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THE KELLOW DRILL

Moses Kellow's hydraulic drill was undoubtedly his most original contribution to the technology of the slate industry, and although it was never adopted widely outside the Croesor Valley it was clearly a technical success. Wider applications seems to have been foiled by unimaginative promotion and traditional working practices, while its use in other branches of mining or tunnelling was prevented by adverse financial conditions and apparently by greed on the part of the Kellow Drill Syndicate. Nevertheless, the Kellow Drill was, and still is, the fastest and most powerful rock drill ever used commercially.

The Kellow drill had origins going back at least as far as the reopening of Croesor Quarry ijn the early 1890s. Moses Kellow, a young and imaginative Manager, was not long in making his mark and in retrospect it was here that he laid the foundations for the successful use of his drill in later years. He persuaded the men to give up the traditional "bargain" system whereby a partnership of four men – two rockmen and two mill men – worked an exclusive chamber underground and processed the slate therefrom on their own saw and dresser. Instead, Kellow had two-man underground partnerships supplying slab to a mill in which other two-man partnerships were allocated those slabs by ballot, the object being to keep the mill working at full capacity. The next stage in improving efficiency was mechanisation and an obvious target for this was the process of drilling holes in the underground rock faces. Hand drilling with a jumper was extremely slow – it could take a man all day to drill a single 7ft hole – and therefore compressed air drills were coming into use. These were faster, but they were noisy, uncomfortable to use for long periods, created vast clouds of dust - and Kellow did not like them. Looking for alternative methods he decided to abandon percussive drilling in favour of constant-pressure rotary drilling, in other words he proposed to drill slate in the same way that one would drill wood or metal. If it can be done this is quicker and more efficient than percussive drilling but it required a powerful motor to turn the drill bit and a firm means of anchoring the drill against the reaction of the forward load on the bit.

Having already installed a pelton wheel to drive the mill, Kellow did not have to look far for a compact but powerful means of powering his drill – he would use hydraulic power. His first drill, produced in or around 1896, employed a miniature pelton wheel running at high speed on a water supply pressurised to around 500psig – the equivalent of an 1100ft head. This wheel was mounted on a hollow shaft which was geared down to a further hollow shaft, running inside the turbine shaft, by a two-stage epicyclic gearbox bolted to the front of the turbine case. The inside of this shaft was hexagonal and through it passed a long hexagonal drill spindle on the front end of which was a tapered socket to hold the drill bit. The rear end of this spindle projected into a long cylinder bolted to the rear of the drill motor and carried a piston, high pressure water being admitted to the rear end of the cylinder to drive the drill bit into the rock face. The spindle was drilled longitudinally to supply water to the rear end of the drill bit, which itself incorporated cooling/lubricating passages to feed this water to the cutting edges. Water was admitted to the hole through the spindle by a restrictor plate in the piston, and this deliberate leakage from the driving cylinder enabled a fine control to be exercised over the pressure in the cylinder by throttling the supply from the high pressure mains. The drill bit was, at this stage, a large twist drill with the cooling passages forged into each flute – a rather demanding item to manufacture at such an early stage in the history of twist drills themselves.

Anchoring the drill could be done in two ways. On large rockfaces it was anchored to the rock itself and for this purpose the drill body was fitted with two heavy (about 1½in diameter) threaded rods which projected from the lower edge of the body. Between these rods, in front of the drill, was a right- and left-hand threaded turnbuckle which, when turned, pulled the rods together or pushed them apart. To mount the drill, two shallow holes – no more than 2½in deep – were drilled in the rock the same distance apart as the threaded rods. The latter were then placed in the holes and jammed in place using the turnbuckle. The pilot holes were drilled at a slight downward angle to the line of the intended main hole, and the drill was thus mounted in a nose-down attitude. In the top of the drill was a third threaded rod fitted with a handwheel, and this was now screwed down against the rockface to bend the drill body back into the correct position, thus increasing the jamming action of the two support rods. All that was now needed was to couple up the water supply and turn it on, when the drill would bore a 7ft hole in about 90 seconds. Little data has survived on the pelton wheel drill, but in later types the turbine ran at about 5000rpm and the drill at 250rpm. The axial load on the drill bit was generally about two or three tons, although in trials on granite loads as high as twenty tons were employed.

In tunnels or elsewhere where there was a low roof, the drill could be mounted on a frame wedged between floor and roof by hydraulic jacks. This would have been very convenient where a large number of holes were to be bored in a near vertical face, but such conditions never obtained in the Ffestiniog area and there is no evidence that this method of mounting was ever used in practice. It was, however, included in Kellow’s first patent, No. 19292 of 1898.

In practice, the first Kellow drills were unsatisfactory for two reasons. The pelton wheel discharged directly out of the bottom of the casing, so that any attempt to use the drill in a horizontal or downhill passage quickly flooded the workings, while even in places where this water could escape the unfortunate operator had to stand in a miniature edition of Niagara Falls to work his drill. The quantity of water involved was not inconsiderable, despite the speed with which the drill worked – to drill a typical 7ft hole in 90 seconds the drill motor would consume about 400 gallons of water. In addition, there would be a steady trickle of muddy water from the hole being drilled due to the water bled down the drill. On top of this, the drill would have been very noisy – pelton wheels always are. But at least it was not dusty.

Those to whom the drill was demonstrated in the early years objected to it on two grounds – that it introduced a lot of water into the workings, and that it was no quicker than compressed air drilling when one took into consideration the time to drill pilot holes, set up and dismantle the drill, and dry out the hole before placing a charge in it. The first criticism was undoubtedly true of the original design with the pelton wheel, but the second was unfounded given the method of use adopted at Croesor and this aspect will be discussed later.

It is not known where Kellow made his prototype drills, but by 1904 he was working on an improved version in collaboration with Gilbert Gilkes & Co. Ltd of Kendal, who were then – as they are today – one of the leading producers or water turbines. Gilkes had supplied the pelton wheels installed at Croesor in 1895 and in Kellow’s Blaen y Cwm hydroelectric station of 1904. Kellow claimed the credit for introducing the cutaway lip to the buckets of pelton wheels which resulted in a significant increase in efficiency and is standard practice today, though how much of the credit was truly his is hard to say. At any rate, Gilkes undertook the manufacture of a prototype drill embodying an inward-flow reaction turbine similar to the “Vortex” turbine then manufactured by the firm. The association was not particularly fruitful, although Gilbert Gilkes did become a director of the “Kellow Rock Drill Syndicate Ltd” when this was set up in 1908. The problem was basically Kellow’s personality: he was a perfectionist with absolute confidence in his own judgement. He designed the turbine for his new drill without any regard for Newton’s Laws of Motion and as a result it imposed a considerable axial load on the shaft bearings, a load for which there was no provision in the design. With his turbine rotor mounted around the central drill shaft there was obviously going to be such a problem, and it could have been overcome by using a more elaborate turbine rotor, but Kellow would not accept advice even from those better qualified to discuss such matter. Eventually Kellow and Gilkes parted company and Kellow established his own drill factory in part of the Croesor Mill complex. The former Chairman of Gilbert Gilkes and Gordon Ltd., Lord Wilson of High Wray, recalls his father talking about the Kellow drill – he had worked on the project and was of the opinion that Kellow was too much of a perfectionist, an opinion which tallies with that held locally, although locals say that his perfectionism tended to stop short of spending his <u>own</u> money.

Kellow's improved drill with the single stage reaction turbine was patent No. 20317 of 1906 and on this patent was based all subsequent development. Besides altering the turbine, Kellow now used a recycling system for the water, this being supplied through a coaxial flexible hose about 5in. outside diameter which had an inner hose of 3 in. outside diameter conveying the high-pressure feed water while the exhausted water ran back through the annular space between the two hoses. Despite the apparent difficulty of coupling up such a hose, Kellow's coaxial unions are remembered as being completely watertight under 900psi even when only hand-tight. At this stage it is worth recalling that the Kellow drill made extensive use of aluminium castings – an early use of this metal – and that the hoses themselves had aluminium alloy reinforcement. Despite the complexity of the coaxial hose, it was probably better to have one large hose trailing behind the drill than two smaller ones which could get entangled. Water used in the drills was returned through a pipe paralleling the hydraulic mains to the sump from which the main pump drew its supplies, so the only water now introduced into the working area was that which passed through the drill bit. As the new turbine would be much quieter, the 1906 version of the drill had gone a long way towards overcoming the early objections and was unquestionably more pleasant to work than a pneumatic one.

Having built a reasonably workable drill that was light and reliable, marred only by the unbalanced hydraulic forces on the turbine rotor and by water leakage into the gearbox, Kellow next improved the drill bit. The big twist drills were costly to make so he devised a D-bit with replaceable cutter, the latter being mounted on a pin passing through a disc of leather in an oversize hole so that it could centre itself relative to the drill axis without the need for precision machining of individual parts. This bit was patented in 1910, No. 19597, and besides the change on form it had more direct water passages to improve cutting edge lubrication and cooling. It was also adaptable, by the use of suitable cutters, to drilling holes of different diameters without the need to change the whole drill.

Further improvements were covered in three patents obtained in 1914/15 which brought the Kellow drill to its final form. The first, No. 13067 of 1914, covered a new type of gearbox in which four or five gear clusters replaced the previous two-stage layout. The object of this was partly to reduce the size of the gearbox but also to permit quick and easy alteration of the gear ratio by the substitution of gear clusters all of which were interchangeable. This feature, taken in conjunction with the interchangeable cutter bits already described, enabled one drill to be used to drill holes of widely different diameters without sacrificing efficiency, the optimum drill speed being attainable for any size of hole.

Patent No. 24625 of 1914 described a drill fitted with a two-stage reaction turbine. This turbine was not only smaller in diameter than the equivalent single-stage one, but it also lacked the unbalanced hydraulic loading and therefore did not impose undue loads upon the thrust bearings in the gearbox. Kellow must by now have become acutely aware of the defects in his 1906 design, for, in addition to altering the turbine he now proposed to use a four-point-contact ball bearing in the drive end of the gearbox to act as a combined load-carrying and thrust bearing. At the same time he sought to reduce the drag induced by oil flowing between shafts turning at widely different speeds and therefore introduced a loose, intermediate sleeve between the turbine shafts and the drill shaft to cut down the differential speed. (His argument was that drag increased with the square of the relative speed, so by introducing this sleeve he halved the relative speed between any two surfaces, and thus halved the overall drag.) The inside of the turbine shaft was also tapered so that oil flowed quickly from one end to the other under the action of centrifugal force.

Patent No. 11564 of 1915 covered improvements to the feed cylinder – the long hydraulic cylinder on the back of the drill which applied the forward thrust on the drill bit. This was now made readily interchangeable, and its manufacture simplified by the use of drawn tubing for the inner and outer cylinders (the high pressure feed to the cylinder passed down the annular space between them). There were also improvements to the method of packing the feed piston, partly because the piston was readily interchangeable too but also one suspects because leakage past this piston found its way directly into the lubricating oil of the turbine and gearbox assembly. According to Jack Morgan, who worked on the Kellow drill project for most of his time at Croesor from 1919 until 1930 and subsequently worked the big Kellow Channelling drill at Llechwedd Quarry up to 1939, leakage past this piston was never satisfactorily cured and water finding its way into the gearbox was one major fault of the Kellow drill. The patent also covered improvements in the feed cock which regulated the water supply to the feed cylinder.

Mention of the channelling drill brings us to the final documented improvement in drilling technique, the channelling frame patented in 1929, No.323328. This was a long frame anchored to the rock in the same way as a singled rill, and upon it was mounted a Kellow drill capable of being traversed along the frame to dill a series of holes which were subsequently enlarged to form a continuous slot. It was proposed in the 1910 patent to use a two-diameter drill bit for channelling, the smaller pilot bore always being into solid rock while the larger diameter bit following it would overlap the previous hole, thus drilling a slot with a single pass of the drill. In practice the uneven cutting action of the larger bit, which was only drilling about 90% of a complete circle, caused the drill to seize in the hole and the two-diameter bit was abandoned. It was easier, and probably as quick, to drill a series of holes separated by something less than their own diameter and then break out the rock between them on the second pass, when the bit, although not drilling a complete hole, was at least drilling a symmetrically incomplete one and did not therefore wander off line. The Kellow drill used for channelling in this way was probably the fastest method ever devised for removing solid rock other than by the use of explosives.

From 1908 until 1910 or 1912 Kellow made his drills in a small but well equipped shop which had once been the original slate mill, erected circa 1861. Almost certainly empty when Kellow took charge in 1895, it had never been re-equipped and was converted into the “Keldril Works, Croesor, Penrhyndeudraeth, Portmadoc, England” at some expense to the syndicate. The building was plastered internally and cement rendered externally, a new roof with extensive areas of glass being provided plus a large window in the end wall. The floor was levelled and then given a coating of cement. Sturdy wooden partitions separated the stores from the workshop proper and by careful use of a short-focus lens the photographer who took a series of official photographs (all of which featured Moses Kellow complete with bowler hat) managed to convey an impression of spaciousness. In fact the whole works measured about 55ft by 45ft, and contained two lathes (one of them capable of boring the feed cylinders which were nine feet long), two milling machines (one horizontal, one vertical), two pillar drills, a planer, a polishing spindle, an emery wheel and a drill bit grinder. It did not last long, being burnt out some time between 1910 and 1912. Locally the fire was regarded, and still is, as an “Insurance Job”; for it is understood that the assessor considered the machinery to be a write-off because the roof had fallen on it, yet, once he had gone, Kellow salvaged everything from the wreckage and installed it either in the old fitting shop or in a corner of Belen y Cwm power station. It is easy to imagine an assessor, having just suffered a journey from the comfort of a Portmadoc hotel to the wilds of Croesor on a typically wet day, taking the easy line of least resistance when confronted with the soggy remains of the Keldril Works. From 1912 until the quarry closed in 1930 Kellow drills were made and serviced using the makeshift facilities just described, the costing of Kellow Drill Syndicate and Parc and Croesor Quarry work done on the same machines by the same men being equally makeshift.

That the Kellow drill was a technical success is undeniable. By 1910 he had a machine which, once the pilot holes were bored, could be set in place by two men (or a man and a boy) in a matter of minutes, could then bore a 2½im. Diameter hole to depth of 7ft in ninety seconds, and be removed from the rockface as easily as it was put there. Even in 1978 there is no drill that can repeat this performance. Why was it not more widely used? For an answer one must look at the way its drilling capability was exploited. If one took the time to drill a <u>single</u> hole, from starting to drill then pilot holes to drying out the final hole ready for a charge, then it probably was not any quicker than a good pneumatic drill, but this was not how Kellow meant his drill to be used. At Croesor the rockmen in their own chambers marked out where they wanted holes to be drilled, drilled the pilot holes – probably to a template - and then sent for the driller. The latter worked, with an assistant, no doubt, on the same sort of monthly contract as the rockmen – he was paid by the footage of hole he drilled. He entered a chamber to find the pilot holes already drilled, so he had only to set up his drill, drill the holes, and leave. A single hole would probably take five to ten minutes of his time, a dozen would perhaps detain him for an hour. The point is that it was far quicker and much easier for the rockmen to drill two pilot holes in each location than it would be to drill the main holes themselves, and even allowing for the drying out operation they were clearly saving a lot of time. The expensive hydraulic drill, on the other hand, was not lying idle while pilot holes were being drilled for it, nor was it left in the hands of inexperienced users. One drill, in the hands of one experienced man whose earnings depended upon keeping it in good condition, was doing the work of several dozen rockmen. That it was able to do so was due to Kellow's alteration in traditional working methods – having persuaded the men to try something new once, and got their agreement to it once they found it meant better pay, he could more readily get his rockmen tot accept an "outsider" working on their bargain, and once they saw that this "outsider" – the driller – was earning them more money by earning his own money they were ready to accept the new system. Elsewhere in the distract the traditional right of the rockman to work his chamber was inviolable – miners were accepted when tunnelling or safety work had to be done, but the commercial production of slab was the sole preserve of the rockmen. It would have been a much harder job to persuade these men to allow a driller into their chamber, but it could have been done. The sad thing is that nobody ever seems to have tried. Kellow never demonstrated his drill to anyone in the way it was used at Croesor as a means of mass producing holes, instead he seems to have brought along a couple of fitters who proceeded to drill two pilot holes , set up their drill and drill a single hole. Any rockmen who may have watched such a demonstration would have been left with the impression that the drill was an expensive toy, quite useless to them as working quarrymen. Had Kellow, in association with the quarry management, approached a pair of rockmen with the proposal that they mark out a set of charge holes that they needed drilling, and then drill the 2½in deep pilot holes, ready for Kellow's men to drill the holes for them, the drill would have been seen in it's true light and might have been more favourably received, but as far as one can tell no such demonstration was ever attempted. It is sad that this was not done, for the faster rock winning permitted by the Kellow drill was just the sort of thing the ailing slate industry needed, particularly after World War 1.

The Kellow drill should have been more successful in other underground applications, such as mining or tunnelling, but it was not. Quite probably it was Kellow's poor way of demonstrating his drill that let him down, but there was also the entrenched position of the pneumatic drill to consider. In many places, compressed air was used as a comprehensive form of motive power, not just for drilling, and although Kellow was rightly critical of the low efficiency of compressed air transmission it cannot be denied that compressed air was simpler and safer for many applications that would a hydraulic system, - for underground haulage, indeed, one could not replace a compressed air locomotive by a hydraulic one. Again, the major suppliers of drilling equipment – for example Holman and Ingersoll-Rand – had invested heavily in pneumatic engineering and could only regard the Kellow drill as a threat. During the 1920s I-R did try out the Kellow drill, and proposed to market it worldwide – drills to be made in Britain and used in conjunction with I-R high pressure pumps. To do this they wished to buy up the remaining term of the patents for £25,000. Kellow later wrote that "regrettably" this offer was not taken up, but it isn't clear whether it was Kellow himself, or the Syndicate, who turned down the offer. I-R withdrew at this point, partly because recent changes in British import duties would have made the import of I-R pumps uneconomic. (It must be remembered that at this time the only way one could sell to the British Empire was through a London Office and a British based subsidiary, and the British Empire still represented a large proportion of the industrial world!) But perhaps I-R were only interested in getting rid of a competitor: £25,000 probably represented their estimate of the costs of fighting a patent infringement action if they decided to make a Kellow type drill of their own, and so they could ignore demands in excess of that figure. After I-R withdrew and Croesor Quarry closed down, Kellow arranged for Holman Bros. Of Camborne to supply spares for existing drills, but Holman never showed much interest in marketing a Kellow drill of their own.

It is unlikely that many drills were actually made. Croesor Quarry would have needed no more than four, two small ones for plain drilling, two bigger ones for large holes or channelling. Of these, one of each would have been in use at any one time with the other as a necessary spare, for Croesor was small enough to be serviced by one driller. It is believed, from what Jack Morgan has said, that the smaller drills were built to the 1906 patent, and the larger ones to the 1914 one. Most demonstrations were probably carried out using the spare Croesor drill. The most noticeable employment of the drill outside Croesor was at Llechwedd during the 1930s when it was decided that chambers directly below the pipelines to their hydroelectric station could not be worked by explosives. The large drill and channelling frame were therefore obtained from Kellow and set to work in these chambers, where it remained in use until 1939. Cessation of work due to the outbreak of War, following which Jack Morgan – by then the only man who knew how to use a Kellow drill and, more importantly, to maintain one – left to work at Cookes' Explosives at Penrhyndeudraeth, brought the ere of hydraulic drilling to an end.

Ironically, during a visit to Gloddfa Ganol on the day following the end of the August course, it was learnt that modern regulations are causing problems there because of the difficulty in keeping down the dust produced by pneumatic drills. A short discussion soon revealed that if a Kellow drill were available today, it would meet a much more enthusiastic welcome than it did during the inventor's lifetime.

Rodney Weaver.

GI Postcript 2009:
As will be gathered from the above, the Course members were privileged to meet and speak with Jack Morgan, Kellow's last driller and it was following his comments on where the drill was put or rather abandoned at Llechwedd that led to a search to see if it had survived. One drill was found under jute bags of salt in a chamber (if I remember correctly), the salt having wreaked its worse on the aluminium castings of the drill. Further investigation eventually led to the discovery of a complete drill, still in its transportation and storage box under a bench in a fitting shop, long forgotten.

I have left the tense and Rodney's suppositions as they were when this was written, over 30 years ago. In the interim Adrian Barrel has continued researching into the History of Croesor, Kellow and his drill and some further information has come to light. Rather than disturb the text with comments, I will add these as a secondary document at another time.