Discussion.

Mr. Daglish. Mr. JOHN DAGLISH said, before the discussion upon the Paper commenced, he would describe the expansion-gearing attached to the large engine which actuated the pumps.[1] There were several difficulties in applying expansion-action to winding engines. The engine was reversed about every minute; it must be under such control of the engine-man that it must have full steam, at the commencement of the winding when full power was required, and at the termination to bring it to a state of rest; it should also be under such control as that at any moment full steam might be applied. The ordinary mode of working the Cornish valves of these large winding-engines was by a rocking-lever which moved the lever attached to the steam-valve, which rested upon it during the whole stroke. The first of these engines was erected by Mr. Barclay at Silksworth Colliery, in the year 1870. There was a piece of mechanism attached to the end of the lever. By lengthening or shortening the screw attached to this the lever itself was in effect lengthened or shortened, so that at a certain point the valve-lever slipped off the rocking-lever, and the valve fell. The appliance was variable, however, only through the action of the screw; it could be set to cut off at any point, but it was not automatic or varying strictly speaking; it had to be varied by hand to a set point. This appliance was greatly improved at the second engine that had been recently erected at the Silksworth Colliery by substituting a sliding-wedge for the screw. This wedge had the same effect as the screw. When the point of the wedge was just entered the lever was at its greatest length and the engine worked with full steam; when pushed through about half way the engine cut off at about half-stroke; when pushed to the full extremity the valve-lever was shortened so that the rocking-lever did not touch at all, and the valve was therefore not lifted. The sliding-wedge, by a mechanism that could be seen in the larger diagram, was attached to a governor. This was the first winding-engine in England to which a governor had been attached. The action was very satisfactory in steadying the engine. It would be observed from the indicator diagram that during the first four strokes of the engine the steam was at full pressure; the governor now came into action and gradually

[1] North of England Institute of Mining and Mechanical Engineers. Transactions, vol. xxv., Plate 52; and vol. xxix., Plate 1.

cut it off as the velocity increased from the sixth to the nineteenth stroke; then at the last stroke full steam was again put on. That description of expansion valve-gearing had been alluded to in a Paper by Messrs. T. Forster Brown and G. F. Adams, in reference to an engine that was erected at Harris' Navigation Colliery in 1878.[1] Mr. Daglish.

With reference to the Paper on the Marsden sinking, he had been asked to mention that the operation of sinking in the way described consisted of two distinct operations; first, boring the pit completely through to the required depth in the water; and secondly the lowering of the Tubbing in one operation, by attaching, piece by piece at the top of the water, until it reached the bottom, and the Moss-Box was compressed, and after that the filling in of the cement behind it.

Mr. Arnold Lupton said that he had had the opportunity of seeing the sinking at Marsden whilst it was in operation, and he hoped he should not be considered presumptuous if he ventured to express his admiration of the excellent work that had been carried out. The question of sinking through water-bearing strata where the amount of water was too great to permit of sinking by the ordinary method, had engaged the attention of engineers on the continent for forty years, and he believed it was nearly thirty years since the first successful sinking and tubbing was accomplished by Messrs. Kind and Chaudron. With regard to the shaft-sinking by this method, he might mention that his attention had been first directed to the subject by the engineers with whom he was connected nearly eighteen years ago, who went to France and recommended the adoption of the process in the sinking of some pits in the Moselle coal-field, and he believed their recommendation was very successfully carried out. As to the special method described by the Author, it would be remembered that he had mentioned that the shaft first sunk had three diameters, 4 feet 11 inches, 5 feet 5 inches, and 14 feet, the reason had not been given; but he supposed it might be that the chisel falling in a straight line across the shaft struck each successive blow, as the tool was turned, more closely near the centre of the shaft than near the circumference. If the hole was bored all at one time there was some waste labour in striking the middle of the shaft, and it had therefore been found economical to bore out the centre of the shaft. But another engineer had sunk the shaft in one operation, which was described by Mr. A. Demmler, in a Mr. Lupton.

[1] Minutes of Proceedings Inst. C.E., vol. lxiv., p. 23.

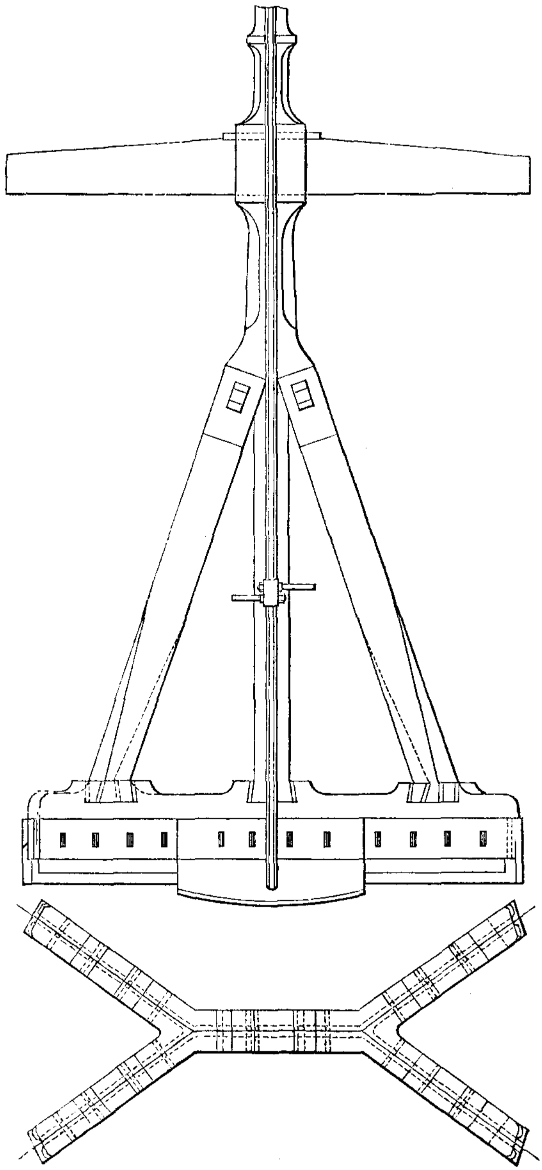
Mr. Lupton. Paper read before the Manchester Geological Society in 1878,[1] in which he had mentioned how Messrs. E. Lippmann and Co. had bored a shaft to the depth of 96 yards. Beginning at 12 yards from the surface where the water overpowered the pumping apparatus, they proceeded to sink by boring to a depth of 96 yards, where they put in the foundation of the Tubbing. The cutting was 14 feet in diameter, and the shaft when complete was 12 feet in diameter, the same size as that of No. 1 shaft described by the Author. In order to overcome the difficulty to which he had alluded of the straight cutter making the blows more closely together near the centre of the shaft, and not sufficiently closely together near the periphery, they had a different description of cutting tool, which was shown in Fig. 1, p. 200. The drill was in the shape of a double Y fastened together. There were two blades at that part of the tool which cut round the circumference of the shaft, and only one blade cutting in the part of the shaft which was at the centre, so that there were more blows in cutting the stone near the periphery than at the centre. Owing to the angle at which the blades were placed the stone was cut into checks or squares, so that it was broken up more certainly into small pieces. Not only was there that advantage but, owing to the breadth of the tool, when it struck the ground there was less liability for it to be deflected sideways if it happened to strike upon hard stone. He had read that in some cases a shaft sunk with simply a straight cutter, was sunk not quite perpendicularly, owing to that tendency to deflection; and Messrs. Lippmann claimed that their shape of cutter overcame this. Of course it was a great advantage if only one hole had to be bored, because it appeared that the shaft could be bored all at once as quickly as the enlargement could be done after boring the centre, as in the ordinary Kind-Chaudron method. The rate at which the work was done by Messrs. Lippmann, in sinking the pit in Westphalia, was about 10 inches every twenty-four hours, compared with 7 inches for every twenty-four hours' work in the shaft sunk by Mr. Daglish. In each case the rate was obtained by dividing the depth bored by the total number of days from the beginning to the conclusion of boring operations. Taking into consideration the time occupied, not merely in boring the hole but in tubbing it also, the speed was about in the same proportion. It therefore appeared that there was some advantage in using that shape of cutter; still, it should be borne in mind that no comparison of speed was of any value without taking into consideration the relative hardness of the strata. He had

[1] Transactions, vol. xiv., p. 374.

not seen the pit in Westphalia, and therefore could not say whether the stratum was as hard as that which the Author had bored. Very likely it was not. The cost seemed to be about the same, £170 per yard, when finished, including the cost of all the materials and the Tubbing. He might be permitted to refer to another method, in which he had been himself engaged, of overcoming a similar difficulty to that which the Author had encountered in Durham, the point of similarity being that a great body of water had to be encountered without pumping. The case to which he referred was in North Wales, where it was necessary to sink through a bed of very fine running quick-sand on the seashore, where pumping was of no use, because not only was there a great body of water to deal with, but the sand ran in, and it was almost impossible to sink a pit by pumping. The compressed-air process was therefore adopted, which was commonly used in sinking the cylinders of bridge foundations. That process had been adopted in France for sinking a coal-pit upwards of forty years ago, but only on a very small scale. The instance to which he had referred in Wales was, he believed, the first of the kind in this country. The shaft was sunk down to a depth of 100 feet below the water-level by compressed air. There was a cast-iron cylinder 13 feet in diameter, in which air was pumped at a sufficient pressure to force out the water, the pressure of the air being exactly measured by the depth of the water. The tide coming in round the pit the level of the water was above the level of the land. By means of that process the sinking was easily performed, the workmen standing upon the sand and excavating it just as if they were on the surface and the tide was out. No doubt it was an operation that demanded some care in managing the men, who were subject to pains in their shoulders, which, in some cases that had come under his observation, made them dance and cry in a manner which was somewhat ludicrous to unsympathetic people, but if treated with care they did not suffer any great injury. It would take too long to describe the details of the process by which the Tubbing was connected with the solid ground at the bottom. He had, however, exhibited a diagram (Fig. 2, p. 201) showing the cylinder as it descended through the sand. Inside the outer cylinder was a smaller cylinder 6 feet in diameter, connected with a larger one at the bottom by a conical piece or bell. The pressure was inside the smaller cylinder, and in the conical piece at the bottom. At the top of the smaller cylinder was an air-lock, through which the men and materials could enter and leave. The pit was sunk through sand, boulder Mr. Lupton.

Mr. Lupton.

FIG. 1.

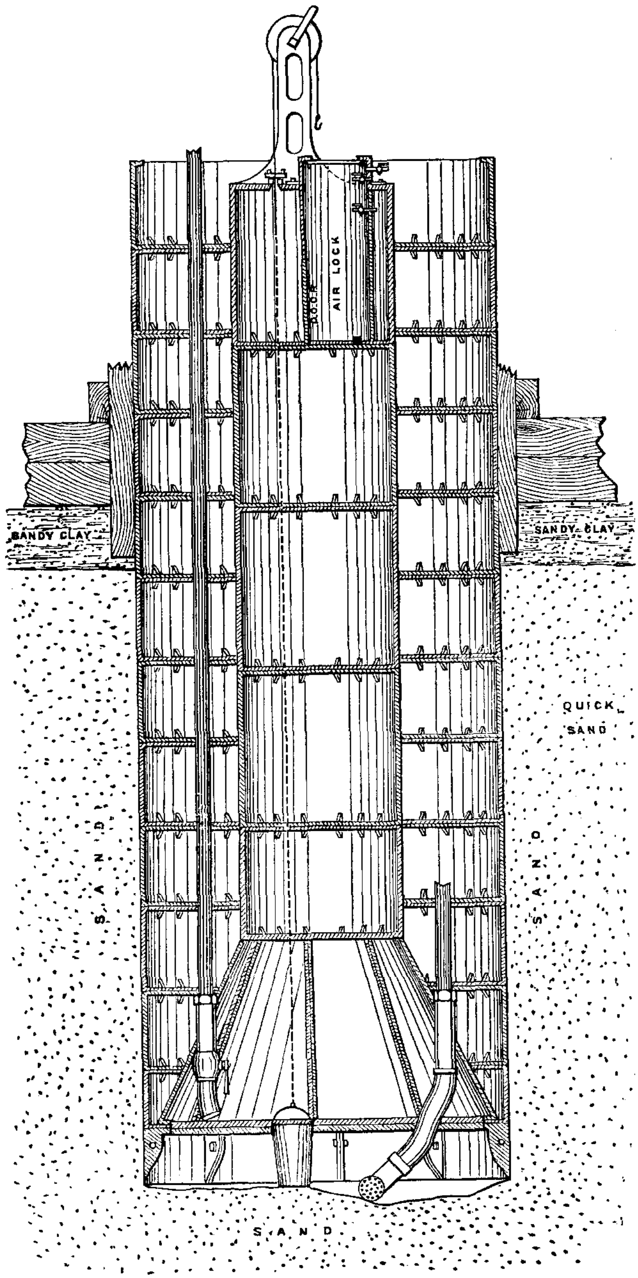


Scale $\frac{1}{80}$.

LIPPMANN'S BORING TOOL.

Mr. Lupton.

FIG. 2.—COMPRESSED-AIR SINKING AT BETTISFIELD.



Scale 7 feet = 1 inch.

Mr. Lupton. clay, and gravel, into the red marl, where a firm joint was made with a solid stratum. The cost in that case was also about the same as that of the Kind-Chaudron process, about £170 per yard, including the cost of the materials left in the ground, and a fair proportion of the cost of materials used during the process. It had sometimes occurred to him that possibly the compressed-air process might be of advantage in making tunnels beneath estuaries or rivers, where the depth was not too great to admit a man working under pressure. He had often been under a pressure of 45 lbs. to the square inch above the atmosphere, or 4 atmospheres. Divers of course were sometimes under still greater pressure, but a pressure of 4 atmospheres was about as high as was comfortable for divers. No difference, however, was felt in the compressed-air cylinder between that pressure and the ordinary pressure of the atmosphere, except that one was apt to get rather warm with very little exertion.

Mr. Redman. Mr. J. B. Redman said the first application of the "plenum" process referred to by Mr. Lupton was the sinking of Tubbing by Mr. Triger, a French Engineer, through a semi-fluid stratum of sand to a coal-field on the banks of the Loire, near Chalonnes,[1] the particulars of which were given in the early editions of Dr. Ure's "Dictionary of Arts, Manufactures, and Mines," in the article "Ventilation of Mines." This was about 1840.

Mr. Smyth. Mr. Warington W. Smyth said he would confine his remarks to the subject of sinking by means of boring; and, secondly, to securing it against water by means of the Tubbing specially devised by Mr. Chaudron; but he desired first to express his approval of the clear and simple manner in which the Author had described the details of his operation. His criticism would merely be with reference to one or two points which, in the unavoidable brevity of the Paper, seemed to have been omitted. Mr. Daglish appeared to be scarcely aware that one important method of saving time, to which he had alluded, had been adopted long ago by Mr. Chaudron, namely, the placing of a cylinder or conical receiver suspended in the smaller shaft to receive the broken material coming away from the sloping bottom of the larger shaft during the operation. He had seen it at work in 1871, and he then read a Paper on the subject before the North of England Institute of Mining and Mechanical Engineers.[2] He

[1] Comptes Rendus hebdomadaires des séances de l'Académie des Sciences. Tome Treizième, 1841, p. 884. *Also* Annales des Mines. Quatrième série. Tome ix., p. 349.

[2] Transactions, vol. xx., p. 187.

found the plan was already in operation at the pits of Maurage. Mr. Smyth. Moreover, members ought to be reminded that the same arrangement was to a certain extent adopted many years ago by a famous French borer, Mr. Mulot, who he believed was the first person to attempt to replace the ordinary method of sinking by boring on a large scale. He had carried out certain operations of that kind in the Pas de Calais, where he had made borings on a considerable scale as far back as 1839; and in 1849 he bored one hole of 13-feet diameter for the purpose of a shaft, putting in a smaller shaft which he sank at the commencement, and a suspended cylinder or recipient to which at the time many engineers had taken exception. Then came the very remarkable bore-master, Mr. Kind, who was originally a simple Saxon mining captain, but a man of the highest intelligence and honesty in all that he carried out, who proposed systematically to sink shafts by boring. It was the ingenious classes of apparatus devised by Mr. Kind that had enabled the shafts to be bored with such facility, certainty, and immunity from accident. He was the first person to employ, and was recommended to take a patent for, the introduction of wooden rods instead of iron rods, which by their greater power of floating in water undoubtedly enabled the Germans to make a series of bore-holes exceeding in depth those in any other part of the world, and also in the economy with which they had been carried out. Mr. Kind proceeded to a very great extent with remarkable success. When the district of the Moselle was being explored for coal, he put down shafts successfully by means of borings, the shafts standing full of water, without introducing any pumping arrangements, and he succeeded in a boring at Steyringen in the Moselle, about the year 1848. He would have succeeded entirely but for the grand difficulty, which was afterwards solved by Mr. Chaudron, namely, that after his bore-holes had been carried down of sufficient size for a coal-shaft through all the difficult ground which they had to intersect, into the Coal-Measures below, he failed to establish a secure base for the Tubbing. The attempts to pump out the water were unsuccessful, and for several years the whole process remained to a certain extent in abeyance. Mr. Chaudron then came to his assistance, and, with the simple and beautiful arrangement of his Slide-ring and the Moss-box at the back, was enabled to put down a series of shafts with unvarying success. In Belgium, in France, in the district of the Moselle, and in Westphalia, he had sunk, at the time of Mr. Smyth's introduction to him, no fewer than twelve or fourteen shafts, each beset with difficulties, but each

Mr. Smyth. entirely successful in its results. No doubt the union of those two men had been the means of introducing one of the most remarkable improvements ever effected; whatever the quantity of water, they were enabled to cope with it without the introduction of the expensive arrangements needed for pumping. Scarcely an accident occurred, and in the end the water was substantially and thoroughly tubbed out from the shaft, so that further proceedings could be at once undertaken under the usual system of sinking. When he had the pleasure of examining the arrangements carried out by Mr. Chaudron in Belgium, he was sinking the two shafts at Maurage, in which a length of Tubbing weighing 800 tons had to be lowered by the simple but effective contrivance which he had introduced, and the operation was performed with such success that the water was entirely plugged out, and further workings could be carried on in safety and without difficulty. Those examples, crowned by that of the Whitburn sinking, had taught engineers two important lessons in respect to the two divisions into which the subject naturally fell. In his whole series of borings, including the remarkable well at Passy, and a number of other Artesian wells, besides his wider shafts Mr. Kind might be regarded as unrivalled in fertility with regard to the general arrangements for boring and the contrivances he had introduced on all sides for easily and securely carrying out the lowering and lifting, the arrangement of the rods and the like, by a very moderate-sized steam-engine, and sparing as far as possible the large number of men who were generally considered necessary in a great sinking undertaking. But it should be remembered that unless the process was carried out with the simplicity which belonged to the true Kind-Chaudron process, and which the Whitburn Company had, through Mr. Daglish, adopted in its entirety, very serious dangers and difficulties might be encountered. He made that observation especially because he had been conversant, through the introduction of Mr. Chaudron, with the sinking of several other pits in Belgium, where, after an examination of his process as carried out in the Moselle, an effort had been made to do the work without touching his patent, by means of some little modification which had ultimately resulted in total loss or destruction of the undertaking. One example had struck him forcibly at Havré, between Manage and Mons, where the district was of the most difficult character to deal with, having a quantity of extremely water-logged layers or strata lying between the surface and the Coal-Measures, near where Mr. Chaudron was at the time successfully carrying out his system. He had kindly given Mr.

Smyth a letter to a most ingenious engineer, Mr. Bourg, who, at a colliery placed on the line south of and close to the railway, had, after seeing Mr. Chaudron's method, nevertheless thought fit to adopt a method of his own. He commenced by putting down three shafts within 50 metres of each other, the one to help the others, then erecting three powerful direct-acting steam-engines, one over each of the shafts, and each attended by a winding-engine. He went to work pumping the water in the old style, passing through the same series of difficult measures that Mr. Chaudron had to deal with in the shaft nearly alongside. He saw that shaft nearly completed. Mr. Bourg, who generally kept his doors closed against visitors, kindly permitted him to see his arrangement, which was certainly very ingeniously carried out. His plan of pumping the water out by three contiguous engines entirely failed. Mr. Bourg then, after a partial use of compressed air, adopted a system closely approaching Mr. Chaudron's, and employed cutters as nearly as possible of the same form, lowering the Tubbing as he proceeded, armed with a sharp edge at the bottom, which was to cut into the lower measures as soon as he had got through the watery ground. He need not enter into the details, but it was interesting to compare them with the much simpler arrangement of Messrs. Chaudron and Kind. The method adopted was that of a treble cutting tool, the upper part of which was composed of a cutter like the large Trepan shown in Plate 3, Fig. 3, of 14 feet or 15 feet diameter; below it a smaller cutter, to cut out a preparatory bore, and below that a recipient tool to receive the dirt and gravel as they were cut away, and bring them to the surface. The operation was a complicated one. It went on for a short time, but the breakages were frequent, and in the course of a few weeks the system was found to be a total failure. When they attempted the lowering of the Tubbing equal difficulty was experienced, and at the time he was there they had only done about a third of the work. They had to put in a smaller inner Tubbing, but again found so many difficulties that, after working from the year 1864 to 1871, they had not approached the principal difficulty of the whole affair, namely, the shutting off the water from the interior of the shaft. It was estimated by engineers in the neighbourhood that the works had cost about £140,000, and there was not the least appearance of their coming to a conclusion. He had not heard whether the winning had been completed, but he very much doubted it. He merely mentioned those facts in order to show that the simplicity of the arrangement that had been described in the Paper constituted one of

Mr. Smyth.

Mr. Smyth. the great virtues of the system, and that the Company had been well advised in adopting the method pure and simple, instead of endeavouring to import into it any novelties which, like those of Mr. Bourg, might appear to be extremely judicious and ingenious. Having known the great Whitburn undertaking from the time when it utterly failed as a simple sinking, from the time when descending the shaft he saw two 30-inch pumps working at extreme speed, besides several smaller ones, amidst a sea of rushing water, tumbling to and fro—having known it in that state, and having within the last two years seen all those difficulties surmounted, he thought there was every prospect that millions of tons of good coal might be drawn up through those shafts, and that engineers might take heart from such an example in the expectation of being able to go down in the midst of salt-water, and safely reaching the mineral treasures, which they would find in the watertight Coal-Measures below.

Mr. Galloway. Mr. W. GALLOWAY observed that as early as 1823 bore-holes of from 12 to 18 inches in diameter were sunk in order to facilitate the ventilation of the workings. In 1843 Mr. Kindermann took out a patent for sinking shafts and lining them with a watertight lining, and during the last years of his life, from 1843 to 1848, he sank no fewer than seventeen such shafts at depths varying from 4 to 29 fathoms. His process of making a watertight joint at the bottom of the cylinder was somewhat similar to that of the Moss-box; but instead of using moss, like Mr. Chaudron, he took a linen cloth rolled up and steeped in some kind of adhesive substance, and this was compressed against the ground by the bottom of the cylinder as it passed over a ring in the bottom of the shaft, exactly in the same way as in Mr. Chaudron's process. As Mr. Warington Smyth had referred to the commencement of Mr. Kind's career, he need not further allude to that subject; but, in regard to possible improvements in the system, he might be permitted to mention that Mr. Chavatte had a colliery in the north of France, and had made a sinking through 34 metres of wet running ground, and 103 metres of chalk down to the top of the Coal-Measures. The whole of the sinking was done under water by Mr. Chavatte himself, without any assistance from Mr. Chaudron; his reason for attempting it being to avoid the payment of a premium of 75,000 or 80,000 francs. In sinking through the running ground he commenced with a ring of masonry about 2 metres in depth and 15 feet interior diameter. Inside of that, he placed a sheet-iron cylinder and then commenced with what the Germans called a "sackbohrer," working the shaft down in that way, and pressing the cylinder down by means of screws. He had lowered four cylinders of that kind, one inside the other telescope fashion, before he reached the bottom of the running measures, 34 metres in depth. At last, having reached that depth, he had not to line the shaft in any way with a temporary lining, the ground being good, but he proceeded to bore it out. He then bored out the remaining 103 metres with ordinary tools, such as those of Kind and Chaudron, with a diameter of 4·24 metres, and he introduced the same kind of cast-iron Tubbing. Instead of using the Moss-box, he placed a ring in the form of a truncated cone at the bottom of the cast-iron cylinder, and floated it down in the same way as was done by Mr. Chaudron. He had contracted the boring somewhat at the bottom, so that when the truncated cone came to rest on the bottom, it crushed away a little ledge that had been left, and made what was thought to be a watertight joint. No dependence, however, was put on that joint, but concrete was inserted in the most careful manner. Mr. Chavatte thought that he had introduced a better method of concreting than that used by Mr. Chaudron. He did not use four windlasses, but only two, and on each windlass there were two ropes, one of which let down a box of concrete while the other drew up the empty box, so that instead of men being employed alternately pulling up an empty box and letting down a full one, the full box helped to draw up the empty one. Mr. Chavatte thought that in the Chaudron process sufficient care was not used in making the concrete tight enough, and that if that were done there would be fewer failures. He alleged that in the Chaudron process eight out of every ten shafts leaked to a large extent after the Moss-box had been compressed, but whether that was the case or not, Mr. Galloway was not prepared to say. He might mention that Mr. Chavatte's article was to be found in the "Bulletin de la Société de l'Industrie Minérale."[1] Mr. Galloway.

Mr. FRANCIS FOX (of Sir Charles Fox and Sons) said that, having on more than one occasion visited Whitburn during the progress of the sinking, there were one or two points to which he should like to direct attention. The great difference noticeable between that method of sinking a pit and the ordinary system, was the exceedingly small number of men seen about the works. Hardly anybody was visible. There was the Belgian foreman standing with his hands behind his back and a pipe in his mouth, uttering a word or two here and there to the others, and every man Mr. Fox.

[1] Deuxième Série, Tome xi., p. 767.

Mr. Fox. seemed to know exactly where to put his hand upon the tool necessary at the moment. The system of making the Tubbing float until it came to a final rest at the bottom of the shaft was admirable, but it was a matter requiring great care, as was proved at Cannock Chase. There, owing, as he was informed, to the carelessness of some workmen, the siphon pipe, used for letting in water from the outside of the Tubbing to the inside, to bring the Tubbing to its proper line of flotation, was allowed to run too long. The result was that the whole of the Tubbing went to the bottom. That, however, was not due in any measure to the system, but simply to a breach of the rules, and the failure could in no respect be attributed to the Kind-Chaudron method. The Tubbing under discussion was "open-top" Tubbing; in other words, there was no wedging crib or "up-over" crib as in some pits. In a shaft where it was necessary to place an "up-over" crib so as to tub off water in a certain stratum, theoretically the pressure behind the Tubbing was simply due to the head. It had been found in many cases that the Tubbing had cracked and blown, and it was difficult to account for it. It was made thicker and thicker, but no matter how thick, the inevitable result was that it became cracked, or some catastrophe happened. He believed it was Mr. William Coulson of Durham who had suggested the idea of putting a small safety-pipe up the shaft to allow any gas or air that might accumulate in the stratum behind the Tubbing to escape. He could not explain, and he thought it had never been explained, how it was that the air or gas behind the Tubbing could possibly have a greater pressure than was due to the hydrostatic head; yet it was so, and ever since the insertion of that small pipe, about 2 inches in diameter, and carrying it through the "up-over" crib, bringing it sufficiently high in the shaft above the water-level, no failure had occurred. It was stated in the Paper that the 30-inch pumps were worked at seventeen strokes per minute. That was on the 6-feet stroke, which gave a bucket-speed of 204 feet per minute. Those identical pumps were now in use at Liverpool and Birkenhead in connection with the Mersey Tunnel, of which Mr. Brunlees, Vice-President, was one of the engineers. The pumps were worked regularly at about $7\frac{1}{2}$ strokes on a 10-feet stroke, which gave 150 feet bucket-speed. He thought it unadvisable to let them run at a higher speed, but, as admitted in the Paper, it was a case of extreme pumping, and the method was adopted as a desperate resource. It was no doubt due to the admirable design of the pumps, and the machinery connected with them, that no breakage had occurred. At Birkenhead 20-inch pumps had been run with a direct-acting engine, at seventeen strokes per minute, but he had always thought it unadvisable to adopt so high a speed. The pneumatic system of sinking would of course apply to comparatively shallow depths, and not to any depth over 100 feet. He believed the bridge at St. Louis was an instance of the greatest depth in which the pneumatic system had been applied, namely, 113 feet. The results in regard to the workmen were more objectionable than those which had been described, because at one of the piers twelve men were lost from what the Americans called the "caisson disease." At Omaha bridge all the piers were sunk by the pneumatic system, but it was a recognised rule that that system should not be adopted until every other device had been tried. It was found at Omaha that the ill effects produced upon the men working under pneumatic pressure were due to the varying pressure of the air, even if only to a very slight extent. It was therefore essential, in all pneumatic work of that kind, that there should be a reservoir of air compressed to a high degree, and arranged with an equilibrium valve, so as to keep the pressure of the air exactly the same. During last spring he visited a tunnel under the Hudson river, which was being driven by compressed air, but which would have been driven by the Kind-Chaudron or any other system, if only it could have been applied in a horizontal direction; this was, however, impossible. Mr. Fox.

Sir GEORGE ELLIOT, Bart., M.P., being connected with the county in which the sinking under discussion had been made, was induced to say a few words upon the subject. He remembered the sinking of a number of deep collieries, such as Monkwearmouth, Seaham, Seaton, Merton, Haswell, South Hetton, Shotton, and Harton, some of which had cost as much as £250,000 or £300,000 to sink, and he believed the sinking of the Whitburn Colliery itself, before the new method was adopted, had cost upwards of £100,000. He had taken the opportunity of going over it with Mr. T. E. Harrison, Past-President, two years ago, when the work was in progress, and he was astonished to see the certain manner in which it was conducted. He thought that in no part was such a demonstration so necessary as in the county of Durham. The coal-field there rose to the west, and proceeded to dip to the east, taking the coast line for 18 or 20 miles, and passing under the sea at a great depth. The inference to be drawn was that, as the coal extended from the sea westward to a distance of 25 or 30 miles, there was no good reason why it might not extend a long way under the sea. The experiment was a bold Sir G. Elliot.

Sir G. Elliot. one, and nobody in the north of England anticipated success when it was begun. He had seen nearly all the sinkings except Hetton Colliery, which was a failure to begin with, and he had great doubts as to the possibility of sinking in that way so simply and inexpensively as compared with the mode in general use for the previous fifty years. Now that the result had been accomplished, he thought engineers had within their reach the means of exploring the coal-fields by very deep sinkings. Those in Durham were generally in Magnesian Limestone, containing a large quantity of water, and often a large thickness of quicksand at the bottom of the limestone, but by the new method the coal might be reached with some degree of certainty as to cost. Until the present experiment had been made it was impossible for any mining engineer to form an estimate, first, as to whether the thing could be done, and secondly, as to what the cost would be; but the experiment at Whitburn had reduced the operation to a certainty. He knew well the coal-fields in Durham and Northumberland, and he was a member of the Royal Commission appointed to ascertain what amount of coal there was in the country. He believed that, taking the output of the coal-fields in Durham and Northumberland as at present, with no further increase, there was not coal enough down to the coast to last one hundred years. It was perhaps a bold thing to say, but that was the result of calculation, and he thought it was correct. By the method in question, however, the time might be considerably extended, as it would be possible to penetrate further, and, if necessary, to go into the sea. He saw no difficulty in making sinkings there. Of course it would be expensive, but small islands might be constructed and pits sunk, so that the coal might be worked to any distance from the coast. The new method made it certain that coal could be reached in the remotest parts under the sea, and thereby the great source of wealth lying under the ocean in that part of the country be realised.

Mr. Thomas. Mr. J. L. THOMAS believed that the Kind-Chaudron process of shaft-sinking was destined to exercise a marked and beneficial influence on mining where minerals had to be reached through water-bearing strata. The Author did not say what diameter it was originally intended to sink Nos. 1 and 2 shafts, and to what extent the size of the shafts had been altered; but he mentioned that a diameter of 14 feet 3 inches was chosen for the shafts to be sunk by the Kind-Chaudron process at Marsden, because that was the largest size hitherto sunk by this system on the Continent. Mr. Thomas believed that a shaft on this system had been commenced in the Cannock coal-field, the diameter of the boring of which was 19 feet, and the diameter inside the tubbing 15 feet. Should circumstances require it he believed that the size of the shafts described in the Paper might be safely exceeded. Mr. Thomas.

The first operation appeared to have been the lowering of a wrought-iron tube 54 feet long and 14 feet 4 inches in internal diameter. He would ask whether this tube was lowered in one piece or in sections? In boring No. 1 shaft a small Trepan 4 feet 11 inches in diameter was adopted, its weight being 7 tons, the boring-rods being formed of pitch pine timber 5 inches square. He would enquire whether the same size of boring-rod was used with the large Trepan as with the small one? also whether any breakage of the rods took place, and if so at the iron terminations; and further, whether the Author's experience had led him to the conclusion that steel could be advantageously used for these terminations? Pitch pine was often employed for the main pumping-rods in Cornish pitwork, and could be procured in suitable lengths. When clean and free from knots it was a good material to use where toughness under jars and unequal strains was essential.

The Author stated that in very hard rock comparatively few and light blows were given by the boring apparatus; it would seem desirable, however, that the blows should be vigorous, and as many as possible, in dealing with such material. He would enquire what was the extent of fall of the Trepans, and the number of blows per minute given in boring through hard Magnesian Limestone with the large and small Trepans respectively? The hindrance to hard blows would, he presumed, be the jar on the rods; but that would be in some measure prevented by the sliding joint, or, in the event of that not being sufficient, by the Freefall.

The rate of progress of sinking seemed to have been greater for the small Trepan in shaft No. 1 than in No. 2. This he thought arose from the size of the Trepan in No. 1 shaft being 4 feet 11 inches and in No. 2 shaft 6 feet $6\frac{3}{4}$ inches. With the large Trepan, however, shaft No. 2 was deepened more quickly than No. 1; and this was no doubt owing to the greater size of the preliminary bore-hole, namely 6 feet $6\frac{3}{4}$ inches as against 4 feet 11 inches in No. 1 shaft. In the latter the bore-hole of the small Trepan seemed to have been kept from 30 to 40 feet in advance of the large boring; but this practice was apparently departed from in No. 2 shaft, in which the boring with the Trepan, 6 feet $6\frac{3}{4}$ inches in diameter, was at once completed to a depth of 383 feet, and at that depth a ledge formed for the Hanging Sludger to rest upon. He thought it was chiefly owing to this additional depth, from which the débris

Mr. Thomas. had to be removed, that in No. 2 shaft nine hundred and twenty-one hours were occupied in lowering, working and changing the Sludger, as compared with five hundred and twenty-two hours for the same work in No. 1 shaft. It seemed that at Marsden only two sizes of Trepans were used in each shaft; but he believed that it was not unusual to employ three; and he could understand even a greater number being employed under circumstances where the size of the boring and the hardness of the rock might render their use advantageous. Finally he would enquire whether the chisels or teeth were of steel or of iron faced with steel, and whether they often needed removing from the Trepan for repairs? One of the teeth appeared to have got away from the small Trepan, and to have been imbedded in the rock at the bottom of the bore-hole; did this occur from fracture, or from its having worked loose?

He feared the process would not be of much value in metalliferous mining, which was a tentative process necessitating the examination of the vein at frequent intervals during the sinking of the shaft.

Sir Frederick Bramwell. Sir FREDERICK BRAMWELL, Vice-President, said the Paper had not entered into the detail of the various tools shown in the drawings, and therefore he could not be sure that that which he was about to mention was amongst the tools used; but he did not gather that it was, and he could not recognise it among the drawings. Two or three years ago he was interested in a boring of small diameter, only 13 inches, but it was 700 feet deep, through Chalk and Gault, into the Lower Greensand. On reaching the Lower Greensand it came up into the bore-hole, and the question was how to clear it out. The implement which he had made for the purpose consisted of a cylinder 15 feet long, and of a diameter that would admit of its easily going down into the bore-hole. In the cylinder there was a piston, and at the bottom of the cylinder there was a foot-valve of the plainest character. The apparatus was lowered by a crab having two flat wire ropes, one attached to the piston and the other to the cylinder. The ropes were made flat so that there might not be any tendency for them to twist round one another as they hung in the bore-hole. The steam-crab was made specially, so that either rope-wheel could be unclutched, and could be held by its brake. During the lowering the ropes were paid out equally, so that the piston remained in the same place in the cylinder, namely, close to the bottom. As soon as the surface of the material in the bore-hole was reached, the rope which had lowered the cylinder was eased off by the wheel being unclutched while the piston-rope was hauled up. The

Sir Frederick Bramwell.

result was to cause the cylinder to sink down in the manner of pneumatic pile-driving into the material that had to be raised, and to do so with very great rapidity, and at the same time to cause the material at the bottom of the cylinder to flow into it, urged by a pressure due to the head of 400-feet of water above the cylinder. Although the material, as a rule, was fine sand, there were occasionally found pieces as big as one's hand, and they were brought with the greatest ease through the bottom valve into the cylinder, and got out. The implement was extremely successful in getting up anything presented to it, as obviously under the heavy pressure the moving of the piston up the tube involved anything that was below it being driven in with great violence, and he did not know any limit of what would go in, except the size of the aperture of the tool itself. He should like to ask the Author, with regard to the valve-gear, whether there was any, and if so, what provision to check the fall of the steam-valve when the rocking lever, as in Figs. 3 and 4,[1] had quitted the arm, and had left the valve at liberty to fall. He gathered that the indicator diagrams 1, 2, 3, 4, represented the pressure required to get the heavy mass of the drum-wheel, and so on, into motion, and when the velocity was reached, that the governor came into operation; from stroke 6 to 19 there was a gradual increase in expansion. Sir F. Bramwell would be glad if the Author would explain why it was that, in the act of stopping the machinery, the full pressure was put on. He should like to know whether, in the act of stopping, the steam was not put on in the reverse direction, and whether there were not diagrams of that character? He had seen such diagrams, and they had given indications of what he had before mentioned; the ram action of the steam when going by back-gear into the cylinder, which he obtained in a very marked degree in some experiments on the Le Chatelier brake on the South-Western Railway twenty years ago. They showed this when the winding-engine was brought to rest by the steam being admitted when the engine was in reverse-gear.[2]

Sir James Douglass.

Sir JAMES DOUGLASS remarked that Mr. Daglish was a neighbour of his, having commenced operations close to one of the lighthouses of which he had charge. He well remembered the commencement of the works at the colliery, and the feeling that came over that part of the country when it was supposed that they were a failure. He had had the opportunity of watching the works

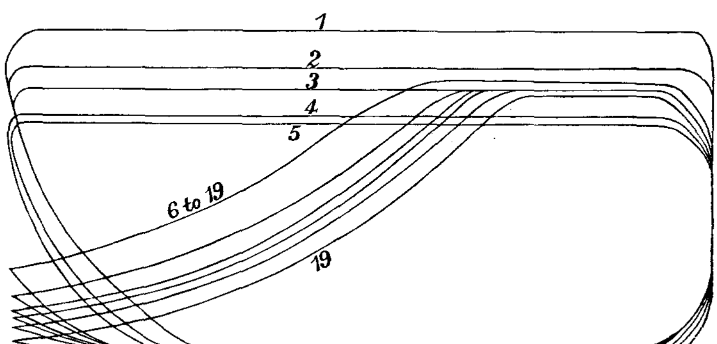
[1] North of England Institute of Mining and Mechanical Engineers, Transactions, vol. xxix., plate 1.

[2] Minutes of Proceedings Inst. C.E., vol. xxxvi., p. 119; vol. xxxvii., p. 24.

Sir James Douglass. during their progress, and he desired to add his testimony as to the extraordinary skill and steady perseverance with which they had been conducted, their perfect machine-like regularity, and the absence of the tumult generally expected in large operations of that kind.

Mr. Daglish. Mr. DAGLISH, in reply, said, that many of the points raised during the discussion had already been answered by other speakers. The question of the use of compressed air had been taken into consideration, but as the depth was known to be 300 feet, it was considered impossible to adopt that method. The number of men employed in the operation at one time was never more than five or six. The Cannock Chase pit was commenced after the arrangements had been made for the Marsden pit, or about the same time; 14 feet 3 inches was the largest size adopted on the Continent up to that time, and that was the reason why it was adopted at Marsden. The tube mentioned by Mr. Lee Thomas was one large piece, like a very large boiler, and it was lowered down within the part of the pit that had been excavated, by the ordinary operation of sinking, and then backed up with cement, so as to form a secure lining, and prevent stones falling during the rest of the operation. The rods were all of the same size, with iron terminations, the breakages of which were not unfrequent; but the various appliances for extracting the rods made it a matter of very little moment, because the extraction of the rods was a matter of certainty. Perhaps the iron terminations broke more than the rods themselves, but there were breakages of both parts. Respecting the rate of speed, it was found that when the rock was very hard there was great vibration of the rods, and time should be allowed for them to steady, before the blow could be repeated, so that the progress was slower in the harder than in the softer rock. As to the Freefall, he might state that in all the pits that had been sunk by this method there were more or less variations in the character of the strata: and the case at Marsden was special, because the character of the rock was entirely different, and he had been given to understand very much harder than it had been met with elsewhere. Of course the question of expense was very carefully considered throughout, and no tools were prepared or purchased except those that were necessary; therefore the Freefall, which was an expensive tool, was not prepared until it was found that the second pit was being sunk rather slowly. It could not be adapted to the larger Trepan. There was some little difference of opinion among the various engineers about it, but it was thought that the larger Trepan was too heavy for the Freefall apparatus. There was no such tool as that which Sir Frederick Bramwell had described in operation at Marsden, because there was no soft sand to extract. Very frequently pieces of the size of 2 feet were struck off the edge of the top of the small inner pit; indeed so large were they that they indicated the inclination of the beds, and in going through the Coal Measures that was a matter of great importance, because it was known exactly how the Measures were lying by the pieces brought by the Sludger. Tool Fig. 15, Plate 3, was an apparatus somewhat resembling that which Sir Frederick Bramwell had mentioned, but it was used for lowering in cement. It had a piston inside, but there was a piece of cord attached to it. It would be seen by the diagram that it was a loose piston, and when the tool was lowered rapidly behind the tubbing filled with cement—when it got to the bottom the rope was pulled and the contents were discharged by the piston. Sir Frederick Bramwell's observation was perfectly correct, that in ordinary coal winding the steam was thrown against the engine at the termination of the winding, especially so where the appliances which were attached to this engine, for counterbalancing or equalising the load, were not in operation. This engine had what was called a Scroll or compensating drum, by which the load upon it was equalised. In the case of engines that were not counterbalanced in some way, as in the great majority of winding engines in England, the steam was thrown against the piston at about half winding. Mr. Daglish.

Fig. 3.



The diagram (Fig. 3) was taken specially, and the engine was not running hard; therefore the compression line at the termination was slight. But it was an ordinary indicated diagram, Mr. Daglish. taken off the engine when going rather slowly, and exhibited slight defects in some respects. There was a certain amount of wire-drawing in the steam pipe. At the first stroke the engine was going very slowly, and it had full boiler pressure, but as it increased in velocity there seemed to be wire-drawing in the steam pipes or ports, and the pressure was reduced several lbs. until the cut-off came into operation—then the pressures increased again. There was a favourable action shown in the back pressure at the bottom. When the expansion was in operation there was slightly less back pressure than when the full steam was on throughout the stroke.

Sir J. W. Bazalgette. Sir J. W. Bazalgette, C.B., Vice-President, said that the subject of the Paper, and of the interesting discussion that had followed it, was one of the greatest importance to the Institution. It might be said to be a Paper on the means of obtaining a more ready access to those necessaries of life—water and coal. It was also a subject of peculiar interest to engineers who had to do with underground works, for they all knew that in water-bearing strata, when once they could subdue the water they had overcome nearly all the difficulties with which they had to contend. It had further been noticed that in passing through running sand the difficulties of pumping water without the sand had been very much diminished, and in pumping and excavating near buildings that was a matter of great importance. In his early days, making excavations in the metropolis was a work of great danger, and many buildings were allowed to settle from pumping in their neighbourhood. The means adopted for pumping water, and preventing the sand from being drawn out also, were now so improved that there was seldom anything of that kind occurring.

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12 December, 1882.

Sir J. W. BAZALGETTE, C.B., Vice-President, in the Chair.

The discussion upon the Paper "On the Sinking of Two Shafts at Marsden, for the Whitburn Coal Company," by Mr. Daglish, occupied the evening.