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CLEVELAND DRILLING MACHINES.

by Nigel A. Chapman

SYNOPSIS

In the late 19th century, the need to cut unit costs led to experiments in mechanising the drilling process. This paper discusses the development of such technology in the Cleveland ironstone mining industry in Yorkshire.

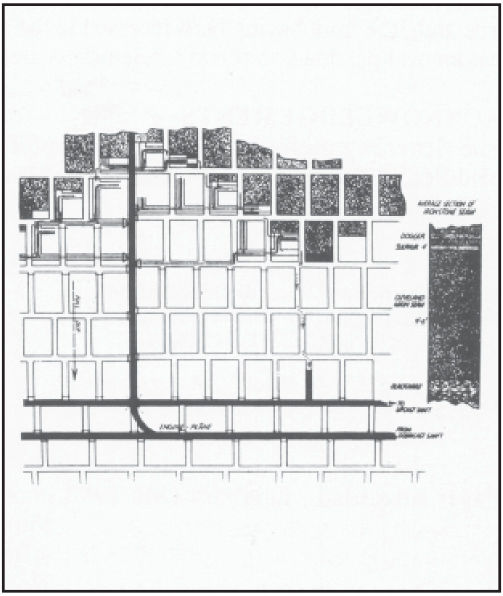
INTRODUCTION

During the 1830s the removal of nodules of ironstone from the beaches between Kettleness and Staithes started. Because of the severe weather along this coast, the transportation by sea to the Tyneside ironworks was a seasonal activity and dependant upon the tide. In 1849 Messrs Bolckow Vaughan began working the Main Seam of ironstone near Skinningrove and shipping this along the coast to their ironworks in County Durham, again being very dependent on the weather and the state of the tide.

Then, on June 8th 1850, John Marley and John Vaughan discovered the Main Seam of ironstone on the Eston Hills.[1] Messrs Bolckow Vaughan quickly took out a lease of this ironstone and began quarrying operations along the outcrop. As these workings developed, quarrying gave way to mining, with eventually three major drift entrances being developed on the hillside. Because of the strong links with the Durham coalfield, the expertise and mining methods were brought across the River Tees to exploit the Cleveland ironstone and so, from the beginning, the Bord and Pillar form of working became the standard method of extraction, as it was north of the Tees.

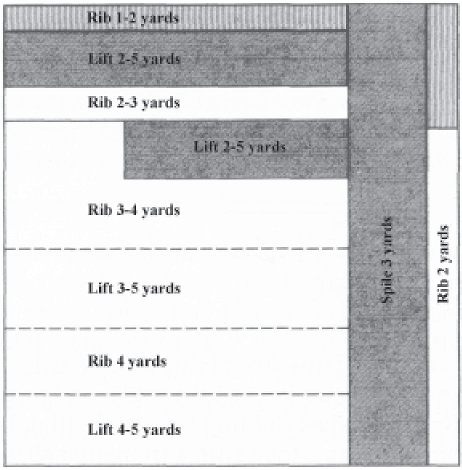
BORD AND PILLAR

In the first or 'Whole' working, two bords of 14 feet wide were driven about 40 yards and these were linked every 30 yards apart by bords driven at right angles. By this means, pillars of 35 yards by 25 yards were formed. The general practice was to drive the bords to the royalty boundary before any pillar removal started.[2] This meant that these bords stood unused or unmaintained for years, with all the problems of collapse, before being used again. In later years, therefore, the removal of the pillars was started about three



Bord and Pillar method of working the ironstone.

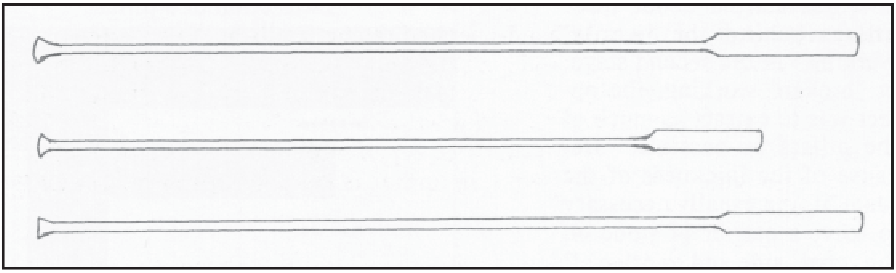
Extraction of a pillar.



pillars behind the 'whole' working. In the second stage, or 'broken' working, the object was to extract as much of the pillars as possible. Because of the thickness of the seam, it was usually necessary to leave a barrier of stone on the 'goaf' side and to drive all the 'splits' and 'lifts' in the solid pillar. From the illustration, it will be seen that a stepped line of 'goaf' was used to control the weights, or crush, and to maintain the ventilation. The ideal district was one of six to eight pillars each side of the main haulage road. When a new row of pillars was to be extracted, a tubway was laid along the bord. If this had collapsed, a heading was driven along the outbye end of the pillars and 'spilings' put through the collapsed bords. These spilings were driven nine feet wide between timbers and the full height of the seam. Naturally this redriving added considerably to the cost of working. The illustration shows the method of extracting a pillar. A split was driven along the outbye side of the pillar, followed by a lift of five yards wide driven at right angles through the pillar. Having left a supporting rib two to three yards thick, a further lift was taken through the pillar. After each lift had been driven, the supporting rib was removed. This sequence of operations was then repeated. The next operation was to extract the timber. This was the most dangerous part of the activity and was carried out by skilled timber-drawers. Assuming that the pillar had been completely extracted, its place would have been taken by a series of props in rows. These were taken down with the aid of a Sylvester, starting from the area near the goaf. As this work was proceeding, one man would take an axe and cut notches into various props to give an audible warning when the weight came on to them. This operation was known as '*Drawing the Jud*'. Timber removal would continue until the roof began to show signs of collapse. It was considered essential for the jud to close up completely to relieve the other pillars of the weight.

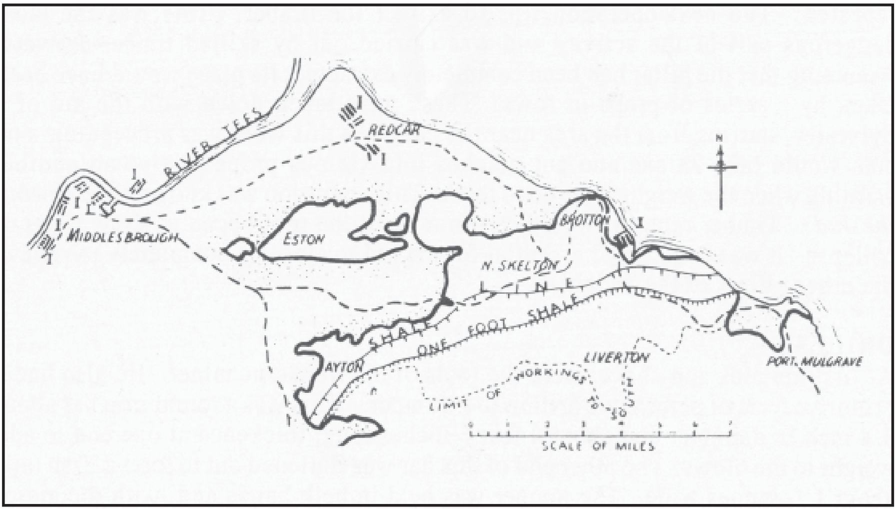
DRILLS

At first the pick and shovel were the tools of the ironstone miner. He also had a primitive form of percussive drill in the 'Jumper'. This was a round iron bar about 3/4 inch in diameter and about 4 feet 6 inches long, thickened at one end to add weight to the blows. The other end of this bar was flattened out to form a 'fish tail' about $1^1/_4$ inches wide. The jumper was held in both hands and, with the aid of a heavy hammer, 'started' to drill a hole. Once this hole was started, the miner was able to chip away with the drill and 'jump' a hole by percussive action into the ironstone. As he proceeded at his work, the hole took on a triangular shape that was



Jumper Drills.

very distinctive of this type of drilling.[3] The skill of the miner was said to be in the way that he used the angles and position of each hole created by this method. So established did this form of drilling become that it was believed necessary to work the ironstone with a triangular shaped hole and that it was only the miners' skill and the use of these angles that made mining possible. On average the miner was able to drill three holes per shift, each hole taking upwards of 30 minutes to jump the three to four feet required. An experienced miner was expected to produce from three to four tons per shift. When mining engineers and managers began to study the economics of ironstone mining, they found drilling was the most expensive and time consuming item. This one item exercised more minds and provided more work for engineers than anything short of the mines themselves.

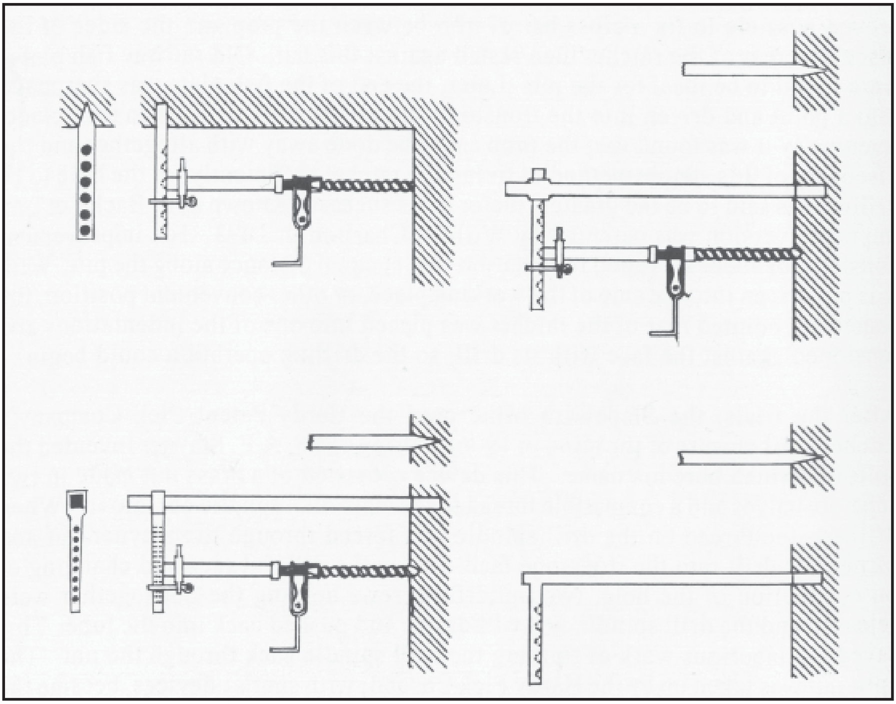


Sketch plan of mining area in the Cleveland Main Seam. Outcrop of ironstone shown by thick line.

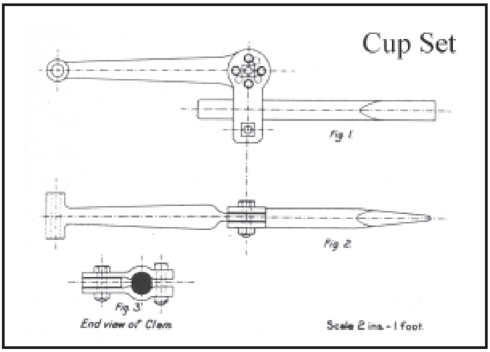
EARLY EXPERIMENTS

There were trials of the early hand-operated ratchet drills at the Liverton Mines and a few were also used at the Belmont and Spawood Mines before 1880, but very little appears to have followed from these trials.[4] The French Villepigues drill, a rotary hand drill complete with a stand, was tested in 1870 at the Normanby Mines of Messrs Bell Brothers. It proved to be capable of drilling at the rate of nine inches per minute maximum.[5] Nothing further is heard of this machine and the jumper reigned supreme.

A major problem of the Cleveland ironstone field was that the further from Eston and the coast that a mine was placed, the thicker became a band of shale in the middle of the Main seam. So the seam at Eston Mines was 12 feet of clean stone, but at Brotton Mine it was down to 8 feet 4 inches of stone, 2 feet 1 inch of shale and a bottom block of 2 feet 7 inches of stone. From this it will be realised that not only was there less ironstone to work, but it was also the added problem of the handling and disposal of a considerable amount of rubbish. The inland mines of Kilton, Liverton, Slapewath, Stanghow etc were at a great disadvantage in production costs when compared to the clean stone coastal mines. In times of depression in the iron trade, these mines with the shale band were the first to close and in several cases they had very precarious lives. Because of these constraints, when technology was available it was used by the



Hardy Ratchett and the Charlton Back Set.



'shale band' mines, which were thus in the forefront of the development of this technology.

In 1884, because of the depressed state of the iron trade, the Slapewath Mines, near Guisborough, were closed. When, in 1886, it was decided to reopen them, it was necessary to reduce the cost of winning the ironstone to make the mine a viable concern. William Charlton, the manager, conducted a thorough trial of the types of hand drill available.[6] Most of the machines on the market were of crude manufacture, having loose brasses in the barrel and thick edged drills. It was soon found that a major problem existed in the method of setting up these drills, as an extra timber prop had to be set between the roof and the floor, before the ratchet was set up between the prop and the working face. All the setting up wasted the time saved by the use of the machines and on many occasions the ironstone blown down from a previous shot would be lying where the prop needed to be for the next one. Alternately, the projecting side walls of the place prevented the prop being set near enough for the hole to be drilled in the required direction. With time, it proved possible to fix a cross bar of iron between the prop and the sides of the place; the rear of the ratchet then rested against this bar. Old railway fish plates were found to be ideal for the job. Later, the end of the fish plate was sharpened into a point and driven into the ironstone and allowed the drilling to take place. Eventually it was found that the prop could be done away with altogether and the discovery of this simple method of fixing the ratchet sufficiently for the hole to be drilled was said to be the greatest factor in its success. Known as a 'Back Set', an improved version was patented by William Charlton in 1893. His improvement consisted of about six round indentations cut at equal distance along the pin. With this pin driven into the side of the working place, or other convenient position, the somewhat pointed rear of the ratchet was placed into one of the indentations and tensioned against the face with its drill, so the drilling operation could begin.

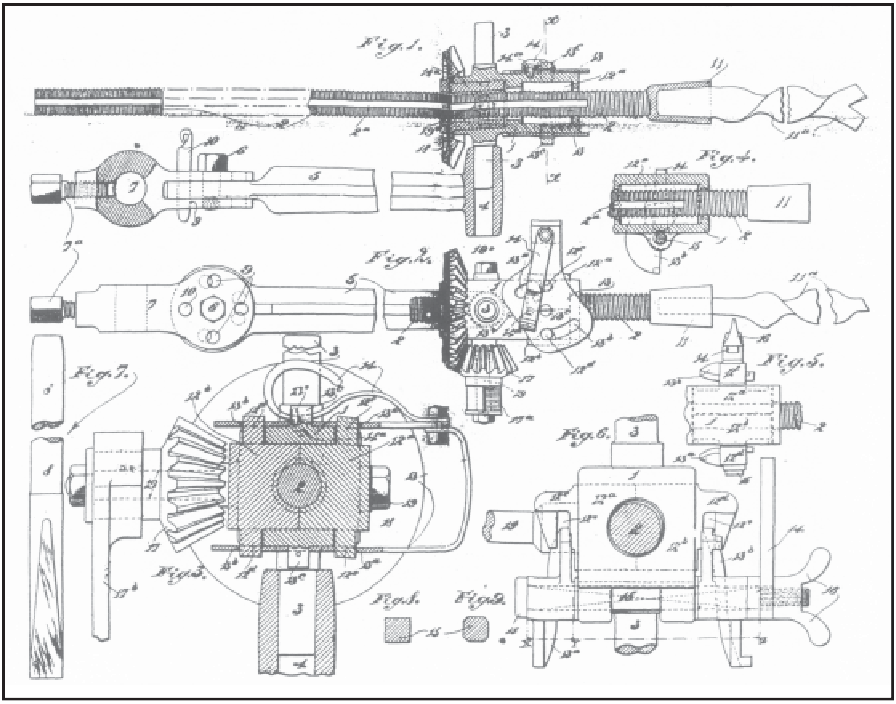
After the trials, the Slapewath Mine used the Hardy Patent Pick Company's ratchet until closure of the mine in 1906. During 1886, A.E. Stayner invented the split nut which bore his name. This device consisted of a brass nut made in two separate halves and a compatible thread to the main drill spindle cut into it.[7] When drilling, the thread on the drill spindle was forced through the Stayner nut and turned the drill into the ironstone face. When the drill bit required changing or on completion of the hole, two butterfly screws holding the nut together were released and the drill spindle was withdrawn and pushed back into the tube. This saved the laborious work of running the drill spindle back through the nut. The split nut was taken up by the Hardy Pick Co. and, with similar devices, became the standard quick release mechanism on a ratchet for a period. A further improvement was to supply each working place with two ratchets, one for right hand use and the other for left. This permitted the advantage of the weight of the handle plus the pull-down stroke to advance the drill. Each pair of miners, having been supplied with one of each type of machine, could use them to best advantage. Having shown what could be done with the ratchet as against the jumper drill at Slapewath Mine, the machine came into more general use in Cleveland, but only after a great deal of opposition from the men and a strike. That, however, is beyond the scope of this paper.

GRAY AND TARBUTT ROTARY HAND DRILL

Probably the next improvement was the Gray and Tarbutt machine in which a rotary motion of the handle was converted at right angles to drive the drill.[8] Gray and Tarbutt were the manager and engineer at the South Skelton Mine, so this machine was developed and much used there. Patented in 1893, it was the first successful rotary ratchet to be in common use. It suffered from problems with the split nut arrangement, however, and this required careful use because the threads were prone to damage. Probably this weakness prevented the more extensive use of the machine.

HALL'S ROTARY HAND DRILL

The next step was the development by William Hall, engineer at the Upleatham Mines, of the Hall Rotary Ratchet in 1895.[9] In his patent application he states "*The object of my invention is the production of apparatus suitable for drilling rock and*



Hall's Rotary Drill and the Cup Set Stand.

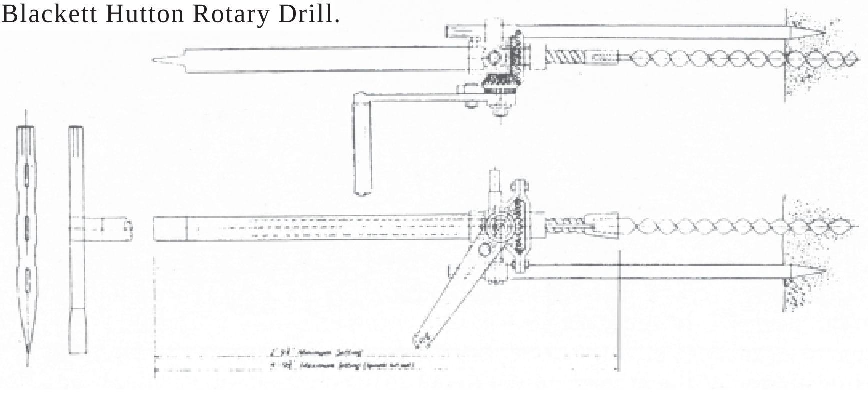
which shall be simple in construction, light, portable and easy to manipulate". This seems to sum up the ideal for any drilling machine and applies today as readily as in 1895. Used at first in the Upleatham Mines, this drill was to be for a short period more widely used in the Cleveland Mines. The most important feature was the development of a new stand. Because the drill spindle was not encased in a metal tube, the usual 'back set' position could not be used and so a new stand, known as a 'cup set' carried the machine during drilling operations. A chisel-pointed iron bar about 20 inches long and $1\frac{1}{2}$ inches in diameter was driven into the ironstone. Along the bar slid a clam which could be held firm at any point by tightening a nut. The last part of the stand was a radial arm, with one end fitting into the clam and the other end having a small cup into which a projection on the drill fitted. The radial arm was fixed into place by inserting a pin through one of the holes in the clam and also in the radial arm. The ratchet was then placed on the stand and drilling began. It proved unnecessary for the bar of the stand to be placed directly under the hole to be drilled. Instead, it could be placed to one side or even at right angles. William Hall claimed that it was possible to move the stand to such an extent that two holes could be drilled from the one location.

There appears to have been very little trouble with the stand working loose during drilling operations and it seems that, in practice, the stand was pushed downwards by the drill and this held the bar in place.

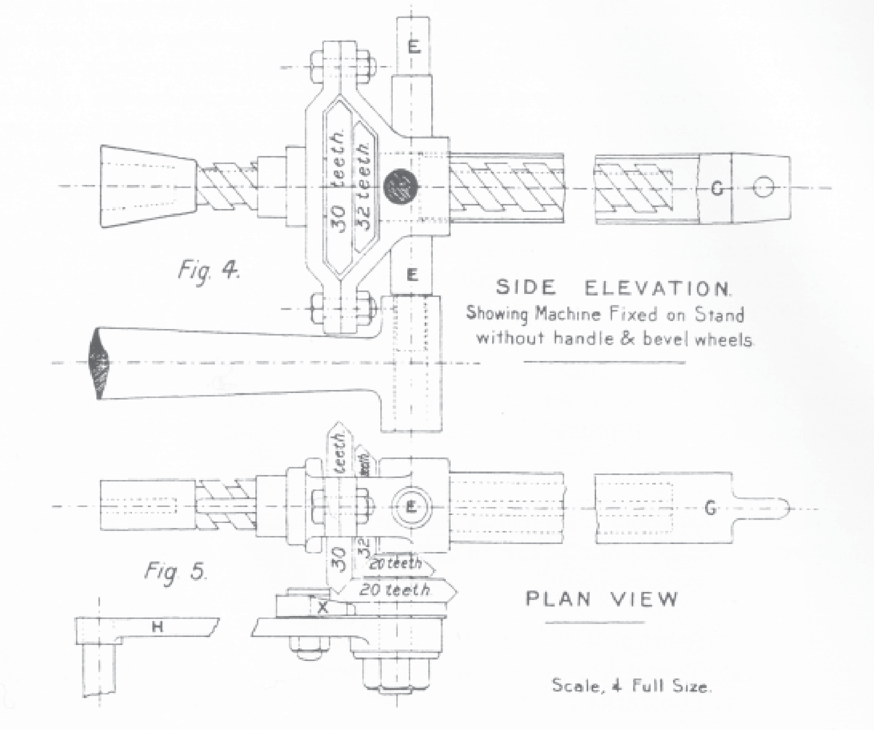
BLACKETT HUTTON ROTARY DRILL

By this time the shortcomings of the ratchets were well known. The fact that the split nut had a problem of thread stripping, which required constant attention, led to further developments. Most of these locally designed machines were produced by the firm of Messrs Southern & Co. at its Guisborough Foundry. During 1894, John Blackett, foreman fitter at the foundry, patented a simple form of ratchet drill.[10] Then, in 1896, in partnership with William Hutton, engineer, he produced the ratchet that improved on all the previous models. This drill, known as the Blackett Hutton machine, was designed to improve the durability of the machines by the use

Blackett Hutton Rotary Drill.



Blackett Hutton Rotary Drill.



of bevel gears to provide the feed for the drill (as in the Hall machine).[11] Also, by having a coarse pitch on the drill spindle, it was possible to retract the spindle and dismantle, or change, the drill more quickly. By this means, the split nut system and its drawbacks were avoided.

The drill was fitted into a double threaded bar of two inches pitch by $1\frac{1}{8}$ inch diameter by two feet six inches long. The bar, instead of working in a split nut, worked through a cast steel nut ‘A’ screwed to the same pitch; at the end of the nut was a bevel wheel fitted with 32 teeth and geared into a bevel wheel of 20 teeth ‘B’, which was turned by the handle ‘H’. In front of the nut was a sleeve and bevel wheel with 30 teeth ‘C’, with a feather fitted into a keyway on the bar. This geared into a larger bevel wheel with 20 teeth ‘D’, which ran loose on the collar of ‘C’ and could be put in and out of gear by the pawl ‘X’. The wheel ‘C’ turned the drill spindle, and the nut ‘A’ turned in the same direction, but because ‘C’ had fewer teeth than ‘A’, the difference gave the required advance to the drill. As the teeth in ‘C’ and ‘A’ were as 30 to 32, the drill spindle would make 32 revolutions while the nut made 30 revolutions, so two revolutions advance was made. This was equal to an advance of four inches per 32 revolutions. Thus the feed was 1/8 inch per revolution of the drill spindle, or 1/12 inch per revolution of the handle.[12]

The two studs ‘EE’ were fitted one on each side of the machine, so that it could be fixed either way up on the stand with the handle on the most convenient side for drilling. This avoided the ‘handed’ machines mentioned earlier. The drill spindle was protected by a steel pipe ‘G’, 1½ inches in diameter and closed and pointed at one end. Besides protecting the drill spindle, the pipe was used to provide a hold against the side of the place when possible. When the Blackett Hutton was set up and ready to drill, the pawl ‘X’ was in gear and both the bar and the nut turned in the same direction. Once the hole was complete, or to change the drill, the pawl was disengaged and the handle turned in the same direction. This turned the nut alone and the drill spindle was brought back at the full pitch of two inches per revolution. Also, when setting up the machine to drill with the pawl out of gear, the drill could be tightened up to its work by turning the handle in the opposite direction.

The Blackett Hutton became the standard drill of the Cleveland mines and survived into the 1950s in some mines, having gradually replaced all the other hand-operated drills. It proved to be popular, versatile and above all robust.

TWIST DRILLS
These varied in length from 1 foot 6 inches to 4 feet 6 inches according to the discretion of the miner. Three drills was the normal complement of a working place.

	Length	Diameter	Weight
Short drill	1' 8"	1¾"	2 lbs
Yard drill	3' 0"	1⅝"	3½ lbs
Long drill	4' 6"	1 9/16"	5 lbs

These drills were made of hard steel of fish-bellied section 1⅜ inches thick and were usually hand twisted by the mine blacksmith. The short and yard drills were sharpened to produce a larger hole than the long drill so that they could be extracted by hand. A drill key was provided among the tools of a place for this job.

DRILLS

WORK DONE BY RATCHETS
When these machines were first introduced into the Cleveland mines, the system was for three men to work two places. One would be an experienced miner, with the machine, and he would drill and fire the required shots in both places. The other two were employed to fill the blown-down stone into the tubs. In an 8 feet 6 inches thick seam of clean stone three men with one machine would get from 23 to 26 tons per day in the ‘whole’ workings with 12 to 14 holes.

This arrangement did not work very well and was replaced with a system of two miners in one place with one machine. The earlier system gave a larger output per machine but the latter system gave a larger output per working place. This proved to be an important item when working out the pillars because a lot of difficulty was experienced in making places ready to be used.

When two miners worked together, one man drilled while the other filled. Experienced miners took turns drilling and firing, or filling the tubs. Should the place be working well, an output of 10 to 16 tons per day was possible. If they were working a place removing pillars then an output of much nearer 10 tons per day was likely. When the pillars were being worked, stoppages were caused by the deputies setting timber. More stone required barring down and more care was needed to prevent timbers being dislodged.

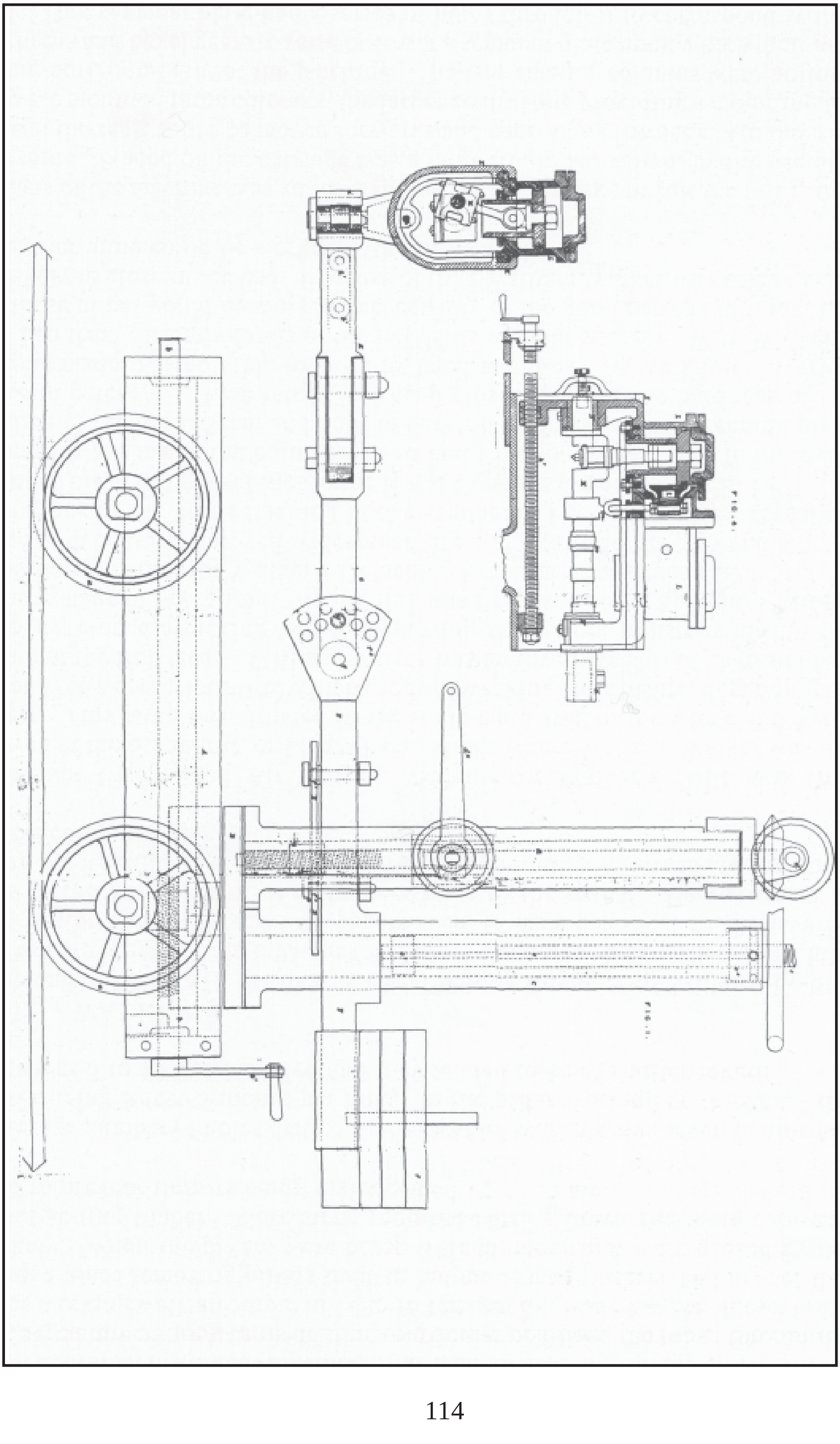
The average number of holes drilled in the 'whole' working was seven to nine per shift averaging 3 feet 6 inches per hole. In the pillar working or 'brokens' the average was 5 to 10 holes drilled and they tended to be of shorter length.

DRILLS - WALKER'S

On September 26th 1874 William Walker, Mining Engineer of Saltburn-by-the-Sea, Yorkshire, applied for a patent for 'Improvements in Rock Drilling Machinery'.[13] Unfortunately, his private papers seem to have been lost so we have no details of the development or influences prior to the patent. He continued to develop the machine over the years, however, and these alterations are shown in the succeeding patents.

The Walker Compressed Air Drilling Machine, or Walker's Drill, was first employed at the Stanghow, or Magra Park, Mines where William Walker was the manager. This mine was situated in the shale band area of the Cleveland Main Seam and led a precarious life, with periods of working and closure, depending on the state of the iron trade. William Walker was an inventive sort of chap and had already developed a picking belt for removing shale from ironstone during the screening stage of operations. Again, this was first used at the Stanghow Mines. He was also to invent the Walker's Detaching Hook for mine cages which, during the late 19th century, enjoyed widespread use and rivalled Ormrod's and King's as being one of the best detaching hooks available. He was to give a revealing account of his drilling machines to the Royal Commission on Labour in 1891. At that time he was managing both Stanghow and Liverton Mines, both in the shale band area of the Main Seam and both to develop extensive shale screening plant (Walker's patent?). These mines had been closed because the hardness of the ironstone made it impossible to work by hand methods. As we know, Liverton mines had tried the early forms of ratchet drills without success. With Walker's drill, these mines could be worked successfully in the good periods of trade, but were likely to close in the bad. Because of this, William Walker was able to state that neither mine could be worked without his drill.

The basis of the machine was an iron, four-wheeled carriage to suit the rail gauge of the mine. Placed on the carriage was a large iron plate which, by the use of a handle at the rear, could be moved forwards and back along the deck. On the iron plate were mounted three columns, the larger central one providing a mounting for the long horizontal arm of the machine. The two smaller columns were hollow, with chains and bevel gears to raise or lower a segment plate upon which their arm rested. This segment plate had a series of holes through it to correspond with a hole



Walker's Compressed Air Drill, 1874 model.

in the arm so that movement within an arc to left or right was possible, with the added feature of pinning the arm in a particular position. On top of the central column was an adjustable jack to secure the machine against the roof of the working place. The long horizontal arm had a counterweight to the rear of the carriage. In front, the arm had two joints. One provided vertical adjustment and the other was capable of fine adjustment near the drill. Both joints were complete with holes and bolts, so that, having decided upon an angle, the drill could be secured in place. At the tip of this arm was a large clamp to carry the drilling machine, again with a fair amount of adjustment being possible. The drill itself consisted of two single-acting air cylinders, of 5½ inches diameter by 2½ inches stroke, operating at 90 degrees to each other. They directly drove a crank shaft which terminated in the drill spindle.

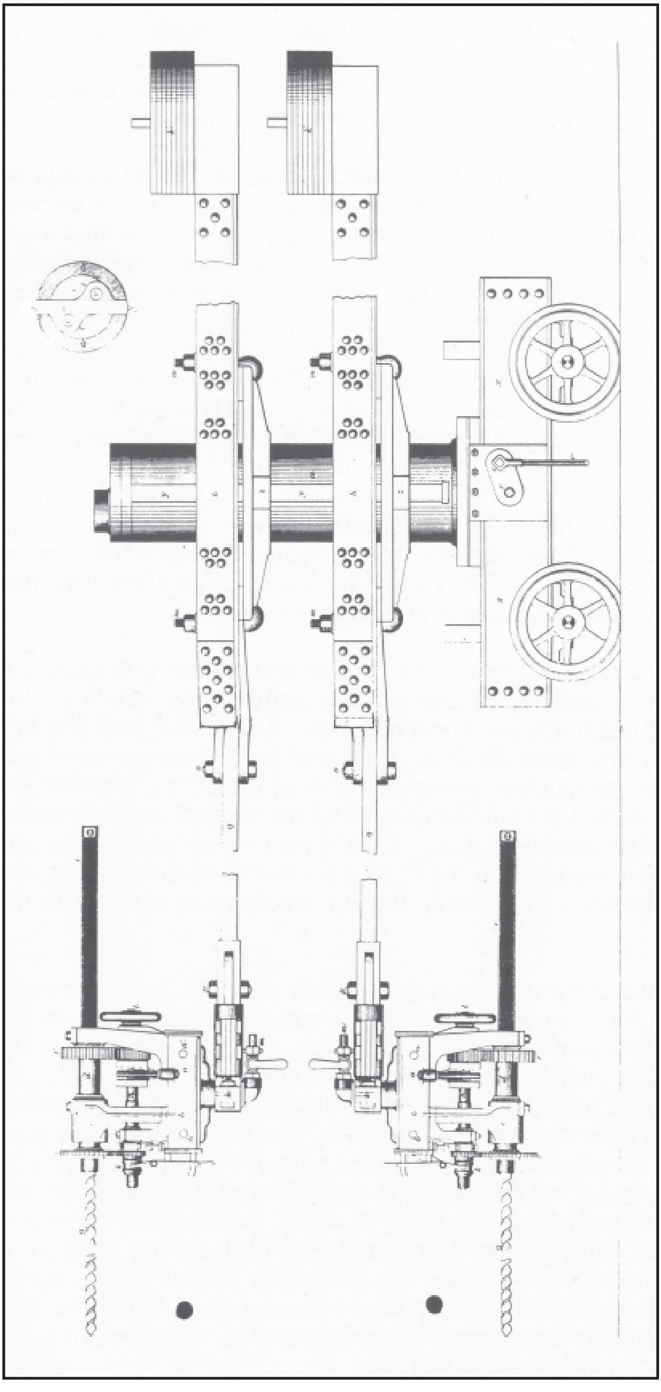
Following their use at Stanghow Mines which, in effect, proved the machines' capabilities, Messrs Bell Brothers negotiated a royalty with William Walker and operated these drills at their Normanby and Skelton Park Mines. How many others of this 1874 model were used is, unfortunately, unknown.

WALKER'S DRILLING MACHINE: 1875 MODEL

By the middle of 1875 William Walker took out patent number 1657 for an improved version of his machine.[14] This was a radical redesign of the machine, probably based on the experience gained at Stanghow Mines.

On the four-wheeled carriage was mounted a large central column with a longitudinal slot on each side. Within the column were the vertical screw spindles to lift and lower the plates fitted to the two horizontal arms. To the rear, each arm had a large counterweight to balance the drill. Each arm had a separate wheel and bevel gear to provide independent movement in most directions, making 360 degrees possible. From the top of the column, an adjustable jack could be raised to lock the machine in place while drilling. Each of the long horizontal arms was fitted with an adjustable section near the drill. This was operated by a rack and pinion, so that lengthening or shortening the arm would place the drill in the required position.

As with the carriage, the drill was extensively modified and improved. It consisted of a casting in which were two air cylinders 5½ inches diameter by 2½ inches stroke with the necessary passages and valves to supply compressed air at 40 lbs per square inch. These cylinders operated a crank shaft which was geared by means of a pinion into a wheel which provided the drill spindle with the necessary forward motion. This gave a ratio of 1.75 to 1. The front end of the crank shaft was geared by means of a wheel and pinion with a ratio of 2.4 to 1 to a large nut. This nut could be engaged or not as required by the operation of a lever and clutch in front of the drill. When disconnected the nut was stationary while the engine advanced the drill one foot for every 84 revolutions. With the nut engaged, it rotated in the same direction and checked this advance at the rate of 8¾ inches, leaving 3¼ inches as the actual advance per 84 revolutions. When the drill entered the rock, the clutch was engaged and the hole drilled. On completion, the clutch was disengaged and the drill withdrawn.

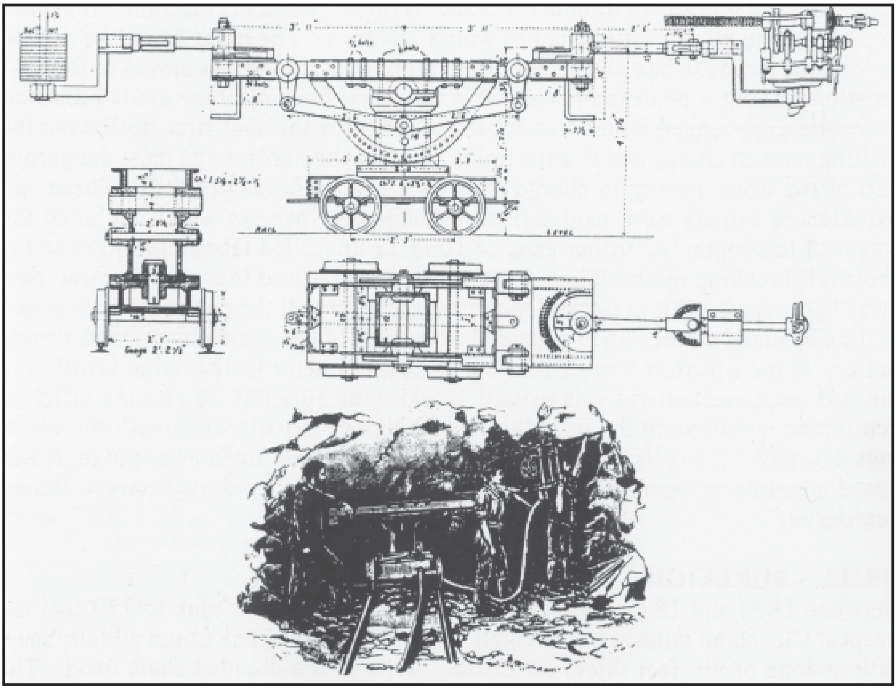


Walker's Compressed Air Drill, 1875 model.

The 1875 model drill was first introduced at the Boosbeck Mines by William Walker, who was at the time mines manager for Messrs Stevenson, Jacques & Co. He was able to obtain 80 tons per shift per machine. Having seen the machine in action, Messrs Bell Brothers Ltd placed an order for an example for Skelton Park and Port Mulgrave Mines and eventually operated four machines.

Further development led to the patent of 1889 (No. 11,472) for what was to become the ultimate Walker drilling machine. It was designed to be moved and operated in the narrow workings of a mine and in such a way that the drill could be directed with facility to work at any angle or level.

The usual four-wheeled iron carriage had a large square-shaped column mounted centrally on it. The base of the square column was bolted to the carriage to form a mounting on which the major part of the column would rotate through 360 degrees. A long horizontal arm, with a secondary arm with short links and joints below, was bolted to the top of the column. The secondary arm and links were designed as a form of parallel motion to stabilise the main arm. This system of horizontal arms and linkages was repeated on the other side of the machine. Below the main arm was a semi-circular plate with a series of holes drilled in it. This could be secured by a pin to the square column. By this means, a reasonable amount of elevation and depression could be obtained. To the rear, the main arm had a large counterweight with a hinge to allow sideward movement in a narrow working



Walker's Compressed Air Drill, 1889 model.

place. To the front, a similar hinge was fitted and this could be secured at various angles by a bolt. Nearer the drill, a second smaller hinge allowed fine adjustments of angle to the drill unit alone. The compressed air drill fitted to this new carriage was exactly the 1875 model. It proved to be the most successful of the Walker drills, with examples working into the 20th century. Over the years, a number of details were changed, eg. the central column developed angled faces, or the parallel motion had straight links.

<u>Walker drills in Cleveland Mines, 1892.</u>

Stanghow	4
Liverton	4
North Skelton	6
Skelton Park	4
Lingdale	3
Grinkle	4
Lofthouse	7
Upleatham	1
	33

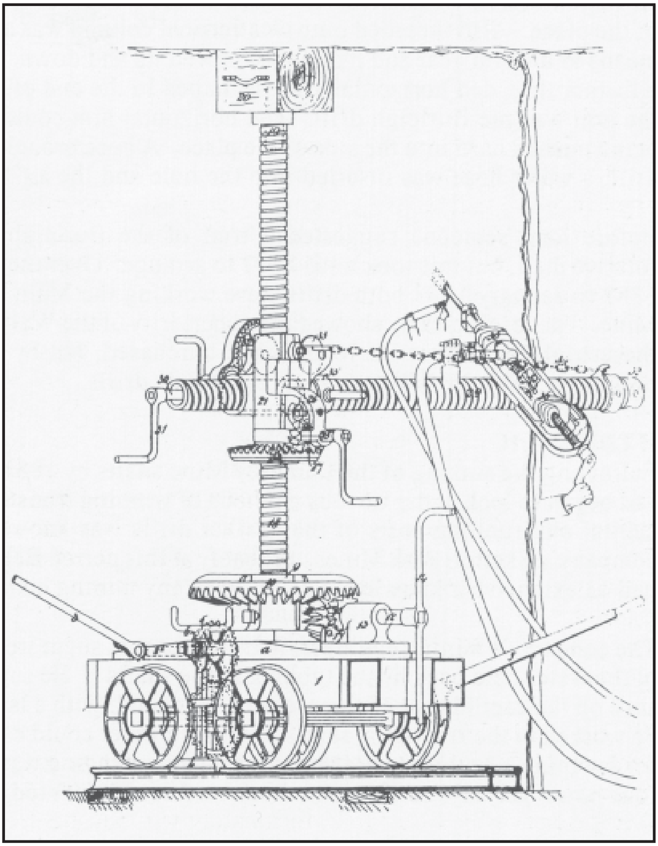
SYSTEM OF OPERATION.[15]

To operate the drill an experienced miner was selected. He was provided with a youth to assist him and to train to the work. A horse pulled the machine from place to place as the machine alone could weigh $2^1/_2$ tons! The place would be drilled as required, ready to be charged and fired, then the machine was moved to the next location. About nine or ten places were the usual for a machine drilled district. A second experienced miner was chosen to train for the shot firer, following the drilling team to charge and fire the holes. He had the hardest and most dangerous part of the work, having to charge and fire 60 to 80 holes per shift. These two experienced miners were paid a fixed tonnage rate per ton which included the wages of the youth. A further gang of 10 to 12 unskilled labourers followed the shotfirer, breaking up the fallen stone and loading it into tubs and sending them away to the shaft. This system of operation applied to all the power machines used in the Cleveland mines. An unexpected advantage of the use of compressed air was noticed at the Liverton Mines, where a 30 feet diameter Guibal mine ventilating fan had been erected and was usually working at 50 RPM, to provide efficient ventilation. Following the introduction of Walker's drills, even with the workings a further $1^1/_4$ to $1^1/_2$ miles from the shafts than when the fan was put in, it was found possible to operate the Guibal fan at 20 RPM, and still have efficient ventilation.

DRILL - BURLEIGH

Between 1870 and 1873, Messrs Bolckow Vaughan & Co. sank to 720 feet the deepest Cleveland mine at North Skelton (NZ675183). They found a Main Seam of ironstone of $9^1/_2$ feet thick, fortunately without the dreaded shale band. The great depth to the seam, however, meant that it was a compressed and, therefore, hard stone to work. To produce this ironstone at a profit, it was necessary to employ power machines, rather than hand mining methods, from an early date. Various machines of the period were tried, but many failed because of the hardness of the stone. Negotiations were opened with William Walker, but the parties could not agree terms. At some date, probably about 1877, Bolckow Vaughan decided to operate the compressed air percussive drills, which seem to have passed under several names, including McKean's, Eclipse or Ingersol, but, as they were more often known as the Burleigh Drill, I will call them that.

The Burleigh Drill consisted of a cylinder with piston inside, the cradle with guide stays in which the cylinder travelled, and the drills. The piston within the cylinder reciprocated at 300 strokes per minute and in every 18 strokes revolved once. As the machine produced the hole, a handle at the rear of the cradle was turned to advance the cylinder and keep the machine following its work. After every two feet of advance, the machine was stopped so that a longer drill could be put on. Drills with half-moon tips were used for depths up to three feet, otherwise four-cornered were the preferred type. The Burleigh drilled at the rate of 16 inches per minute,



Burleigh Drill on the Chisholm Carriage. Patent No.601 Feb. 13th 1878.

which meant that a hole of 4 feet in depth took three minutes to complete. By 1880 this machine was producing about 50 tons of ironstone per shift.[16] At times 75 tons were produced and, in exceptional places, 96 to 107 tons were possible in eight hours. One problem with the percussive system was that, unless water under pressure was put into the hole to flush the debris out, the paste formed soon jammed the machine. This required the double expense of two systems of pipes to each machine. By this date seven Burleigh drills were operating at North Skelton Mine, each serving ten working places. Each machine required a skilled miner and a youth to work it, with a skilled shotfirer to charge and fire the holes. Four labourers followed the shotfirer to break up and load the ironstone into tubs.

Having heavy percussive drills was one thing, being able to operate and move them from place to place in a mine was another! By February 1878 James Chisholm, engineer to Messrs Bolckow Vaughan, developed and patented a four-wheeled carriage from which to transport and operate the drill.[17] Between the wheels a jack was fitted on each side to keep the carriage in position while drilling. On the carriage was a vertical narrow threaded column, capable of being raised to the roof of the place. Also threaded onto this vertical column was a block which could, by means of a worm gear and handle, be moved up and down. Through the block ran a further threaded horizontal arm. Clamped to the end of, and at right angles to, the arm was the Burleigh drill. The horizontal arm could be further secured by being pushed hard into the side of the place. A hose brought compressed air to the drill, a water hose was inserted into the hole and the air turned on.

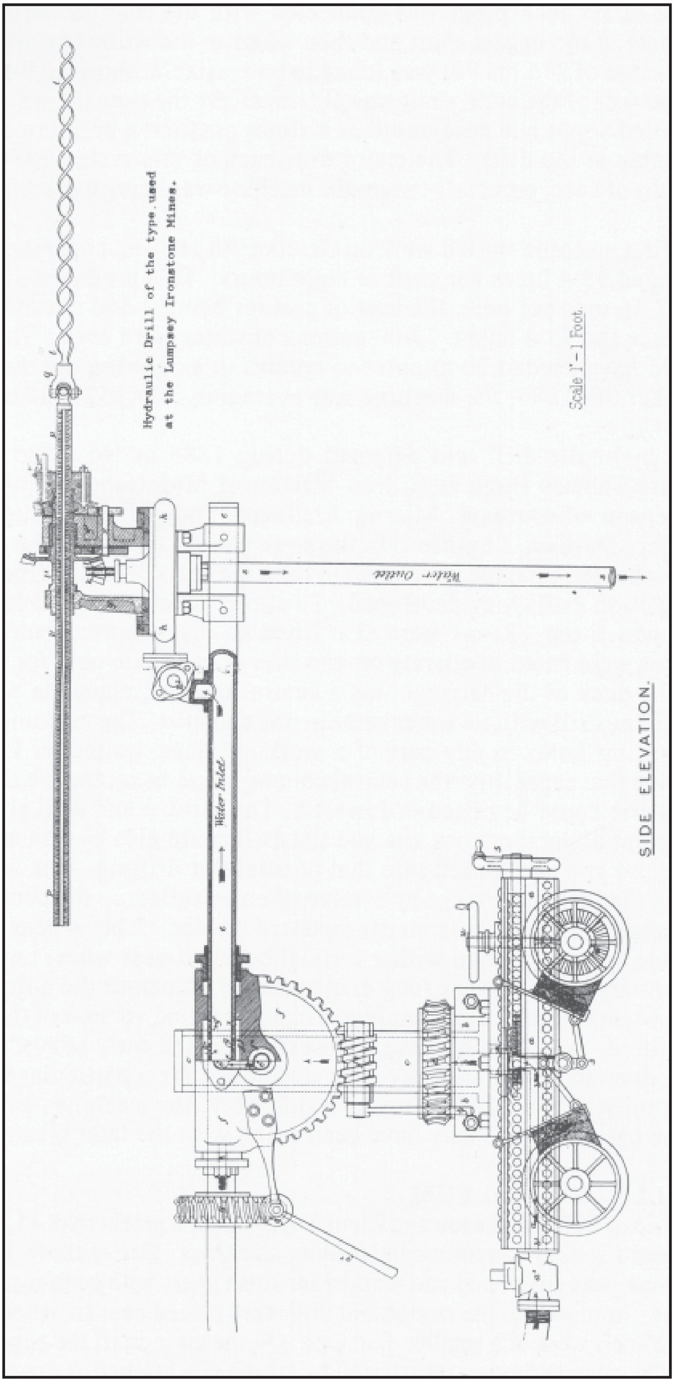
Before long someone suggested a trial of the Burleigh against the Walker's rotative drill, but this took until 1882 to arrange. Over the period from November 1882 to January 1883 both drills were working the Main Seam at North Skelton Mine. The result clearly showed the superiority of the Walker's rotary drill. After these trials no further Burleighs were purchased, but by 1893 the whole of the output was won by Walker's compressed air drills.

HYDRAULIC

Following the sinking of the Lumpsey Mine shafts by 1881, Messrs Bell Brothers Ltd began to look at the various methods of winning ironstone. The experience of capital and running costs of the Walker drills was known from their use at the company's Skelton Park Mines. Probably at this period Bell's Mining Department had as extensive a knowledge of drills as any mining company in the north.

The company's mining engineer, A.L. Stevenson, suggested utilising the pressure of the water held back by the tubbing in the shafts.[18] He suggested that this would save on the capital cost of compressing plant and, with a large area of ironstone to be worked to the rise of the shafts, the waste water could easily be run to the sump for pumping. At this stage the mine's pumping engine was only working three or four hours per day, so the extra work was not considered excessive.

Messrs Gilkes of Kendal were known to make a suitable water turbine and they were eventually asked to tender for the whole machine. To operate the drill, a range of six



Hydraulic drill, of the type used at the Lumpsey Ironstone Mines.

inch pipes was connected with the shaft tubbing at a depth of 50 fathoms in the upcast shaft and then taken to the workings. At the shaft bottom a pressure of 215 lbs PSI was found to be available, showing that the full pressure of 500 feet of the mine shaft was obtained. By the time the water in the pipes had travelled about one mile uphill at a slight gradient a pressure of 140 lbs PSI was available at the drill. The major drawback of this system proved to be the long lengths of hose, especially when the machine was being moved from place to place.

The first machine started work on October 9th 1884 and over the first three months averaged 55.4 holes per shift of eight hours. This produced 125.3 tons per shift and 2.26 tons per hole, the cost of powder being 2.66d per ton of ironstone. To produce the 55.4 holes, 7,000 gallons of water were used. The pumping engine would have needed 20 minutes to remove this. During the three months ending October 9th 1886, the machine was averaging over 152 tons per shift.

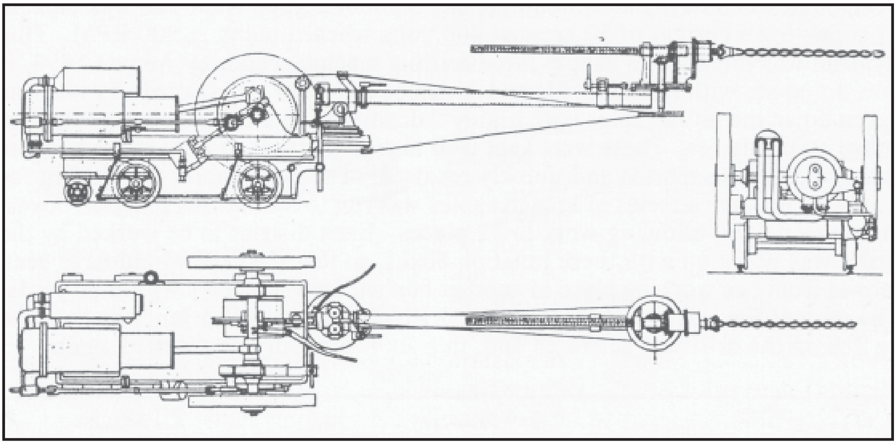
This hydraulic drill was patented during 1885 as No. 9985 by the inventors, Messrs Thomas Hugh Bell, Iron Master, of Middlesbrough, Addison Langhorn Stevenson of Durham, Mining Engineer, and Robert Clough, of Page Bank Colliery Durham, Engineer. In the same patent, they describe a standard form of four-wheeled carriage which was to form the basis of most of the experimental and production drills they developed. To allow movement, a handwheel geared to an axle was fitted. Rings were also fitted so that a horse could provide haulage. Brakes were fitted to operate on one side of each axle only for use when drilling. On the deck of the carriage was a central column, complete with a cross arm to which the drill with its water turbine was clamped. The machine had to be capable of drilling holes in any part of a working place, no matter how awkward! To provide that capability, the central column could be rotated on the carriage and the cross arm could be raised or lowered. The turbine and drill could be clamped at any point along the cross arm and the drill could also be turned at right angles to the cross arm and locked into that position for drilling. The water was admitted to the rear of the carriage by a valve, then travelled up the central column, along the cross arm to the horizontally mounted turbine. A bevel gear wheel fixed on the turbine spindle meshed with a vertical bevelled gear wheel to provide the necessary rotary motion to the long drill spindle. To permit the quick retraction of the drill when the hole was complete, a hand operated version of the Stayner split nut was fitted. Accounts of these drills exist from the early 1890s, then nothing more is written about them. They were developed for a particular series of workings existing at one mine. Having done this work, the machines either went for scrap or the basic carriage may have been fitted with the later electric drills.

DRILLS - PETROLEUM

The trio of Bell, Stevenson and Clough applied for a patent (No. 11,394) in 1890 which covered a series of experimental drilling machines. One of these, for a petrol-engined machine, was developed and worked for some years with good results at the Lumpsey Mines. In this case, the engine and drill were placed on a six wheeled carriage whose rear wheels were of a smaller diameter. On the main shaft the engine was a V-shaped belt sheave with motion transferred by means of a leather or gut belt.

The drill was carried on a long arm which could be raised or lowered by a screw. The drill unit was similar to the model fitted to the hydraulic drill.

The oil or petroleum engine was that developed by Messrs Priestman Bros. Ltd.[19] In this, the air pump was worked from the main shaft, forcing oil into a reservoir and sending a stream of oil and compressed air along separate tubes to a spray maker. The oil injected through this nozzle was broken up and mixed with the air, becoming vaporised by the heat from the engine. If the engine was being started then the heat of a blow-lamp was used. Once vaporised, the mixture was drawn through into the engine cylinder.



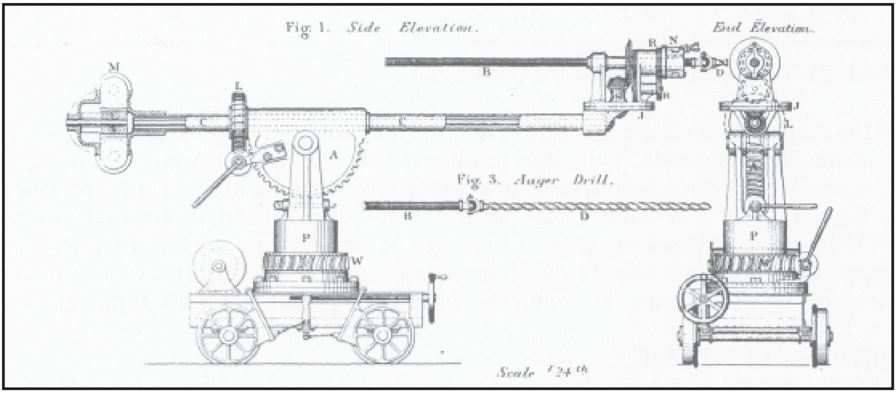
Rock drill driven by Priestman's Oil Engine.

In the mine, this machine was able to drill 70 holes of $1^{3}/_{4}$ inches diameter by 4 feet 6 inches deep in seven hours and produced 150 tons of ironstone. Being self-contained, they moved about the places of the mine without hoses, wires etc, much to the delight of A.L. Stevenson. He saw them as the ideal drill machine and by 1893 had five of them working in Lumpsey Mine. Yet, by the end of 1896, the petroleum engine was found to be objectionable on account of the poisonous fumes given off by the exhaust, although the work done by it was highly satisfactory.

DRILLS - ELECTRIC

With the advent of electricity, it was soon realised that here was an ideal form of transmission for power in mines. Compressed air and steam were prone to leaks and large losses. Electricity, on the other hand, had a smaller percentage of loss and, instead of large pipes, only required wires for transmission. Among the experiments undertaken by the Bell Brothers team of Bell, Stevenson and Clough was the use of electricity to operate drilling machines. By 1893, they were able to put the first machine to work in the Carlin How Mines.[20] On to the standard four-wheeled carriage, complete with vertical column, they fitted a long horizontal arm with, as a counter weight at the rear, the electric motor. The motors were of the Goolden enclosed type for mining purposes, shunt wound and using a current of 20 amps at 300 volts. These motors were completely enclosed in gun metal cases which were both gas and dust tight. Each drill was provided with a starting switch on the carriage equipped with resistance coils so that the drill could be started gradually and stopped either gradually or instantly. On the carriage there was also a cable reel with 50 yards of twin core cable, complete with plug. The electric motor drove a shaft which was within the horizontal arm. At the front was a bevel wheel which rotated a vertical shaft to further bevel wheels. These operated the drill spindle through retarding wheels which were geared down to suit the nature of the stone.

The current for working the drills was generated at Carlin How Mine by a compound wound dynamo which gave an output of 20,000 watts and was capable of supplying a current of 50 amps at 400 volts when running at 900 RPM. This dynamo was intended to supply three drilling machines and, by August 1893, it was doing so, with further drills and dynamos to follow as required. Power was taken down the pit in cables with highly vulcanised india-rubber casings and run inbye on insulators. These were kept well in sight, so that a fall of stone or other damage could be spotted and quickly repaired. The main cables were taken for 1,000 yards, then a series of branch cables was run to the various junction boxes, six to each drill, allowing work in 12 places. Each district to be worked by the drills was wired up with these junction boxes, so that the drill would have been moved from one working place to another box which was always within 50 yards. The plug at the end of the cable on the drill was locked into a junction box, the switch on the drill was activated and, in a short time, drilling started again.



Electric Drill.

The joint output for one week for two machines soon reached 1,577 tons with 790 holes. From 80 to 100 holes could be drilled by one machine in a shift.

FOOTNOTE *- The first use of electricity inbye in this country took place at Trafalgar Colliery in the Forest of Dean in the early 1880s when a small electric pumping plant was used, which meant that the above use of electric drills was an example of being at the front of technology at the period.*

CONCLUSION

From the early days of Cleveland mining, the jumper drill was the only effective drill. The trials at Slapewath in 1886 brought the ratchet drill to a reasonable form and, by 1900, this had almost replaced the old jumper method. The power machine developed from 1874 and, as long as the 'whole' workings were being created, reigned supreme. When working the broken became general, the awkwardness and size was very much against power machines. Labour unrest in the early 1920s permanently closed several of the machine-worked mines, e.g. Liverton and Stanghow, and this was the end of the machines. After 1900, the ratchet drill gradually replaced the power machines until the Blackett Hutton was almost the only drill used in Cleveland. This lasted until the 1940s when American, carriage-mounted and, later, hand-held power machines were introduced.

General Results.

	£ cost	Holes per hour	Ironstone per shift
Jumper drill	-	1	5 to 8
Ratchett drill	3	-	about 18
Compressed air drill	250	8	100 to 130
Hydraulic drill	220	8	100 to 130
Petroleum drill	375	8	100 to 130
Electric drill	350	10	140

WALKER'S 1875 MODEL DRILL

Produced 80 tons per eight hours, with 40 lbs PSI, two feet per minute = in 8 hours 20 holes. Working two shifts 300 tons for three machines. Tons per hole averaged 2.98 tons. Cost of powder 2.01d.

BURLEIGH

16 inches per minute = 50 tons per shift. 75 to 90 tons sometimes.

WALKER'S 1875 MODEL

North Skelton, averaging daily 2 shifts, 325 tons.

WALKER DRILL

800 to 1,050 tons per week of 45 hours average of 10.25 tons per man per shift. 80 to 85 holes per eight hour shift.

HYDRAULIC DRILL

Averaged 55.4 holes per eight hour shift producing 125.3 tons and 2.26 tons per hole. Powder cost 2.66d per ton. October 1886 averaged 152 tons per shift.

FOOTNOTE *- During the days of the electric drills, two examples were sold to ironstone mines at Irthlingborough, Northamptonshire. At some time in the 1930s, a Cleveland mining engineer went to manage these mines. He found the two drills abandoned somewhere about the mine and, remembering them from Cleveland, decided to put them back to work. They were refitted and had new electric motors put in and went on to serve these mines into the 1950s.*

PETROLEUM DRILL
70 holes in 71/5 hours = 150 tons or 900 tons per week. Powder 3.25d per ton. Cost of oil 1d per HP per day.

ELECTRIC
80 to 100 holes in an eight hour shift. One week two machines produced 1,577 tons with 790 holes.

By 1904:- 47% of ironstone was ratchet mined.
28% of ironstone was power machine mined.
25% of ironstone was jumper mined.

WALKER'S DRILL 1880
Each machine produces 56 tons per day. Say 300 working days, then output of 16,000 to 17,000 tons per year. Each filler fills 11.25 tons per day.

DRILLS. AIR COMPRESSING PLANT
Part of the capital cost of the compressed air system was spent on the large steam driven compressing engines. Details of several of them are available.

NORTH SKELTON MINE
The air compressing engine was built by Messrs John Fowler & Co. of Leeds.[21] It had a steam cylinder of 20 inches with a 22 inches air cylinder mounted in tandem. Both cylinders had a stoke of 60 inches with steam supplied at 50 lbs PSI. This engine was supplied to operate the Burleigh drills; when they were replaced by the Walker drills it was capable of supplying air to them and continued in use for many years.

LOFTHOUSE MINES
During 1891, Messrs Walker Brothers of Wigan supplied a single tandem compound air compressor of High Pressure 28 inches and Low Pressure 48 inches, air cylinder 40 inches, all with 72 inches of stroke.[22] The house was built to take two of these machines but it was only in March 1896 that the other half of this compressing plant was ordered. When complete, this was one of the largest compressors in the north of England. It was supplying air at 60 lbs PSI to 17 drilling machines, three hauling engines and three pumps during 1904. At the time the nearest drilling machine was $1^1/_2$ miles inbye with the furthest machine supplied being $3^1/_2$ miles away. This mine was the greatest user of the Walker drill with an average weekly output of 10,000 tons.

ACKNOWLEDGEMENTS

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