

Mr. S. P. BIDDER, jun., having explained his invention and illustrated the operation of the machine by means of a specimen of the apparatus described in his Paper,

Mr. CHUBB said there were three systems of working coal, called respectively the 'single stall,' the 'long wall,' and the 'double stall.' These systems were represented in Plate 11, Figs. 1, 2, and 3, in which the breaks in the coal vein showed the way the strata ran. The white lines represented the position in which the machine was placed in the coal. The first trial was made in the double stall, just over a flat hole then ready for firing, and the machine brought down about 3 tons of coal, as shown by the thin lines in the Figures. The shot itself would probably not have brought down more than three-quarters of a ton. The next trial produced a still better effect. The number of holes made in this stall in three hours was five, and about 25 tons of coal were brought down. The coal was of a hard quality, and extremely difficult to work without powder, the use of which the Government Inspector had prohibited in that pit. In all three systems of working the machine had been successful, and the diagrams represented in the aggregate thirteen trials which had occupied seven hours and thirteen minutes, and produced 88 tons of coals, all of which had been done without the coal being cut as usual either at the top, side, or underneath. In South Wales the most difficult seams to work were 2 feet 9 inches thick, and in some places they could not be worked at all. This machine had recently been successfully tried in one of them, where the coal was so hard that the stone had been wrenched away with the coal.

The machine with all its parts weighed about 150 lbs. He had entertained the idea of the wedge system at first, but having found, by calculations, and from the experiments of others, that the principle of wedges and hydraulic pressure would fail, he had not adopted it. It was not from the failure of any experiment of his own: he had ascertained that a liner was unnecessary, and, in fact, that a stroke of about 1 inch was amply sufficient to loosen the coal.

Mr. Chubb then proceeded to describe a specimen of a new boring tool, in which he said, the upper part of the stand represented the roof of the coal-pit, and the lower part the floor. He had, contrary to general custom, placed the apparatus at an angle, to show that the upright could stand in any position, by a ball socket being put in at the top and at the bottom. To the upright was fixed a brass block nut with a thread made to fit a screw, and on the end of that was placed the spiral drill, the two separate teeth of which were so arranged as to cut an annular space in the coal, leaving a round block in the centre, which was easily broken up, as the sides were loosened by the operation of the teeth. The drill advanced $\frac{1}{8}$ th of an inch each revolution, and could be worked by a

boy turning the wheel which ran loose on the screw outside the thread, fitting the key-way running along the screw. As the screw advanced, the boss of the wheel pressed against the nut through which the screw moved, and thus it was kept back and did not advance with the screw. To drill a hole along the rib of the stall, or in a corner, a ratchet was provided, so that it could be turned without the necessity of a support on the wall side of the apparatus. This upright was so made that it could be fitted to any seam from 2 feet 9 inches to 8 feet thick, by placing various distance pieces either at the top or the bottom. One of these measured 3 feet 6 inches long, another 2 feet 4 inches, and a third 1 foot 6 inches, and these three could be combined. The drill was keyed to the screw, so that the screw pushed forward the drill, and turned it at the same time. He had also arranged the screw so that it would work out of the centre of a hollow drill. The end of the screw was fixed in the upright, instead of working through it, which lessened the distance between the working face and the upright, and this in pits with little room in front of the face was of great importance.

Mr. CRAIG, Manager of the Harecastle Colliery, said, that when the Moss pits at Harecastle were opened about five years ago, and the levels commenced from the bottom of the shaft, great difficulty was experienced from the explosive gas, preventing generally the use of powder, and it was frequently necessary to stop up the places for days on opening out seams which generated large volumes of gas.

It sometimes happened, while driving the first roads, that gas was given off in such quantity and with such force, that sufficient air could not be sent into the place to render it inexplusive. Hence more passages between the intake and the return had to be made as the drifts proceeded, much to the detriment of the ventilation, because every connection required stopping, and that gave rise more or less to subsequent leakage in the main airways.

The machine brought forward by Mr. Bidder did away with the necessity of blasting with powder, and thereby removed a cause of great danger to life; secondly, it reduced the amount of small coal produced by the shot; and thirdly, it supplied the means of expediting the opening of fiery collieries. The trials had been made with this machine in two seams, both of which gave out a large amount of explosive gas. His attention had previously been directed to the machines of Mr. Chubb and Mr. Cochrane. The former had been tried in South Wales, where the coal was of a different character to that at Harecastle, and he was informed it had succeeded there. Repeated trials were made with it at Harecastle, but it was found that the expansion of about $1\frac{3}{4}$ inch, which was all that the machine permitted, was inadequate to bring down

the coal, or to loosen it sufficiently to admit of the crowbar being applied to bring it down. Mr. Cochrane's machine, which was in some respects similar to the other, had proved equally unsuccessful. Both machines required the hole to be drilled perfectly true, and even then he found they were not applicable to the seams he was working. In consequence of the expansive part of the machine extending the entire length of the hole, the plates bent at the front where the coal was tender and the power was expended uselessly.

It appeared that Mr. Chubb had improved his machine, since its failure at the Harecastle Colliery, by shortening the expansive part of the apparatus. He had also produced a drill, by which it was stated, a hole, $4\frac{1}{2}$ inches in diameter and 4 feet in length, could be drilled in ten minutes. That statement was so remarkable, that Mr. Craig could only account for it by the difference of the coal in South Wales from what he had been accustomed to deal with. He could conceive no apparatus which would drill such a hole in the time. The coal of South Wales was of a different structure to that of other districts. It had an earthy fracture, and the lines of cleavage were very distinct, having clear vertical partings, running parallel to each other at intervals of 18 inches or 2 feet, so that but little force was required to bring the coal down, compared with what was necessary to work the coal to which Mr. Bidder's machine had been applied at Harecastle. He had not had an opportunity of seeing Mr. Chubb's second machine at work, or possibly it would have enabled him to modify the views he had expressed with regard to the original apparatus.

After trying the machines referred to, he directed the attention of Mr. Bidder to the matter, and the result was the production of a machine which allowed considerable expansion, and did away with the necessity for finely-drilled holes. The hole which the collier was accustomed to punch for the powder shot sufficed for the admission of the straps, and the fireman who now fired the shots, or even a lad of twelve years of age, was competent to apply the ram. He found that it required two wedges and an expansion of 6 inches to produce the desired effect. Experiments convinced him that the whole process could be effected by this machine as quickly as by the use of powder, if not more so; in fact, as there was no smoke, he believed there might ultimately be a saving of time. Where powder was used an interval of about ten minutes elapsed before the smoke cleared away sufficiently for the colliers to resume work. In mines of bituminous coal one source of danger in firing was the starting of the gas in goaves or hollows where the coal had been worked out, and the superincumbent strata had fallen in. Cavities were thus formed in the roof where gas collected, which no ventilation could clear

away so as to prevent danger. He had been called upon to examine a pit in which seven men were killed by the firing of a shot. A great fall had taken place at the face of the coal, and, although it had been forbidden, the men had fired a shot which blew out the stemming and caused an explosion. The verdicts of the juries frequently bore testimony to the fact, that although there was not sufficient evidence to enable them to arrive at a reliable opinion as to the immediate cause of explosions, there could be no reasonable doubt that they were really due to the firing of shots; and they were often accompanied by strong recommendations, that gunpowder should no longer be used in coal-mines. The difficulty of accounting for explosions would always be felt, because the results of an explosion rendered it impossible for any one, however skilled and sincere in such investigations, to ascertain the exact cause. Although the selection of a class of men of superior skill and integrity for firing the shots might prevent accidents from the direct ignition of gas, by the projection of the flame from the shot, there was a source of danger, far more subtle and serious, to be apprehended from the concussion of the shot dislodging gas from the goaves, and bringing it into contact with naked lights, possibly hundreds of yards distant from where the shot was fired. He had known the flame and smoke of a furnace affected by an ineffectual shot fired at 500 yards distance; and of a man who had his hat blown off his head by the concussion of air caused by the discharge of an ineffectual shot fired at a long distance from him. It therefore appeared to him of great importance to provide some substitute for gunpowder which would not produce concussion, and he thought the machine invented by Mr. Bidder, would secure all the advantages of powder without its concomitant evils.

He would now briefly point out how its adoption led to the saving of cost. It was important that the main roads in a seam of coal should be well supported and kept open; and this was particularly the case in steep measures, where a single level was often applied to a large district of coal, from which no deviation was possible without getting above or below the level of the bottom of the shaft. The longer these levels could be kept open without timbering the better; because when the roof began to fall and timbering was required the cost was greatly increased; not so much owing to the price of the timber and the labour of setting it, as in the frequent stoppages to the work. Suppose a seam of coal, where the inclination was 1 in 4 and levels were carried on each side for 500 yards, was opened for a width of 100 yards in a 6-feet seam, there would then be an aggregate of about 200,000 tons of coal which must pass along those levels. It would take about twelve months to drive those levels, and after having driven them there

must be two 'jigbrows' or roads, in the line of the full rise and dip, kept at work on each side to enable 100 tons of coal a day to be sent from each side of the shaft. These levels would require to be maintained upwards of three years, and each jigbrow for about fifteen months. Now when these roads were driven by powder they soon failed. The continual tremor through the shale roof occasioned by the shots caused it to fall; and when coal was left at the roof to support the shale above, as was always the case when circumstances admitted, it became so shaken that usually in twelve months' time timber was required for the maintenance of the roads. Whereas roads driven without powder would stand for two or three years. It was therefore important to find an efficient substitute for powder, which would not occasion this vibration and consequent weakening of the roof.

With regard to the saving of time, the last trial by Mr. Bidder at Harecastle Colliery was upon a block of coal 10 feet long by $3\frac{1}{2}$ feet wide; this was quickly brought down by one operation; whereas if powder had been used, two shots at least would have been required. This he attributed to the difference of the two forces employed. When powder was used, a force was put in action sufficient to overcome the coal in the line of the maximum cohesive resistance, and the instantaneous exertion of such force prevented the coal from splitting in the direction of the line of cleavage, breaking it short across in several pieces; but in this machine, force was accumulated by the gradual insertion of wedges, which gave time for the coal to break up in the direction of the line of cleavage, which was that of the least cohesive resistance; and when applied in a bed of coal, where the line of cleavage was distinct, it had greater effect than powder. He thought it probable that a single application of the machine would be equal to two or three blasts by powder; and this would result in a saving of time. The economy consisted principally in the gentle removal of the coal from the face by a continuous pressure, instead of the sudden blow from the explosion of powder. There was one point, however, in Mr. Chubb's recent machine that required notice; that was, the increased expansion obtained by the introduction of liners. If the expansion was found insufficient—and it was insufficient for the Harecastle coal—he had to release the force and introduce a liner. Now in releasing the force it was clear that the coal in most cases would to a great extent resume its normal position, and instead of getting in a liner equal to the full expansion of the machine, he would probably only get in one half: and there must be loss of time in releasing the force for the introduction of these liners. Then the apparatus was so constructed that it required entire removal from the hole before it could be applied elsewhere; whereas with Mr. Bidder's machine, to obtain increased expansion,

no release of the pressure on the coal was necessary; the coal being kept in tension all the time that preparations were being made for the introduction of the second wedge, as indicated by its cracking; and when the second wedge was pressed it was driven in with ease: therefore increased expansion with Mr. Bidder's machine entailed no loss of time. The apparatus did not require to be removed out of the hole to proceed elsewhere, which was important when applied to a thick seam of coal; for in such a case it was not safe to bring down the coal bodily, but rather to bring it into a state which would admit of its being pulled down by the crowbar. All that was necessary in reapplying Mr. Bidder's machine was to unship the jack which was attached to the straps outside the hole; and the colliers took out the straps as the coal was removed, which must be done before they were ready for another application of the straps and wedges remaining with each set of colliers. When he called Mr. Bidder's attention to that matter, he suggested that the machine should not exceed 3 inches in diameter, that it should admit of a lateral expansion of 6 inches, and be capable of being managed by ordinary workmen. Mr. Bidder had, by repeated underground examinations, made himself acquainted with all the circumstances which must necessarily govern the application of the machine, and had succeeded in producing a simple and efficient apparatus.

Mr. J. T. WOODHOUSE said it was almost impossible to overrate the value and importance to coal-mining of these inventions; though he was not prepared to express an opinion on their relative merits. Nor was he aware, though largely connected with coal-mining, how far these inventions had been tried or adopted. He concurred generally in nearly all that had been said, with reference to the safety of the machines as compared with gunpowder. Of course in machinery worked by water there was no fire, and there could be no explosion from powder. It often happened that the goaves could not be ventilated, but were partly filled with explosive gas; so that when a shot was fired, the flame was driven back into the goaf, and fired the gas, from which grievous effects had on many occasions been produced. These water-machines would do away with that danger, and there would be no explosions from that cause. The extent of economy would depend upon the way the machine was applied, and upon the character of the seams, as no two seams were alike. Thus the coal in some was cubical in its fracture, while in others it was long in grain, as the hard steam coal of Derbyshire; again, some coal required mechanical means to bring it down, while other coal could be dislodged with very little force. But under any circumstances, though he could express no opinion, without further trial, as to which machine was likely to be most practically useful,

he thought all the machines were of great value in an economical point of view. In the Midland district there were plenty of opportunities for experiments on all kinds of seams, and he should be happy, as far as he was personally concerned, to render every assistance in bringing these machines into operation. He might say, by way of caution to the inventors, that although the machines presented a remedy for many difficulties, yet there were some things they could not do, as, for instance, they would not undercut or hole the coal. It had been assumed that one of these machines was so complete, that it had only to be inserted into the face of the coal and out would come the piece. But it would be found that it was not so. To tear out a piece of coal from the face was a violent operation, and sometimes attended with wasteful results. The most economical way of working coal—particularly on the long wall system—was to employ a cutting-machine. There were several sorts of cutting-machines—not the hammer which struck a blow, but a slotting-machine—one of which was in use at Kippax Colliery, near Leeds. That machine undercut the coal, with but small waste. If, after this, the machine was applied horizontally with a steady pressure, the coal would come down of any size that was desired, and by this means the largest amount of round coal would be obtained. In addition to the inventions of Mr. Bidder, Mr. Chubb, and Mr. Grafton Jones, there was another machine, by Mr. Bartholomew, of Doncaster, with which he was accidentally made acquainted recently.¹

Mr. S. P. BIDDER, jun., in reply to an inquiry, said that in his machine the so-called straps passed continuously round the cast-iron nozzle, and the lateral pressure of the wedges was exerted between the straps, which received in tension the endways pressure of the hydraulic ram.

Mr. GRAFTON JONES had for some time past given attention to the breaking-down of coal by mechanical means to avoid the use of gunpowder. The first apparatus he constructed for the purpose consisted of a wedge between segments. The wedge was moved forward by a hydraulic ram, so as to force apart the segments, and thus break down the coal. In a ram apparatus which he next tried, if the hole bored in the coal was not made perfectly true, the instrument was invariably bent to the form of the hole, the ram in this case being permanently injured, but the wedge, which was an extension of the ram, could be straightened. He had now constructed an instrument which would not bend. The holes were bored through the barrel, and in each hole there were two rams, and the water was introduced between them. The thrust was taken on the ends of the rams in a direct line, and they adapted

¹ *Vide* p. 135.

themselves to the hole whatever the shape might be: so that no bending strain was communicated to the barrel of the instrument, as was the case when a single ram was used. A machine, which had been in successful operation for some time, had brought down 7 tons of coal in one operation in a 5-feet seam, and it was capable of being worked by a boy.

In reply to an inquiry, Mr. Jones said he had not noticed that there was any leakage in the instrument. In working Welsh coal a lateral stroke of 3 inches, at the utmost, was all that was required, and that was sufficient to break down any coal he had met with, so that it could be dislodged with a crowbar afterwards. If further expansion was needed, the rams could be drawn back, and a liner be introduced over them.

Mr. R. MALLETT asked how the small plungers were drawn back again after having been pushed out through the cup-leathers? If the coal was not broken the plungers in Mr. Grafton Jones' machine would be embedded into and be more or less gripped by the coal; they must be brought back again flat for a fresh pinch, without withdrawing the instrument, in one machine and in the other, before the new-lining piece could be introduced.

Mr. BEARDMORE remarked that the pistons in Mr. Chubb's apparatus worked with two liners of plate iron, so that the instant the relief cock was turned, and the pressure removed, the machine could be drawn out of the bore; it could not be otherwise when the pistons no longer pressed against the plates. It should be noticed that in all Mr. Chubb's experiments the coal was broken down without any undercutting.

Mr. GRAFTON JONES remarked that the water was forced from an air-tight chamber which formed a partial vacuum, and as soon as the communication was open with the chamber, the rams were drawn back by the water returning into it. Tangye's pump was constructed upon that principle.

Mr. WARINGTON SMYTH said it fell to his lot to visit as great a number of different workings of coal in a year as to most men engaged in mining operations. He was afraid the firing of shots was frequently made the scapegoat upon which the blame was laid of many of the accidents in coal-mines which were really not due to the combustion of powder. It was not unfrequently the case that when the absolute cause of explosion was involved in mystery, the firing of a shot was referred to as the most probable cause. He would be far from saying that the introduction of machines of the nature of those exhibited would not be an immense boon to collieries in regard to that point, since not only was there danger in the fact referred to by Mr. Woodhouse of the striking back of the flame to the neighbouring points of the goaf; but not unfrequently in advanced drifts, carried on as a method of preparation

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and exploration in collieries, gas was tapped and issued through the bore hole in such quantity, that, if inflamed, it taxed all the energy of the persons employed in driving the shaft to extinguish it. The most calamitous explosions had taken place in these advanced workings, in consequence of sudden incursions of gas ; and supposing even careful overmen were employed for the purpose of firing the shots, he would point to the fact that there might be stored up in fissures in the coal, under high pressure, such a quantity of fire-damp, that though at the moment of loading the charge and firing, everything might appear safe, still, when fired, gas might be released in quantity sufficient to produce an explosion the extent of which it was impossible to predict.

With regard to the economy undoubtedly to be introduced by a 'falling' apparatus, he premised that there were numerous collieries in the west as well as in the north of England where powder was never used as an habitual practice ; where the whole of the coal was got by wedging ; and where it came down with the application of that simple mechanical force, in fact a large quantity almost fell of itself after undercutting. But where powder was customarily employed, the result in economy from the use of these machines would be considerable ; and he looked with interest to further trials in some of those mines where the coal was so tender that the use of gunpowder produced from 20 per cent. to 50 per cent. of small coal. There were coals in some parts of the country, where it became a question with the managers, whether they should continue working the seam, in consequence of the great amount of small coal produced. Under such circumstances gunpowder could not be employed with advantage. If it was used, the coal was so shaken throughout, that it would ill bear carriage, or even exposure to the air when stacked, and thus a large quantity of small coal was produced. The machines would be invaluable for securing a larger proportion of round coal and avoiding waste. As Mr. Woodhouse had remarked, it was difficult to decide on the relative merits of the machines till they had been brought more into play ; on the whole, he thought Mr. Bidder's appeared to be an efficient substitute for the common wedging system, in those seams where the present plan was found to be inefficient, and where, although powder might be efficacious enough, it was attended with great want of economy in producing a large proportion of small coal.

The collieries in the west of England, to which he had alluded incidentally, included a considerable area in Somersetshire, belonging to the Prince of Wales, and in the Forest of Dean. These were almost entirely free from fire-damp, so that there was a remarkable immunity from accidents from explosion. The Inspectors of Coal Mines were impressed with the desirability of introducing other methods than the use of gunpowder for breaking

down coal ; and in one colliery the Inspector had gone so far as to desire that no powder should be used for bringing down the coal—no doubt much to the inconvenience of the owners. There was abundance of evidence scattered through the reports of those gentlemen, that in mines where powder was used, accidents were of most frequent occurrence. It would, however, be difficult to assert that where wedging was employed without the use of powder, and where the coal was of a fiery character, there was a smaller number of casualties. It would scarcely be fair to judge by the ratio of the number of accidents which had occurred to a certain number of men employed, and to infer that the one system was preferable to the other upon a statistical return, in consequence of the great variety of condition and character of seams that were worked.

Mr. H. JOHNSON stated, through the Secretary, at the request of the "South Staffordshire and East Worcestershire Institute of Mining Engineers," that, after hearing at Dudley the lucid description by Mr. Bidder, of his invention, a unanimous opinion was expressed, in a full meeting of the practical mining engineers of the district, that it was an invention of the highest practical value, in economizing the working of coal, improving the produce, and preventing the deplorable accidents that result from the blasting of coal by gunpowder ; and that they had every confidence in the ultimate utility of the invention both in thick and thin seams.

Mr. A. LUPTON observed, that 1,484 lives were lost in the year 1866 in connection with coal-mining operations ; but out of that number only 34 deaths were directly traceable to the use of gunpowder. In the case of 120 lives lost by explosions of fire-damp, where the direct cause of the explosions was not ascertained, it would be unfair to attribute the whole to gunpowder ; but on the supposition that one-third were so caused, it would raise the number to 74. The total number of men and boys engaged in coal mining exceeded 300,000, so that only one life per annum in 4,000 was lost from the use of gunpowder in collieries, a very small proportion in comparison with the death-rate of large towns.

The machines under discussion were of great ingenuity, and he believed they might come into extensive use ; but although powder did not entail so many disastrous results as some thought, he might state that in the coal-fields of Derbyshire and Yorkshire, the mining engineers and managers had for some years past decided that it was not right to subject the miners in fiery mines to the risk of accidents from blasting. Recourse had, therefore, been had to the use of those natural forces which existed in every coal-mine—the weight of the superincumbent strata. When the coal was holed, or undercut, the weight of the rock on the top tended to bring it down, and

if a pit was properly laid out, it often happened that no other means were necessary to effect this. Fig. 1 represented a section of a stall in a coal-pit in good working order on the long wall plan. The face was from 100 yards to several hundred yards long. The black part indicated a seam of hard coal 3 feet in thickness. The lighter colour (lettered 'roof') indicated a seam of inferior coal, and above that was the rock. A little to the right a pack of wood supported the roof, and this was sufficiently 'elastic' to allow the roof slightly to subside, and put a pressure on the coal that was undercut, when a comparatively small mechanical force sufficed to break the coal down, and that was effected by the old-fashioned contrivance of a wedge and hammer. Several holes were made in the coal with a pick, into each of which a wedge was inserted; these were then driven in simultaneously, all being kept tight, when the coal was brought down. The amount of the fall of coal and of the size of the coal under this operation depended upon the distance apart of the cleavage planes—9 inches, 1 foot, or 2 feet, as the case might be. In the seam of coal shown in Fig. 1 a man might bring down about 30 cubic feet, with four wedges, in ten minutes.

Fig. 1.

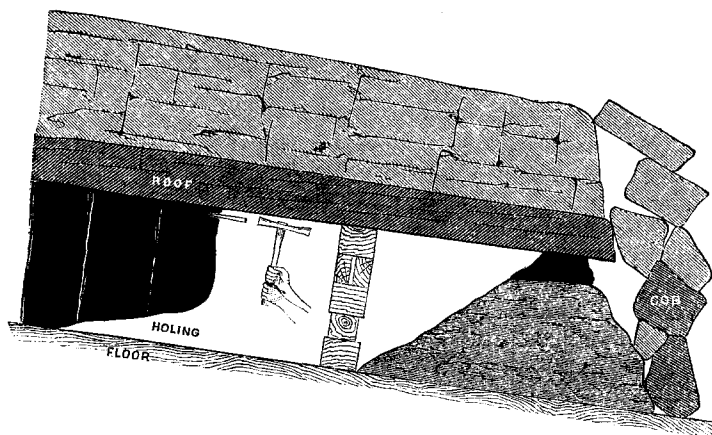
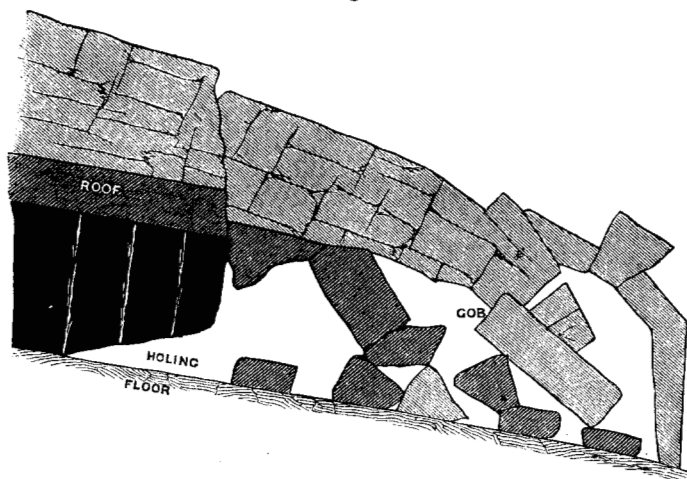


Fig. 2 showed a portion of the mine where the superior stratum had been broken through, and the rock had come down. To break down the coal in this case great mechanical power was required. Therefore it was the object of the collier to keep the roof up as well as he could, so as to throw the weight upon the coal he was working. The cost of the wedging was computed at sixpence per ton in this pit. If the inventors of these machines could prove that their operations could be effected at less cost than

Fig. 2.



The seam shown black is hard coal. The vertical white lines in the coal show cleavage planes.
Scale, $\frac{1}{4}$ of an inch to 1 foot.

that, it would be a good thing for the owners. But many seams could not be worked in the way he had described. In the hard seams the wedges did not sink into the coal, but broke it down at the 'slines.' In a soft seam of coal, however, the wedge only broke off the coal in little pieces, and to get the coal in lumps, it was necessary to apply a force at the back of the piece to be brought down, by boring a hole into it about 3 feet in depth, and there gunpowder was applied; but if the pit gave off gas then there might be danger. In such cases the machines would be of great use in breaking down the coal. Although the machines would be most valuable in pits where the coal was fiery, yet where the coal did not give off much gas, they would come into competition with gunpowder, gun-cotton, nitro-glycerine, and other explosive materials. It was urged in favour of these machines, that shots knocked the coal into slack to the extent of from 30 per cent. to 60 per cent. But a careful collier did not knock the coal into slack. A good collier, so to speak, eased the coal down in lumps, and applied only sufficient powder to do the work. These machines would be a great boon to owners where the colliers were careless; but on the other hand, where the colliers were careful, powder, or some other explosive substance, would maintain its position, unless the machines could be shown to do the work at less cost.

With regard to the relative merits of the three machines, it appeared that Mr. Bidder's and Mr. Chubb's gave out about the same amount of force. Mr. Chubb's exerted a force of from

200 tons to 300 tons for a distance of $2\frac{1}{4}$ inches; and Mr. Bidder's a force of 75 tons for a distance of 9 inches. Mr. Bidder's machine had been tried in soft coal, and a large measure of expansion was apparently required in getting it down. The ends of the expansion bar probably sank into the soft coal. If it was modified to prevent sinking so much into the coal, it might increase the facility of bringing the coal down. Mr. Grafton Jones' machine appeared to be the most powerful of all, inasmuch as with the same pressure it expanded nearly twice as much as Mr. Chubb's, having rams on both sides of the cylinder, giving from 3 inches to 4 inches expansion. He had no doubt all three machines would be of use in the different localities for which they were best adapted. It would be well if the inventors would give some idea of the cost per ton of getting the coal. A saving even of a penny per ton would, in some collieries, amount to £1,000 a year; and unless a saving were effected to that extent, he did not think the machines would make much way.

Mr. BRAMWELL inquired whether, in those cases where the coal was brought down by its own weight, it was necessary to hole the coal underneath to the extent shown in Fig. 1, and whether the portion holed was thereby made into waste? Also whether, in the event of these machines being used, it was necessary to hole the coal to the extent there shown? It would appear from Fig. 1, that a large per centage of the seam was broken into small coal by that operation.

Mr. LUPTON said a large per centage was waste. The amount depended upon the character of the seam. If it was steam coal, the slack was comparatively valueless; if bituminous, suitable for coking, the slack was as valuable for coking as the large, though it sold for less. As a rule, the waste from holing was considerable, but holing machines had been introduced, by which the waste was reduced to a minimum, the cut being only 3 inches wide. He did not know if they had proved generally successful; indeed it required an excellent machine to make way with coal owners and managers.

Mr. CHUBB said he had worked 300 tons of coal with his machine, and had never in any case had occasion to hole the coal, or to cut it. In one trial only had there been any cutting, and that was where an experiment was hurried in order that an owner might witness it. A few days previously the machine had been tried in a seam 2 feet 9 inches thick in South Wales, where, from the great hardness of the coal, it had to be holed, when gunpowder was used; but with the machine it was not found necessary.

Mr. S. P. BIDDER said, in a trial with his machine, in pillar working, where the seam was 9 feet high, the hole to take the machine was made 6 feet from the side, and 4 feet from the bottom. No

holing was required, and the block brought down was 5 feet high by 4 feet wide, and 8 feet long, and weighed 12 tons. Although in pillar working no holing was necessary, in drift work he thought holing expedited the formation of the roadway.

Mr. BRAMWELL remarked that, in the year 1864, Mr. Bartholomew, impressed with the danger of using powder, proposed to apply hydraulic pressure, in a way which was stated by Mr. Bidder in his Paper to be unsuccessful. Mr. Bramwell was surprised to hear that, because it appeared to be the natural way of doing it, if it would answer : that was, first to make a hole in the coal by some boring tool, then to put in a special tool which would chamber out a disc at the extremity of the first hole, and afterwards to apply hydraulic pressure. He thought if this chamber were hollowed out to a sufficient area, the beginning of the crack might be set up by putting on the water pressure ; and, as Mr. Bartholomew said, that might be done with the head of water which the height of the pit would give. Besides, Mr. Bartholomew proposed to lay hold of the coal by a species of gripper ; and Mr. Bramwell thought, from reading the specification, that the plan was practicable. Then there were the machines of Mr. Grafton Jones, Mr. Chubb, and Mr. Bidder. The machine of Mr. Jones exerted a certain amount of force, on a definite area, by separate pistons at right angles to the axis of the tubes by which they were introduced. He understood in hard coal it did that which was wanted ; for though hard coal required more power to break it, the work done was not so much. The trials of the steam ploughs at the Exhibition of the Royal Agricultural Society, in the summer of 1868, afforded an illustration of this. Last July the earth was baked as hard as stone, but it was a fact that the power required to plough that earth was less than was expended in ploughing through the soft earth four years before ; because when it was separated, it was done by the application of considerable power, but acting through no great distance ; and he understood that to be so in respect of hard coal. In soft coal he feared the plungers would bury themselves. Then Mr. Chubb proposed to put a cover over the plungers, so as to increase the surface of pressure on the coal ; but he thought Mr. Bidder was the only one who had brought forward a cumulative apparatus — that was, an apparatus in which, if the amount of expansion in the first case was not sufficient, that amount of expansion could be increased without withdrawing the apparatus from the work. He did not think either of the other machines provided for that. If the expansion were not sufficient in those machines in the first instance, the tool must be withdrawn and lining pieces be added, but to do this the pressure must be taken off ; whereas, with Mr. Bidder's machine, if the expansion were not sufficient at first, further

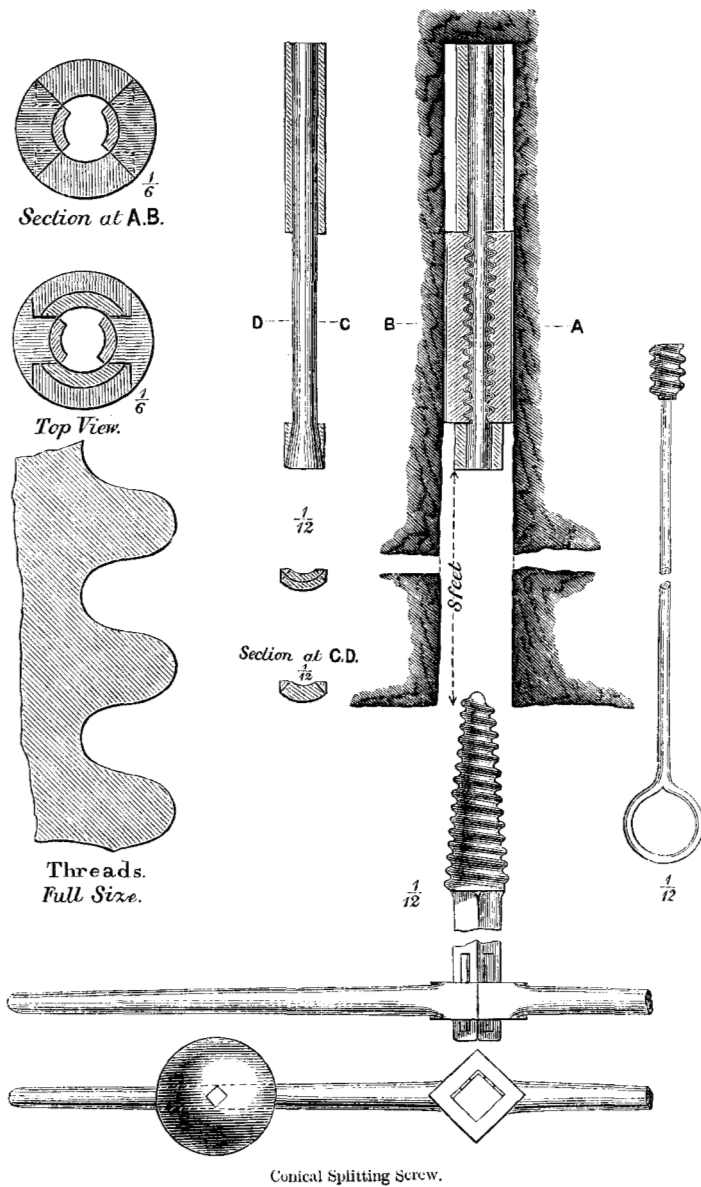
expansion could be got without the necessity of removing the machine, or taking out any portion of it. It seemed to him that, in that particular, the machine of Mr. Bidder should be preferred for the general qualities of coal, rather than machines which did not admit of indefinite expansion; though he believed, with hard coal which did not require pressure through a long distance, the other machines might be equally applicable. The practical and scientific men who had taken part in this discussion appeared to be unanimous in the conclusion that, though powder was not the cause of all the mischief attributed to it—any more than the admission of water into red-hot boilers was always the cause of explosions—yet that it did frequently give rise to loss of life, and did cause the conversion of a considerable quantity of coal into slack. No one during the discussion had suggested, that the use of hydraulic machines would either endanger life or increase the amount of slack; nor had any one suggested that the cost of working coal would be enhanced by the use of these machines. On the contrary, an element of danger to human life was avoided, and the risk of good coal being turned to slack, by the improper use of powder by careless and indifferent workmen, was obviated. Although he was aware that slack of bituminous coal made good coke, he was not aware, till he heard the statement from Mr. Lupton, that it was of equal value at the pit's mouth with good coal. These were the points which these machines suggested to him. He had very little doubt that, being brought before this Institution, and as a consequence before others, the attention of miners would be directed to them, and that, in the cases to which each machine was more particularly applicable, it would be used to the saving of life and to the economy of coal.

Mr. R. MALLET wished to mention, as a contribution to the history of the subject, a still earlier invention for breaking down coal than any which had been noticed. Mr. Joseph Bramah, the inventor of the hydraulic press, proposed, for this and other like purposes, the use of a bag formed of reduplicated leather and fitted with a nozzle. This was to be placed in a suitable cavity hewn out in the coal; and then water was to be admitted to fill the bag, and hydraulic pressure was to be applied by a pump. He had some reason for believing that this method was actually tried, with what success he did not know, in one of the Staffordshire collieries, though he apprehended the contrivance, in common with those now before the Institution, was least adapted for thin seams, such as those of Staffordshire chiefly were. Of course no one would think of reverting now to this somewhat primitive arrangement, but it was interesting as one of the inventor's early provisions of the applications of the hydraulic press.

As part also of the history of instruments for the mechanical division of mineral masses, such as rock, or coal, Mr. Mallet wished to place upon record his own proposal of a conical splitting screw. Many years since, at a time when Irish slate quarries began first to be worked, and when it was found that, owing to the dense and shivery character of the geologically old Irish slates, they were greatly shattered and enormous waste produced by the use of gunpowder, he had exhibited these splitting screws in use before Field-Marshal Sir John F. Burgoyne, Bart., G.C.B., then Colonel Burgoyne. This was in the first year of Sir John Burgoyne's Chairmanship of the Board of Public Works in Ireland; and at that time a block of the dense argillaceous limestone of County Dublin, a cube of about 4 feet, was split in halves by two men, with one of these screws inserted in a single hole of about $2\frac{1}{2}$ inches diameter, in a few seconds. He had not, however, followed the invention up, nor was he aware that it had been employed by others, or was even generally known.

The apparatus was simple (Fig. 3, p. 138):—A long cylindrical nut, or tube of some inches in length, had a female screw of suitable pitch cut throughout its interior. This nut of wrought iron was either then, or previously, split longitudinally into four equal segments by sections, parallel to the axis, and this formed two working nuts of two segments each. Two of these segments were placed in the respective positions they occupied before, and were kept in position by two intermediate filling pieces of soft fir-wood. In this way the actual nut was formed, and was held together by two or more rings of thin binding wire of iron lapped round it, and the whole was thrust down to the bottom of a hole, drilled or jumped into the rock, slate or coal, in the usual way. The diameter of the hole might vary, but advantageously was about $3\frac{3}{8}$ inches. The fir filling pieces projected below or beyond the nut to such a distance as it was desired to keep the nut from going to the bottom of the hole, while allowing the conical screw to pass to its full depth. The conical screw intended to enter this nut had, at its smaller end, the same diameter as the latter. It was several inches in length, and the upper or larger end was of such diameter, that the mineral mass should yield by or before the time that this upper end, upon being screwed into the nut, had reached the middle length of the latter. The conical screw was made of hardened steel, and its upper end was prolonged into as large a square shank as possible, by which, and by the aid of a double-ended wrench adaptable to it, the screw could be turned and forced in, by manual power applied at or near the mouth of the jumper hole. The wrench was provided also with two cast-iron balls, at mid-length of the arms, so as to act upon the screw percussively, and so overcome the friction of rest,

Fig. 3.



like the so-called hammer of the breech-plug handle of the Armstrong guns. The nut being in place, the screw was inserted, and it was then a mere question of power, whether the surrounding mineral mass should yield or not, by the force of the conical screw tending to separate the two opposite segments of the cylindrical iron nut in the direction of the transverse line joining these. The friction between the interior of the hole and the exterior of the nut prevented the segments turning with the screw. The force available by this combination was practically very great; it was obviously that of a wedge whose terminal angle was equal to that of the cone of the conical screw, urged forward by the power as applied to a screw of the given pitch, and with the given leverage of the wrench. The resistances were the cohesion of the mineral mass, and the friction of the conical screw at its bearing surfaces against the threads of the cylindrical split nut. It was obvious that a conical screw could only work into the threads of a cylindrical nut, by allowing a certain amount of play in the threads, or between the nut and the screw. But as the pitch was relatively large, the threads rounded, and the angle of cone of the screw very moderate, no difficulty was found to arise from this, beyond a rather more rapid wear of the threads of the nut than if they all bore uniformly at the same time, as in a common nut and screw. The nut was made of soft wrought iron, in order that it might bend, if distorted against a partially-yielding mass, without fracture. At the present day these nuts might be cheaply made in wrought iron. Originally he had proposed to make the nuts of wrought or of malleable cast iron; the threads in the latter case being formed by casting the iron on to the already screw cut surface of a wrought-iron cylindrical male screw, of the required pitch and length, laid into the mould. All mechanical combinations such as this, when acting against a dead and compressible material, such as coal, would necessarily act at great disadvantage, so much so, that he would, for such purposes, prefer the direct application of one or more hydraulic pistons. But for the quiet and economic splitting asunder of any hard, dense mass, such as roofing slate, or certain rocks, he believed that these conical screws, as well as the hydraulic driven wedges proposed by others, might be, with advantage, occasionally employed. The disadvantage of the wedge driven by pressure, as well as in a less degree of these conical screws, was, that the point of action against the resistance was almost limited to one end of the wedge, and partly to one end of the nut of the conical screw. Much power was thus wasted in mere disintegration of the resisting material, if that was of a soft and friable nature, such as coal.

Recurring now to the general subject, nothing, as it seemed to him, could be more pertinent and important than the remarks made

by Mr. Woodhouse and Professor Warington Smyth. It seemed to him, from the limited observation and experience he had of coal mining, that any attempt to split out the coal by wedges or hydraulic contrivances, without previously freeing it from either the roof or from the seat, (that was the upper or the lower beds adjacent,) must prove a failure; for as far as he had seen of the working of either hard or soft coal, it was absolutely necessary that it should be so freed in some way before it was attempted to dislodge it, otherwise there would be great waste, in time, labour, and in the coal itself. If the coal were so freed, the mass would soon part and drop loose by its own weight. In such cases, he did not see much advantage or many applications for the use of wedging. Mr. Warington Smyth and himself had spent a whole night and a large portion of the next day in the Hetton Colliery, near Fence Houses, Durham, looking at Donnisthorpe's coal hewing machinery at work. The coal hewing, on that occasion, upon seams about 4 feet to 5 feet thick, was very satisfactory. About 30 feet in length, by $3\frac{1}{2}$ feet to 4 feet in from the wall face working, was rapidly undercut for a width of 4 inches or $4\frac{1}{2}$ inches, and no sooner was the coal thus undermined, than the block parted from the roof and from the rest of the seam, and the block came down by its own weight, and only needed breaking smaller for removal. In the case of exceedingly hard coal, such as the anthracite of Kilkenny, nothing but gunpowder would break it out of the seam. It was nearly as hard and difficult to dislodge as the highly resisting carboniferous limestone in which it was embedded. In somewhat softer coal wedging would no doubt be more effective, but the advantage would much depend, amongst other conditions, upon the hardness, softness, nature of fracture, or quality of the coal, and he apprehended that the machines, if employed upon very soft and tender coal, would produce a great deal of slack, though possibly less than blasting with powder. He would only add, that Mr. Bidder's diagram suggested some interesting theoretical points. A large portion of the actual work done upon the back of the wedges, would obviously be expended uselessly upon the coal, and more and more as the total angle of the wedges increased; when this became large, not much more, in fact, than the upper corner of the wedge would act effectively in splitting the coal. On the other hand, the action of the plunger system was the same in direction and equally effective, all through the range. He thought a great deal of the effectiveness of Mr. Bidder's wedges would depend upon the angle chosen for each wedge. It was a dynamic truth that the sharper the angle of a wedge driven by pressure, the less would be the useful effect, or relation between the power expended upon the wedge, and the work done by it; because, though the friction was the same within the limits of abrasion,

whether the surface was larger or smaller, still the smaller the angle the greater would be the distance through which the wedge must be pushed to obtain a given increase of breadth. It followed, therefore, that there must be some point at which the angle of the wedge would be the best possible, and hence it would be better, probably, to apply a large hydraulic power to the end of a blunter wedge, than to use a much smaller power to drive in a longer and sharper wedge. Mr. Bidder had not, apparently, investigated that point; but it appeared an important condition to the best success attainable by his invention.

Mr. C. W. SIEMENS remarked that it was of the greatest interest to all that coal should not only be got economically, but without involving human suffering. Although it had been asserted that the casualties caused by the explosion of powder were not so numerous as might have been supposed, nevertheless it was acknowledged that there was a serious loss of life every year. Independently, however, of that, there was the question of annoyance and injury to health that might be produced by noxious vapours arising from the explosion of powder in confined spaces. Moreover, it had been shown that coal could be got more economically by wedging than by blasting. The quantity of coal released by wedge action must be greater than that released by explosions, inasmuch as powder threw out the cone of least resistance, whereas a wedge would exert its power upon a larger range of coal. The question of undercutting the coal was no doubt important. He had been endeavouring to calculate what force would be expended in each case, but he had not been able to obtain a satisfactory result. If the coal was holed, or undercut, a disc of it had to be dealt with, and with the wedge the line of cleavage would be contained in that disc. He expected that the force expended would increase with the depth at which the force was applied; so that if the machine was inserted into a hole 4 feet deep, it would expend four times the force that it would if the machine was put in only 2 feet deep. But the question became much involved if the coal was to be torn out of the face, because then the top and bottom rocks formed an element which he thought no calculation could reach. If the working was carried out in a mass of coal of infinite extent, then one might be disposed to consider the resistance to the circumference of the semicircular or shallow cylinder and the sphere which would have to be separated if the force were applied in a mass; but inasmuch as the layer was confined between sides of rock, and that rock was pressed by a superincumbent weight of untold amount, the question was incapable of solution. On general grounds he believed it would be impossible for the Institution to arrive at any definite conclusion with regard to the best machine. The machines of Mr. Chubb and of Mr. Jones

were similar in principle, and were both no doubt powerful though limited in range of expansion ; but, while such limited range was sufficient to separate the coal, he believed that the largest quantity of coal could be got with a minimum expenditure of force, because all the force of that short range was directly applied. It was, however, necessary that the coal should be sufficiently hard to allow of a perfectly cylindrical hole being drilled or bored, and that it should not yield more than the length of the stroke of the pistons. Mr. Bidder's machine, on the other hand, was capable of greater range, and by it greater force could be brought to bear upon one point. It seemed also to have the advantage that a smaller hole sufficed for its action ; but, on the other hand, that hole must be deeper than was necessary in the case of Mr. Chubb's machine. He subscribed to the objection urged by Mr. Mallet, that a proportion, not easily ascertained, of the force expended must be lost by pressing the front of the wedge against the mass of dead coal. The wedges pressed not against the coal that was going to be loosened, but against the dead mass of coal further on ; and it was a question, which would puzzle a mathematician to determine, what proportion of force was expended in compressing the coal, and what proportion in cracking it away from its position. With Mr. Bidder's machine the loss of a portion of the pressure by the compression of the coal suggested to Mr. Siemens a modification which was this :—where coal was naturally tender, and where it was advisable to work it in comparatively thin layers, there might be applied a machine composed of three strong steel bars, arranged like a pair of scissors, with a hydraulic ram driving at the ends into gudgeons, so as to press out the ends of the scissors ; the ends of the bars being provided with little surface-plates to distribute the pressure over a certain extent of surface. Such a machine, in coal sufficiently tender, would work rapidly, because with one piston in operation a range of at least 9 inches could be obtained, and the fissure in that case would be in aid of the separation of the mass.

Mr. GRISSELL suggested, with reference to the machine of Mr. Grafton Jones, that if a centre-bit point were placed on the end of the ram it might be used first as an auger, and afterwards as a ram when so screwed into the coal. It would clear itself from the cut coal up the sides of the ram, and then the ram would thrust out the pistons. He directed attention to the explosive substance lately introduced by Mr. Nobel—dynamite, or nitro-glycerine mixed with sand—which could be passed into a hole $\frac{3}{4}$ of an inch in diameter, and which evolved in exploding more force than powder, without giving off flame, gas, or smoke. In all respects he believed it was superior to powder for blasting operations.

Mr. BIDDER, Past President, confessed that he approached the subject under discussion with strong personal feelings. As a coal-owner he was deeply interested in any apparatus, or system, which would tend to prevent the present sacrifice of human life, and at the same time effect economy in the working of coal—whether in the labour necessary for bringing it ‘to bank,’ or in ‘getting’ the coal in such a manner as to avoid the breaking up of the valuable large coal into small and ‘slack.’ He was also interested in the success of his young relative, the inventor of one of the machines. He was desirous of mentioning the active part taken in this invention by his friend Mr. Jones, who had brought to bear upon it the same practical skill that he had done in the case of another invention of great merit—Mr. Edwin Clark’s Hydraulic-lift Graving Dock,—which had been raised by Mr. Jones’ exertions from a state of pecuniary loss to a condition of prosperity.

Mr. Bidder had heard with dismay the subject of the use of gunpowder in coal-getting treated with a levity for which he was not prepared. When it was stated that out of the 1,484 persons killed in one year in mining operations, not more than 34 deaths were attributable to gunpowder, he repeated, that he received such an observation with dismay.

On the subject of these inventions, it must be recorded that, whatever might be their several merits, they had been chiefly induced and encouraged by his partner, Mr. G. Elliot, M.P., M. Inst. C.E., whose large experience need not be recalled. For years past Mr. Elliot’s tranquillity had been much invaded, by a constant dread of the results of the use of gunpowder in mines subject to fiery gas, and he had repeatedly pressed the Government to offer a premium to stimulate inventors to apply their minds to the subject. Notwithstanding the statement which had been made, it was generally admitted, by mining engineers of experience, that the employment of gunpowder in coal-mining did occasion serious apprehension on the part of all practical men. Mr. Bidder knew that it affected, to a great extent, the profitable results of coal-mines. He did not pretend to be a practical coal-miner, but he happened to know a good deal about the financial results of coal-mining, and that breaking up the coal into small fragments occasioned considerable loss. Therefore anything that tended to mitigate that result was of importance in a pecuniary point of view; but he regarded that as of secondary importance, as compared to the question of the saving of human life.

The first he heard of these inventions was from being consulted by Mr. Chubb, who had been instigated by Mr. Elliot; and he believed the original idea was the direct application of water. Mr. Bidder expressed the opinion that, as there existed so many fissures in coal, the direct application of water would be impracticable; and

the result had shown this view to be correct. Alluding to the machine brought forward by Mr. Chubb, though he did not think the invention was entirely successful, yet the inventor was entitled to credit for having addressed his mind to this great practical problem. Long before the attention of his relative had been turned to this subject, Mr. Chubb had been considering it, and, having prepared a machine, made application to Mr. Craig, the Manager of the Harecastle Colliery, for permission to make experiments with it there. That permission was readily accorded, and, if his recollection were correct, Mr. Chubb then stated that the machine had been successfully applied in South Wales. Of course success in one case did not imply equal success in all other cases; and after a trial extending over three weeks, during which the inventor was left entirely uncontrolled, and was allowed to work at his own discretion, the machine, then experimented with, was not successful, equally to the regret of the inventor and to that of the proprietors of the mine; and it was somewhat surprising now, as the machine was stated to have been successfully applied in South Wales, to find that, after modification, no application had been made to repeat the trials at Harecastle. But if the machine was successful anywhere, that omission was not material. It would have been more conclusive to have had a report from the colliery manager, with regard to the experiments with this machine in South Wales, after the manner of that which had been made upon the trial of his nephew's machine at Harecastle.

There was one point which Mr. Chubb would probably be able to explain. It was stated that the pressure in his hydraulic machine was 12 tons to the inch. How that pressure was to be attained, and what sort of lever was to be used, had not been stated; but whatever might be the pressure in one case, it was equally obtainable in the other. Apart, however, from that, he would mention that three leading principles had been laid down by Mr. Elliot as the main objects to be sought for, in any machine for breaking down coal. First, that the apparatus should be so portable that it could be easily carried about the workings of a coal-mine; secondly, that it should be capable of being applied by the men who were ordinarily engaged in working the mine; and, thirdly, that there should be freedom from liability to accident. It was all very well to assume that the operations of coal getting were performed in a gallery of perfect form; but the workings of a coal-mine were the most dislocated places that could be conceived, and were such as men could not work in with accuracy. The machine then, as before stated, required to be portable, easily applicable, and free from the liability to accidents from the casualties to which these workings were subject. Any machine which, after the pressure was applied, failed to bring down the coal, was obliged to be withdrawn to

insert 'liners,' and to perform other operations, could not be considered perfect. It must be borne in mind that the first operation of the wedges was to dislocate the coal; and the subsequent application was to remove the coal to a sufficient extent to enable it to be worked out; and as to loss of power, the question was whether the power applied was economical and sufficient, and whether the cost of getting coal by these means was within the limits of that which was the result of the application of gunpowder.

It appeared, from the best information that could be obtained, that the cost of labour, connected with the application of this machine and working with gunpowder, was nearly the same. That was to say, the cost of the extra time required to drill the holes and break down the coal was as nearly as possible the same as in the application of gunpowder: in other words, though it took more time to make the hole, there was a saving of the time necessary to clear the working of the vapours evolved by the explosion of the gunpowder.

With regard to undercutting, in many instances that process could not be employed, and he believed that was the case at Harecastle. He did not mean to give any direct preference to any of these machines; but he was puzzled to know in what respect Mr. Chubb's machine differed in principle from that of Mr. Grafton Jones. If there were any success in the one, it might be expected from the use of the other; and the inventors must settle how the merit was to be divided, and also the emolument, which he hoped would be eventually derived from it; but it was surprising it had hitherto escaped notice, that these two machines were essentially the same in principle. It was true Mr. Chubb suggested a mode by which the insufficient expansion was supplemented by 'liners,' but that would appear to be an inefficient application. In all other respects the machines were similar.

There had been read to the meeting, during the course of the discussion, a letter from the "South Staffordshire and East Worcestershire Institute of Mining Engineers," which was composed of men who possessed an amount of practical information on the subject of coal-mining far beyond what The Institution of Civil Engineers could command. That Institute had clearly arrived at the opinion, that a machine for breaking down coal was desirable, and also that a particular machine had accomplished the object to a certain extent; but of course it could not be said that any other machine would not do it as well, or better. It struck Mr. Bidder this was a happy commencement of the co-operation between the members of The Institution of Civil Engineers and the members of an Institute of Mining Engineers. The line between them was difficult to draw; but no doubt the

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multifarious experience and aptitude of the members of The Institution of Civil Engineers might be usefully applied to mining in its various phases. He would instance the subject of ventilation, to which attention should be directed, and in which great improvements might be made. The old-fashioned plan, which was almost universally employed, was to have a large fire in the upcast shaft. Now he need not say that the furnace in the upcast shaft was an element of danger. It produced a low barometer; it exhausted the air, reduced the pressure, and thus destroyed the balance between the atmosphere in the workings and the tension of the gases which existed in the fissures of the coal. No doubt could be entertained, that it had a tendency to induce 'blowers' of gas, and to cause explosions. Lately a fan had been introduced, with the view of blowing the air through the workings. That must increase the pressure instead of lowering it, and create an artificially high barometer; and in addition, it materially cooled the mine, by the expansion of the atmosphere after it had been condensed in the workings. He made these few general remarks, because he could not help expressing satisfaction at seeing that the rising generation of engineers were directing attention to a practical problem, which had a marked effect upon the manufactured products of the day; and he preferred to see engineering talent devoted to the pure practice of the profession, rather than to modern financing operations.

Mr. R. PRICE WILLIAMS, having been practically acquainted with mining operations from an early age, could confirm what had been said by Mr. Lupton, as to the necessity of the use of powder in coal-mining operations. He was well acquainted with the Rhondda Valley coal district, and there, as in the Derbyshire coal district, powder was never required for breaking down the coal; in fact, its use was strictly prohibited. He was anxious the erroneous impression that these machines, useful as they might prove to be in their way, would supersede the further employment of powder in coal-mining should not go forth; the fact being that the mere breaking down of the coal, for which these machines were specially and solely designed, was, after all, one only of the many operations connected with that pursuit. No reference had been made in either of the Papers to more difficult mining operations, such as driving the headings and airways, which necessitated the cutting away of large quantities of hard rock, so as to obtain sufficient headway for the passage of men and horses, operations for which these machines were in no way calculated, and where the employment of powder was at present indispensable. The thickness of the upper coal measures in the Rhondda Valley varied from 2 feet 6 inches to 3 feet. In driving the headings and in working the coal it would be necessary to cut, either from the top or the bottom, or from both

occasionally, sufficient headway to allow of the passage of horses and men. These headings in the Rhondda district were on an average 8 feet wide by 6 feet high. The thickness of the lower, or steam coal measures, usually varied from 5 feet 6 inches to 6 feet, and sometimes what was termed the irregular 9 feet varied from 8 feet to 10 feet in thickness. It was therefore evident that, even with this thicker description of coal, there must remain a considerable amount of top and bottom to be cut away. He had recently ascertained that the weight of powder used in blasting the rock in the Rhondda Collieries amounted on an average to 1 lb. per yard of road cut, and that in a colliery such as he now referred to, producing 200 tons of coal a day, about fifteen shots a day would be necessary in driving these roadways. The quantity of rubbish to each ton of coal was usually about 6 tons in the headings and 5 tons in the stalls, the whole of which was left underground in working on the pillar and stall system. The proportion of small coal to round was about one-fifth in Nos. 2 and 3 Rhondda coal, and about one-twelfth in the thicker or steam coal measures. Naked lights were used in working the former, but not in the steam coal measures. The blasting was in both cases done under the supervision of men specially appointed for the purpose, and usually when the men were at work. In these collieries the coal was got in the way described by Mr. Lupton. In the Rhondda upper measures the coal was holed and cut, and came readily down, squeezed out, in fact, by the enormous pressure of the superincumbent strata. If a machine could be devised that would not merely break down the coal, but grapple with the hard rock itself and cut the 'top' and 'bottom,' so as to give sufficient headway, it would greatly conduce to the safety of mining operations; until then powder would still be necessary in coal-mining; and seeing how much its continued use affected the life, safety, and health of the miner, he thought the attention of engineers could not be directed to a better object than devising some practical method for dispensing with it entirely.

Mr. G. H. PHIPPS, whilst agreeing with Mr. Mallet as to the existence of some angle of wedge theoretically more appropriate than any other angle, was inclined to think that enough was done if Mr. Bidder's instrument was shown to possess sufficient power to detach the coal. This was no case for nicely balancing the quantity of mechanical power required to produce the effect in different instruments, as the actual operation of working the pump was always within the power of the workmen on the spot. He thought the arrangement of the wedges in the instrument well adapted to their intended use, as the more acute wedge which first came into action was calculated to exert the high power required in establishing a slight fissure in the coal; while the wedges subsequently

employed did not require to exert so much force laterally, their office being only to push out the mass already detached by the first wedge.

Mr. T. DYNE STEEL held that firing shots in fiery pits, where locked lamps were the rigid rule, was an anomalous state of things that ought to be done away with, at once, and for ever. The hydraulic machines of Mr. Grafton Jones, Mr. Chubb, and others, were really practical machines, and he thought they would, in a great measure, if not entirely, supersede coal-cutting, or holing, machines. If the holes for the 'breaker' were drilled in the seam of coal at right angles to the face, holing in the coal must first be done, either by colliers or by a coal-cutting machine, before the 'breaker' could be used; but if the holes were drilled diagonally, he saw no reason why holing should not then be dispensed with altogether, under favourable circumstances.

The centre of the seam being broken out by the machine, the top and bottom part could be readily got with the pick. In order to carry out this to advantage, it would be necessary, first, to cut 3 feet or 4 feet deep at the right or left of the stall nearest the rib as might be most convenient, and then to insert the breaking machine diagonally, at such a distance from the cut as experience, or the nature of the seam to be operated upon, might determine. The holes following would be drilled in like manner, and the machine used from hole to hole along the face of the stall. With regard to the breaking-down machines, those seen by him were efficient and answered the purpose well. He had little faith in the success of coal-cutting, or holing, machines, except under very favourable circumstances. No machine had yet been produced that could take the place of the collier's mandrel in all situations.

Mr. J. COE, of the Biddulph Valley Coal and Iron Works, observed, through the Secretary, that, many years ago, he had enlarged the shaft of a coal-mine by taper wedges, when naked lights could not be used. In this case, the wedges answered very well, and the cost of enlarging the pit was not much more than if it had been done by blasting. Immediately after the explosions at the Oaks and Talke-o'-th'-Hill Collieries, he tried the application of the wedges on the hard coal of the district, where a great deal of powder had been required for blasting. He holed the coal in the usual way, and drilled holes as if for powder, working them 3 inches in diameter. He then inserted two wedges in each hole, with their thick ends inwards, and drove home the main wedge. The wedges were from 1 foot to 4 feet in length, as the case required. The backs of the minor wedges were round, and the faces slightly concave. The main wedge was slightly convex on both sides. From the results of his experiments, he

was quite certain that powder might be dispensed with in all dangerous places, if mining engineers would take the matter up in a determined manner. He thought that if Mr. Bidder could apply pressure and concussion at the same time, he would accomplish all that was wanted, but that concussion must be applied to his wedge.

Mr. CHUBB, in reply upon the discussion, observed that his Paper had been prepared simply with a view to put himself in a proper position before the Institution, in consequence of the observations which had been made upon his apparatus in the Paper of Mr. Bidder, jun. Some friends, who had seen his machine at work in Wales, came up on purpose to take part in the discussion, but they had, unfortunately, not been able to obtain an opportunity of doing so. He would, therefore, refer to a few letters which he had received on the subject. Mr. W. T. Lewis (M. Inst. C.E.), who was the agent for the Marquis of Bute, wrote as follows:—

“Having been present at the trials at Fforchaman Colliery, I have great pleasure in endorsing all Mr. Richard Bedlington has said respecting the advantages to be derived from the adoption of your machine in the working of our Welsh coals, more especially the steam coals, which are exceedingly hard and highly dangerous to use gunpowder in. Having since then witnessed trials in the two-feet-nine seam, which is the strongest coal in our district, and which cleaves to the top and bottom, I have no hesitation in saying that it has only to be known to be generally adopted, both as a means of doing away with accidents from blasting, and also of reducing the cost of working very materially.”

He would next refer to the failure of the machine at Harecastle Colliery. It was taken there only a short time after it had been brought out, and the experiment was made at the request of Mr. Elliot and Mr. Craig. He asked Mr. Craig a month previously to have a hole bored in the coal $4\frac{1}{2}$ inches diameter to a depth of 4 feet. Mr. Craig wrote in reply, that the hole should be made perfectly straight and true, and that if wished it could be 6 inches diameter. He went down with the machine, and found the hole, which had been made by a jumping tool instead of being bored out, neither straight nor round, and twice the size at the centre that it was at either end; consequently, the machine, being adapted for a round and true hole, had to be expanded in the first instance to fit it, and ultimately was bent. The expansion of the apparatus was $2\frac{1}{4}$ inches. This he had found sufficient for splitting the coal he had up to the present time had to do with; though this limited expansion might not answer for a wedge. In the case of a wedge there were two points bearing on the surface, and there must be a large expansion, in consequence of the small area brought to bear upon the coal. In his machine the area was on one side 75 square inches, and on the other upwards of 100 square inches. And if the expansion of $2\frac{1}{4}$ inches

were not sufficient, it would be easy to introduce a liner between the plungers and the cover plate. The plungers could be brought back by opening a small valve to let the water off, and shaking the apparatus in the hole; then the liner could be put in. The coal did not spring back to the full extent of the expansion of the machine. Where the expansion had been 2 inches, the coal did not spring back more than about $\frac{3}{4}$ of an inch. The liner was a piece of metal sufficiently small to pass between the two sides or cheeks of the cover plate; the end was made wedge-shaped to avoid catching against the plungers.

The drill he had exhibited, had, up to that time, bored about fifty holes in both hard and soft coal, and it had also drilled through 'brass,' or copper pyrites as he supposed it to be. It was worked by one man, and the time occupied in drilling each hole, was, on an average, from twelve minutes to fifteen minutes, and allowing from three minutes to five minutes for placing the drill in position, on the outside not more than twenty minutes would be occupied in each case. When he was at Harecastle two hours were required to drill a hole, and Mr. Craig objected to the machine because it was proposed to use a drill instead of the ordinary jumper, saying that it would be a mistake to introduce a new form of labour among mining men. The only difference, however, would be, that one man would have to turn a wheel instead of two men having to use a large punch as it was called; and the drill would make a perfectly true hole in ten minutes in the coal, whereas the punching took at least two hours for a hole $4\frac{1}{2}$ inches diameter. This drill was worked in the presence of Mr. R. Bedlington, President of the South Wales Institute of Mining Engineers, who had written to him as follows:—

"Having heard that your machine was doing its work very well, I went to Fforchaman Colliery, near Aberdare, to see it at work.

"Several mining engineers were present at the trials. Four holes were bored.

" The 1st hole—Boring occupied	13 $\frac{1}{2}$ minutes.
Fixing the machine, not timed.	
Pumping.	ditto.

" 2nd hole—Boring	14 minutes.
Fixing	6 "
Pumping.	5 "
Total	25 "

" 3rd hole—Boring	12 $\frac{1}{2}$ minutes.
Fixing	5 $\frac{1}{2}$ "
Pumping.	3 "
Total	21 "

" 4th hole—Boring . . .	13 $\frac{1}{2}$ minutes.
Fixing . . .	15 $\frac{1}{2}$ "
Pumping . . .	6 $\frac{1}{2}$ "
Total . . .	<u>35$\frac{1}{2}$</u> "

" The total time occupied in the trials was two hours, and about 36 tons of coal, I am informed, were loosened, so as to enable the colliers by pick and mandrel to extract the coal.

" Compared with the amount of small coal made in holing, the small made by the bore is less. Less small coal is also made by the machine in severing the coals than by powder. This is an important point in favour of the machine in steam coal collieries.

" The necessity of using powder in the extraction of coal is by your machine done away with. I should be glad to learn that the machine could also be applied to the working of strong ground, so as to enable us to rip top, and cut bottom, in our workings without using powder.

" I believe that your machine will effect a saving in the cost of cutting coal; and to the extent of the disuse of powder, will be a step towards greater safety.

" Another important point is, that the coal can be worked more rapidly along a face of work, and therefore a much larger amount of coal can be extracted from a given area within a certain time."

Mr. Woodhouse, Mr. Warrington Smyth, and Mr. Craig, seemed to be of opinion that it would be impossible to get the coal out by this machine without first either holing, cutting, or nicking it. In all the trials he had made, the coal had not been prepared in any way before he commenced drilling, either by holing, cutting, or nicking, and in all those trials with his machine, the coal had been thrown out so that it could be rapidly removed. The chief expense and loss in the ordinary operation of getting coal was the undercutting or overcutting, as the case might be; but with his machine none was required, in proof of which he submitted a report from the managers and agents of the Powell Duffryn Steam Coal Company upon the action of his machine in the Aberaman, the Middle Duffryn, the Fforchaman, and the Lower Duffryn collieries:—

" Report of the Managers and Agents of the Powell Duffryn Steam Coal Company, Limited, upon the action of Chubb's Patent Coal Getter.

" We, the undersigned, have witnessed the following experiments; viz., Aberaman Colliery.—' Four-feet seam.' This seam is six feet thick; strong coal, and powder is used. The experiment was tried in a twelve-yard stall, double road; the left-hand rib was cut two and a half yards in, under the top coal, which is one foot thick. The first hole was drilled six feet from the cut, to a depth of three feet six inches, and the apparatus forced off about three tons. The second was drilled in six feet to the right of the last hole, the same distance in, and because the slips ran diagonally across the stall, this hole reached into the second slip, and forced off about eleven tons. There was in this fall a block of solid coal of three tons weight. The third hole was drilled six feet to the right of

the second hole, and forced off about four tons, making a total of eighteen tons in one hour and three minutes. * * * *

"The second experiment was tried at Middle Duffryn Colliery, in the 'Six-foot seam.' The coal is exceedingly hard, and sticks fast at both top and bottom. The hardest place in the pit was chosen in order to test the machine thoroughly. Only one hole was tried, and it was drilled in a long wall face without either cutting or holing, and about four tons of coal was forced off in twenty minutes. This experiment was made the day previous to the meeting of the South Wales Institute of Engineers, and as the machine had to be sent off that day, time did not permit any further trials. * * * *

"The third experiment was tried at Fforchaman Colliery, in 'Six-foot seam,' being three feet two inches in thickness, and sticks to bottom. A place was selected in the long wall face, and a layer of 'brass' three inches thick runs through that part. No preparation by holing or cutting was made. Five holes were drilled along the face, the machine applied to each, and the result was, that the whole of the face for a distance of forty-eight yards was forced off, being equal to about forty-five tons, in the space of three hours and ten minutes. * * * *

"The fourth experiment was made at the Lower Duffryn Colliery, in the 'Nine-foot seam,' where it is impossible to work without powder, as the coal sticks hard to the bottom. The first trial was in a ten-yard single stall, the coal being six feet in thickness, the top coal left up. The hole was drilled in the middle of the stall, over a shot which was ready for firing. No cutting or holing was made. The machine forced off about five tons. The next hole was drilled close to the right-hand rib in the same stall, and about three tons was forced off. The third hole was in the second stall, and so placed that it forced off the face of the stall, equal to about ten tons. The fourth and fifth holes together, in another stall, forced out about seven tons. On account of the danger of using gunpowder in this seam and the impossibility of working it hitherto without, it has been decided to work it in future entirely with the coal getter, and it will be adopted forthwith. * * * *

"A fifth experiment was made at the Fforchaman Colliery, in the same long wall as the former one. No preparation was made either by cutting or holing. Three holes were drilled, and the machine in this case forced off 36 tons in two hours. * * * *

"From the foregoing experiments we are of opinion the 'Coal Getter' will remove to a great extent explosions of gas, which often arise from the use of powder; it does not shake the top, thereby removing frequent causes of accidents; it works out the coal in better condition, making it bear transit better than when worked by powder; requires no holing, and therefore makes little or no small coal; and, lastly, it works out the coal in less time, and therefore does not require so large a working face—thus making ventilation more efficient; and, in conclusion we would say, that wherever gunpowder is used in getting coal, either in this district or elsewhere, this instrument may be applied with great success.

"Signed—

GEORGE WILKINSON, Manager, Duffryn Collieries.
 THOMAS BURN, Manager, Cwm Newl Fforchaman and
 Aberaman Collieries.
 FREDERICK WILMER, Mining Engineer.
 GEORGE WILKINSON, Mining Engineer.
 JOHN SNAPE, Mechanical Engineer."

A question had been raised as to the possibility of getting 12 tons

pressure to the square inch with the pump he had applied to the apparatus. The lever was divided in the proportion of 30 to 1, and the area of the plunger of the pump was 0.44 square inch; from this it would be found that a force of 394 lbs. at the long end of that lever would give a pressure of 12 tons on the inch. The ratio of 30 to 1 was taken on the assumption that the hands of two men occupied a space of 18 inches, the effective length of the longer arm being diminished by 9 inches, as calculated from the centre of application of the force.

Remarks had been made that his machine and that of Mr. Grafton Jones were essentially the same, and no doubt there was much truth in the remarks; but there was this important point with respect to the time of their introduction, the fact being that his was patented in March, 1868, while that of Mr. Jones was not patented till the following October, and he might add, that his specification described exactly the apparatus exhibited by Mr. Jones. Mr. Jones had, however, previously invented another apparatus, which led to the remark in his Paper about giving up the idea of wedges altogether, and seeking for some other power to be used with more effect. Mr. Jones in 1864 patented a wedging apparatus, and had communicated to him the amount of success and failure that attended it. It was Mr. Jones' opinion that a wedging apparatus would be of no use, as the wedges bent the side plates every time they were used, and as the wedges were cut up and spoilt very rapidly. Besides, when the coal was forced apart with the wedging apparatus, the apparatus could not be removed from the hole till the whole of the coal was brought down; so that there must be a separate wedging apparatus for every block of coal brought down in different places at the same time. In conclusion, he remarked that he should be amply repaid if hereafter his machine, or any other brought out in consequence of the discussion, had been the means of lessening the risks of working coal.

Mr. S. P. BIDDER, jun., in replying upon the discussion, thought it was unnecessary to say anything with regard to the various modes of working, as the special object of the discussion was to determine the most suitable machine to take the place of powder, and capable of being worked in any description of coal. He considered that his machine had certain advantages over the others which had been brought forward. In the first place it was extremely portable. The press was independent of the straps and wedges; and instead of each gang of colliers requiring a complete machine, a strap and three or four wedges sufficed. The machine could be constructed to enter a hole 2 inches in diameter, and in no case did it exceed 3 inches in diameter, as the boring of a hole above that size was attended with considerable difficulty.

He thought Mr. Chubb would find it troublesome, to say the least of it, to transport a drilling-machine of the necessary size through the airways and passages of a mine; besides which, drilling was a class of labour to which the miners were not accustomed. The large amount of expansion in his machine made it suitable for any description of coal. The expansion part of the apparatus acted over the full area of the bore-hole, and the wedges, being made of the best steel, were almost indestructible. The power, once applied, was not removed till the coal was brought down: it was equivalent to 15 tons multiplied five times by the wedges, giving 75 tons outward pressure of the expanding box. He was of opinion that the power necessary to break down a body of coal by his machine, according to the present system of working, would never exceed 100 tons. He could not admit that the use of powder was free from danger when superior workmen were selected to fire the shots; and although so few accidents were attributed to explosions, yet the verdict of many a coroner's inquest—that from the nature of the accident the precise cause of death was wrapped in mystery—was a convincing proof that the majority were caused by the use of powder. Then, again, as to undercutting being sufficient to bring down coal by the force of its own gravity, that could only be when the cleavage was exceptionally distinct, which did not apply to one-tenth of the coal so undercut. Many seams were overcut, owing to a bad parting between the coal and the floor, or there might be soft dirt at the top. At Harecastle, where coal fetched a higher price than in any other part of the country, and where the pit price of coal was always high, he found that while round coal was worth 7s. 6d. or 8s. per ton, the price of the slack sold for making coke never realized more than 4s. to 4s. 6d. per ton. The direct saving to be gained by the use of the machine could only be stated in general terms: one great element, however, consisted in the entire freedom from accident from blasting. Mr. Woodhouse justly remarked that there was such a variety of coal, that in one case the advantage might be one shilling and in another a farthing per ton. Mr. Chubb seemed to think that the wedges were liable to be damaged and destroyed, but they were made of the best steel and tempered, and endured the trials at Harecastle without a scratch; nor were they bent more than $\frac{1}{16}$ th of an inch after bringing down from 25 tons to 30 tons of coal. In the case of the pillar, shown in Plate 10, the test was more severe than the machine would ever be likely to undergo in practice. He apprehended that what was required was a machine capable of dealing with the worst conditions of coal, which he considered his machine had successfully accomplished at the Harecastle Collieries, where it was admitted by Mr. Chubb the coal was exceptionally tough and hard to work.

Mr. GREGORY, President, said he was sure the members present appreciated the interesting discussion which had just been concluded; and, while thanking Mr. Bidder and Mr. Chubb for their Papers, were also obliged to other gentlemen who had given a description of their inventions for similar purposes. He would add his conviction that the members cordially welcomed the presence of their brother engineers, whose attention was more particularly directed to the means of the economical and safe getting of coal, so important to the interests and the greatness of this country; and were pleased to receive into the Institution more of those who had had large experience in this useful branch of the profession. He hoped the gentlemen whose inventions were under consideration would avail themselves of the facilities so kindly offered by Mr. Woodhouse for trying their machines, under various conditions, in the mines under his direction.

Different machines, or modifications of machines, might be applicable to different circumstances: one might be applicable to hard coal, and another mechanical arrangement might be better suited to soft coal. Some coal was of such a hard nature that a small amount of expansion would break out the mass from the seam; while coal of a soft and yielding nature would require a large amount of motion in a part of the apparatus. Again, the position and the cleavage of the coal, and the thickness and inclination of the seams, and the mode of working, would all affect the nature of the apparatus to be used. It would have been interesting to have had before them, when considering this subject, more information with regard to the machines used for cutting and grooving coal; and it still remained to be decided, how far the use of machines for breaking down the coal would supersede the necessity of undercutting or holing. These remarks naturally led to the conclusion, that no general rule could be laid down, and that the machines might have to be varied according to the duty they had to perform. Still, looking at the work to be done, it might be suggested that if the process could be effected by one instead of by a number of operations, there would be a saving as regards simplicity of working and economy of time and labour.

As the hydrostatic press was an important feature in some of the machinery which had been under consideration, and having had the honour, when an apprentice, to work he might almost say at the same bench which had been used by the celebrated Joseph Bramah, he hoped it would not be considered irrelevant if he laid on the table a letter which he had received from Mr. Mallet, containing photographic copies of a letter from Mr. Bramah to Mr. Mallet's maternal grandfather, and of the original drawing, supposed to be by Mr. Bramah himself, of the well-known lock. All who had studied the works of Joseph Bramah must have

been impressed with the great variety of his inventions, which ranged from the simplest and most common objects of daily use, to the most powerful and complicated machinery. The letter was dated 10th November, 1802, and it showed that Mr. Bramah at that time had designed a complete system for the transmission of power by means of hydraulic connection, and had anticipated the immense extent to which such a system might be carried. His words were as follows:—"I have also now applied it, with the most surprising effect, to every sort of crane for raising and lowering goods in and out of warehouses. So complete is the device that I will engage to erect a steam-engine in any part of Dublin, and from it convey motion and power to all the cranes on the quays and elsewhere, by which goods of any weight may be raised at one-third of the usual cost."

He thought that these documents deserved an honourable place in their archives, in remembrance of a man who had done more than most for the good of his fellow-men, by his profound mechanical ability.
