

FIVE (OR SIX) RED HERRINGS THE MYERS HEAD WATER WHEEL SYSTEM

Stuart Cresswell

Abstract: Myers Head lead mine, in Patterdale was very wet and had a very short life between 1866 and 1884. A sudden flood in the bottom level of the 180 feet deep shaft caused abandonment. Closer examination allows modification of previous accounts. Prompted by National Trust plans for "conservation", a photographic and EDM survey of the site was made against which previous information has been compared. This suggests that the wheel was 36 ft diameter - not 30 ft as the literature suggests - and was overshot rather than breast fed. The horizontal drive rods were wood and the vertical drive rods and pumps still exist in deep water. A reconstruction of the water pumping system is provided.

Introduction

This is an engineering detective story about a Victorian water wheel at Myers Head, near Hartsop in Cumbria, which was used to drive the pumps in a very wet mine. It was unusual because there was no underground development before the shaft was sunk. Only the main elements are considered here

The survey was done in metric units but since Victorians used feet and inches, sometimes Imperial are more logical and are given when appropriate..

The Myers Head story

Records of most Lakeland mines are poor and this is no exception. Tyler (1992, 125-129) says the shaft was started about 1866 and completed to 30 fathoms by the end of 1867, before levels were struck off. It was very wet and there had to be pumping arrangements applied immediately. The initial system was inadequate and Cornish pumps were installed in 1868. The wheel was said to be 30 feet in diameter, and worked almost continuously.

In 1879 miners broke into a very wet pocket and there was a great inrush of water. Though the miners escaped, the mine was flooded. It was found impossible to drain the mine and it was abandoned with all the removable equipment being sold in 1884.

However there are still substantial remains of the wheel system accessible and investigation of the site was prompted by several popularly held views which were thought illogical by the

writer: thus the "Red Herrings" of the title. Summarised, these were:

1. The wheel was breast fed
2. The launders were stepped down
3. The holes, in the support walls, were for horizontal beams to the next wall and supported the stepped launder
4. The wheel axle was mounted on a beam half way down the pit
5. The small pit was for a secondary wheel
6. The 30 ft wheel diameter

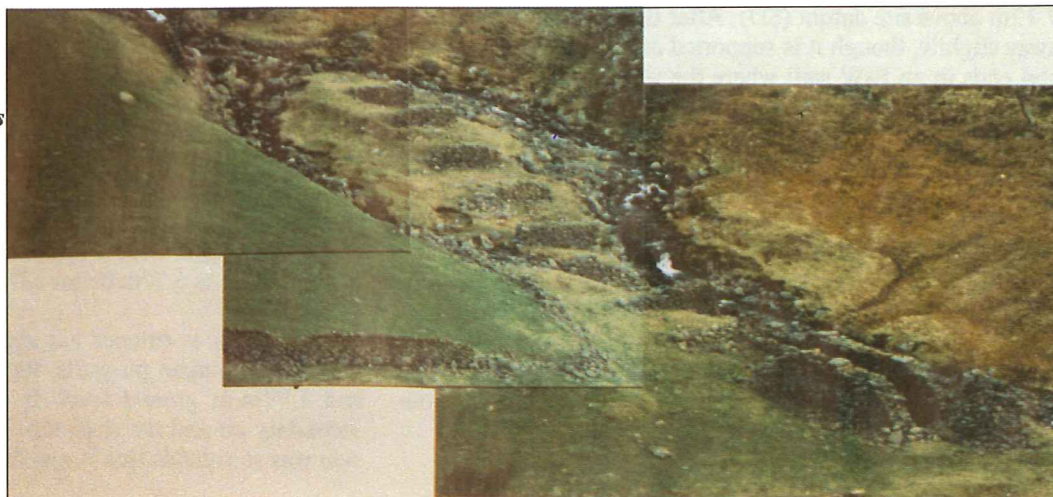
Concern developed on news that the National Trust was going to spend money on conserving the wheel pit but, regrettably, because there were insufficient funds, conservation would not be preceded by a thorough archaeological investigation of the system. As a result a photographic and survey project was started to record the site as far as possible before the National Trust work was started. The detailed EDM survey was carried-out with Keith Clark after the first stage conservation was substantially finished.

After discussion with Ian Tyler it was decided not to attempt any archive searches, but to rely instead on contemporary books and papers on water wheels by John Smeaton and William Fairbairn, and more recent accounts by Frank Woodall and Michael Davies-Shiel.

Site Description

The site is a Scheduled Ancient Monument on Grove Farm,

Plate 1. The Myers Head site before conservation. The wheel pit is at the bottom right with the walls which carried the roadway seen extending up-slope.



National Trust land farmed by Alan and Eric Wear. It is about 800m south-east of Hartsop village (Low Hartsop), where Pasture Beck joins Hayeswater Gill (GR NY416127, about 195m above OD). Hayeswater Gill runs approximately southwards to this point where it turns sharply west and is joined by Pasture Beck from the east. The shaft of the Myers Head Lead Mine is immediately south of the junction.

In recent years the site has been used as a dump, though it was assumed that, because of the cause of abandonment, the pumps and vertical drive rods remain there as well as other significant archaeological artefacts. The following description is mainly before the conservation work in early summer 1999. Site height datum (SD) is the top of the wheel pit walls.

The remains of the water wheel system lie immediately west of, and roughly parallel to, Hayeswater Gill, 183 metres from weir to shaft centre. There are three sections.

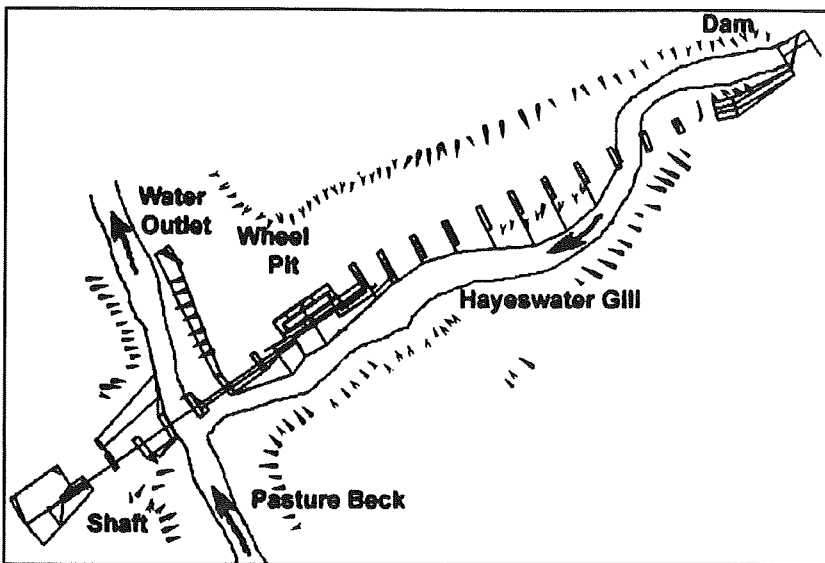


Fig. 1. Myers Head - surface plan.

The Water Supply - Dam to Wheel Pit

Most northerly, at about 210 m above OD, is the remains of a dam or weir. What is left is a wooden beam embedded in a rock rubble supporting structure that appears natural and over which the gill now runs.

A "leat" can be traced from the east end of the dam, indistinct at first because of infilling and grass cover, though there is a supporting wall alongside. After 14m, it enters a man made channel in the rock (4m long tapering, at its foot, from 1.15 to 0.85m wide). The channel ends at a clearly defined sill, at 7.12m above site datum (SD). After the sill, the ground falls away slightly, though it is supported on the gillside by a wall, and ends in an E-W wall where the wall disappears into the hillside at its east end. I have called this: Wall 1.

Between Wall 1 and the wheel pit are ten more E-W walls, each free-standing, and numbered Wall 2 to Wall 11.

Hayeswater Gill splits with the main flow going east. Between Walls 8 to 11 its west bank is lined with a man-made wall approximately 1m high. The minor flow continues to the west of the line of walls and rejoins the main flow between Walls 8 and 9, by falling over the bank wall just described. To the west of Wall 9 is a bank which could have been built to ensure the minor flow returned to the east branch.

The walls are in various stages of disrepair though Walls 4, 5, 6, 7, 8 probably indicate the extent of the original structures and their dimensions and configuration. The heights above present ground level vary from 0.69 to 1.66m (to 2.43m where they abut the Gill). Originally they may have been about 4 ft (1.20m) high above the general ground level. The walls are of "dry" construction tapering slightly towards the tops, and some still have some capping flags.

Each freestanding wall has three rectangular holes in the south face on an approximately horizontal line near the ground. There is one such hole visible in Wall 1. The alignment of the wall system to the wheel pit centre line is 11° to the east in plan view.

The Power System - The Pits

South from the east end of Wall 11 is a small and narrow walled pit aligned N-S. It overlaps (to the east) the large pit.

The walls are topped in part with capping flags. This secondary pit is in line with the massive structure at the south-east corner of the main pit - the SE Block - and the shaft top. It is 6.40m long. At its north end it is 1.28m wide and midway it narrows abruptly to 1.07m wide for the south end. The depth is difficult to measure because of rubbish dumped in it but it is at least 1.76m at the north end and 1.40m at the south end.

The main pit lies parallel to the secondary pit. Before conservation it was partly filled with debris, so the depth could not be measured. During the conservation work some of the debris was removed and the depth is at least 5.10m. On each side massive sidewalls about 1.50m thick at their tops, rise to 2.80m above the surrounding ground. The internal dimensions of the pit appear to be 11.50 x 2.25m at site datum.

Externally there is no evidence of any holes though the sidewalls. Internally (tops about 2.65m below SD) is a row of rectangular holes with some timber remains. At the same level across the north end of the pit is a wooden beam let into the cross wall. There is a timber plank on both sides running over most of the hole tops. The hole timbers are 4 inch (100mm) thick planks parallel to the pit wall. Two of the sidewall holes contain the bottom ends of metal rods. All the other holes had, in similar positions, vertical passages. These passages appear to extend to the wall top, though only one upper end has been found.

The pit is relatively dry (even with most of the soil and other debris removed) despite being 1.35m below the Gill surface. Any water outlet is hidden by the rubble remaining at the south end of the pit. However, on the north bank of Hayeswater Gill, well below the Pasture Beck junction, about 26m from the pit at an angle of 62° to the pit axis, is a portal (0.70 x 0.60m) inside which (for about 5m visible by torch light) is a walled and covered duct with a reasonably steady water flow. This water surface is 6.70m below SD.

The SE Block is ruinous but appears to have been the same height as the main pit walls. Its length and breadth are 4.81 and 1.97m at ground level. It is directly in line with the secondary pit and the shaft top. Before conservation its west side was so ruinous that it was difficult to estimate the extent

of the overlap with the main pit side walls. After the conservation work the ground plan of this structure became clearer. Four rectangular holes are now apparent just above ground level: one in the north face near the main pit wall, one at each end of the east face, and one in the west face near the south-west corner.

The conservation contractor found timber within the block, but no record was made before it was covered and two of the holes were "lost" and one blocked.

The Driven System - Wheel Pit to Shaft

South of the main pit, between it and Hayeswater Gill, there is another wall, but there appear to have been two more walls - one between it and the main pit and another in the beck junction.

Across the gill, partly supporting the steep bank below the mine shaft head, is a wall with three rectangular holes facing north. There is a stud rising from the top of this wall. Above it on the bank, poking out of a spoil heap on the site of a possible wall, are two more studs. Between the beck wall and these studs is a further possible wall. I have called these "walls", rodwalls 1 to 6.

To the west of the possible rodwall 6 there is evidence of a water outlet: a possible lintel with lush grass below. To the east of rodwall 5 there is a "spring" with a steady flow. Could this be the dry weather level of water in the shaft? Lax (1997, 7) says that the latter is a "stone lined drain 0.4m wide" with unknown source.

At the top of the bank there is a wall surrounding the shaft. Formerly ruinous with a housing projecting north, towards the SE block and the secondary pit, over the rodwalls. As one would expect with a rod driven system the Secondary Pit and SE Block are both aligned precisely with the shaft head.

After conservation the shape of the "channel" became clearer. It is tapered and there is a distinct vertical step at mid-length and its bottom, at the beck end, is below the sill. The space appears suitable for a balance bob. The top of a threaded rod (1.5 in dia) was exposed in the position one would expect the vertical pump rod to be.

The shaft centre is 70 m south of the centre of the wheel pit.

Fig. 1 is a plan of these features as found February/March 1999 and surveyed in July 1999.

Elsewhere, in the immediate vicinity but not directly relevant to this paper, are two levels (north east of the shaft), a "smithy" (adjacent to the dam), a dressing area, spoil heaps and additional water leats. There are the remains of trackways. Further away are the Hartsop corn mill, built in 1706 (Davies-Shiel 1978, 66) and its leat (also fed from the Hayeswater Gill), other old mines nearer the village and other adits higher on Hartsop Dodd.

Conjecture regarding the system as built

The main pit contained an overshot water wheel 36 ft diameter, 6 ft wide at its circumference (11.00 x 1.83m). The axle bearings were mounted above the pit wall tops on wooden beams running the length of the walls and held down by

vertical studs through the walls down to the sidewall holes. The wheel axis was 0.75m above SD. The wheel was fed with water from a straight and almost horizontal wooden launder system, from the rock channel, itself receiving water from the dam upstream. The launder was supported on trestles, held down on to the wall tops by studs with lower fixings in the rectangular holes.

At the north end of the wheel pit there was a spillway for excess water. The excess ran under the wheel to join the working water leaving the wheel, and left the pit by an outlet below the south wall. It passed into a covered 26m tailrace (running at an angle averaging 62° to the wheel plane) disgoring into the Hayeswater Gill downstream. The tailrace partly used the original west channel of Hayeswater Gill and may not have been straight.

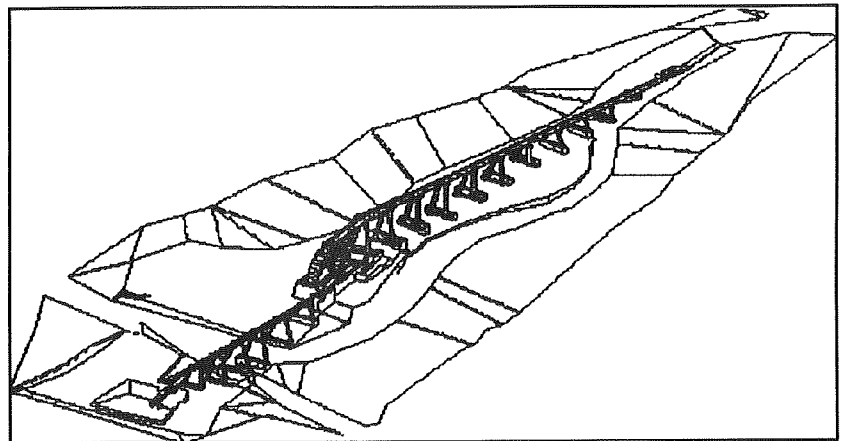


Fig. 2. Myers Head - reconstruction of the system.

A crank was mounted on the wheel axle eastern extension. On the crank outer end were mounted two connecting rods. One ran north to the vertical arm of an inverted "T" balance bob mounted in the secondary pit. The bob's (possibly longer) horizontal arm supported a wooden box for balance weight rocks. The other rod ran south to an articulating joint, at the north end of the horizontal drive rods. A wooden framework was mounted on the SE block using studs to the rectangular holes at its base. The framework contained the first section of runway to support the drive rods and guides to prevent the joint lifting.

The connecting rods ran straight from the SE Block to the shaft-head angle-bob housing, rising at about 1° from horizontal. The rods had, most likely, been rectangular wooden beams, iron bound at intervals where the wheels were mounted. At intervals there were wheels running on short iron rails or plates to minimise friction. The rodway was supported on trestles mounted on the rodwalls.

At the shaft top the angle bob changed the rod motion from approximately horizontal to the vertical needed to drive the pump via pump-rods. This was probably constructed as an inverted "T", with an additional balance weight.

The pump(s) were force pumps.

This conjecture, based on reading and initial observation directly contradicts the "Red Herrings" listed in the introduction:

1. The wheel was overshot, not breast fed and 36 not 30 feet diameter
2. The launder was straight, not stepped down
1. The holes in the launder support walls were for fixings for vertical trestles, not for "horizontal" beams to the next wall and the launder ran on top of the trestles.
4. The wheel axle was mounted above pit wall top, not half way down the pit
5. The small pit was for a balance bob, not a secondary wheel.

The case in detail

In the discussion that follows, the case is made for the above conjectures and for the likelihood of the alternatives. Questions were posed such as:

- What was the type of wheel?
- What was the wheel size?
- How was the wheel mounted?
- How was the power taken off?
- How was the power transmitted to the pumps?
- What was the purpose of the secondary pit?
- What were the balance bob relationships?
- Why was the dam where it was and why was the rock channel needed?
- Was the launder stepped or straight?
- What was the purpose of the wall holes?
- Why did the waste water exit at such a strange angle?
- What was the purpose of the SE Block?
- Why were the rod walls that width?
- What was the construction of the drive rod?
- Why was the wheel pit position chosen?
- What was the pump size?
- What was found?

It may be believed that the Victorians over-engineered their structures, but: that does not mean that they built unnecessarily large, and that was even less likely if, as in this case, they were in a hurry.

In the literature there does not seem any support for:

1. Wheels mounted other than on wall tops or
2. Stepped launders or
3. Power take-off other than by crank for this size and use of wheel, but most, if not, all pumping wheels had a balance bob.

The type of wheel - overshot, pitchback or breast-fed?

The inside length of the pit is 11.5m but room is needed for an excess water spillway and clearances so the maximum wheel diameter was about 11m. With a normal launder gradient (1:200) the end of the launder would be about 6.6m above the pit walls and 11.75m above the pit bottom.

The main arguments for an overshot wheel are that an overshot wheel has to fit between the launder end and the pit bottom with adequate clearances. The sum of the clearances above and below for an 11m wheel would be 0.75m and the axle could be at 0.84m above the wall top, which is easily accomplished with a 2' 6" (0.75m) wall top beam.

On the other hand, with a pitch-back wheel, because the water is delivered at or just below the top of the wheel, the axle of an 11m wheel would have to be at least 1.14m above the pit walls and the bottom of the wheel 0.74m above the pit bottom. This axle level would be more easily achieved with higher walls and the clearance below is excessive.

With a breast fed wheel these figures would have been much

greater; also breast fed wheels normally have curved end walls to maximise water retention. This pit has flat and nearly vertical end walls.

Also, with an overshot wheel and pump drive rods pointing away from the launder, the action of the crank and connecting rod is to hold the drive rod wheels down onto their track. However, for breast fed and pitchback wheels which turn in the opposite direction, the action is to lift the wheels from the track. Being practical, the configuration allows only for an overshot wheel.

Launder - stepped or straight?

Normal launder gradients are 1:200 which gives a total drop of 0.5m for this system. A stepped launder would be quite impractical.

Wheel mounting?

At pit mid height on each side, is a row of rectangular holes. Three arrangements have been suggested for the wheel mounting using these holes for fixings:

1. on a beam, fixed at mid-pit level
2. on an internal frame mounted on such a beam, but with the axle at wall top level
3. on a beam fixed on the top of the walls

If the first, the maximum practical wheel diameter would be about 5m and the wheel top would be level with the wall tops. The launder gradient would be far too steep (about 1:15), and there would be serious engineering problems in getting drive to the pump rods. Also a 5m diameter wheel would not require a pit 11.5m long. Some clearance is needed, but a total of 6.5m is absurd.

If the second, the wooden framework would insulate the masonry from reciprocal and vibrating loads. However in doing so, it would take onto itself large loads, which would try to push the upper part of the frame alternately from one end of the pit to the other. This would soon destroy the frame.

The evidence in the mid-pit holes indicates that they were for access to vertical studs passing up within the walls. These studs could hold down a large wooden beam on top of the pit walls. The end nut on the bottom end of each stud would bear on a washer and the thick wooden planks in the holes.

There is a similar arrangement in the wheel pits of the Glenderaterra and other mines and when the conservation work was in progress across the gill, the bottom end of a stud was exposed confirming that this arrangement was used, at least, for the trestles. This is the most likely wheel arrangement and was normal practice.

Power take-off?

There are several ways possible; by a spur rim and pinion; or by an eccentric system; or by a crank. The first two are unnecessarily complicated and impractical bearing in mind that the pumps required a slow reciprocal stroke. Also the SE Block would be in the wrong place. So it was a crank. This has the merit of maintaining the slow stroke, and being simple in the conversion of rotary motion to reciprocal and, again, it was normal practice.

Secondary pit purpose?

At 6.4m long by up to 2.5m deep at the ends but apparently a metre less in the middle, logically it is not designed for a wheel. The most probable and perfectly normal use was for a

balance bob. Most pumping systems have a balance weight somewhere. The long relatively shallow pit is in the right position and could accommodate an inverted T balance bob of suitable size.

Pump drive transmission?

The literature says by rods. These were almost certainly timber, because the foot walls are much wider than would be required for iron rods.

SE Block - what for?

As the crank turns, the connecting rod generates an alternating vertical load at its little end. This has to be taken by a strong first support. I suggest that the first set of drive rod wheels ran on track mounted on the SE Block and probably in a cage to control them. The Wheal Martyn Clay Works, in Cornwall, certainly used a cage, though with iron rods.

Laundry support wall holes?

For access to the laundry trestle fixing studs, in the same way as the wheel axle support beam. There was evidence (prior to conservation) of vertical holes for studs within most of the existing walls, and the stud in the becks side rodwall gives confirmation.

Wheel size?

Wheel diameter and width are limited by the pit size and other dimensions, some measurable .

1. The pit is 11.5m long at ground level.
2. The pit bottom is at least 5.1m below wall top.
3. The end of the laundry was not more than 6.64 m above the wall tops.

In addition, also needed is::

1. space at the north end, for the spillway and
2. end clearances between wheel, spillway and south wall
3. vertical clearances - under the wheel for excess water, and over the wheel for the laundry.

Minima might be 0.3m each vertically and 0.5m total horizontally.

The pit is 2.25m (8 ft) wide at SD but 1.83m (6 ft) wide at the bottom. The maximum diameter determined by the pit length, less spillway and clearances, is 11m - that is 36 feet - and is less than the maximum pit bottom to laundry end.

A 36 feet diameter wheel mounted on a 2 ft 6 in beam fits neatly both vertically and horizontally with reasonable clearances

Those figures, ignore the literature statements that the wheel was 30 ft diameter. What would we find with 30 ft (9.1m) as diameter?

A 9.1m diameter wheel in an 11.5m long pit has total horizontal space, (spillway and ends) of 2.4 m, which is clearly excessive and unnecessary.

A 9.1m diameter wheel halfway between the end of the 1:200 laundry and the pit bottom, gives under clearance and water delivery drop of 1.3m each. Both are excessive and unnecessary. A 30 ft wheel is too small to fit with what we know, and is therefore unlikely. Indeed any diameter less than 36 ft would have been wasteful of construction time and cost.

Wheel width?

Building a pit that is unnecessarily wide has no value. So I am confident that the wheel was 6 ft (1.83m) wide at its periphery, which fits, neatly, the bottom of the pit.

Estimating other parameters

An empirical formula gives the maximum speed of a 36 feet diameter wheel as 4.5 rpm. With that and assuming six-inch deep buckets and Smeaton's estimate (see note at end) of maximum efficiency at 63%, this wheel had an output of 65 HP. That power (again allowing for efficiency) could discharge about 115 cu ft/min - 43,000 gallons per hour - against 180 ft head.

It is much more difficult to estimate crank length, balance bob weight, and stroke and bore of the pump - indeed was there more than one pump. Though if we could get down the shaft more measurements and estimates could be made.

What was the wheel system like?

The drawing combines the surveyed dimensions of the remains with the deductions made. It is neither complete nor perfect, but it is a basis on which to improve.

The Future at Myers Head and Actions necessary

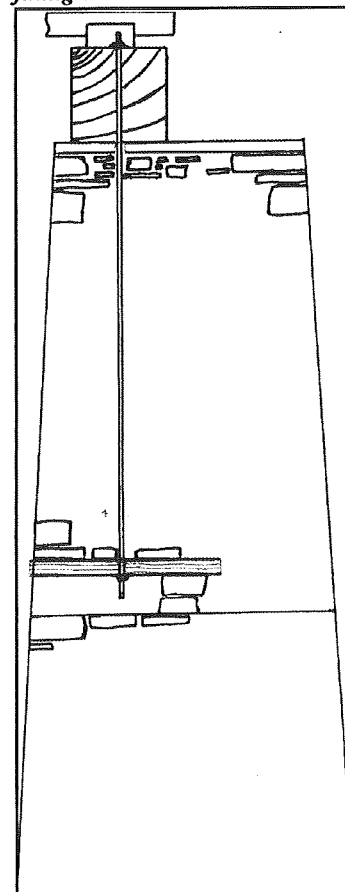
Since most of the photographs were taken, though delayed by foot and mouth, the National Trust has extended its conservation work. The conservation turned into rebuilding and though evidence has been lost, the top of the vertical pump rods was exposed and the shaft head angle bob shown to be more likely to be an inverted T with balance box.

A letter was found in Hartsop from Cowans Sheldon to a subcontractor. This clearly indicates who built the wheel and indicated a possible source of an engineering drawing. However, an examination of the 20,000 or so documents in this collection has, unfortunately, revealed that earliest papers available post-date the Myers Head installation. Hopefully, other sources may yet be found.

Because of the sudden flooding, it is reasonable to suppose that the mine contains many artefacts of historical value. Prime among those are the pump or pumps and the drive rods. Because the water is about 180 ft (60m) deep there will be little oxygen down there and many of the artefacts may be in good condition.

The shaft head must be cleared and protected, while allowing access for research. The most practical approach will be the use of underwater

Fig. 3. The holding-down fixings.



television, recording everything found. Remote controlled vehicles could explore the levels. A mechanism needs to be found to help Carlisle Record Office get the Cowans Sheldon drawings sorted.

All of these will require money. What is absolutely vital is that everything, whether found by archaeologists (amateur or professional) or by conservation contractors, must be recorded.

Acknowledgements

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Postscript: A question after the talk was: "What was the basis of Smeaton's efficiency figure of 63%?" I said I did not know, but had assumed that it was the proportion of the power in the flow of water falling through the diameter of the wheel that was available at the axle. On reflection I thought that that might possibly be a naive assumption and tried to calculate the volume of water in each bucket at each stage of its passage from top dead centre to bottom dead centre.

Assume 100% is the output when the water completely fills each bucket the moment it passes tdc and remains in the bucket until bdc when it empties instantly. This is, of course, impossible for fixed buckets! Clearly the buckets take time to fill and the buckets empty progressively as they descend, and buckets do not retain water at all after the leading board becomes horizontal.

To simplify the geometry and calculations I made assumptions, and used a spreadsheet rather than calculus:

The bucket boards are tangential to the inner wheel diameter
The buckets are filled instantaneously when the leading outer edge of each bucket has passed half a bucket width beyond tdc

I found that there is a significant improvement in the bucket utilization with increasing bucket numbers. For a 36 ft wheel (113 ft circumference), with bucket internal diameter of 35 ft, utilization rose from under 20% with only 15 buckets to over 78% with 120 buckets. The table gives intermediate values.

Table 1.	buckets	capacity (cub. feet)
	15	19.53
	18	26.32
	21	29.57
	24	35.29
	30	42.11
	36	47.31
	42	54.19
	48	57.66
	60	62.78
	72	68.47
	84	71.21
	96	74.25
	108	76.23
	120	78.65

The only other loss between water leaving the launder and the axle end is friction of the bearings and the drag of water on the surface of up-going buckets - say 5%. So a 72 bucket wheel (with 19 in openings) could have an efficiency of around 65%. Though simplified my calculations give me confidence in Smeaton's work. McGuigan (1978, 18) confirms this figure.

Stuart Cresswell (BA, BSc) is Treasurer of MOLES. His Cumbrian ancestors went to South Wales (where Stuart was born) and became prominent coal mine managers and engineers. Retired now, his career has been in engineering development and production management. He is a family and local historian concentrating on his own family, but doing work on other families, and on his home village of Threlkeld, about which he has co-edited a book.