-class colliery engines, was 0'18d. per indicated horsepower-hour for fuel only, including the fuel used in banking fires during nights and week-ends amounting to 18'33 per cent. of the total consumption. The cost of labour employed in firing and removing ashes, including
the cost of water, was 0'05d. per indicated horsepower-hour; the interest on capital expended on boilers, with fittings and seatings, pumps and feed-pipes, house and chimney at 4 per cent. and depreciation on capital at 5 per cent., was 0'04d.; making a total working cost of 0'27d. per indicated horsepower-hour; and, allowing 15 per cent. for loss in conversion, it was equal to 0'31d. per brake-horsepower-hour.

It might be assumed that Mr. Greaves, with his modern high-speed steam-power plant and with coal also at 3s. 6d. per ton, would produce his power at an equal or less cost than 0'31d. per brake-horsepower-hour; and he (Mr. Hodges) could not understand why Mr. Greaves' coal-cutters should have cost 3d. per brake-horsepower-hour, a loss of nearly ½d. per unit in transmission. He (Mr. Hodges) would like Mr. Greaves to state the cause of such a high loss as 60 per cent., and, if possible, give the details, as he was distinctly of opinion that equal results could have been achieved by compressed air. The very small load-factor, it had been pointed out, was the chief difficulty that the Yorkshire Electric Power Company had to overcome in offering sufficiently low prices to collieries. He himself had found great difficulty in guaranteeing a high load-factor, and was not surprised that Mr. Greaves should have been unable to show a higher load-factor than 27 per cent. He congratulated Mr. Greaves on his plant being erected in two units, as he had found from experience that a plant of several units, running in parallel, was the only means of allowing the apportionment of the power to the required load.

Mr. R. Holiday said that ten years ago he read a paper* on the result of prolonged working of an electrical plant. It produced 1,600,000 units: the cost, including repairs, was 0'75d., and by laying out the plant in the manner referred to by Mr. Hodges, the load-factor was 65 per cent. He agreed that the secret of economical electric working lay in maintaining a high load-factor.

Mr. J. Gill (Normanton) said that, with a plant which had been running for five years and therefore was not an experimental one, electricity was produced at a cost of 0'26d. per unit.

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For the purposes of this discussion, the period from 1:30 p.m. on November 29th to 1:30 p.m. on December 6th, 1906, was taken, and 20,052 Board-of-Trade units were produced. Two Lancashire boilers, 30 feet long and 8 feet in diameter, working at a pressure of 100 pounds per square inch, used 89 2/3 tons of coal valued at £15 2s. 3d.; enginemen and firemen’s wages were £5 4s.; stores cost 17s. 9d.; cleaning boilers and flues, 3s.; the total cost was £21 7s., equal to about 0'26d. per unit; and, including capital charges, etc., the cost would be 0'49d. per unit.

Mr. W. B. Shaw thought that Mr. Greaves’ figures were valuable, because they were taken over a considerable period and under working conditions. Few statements of the actual working costs of colliery generating plants, particularly small plants, had been published. Special tests of steam-consumptions at different loads were of little value as a guide to the coal-consumption of a small plant taken over the whole year; for, as had been pointed out, so much depended on the load-factor.

The following results of a test of a small generating plant at Hulton colliery would, he thought, illustrate this point. Two non-condensing engines, each driving by a belt an 88 kilowatts direct-current generator, showed a consumption on full load of 64'5 pounds of steam per kilowatt-hour, equivalent to, say, 10 1/2 pounds of coal. The steam used with no load on the generators amounted to slightly more than 40 per cent. of that used on full load. Taken over a whole year, the coal-consumption exceeded 20 pounds per kilowatt-hour.

Table VIII.—COSTS OF WORKING TURBO-GENERATING PLANT AT HULTON COLLIERY.

<table>
<thead>
<tr>
<th>Year</th>
<th>1904</th>
<th>1905</th>
<th>1905 (10 months)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Totals</td>
<td>Per Kilowatt-hour</td>
<td>Totals</td>
</tr>
<tr>
<td>Weight of coal</td>
<td>3,059 tons</td>
<td>53 pounds</td>
<td>3,298 tons</td>
</tr>
<tr>
<td>Cost of coal at 5s. 6d. per ton</td>
<td>£81</td>
<td>0'054</td>
<td>£92</td>
</tr>
<tr>
<td>Wages</td>
<td>£46</td>
<td>0'084</td>
<td>£56</td>
</tr>
<tr>
<td>Stores</td>
<td>£53</td>
<td>0'031</td>
<td>£63</td>
</tr>
<tr>
<td>Interest at 5 per cent. and depreciation at 10 per cent.</td>
<td>£1,091</td>
<td>0'315</td>
<td>£1,182</td>
</tr>
<tr>
<td>Total cost</td>
<td>£1,031</td>
<td>0'584</td>
<td>£1,229</td>
</tr>
<tr>
<td>Kilowatt-hours generated</td>
<td>1,289,000</td>
<td></td>
<td>1,366,000</td>
</tr>
<tr>
<td>Load-factor*</td>
<td>0'54</td>
<td></td>
<td>0'49</td>
</tr>
</tbody>
</table>

* The load-factor is the proportion of the average load to the maximum load during the year.
The actual working costs for the generating plant mentioned in Mr. Tonge's paper had been accurately kept for the last three years, and the results (Table VIII.) showed that much greater economy could be obtained from a large modern plant as compared with the smaller and older type mentioned above. The total capacity of this plant was, at present, 1,000 kilowatts (an additional generating set having been added in 1905), and steam was supplied by four Lancashire boilers, 30 feet long and 8 feet in diameter. Various classes of coal of inferior quality were used, and the price of 5s. 6d. per ton was perhaps somewhat high. He did not think that power-companies could compete with these results; and, where the amount of power required was sufficiently large, there was no doubt that it was cheaper for a colliery to have its own generating plant. Where the installation of a small plant was contemplated, the offer of a power-company, if at all reasonable, should be seriously considered, and would probably show an advantage over a private supply. If the power required was likely to increase steadily in amount, a temporary supply from the power-company might be arranged for a number of years, until the units used per annum reached a sufficiently high figure to justify the outlay on a private generating plant. The capital-outlay, up to the present time, on the generating plant at Hulton colliery, to which the table of costs given above referred, amounted to £17,817 or £17.8 per kilowatt installed. One third of the plant might be regarded as spare. The importance of the capital-outlay in its bearing on the cost of generating was, he thought, very clearly shown by the large proportion of the total cost chargeable to interest and depreciation, as set forth in Table VIII. There was an item in Mr. Greaves' bill of costs, namely, the charge for oil, which amounted to 0.05d. per kilowatt-hour. In the old reciprocating-plant at Hulton colliery, the lowest cost that he (Mr. Shaw) had been able to obtain was 0.0116d., while with steam-turbines, it was only about 9 per cent. of this or 0.00108d.

Mr. A. J. Tonge thanked the members for their friendly discussion of his paper, and said that whatever merits or demerits the paper originally had, its value had been enhanced by the subsequent contributions from Mr. G. Blake Walker and other members. Several members had raised the question that
electrical engines of modern type were generally contrasted with steam-engines of the old type, and that it was necessary to have some practical information of the actual saving when good electrical engines and good steam-engines were contrasted; but his paper was intended to be a thoroughly practical one, and the costs and figures therein given, so far as they applied to electricity, had been realized over a definite period of time. The difficulty in such cases was not to obtain the electrical results, but the results relating to steam-engines at collieries. For purposes of comparison it was necessary to get a fair average of the steam-consumption in colliery-engines, and he had taken as fair an average as he could, having grouped together figures given by other engineers, and covering some 60 engines in all. Among these were high-class engines, such as compound condensing engines, etc., and he believed it would be found that his assumption of 56 pounds per indicated horsepower-hour would be rather under than over the average of colliery-engines. Mr. Isaac Hodges had corroborated the statement made in his paper, and also Mr. M. H. Habershon's remarks, that it was possible to effect savings upon present steam-plant by modernizing the engines and employing proper condensing arrangements, provided the engines were placed comparatively close to the boilers. Mr. Hodges had also shown how difficult it was to economize; and he agreed with him, if the engine was only a fair distance from the boilers, no matter what type of engine was employed, that the power lost by condensation of the steam in the pipes quite overwhelmed the economy obtained in the engine.

Managers should not lose sight of the fact, that in adopting labour-saving appliances some useful secondary power was generally necessary, and that only in a few directions could labour-saving appliances be applied without the use of either compressed air or electricity. The first question, therefore, was not only as to what saving could be effected by using electricity as against steam, but whether it was possible to develop thoroughly a colliery without the use of a secondary power-plant. Having taken a general view of their requirements, managers would probably find that some other power than steam was requisite; and once they had come to this conclusion they had a further question to decide as to which of the two powers they
would employ. Should it be decided to adopt electricity, it then became a matter of urgent importance to take into consideration the question of doing as much of the other work as possible through the same medium. The full economy of electricity, as against steam, could only be obtained upon such broad lines as these. If it were assumed that electricity was an absolute necessity at a large colliery, say for coal-cutting or other labour-saving appliances, and the capital-expenditure was estimated for so much of the power as was used under necessitous conditions, it would almost certainly be found that the ratio of capital-expenditure to the upkeep of the plant would be considerably reduced by embracing as much other work as possible; winding-engines, however, being quite excepted in this connection.

Mention had been made of the load-factor, and of the reduction in cost per unit to be obtained if a higher load-factor could be guaranteed. It was an interesting question as to how far economies could really be secured by putting on all regular-running engines as well as irregular-running ones, such as coal-cutting machines, and by a judicious arrangement of working the machines throughout the day. The reduction in price charged by large power-companies upon steady and high loads would, in all probability, outweigh the capital-expenditure on such parts of a colliery-plant as were not of necessity required to be driven electrically. He (Mr. Tonge) had, however, not wished to digress into this matter in his paper, but since it was read two years ago, other figures had been obtained, and it might be of interest to record them. In 1906, the average electric horsepower at the generator had been 404 as against 164 for the twelve months covered by the paper. The total coal consumed per hour for this output was 1,220 pounds, and at the rates of comparisons as against steam shown in Table V.,* the saving amounted to £2,410 for the year. Part of this extra load had been used for driving a surface-fan through a high-pressure motor of 150 horsepower. This fan had taken the place of a furnace, burning 1,620 tons of coal per year. The coal required to produce the electrical power necessary for the fan amounted to 1,550 tons per year or 70 tons less; but the real saving was shown when it was stated that the amount of air circulated was twice that of the furnace, and as this corresponded to eight times the power,

it showed a considerable advantage in favour of the electrically-driven fan over the furnace. Further economies had been obtained at the same colliery by employing high-pressure motors driven from the central colliery generating-station. These high-pressure three-phase motors had taken the place of two steam-engines, which were used for driving a direct-current plant, it being found preferable to retain the direct-current installation and so save the cost of replacing all the motors by three-phase motors. The high-pressure motors absorbed 640,000 electric horsepower-hours in the year. The average electric horsepower was 74, the steam consumed per electric horsepower-hour was 22 pounds; and the coal consumed, at an evaporation of 63 pounds, amounted to 1,009 tons per year, and at 5s. 6d. per ton it cost £286. Under the old conditions, the same average electric horsepower consumed 4,610 tons of coal in the year, or over four times the amount used with high-pressure motors. The great difference in the ratio between the electrically-driven plant and the steam-driven plant was largely accounted for by the low loads at certain parts of the day, when the steam-engines were working very uneconomically. When the engines were working at full load, tests were made and it was found that the ratio of electric to steam-driving in coal consumed was only as 1:2. The saving effected by this alteration had therefore amounted in the first year to £981.

Mr. P. C. Greaves thought that 3s. 6d. per ton was a sufficient charge for the coal. With regard to the question of buying current, he did not think that they would be able to get it at less than 1d. per unit from power-companies whose capital-outlay he regarded as a hindrance to their competition with collieries. He agreed that the matter of load-factor was most important. He confirmed Mr. Hodges’ view on that question, because at another colliery, with a plant of similar dimensions, namely, 100 kilowatts, and a larger number of motors than at the plant that he had described, the load-factor was less. There was a loss in the transmission of electricity, and the same voltage was not obtained at the far end. Under perfect conditions, with big enough cables, there might be almost an absence of loss, but he had never yet come across the pit where such conditions prevailed. The coal-cutters took more power than he anticipated,
and he thought that it would be found in practice that they took much more than the so-called 10 or 20 horsepower, as represented. Mr. Lee's figures were hardly a fair comparison, because he only took a few hours' trial with a large load-factor, and if he took a whole week the result per unit would be very different.

The discussion was closed.