The Hetton Railway –
Stephenson's original design and its evolution

Colin E. Mountford

The first two International Early Railways Conferences produced much fascinating new material about the first steam locomotives, now published in *Early Railways* (2001) (1) and *Early Railways 2* (2003) (2). William Chapman (1749-1832) and John Buddle (1773-1843) have received long-overdue recognition alongside the work of George Stephenson (1781-1848). His development of the steam locomotive at Killingworth for his employers, the coal owners 'The Grand Allies; his contributions to the development of the steam locomotive, followed by the patents, with William Losh of the Walker Ironworks at Newcastle upon Tyne, of the so-called 'steam spring' and the half lap joint for cast iron rails, and of course his achievements as Engineer for the Stockton & Darlington Railway, are all well known. Stephenson's locomotives, like those of all the other locomotive experimenters before 1820, were operated on an already-existing waggonway; and yet even his biographers (3) would seem to have us believe that his genius was such that he could go straight from this work to designing in the S&DR a completely new railway nearly thirty miles long. In fact, Stephenson was Engineer for the Hetton Colliery Railway in County Durham, a new line eight miles long between a colliery at Hetton running north-westwards to the southern bank of the River Wear at Sunderland, which opened in November 1822. As built, this was to be the first railway ever to be designed to use steam locomotives and so is an historic landmark in the history of railways. Yet it has been almost entirely ignored by railway historians, perhaps because it was not a public railway; and astonishingly, in over 180 years since it was opened, no history of it has ever been published, until it was included in my recently-published *The Private Railways of County Durham* (4).

Quite apart from its railway, both Hetton Colliery and its owners mark a significant development in the north east coal industry. Before 1820 coal mining in Durham was limited mainly to the north western quarter of the county, with a little in the south west. The seams were shallow or outcropped and were easy to work, but they dipped towards the east. However, over much of the eastern half of the county there was a thick stratum of magnesian limestone, and many believed that no coal measures lay underneath it.

The years 1819-20 were a time of upheaval in the Durham coal industry. In that year Charles Stewart (1778-1854), soon to become the 3rd Marquis of Londonderry, married Frances Anne Vane Tempest and so gained control of her considerable coal royalties. His first action was to dismiss her Agent, Arthur Mowbray, and replace him with John Buddle, the most innovative and technically-advanced colliery engineer of the age. This led Mowbray to join the entrepreneurs who were determined to sink a colliery through the limestone on the Hetton royalty, and who early in 1820 formed the Hetton Coal Company, the first joint stock company to be established amongst the Durham coal owners. Not for Mowbray the slow and expensive system where coal was loaded into small boats called keels, which took it down to the mouths of rivers for it to be trans-shipped into sea-going colliers; he wanted a railway direct to the mouth of the River Wear, so that it could be loaded straight into ships bound for London, where the best prices could be obtained. He was regarded by the traditional men as a potential threat to their control of the trade, exercised through the 'Limitation of the Vend', which allocated output figures in order to control output and so keep the price up, and so was regarded with hostility by men like Stewart and Buddle.

For many years the published view was that Stephenson, having obtained permission from his employers at Killingworth, Lord Ravensworth & Partners (the "Grand Allies"), was appointed Engineer for the line in 1819 (5). There would appear to be no evidence to support this statement, and indeed, other facts would seem to make it very unlikely. The Hetton Coal Company was not formed until early in 1820, and Mowbray seems to have begun by considering whether a line from Hetton could join the Newbottle Waggonway, which ran from Newbottle, 3¾ miles north-west from Hetton, to Sunderland and was opened in 1812; for on 11th February 1820 Buddle wrote to Stewart recommending that they take up the excess capacity on the Newbottle line specifically to deny it to Mowbray (6). On 29th July 1820 Buddle reported to Stewart that various people were undertaking surveys of various lines of railway to Sunderland, including Edward Steel (7), who had been the engineer for the Newbottle Waggonway, while on 10th October 1820 he reported a meeting with Benjamin Thompson, the owner of the Ouston Waggonway, who claimed he had refused to accept a proposal that he should build the Hetton line and operate it under contract (8). All this activity seems impossible to reconcile with Stephenson already being the line's engineer. A more likely interpretation might be that Mowbray, having set up the company and acquired the royalty for the colliery, and then having realised that the only realistic option for a railway to Sunderland was a line of his own, issued an invitation in July 1820 to local engineers to submit their proposals for routes and costs, with Stephenson being one of those who accepted the invitation. The shortest route was not the most ideal from an engineering viewpoint, for between Hetton and Sunderland lay hilly land, rising to 636 feet at its summit, Warden Law.

Only one surviving document (9) records one set of Stephenson's estimates for the line. This is not dated, though the paper is watermarked 1821, and they are written in a volume concerned with Newbottle Colliery, but they do appear to refer to the whole line. Stephenson proposed a line 7½ miles long, with two fairly flat sections, three stationary engines, two at 35 hp and one at 10 hp, five inclined planes (i.e. self-acting) and at the staith two spouts for loading the coal into colliers, for all of which he estimated the cost of construction at £19,301-17s-0d, with an additional cost of £2400 for 120 new chaldron wagons, the standard 'Newcastle chaldron' carrying 2 tons 13 cwts. Very interestingly, his estimates for operating costs included the use of horses, rather than steam locomotives. For an annual vend of 40,000 chaldrons, or 106,000 tons, he estimated a need for five horses on the virtually level southern section and ten horses on the longer northern section, with operating costs at £6546 (including interest on borrowed money), or 3s 3¼d per chaldron; if the vend was 60,000 chaldrons, or 159,000 tons, then 8 additional horses and 10 extra men would be required, increasing the operating cost to £7935, but reducing the cost per chaldron to 2s 7¼d. Estimates for the use of horses is not to say that he did not prepare estimates for the use of locomotives, and in any case these proposals and estimates were not those upon which the line as built, except for one crucial figure: a valuation of the colliery and its railway, undertaken in September 1823 by three men, including Stephenson himself and his close associate Nicholas Wood (1795-1865) (10), is also based on an annual vend of 60,000 chaldrons, which clearly was the total upon which the railway was designed.

Stephenson's final plan provided for locomotive haulage between Hetton and the foot of the climb, a distance of almost 1½ miles, from where two inclines powered by stationary engines would take the full wagons to the top of Warden Law. From here four consecutive self-acting, or gravity-worked, rope inclines would take them down to a place which became known in later years as North Moor, near Silksworth. From here locomotive haulage would work the next section, almost 2½ miles, to Hylton Road in Sunderland, where a fifth self-acting incline would take the wagons down to the Hetton Staith. The sinking of the first shaft at the colliery, in deserted open countryside, began on 19th December 1820 and construction of the railway began in April 1821. In the following month Stephenson was appointed Engineer for the Stockton & Darlington Railway, which left him little time to spend at Hetton, and his younger brother Robert became the resident engineer (11). The first workable coal was found on 3rd September 1822, and the Railway was opened on Monday 18th November 1822, with all the celebrations normal for this period – the first railway built purely for mechanical haulage and to incorporate steam locomotives from the outset. The opening was recorded in the *Newcastle Courant* of 22nd November 1822, and the company issued a lithograph to commemorate the event. The text below the main drawing is interesting. This lithograph went through several transformations, including in Glasgow and Germany.

So Stephenson was able to devote himself to the much greater work of the Stockton & Darlington Railway, re-invigorated by the success of the Hetton Railway.... well, no.

First of all, how much of the Hetton Railway was actually George Stephenson's personal design? The route and the specification for the haulage – almost certainly. The design of the locomotives, and probably the specification for the stationary engines – almost certainly. But curiously, the text on the first version of the lithograph does not mention George Stephenson, which it surely would have done if he had made a significant contribution to the Railway.

We know that Stephenson had little formal education and could barely write. We know too from his horrendous cross-examination by counsel during the Committee stage in Parliament of the first Liverpool & Manchester Bill in 1825 that Stephenson had not taken the levels for this line, did not know precisely where the base line for them was and had not checked the work of those who did them for him. It is perhaps not surprising that he clearly did not do them here either, with this work being undertaken by Thomas Wood, another new name in early railway history. Equally clearly, Robert Stephenson, rather than George, 'fixed and improved' the machinery, presumably including the two stationary engines. Indeed, the 1822 lithograph does not even mention that George Stephenson was the engineer.

Let us look at the gradient profile for the Railway, based on the information from Dodds and from Oeynhausen & Dechen. The well-known account of the opening day in the *Newcastle Courant* states that there were five locomotives. But research amongst the Hetton documents of this period has produced no evidence to support this statement. Stephenson himself, in a letter written on 7th October 1821 (12), states that 'We are expecting to Commence making 3 Locomotive Engines in a fortnight's time for a neighbouring Colliery', which clearly has to refer to Hetton. Even to build three new four-wheeled locomotives in thirteen months would have been a major achievement in 1821-22; but five? And where were they built? At Hetton? That seems very unlikely, given that Hetton was a green field site, a colliery was being sunk, but with considerable difficulties, and a major range of facilities would be required, to say nothing of skilled men. Possibly they were built at Killingworth, where Stephenson had built his first locomotives, possibly at the Walker Iron Works at Newcastle upon Tyne of Losh, Wilson & Bell, with which Stephenson had been associated since 1816. Dodds states that the fourth and fifth locomotives arrived in December 1823 and that all five cost £500 each (13), which would suggest strongly that all five were new. A later engine may have been the now-famous six-wheeled 'Steam Elephant' from Wallsend.

The direct route between Hetton and Sunderland was not the most ideal from an engineering point of view, as in between them the land rose to 636 feet at Warden Law. The line as built was 13793½ yards long, or a little over 7¾ miles, with an ascent of 296 feet to Warden Law and a descent of 557 feet 4 inches from Warden Law to the staith on the River Wear. Historians are extremely fortunate that in 2004 a extensive report entitled *Observations on Railways........* " came to light written by George Dodds, the Railway's Superintendent, describing and listing in detail the whole of the line and its operation between its opening in November 1822 and December 1824. Although this is in private hands, it has been made readily available for research. In addition, within months of their opening the railway and its staith were giving the company's directors cause for serious concern, and between 1823 and 1830 they commissioned a series of reports, now held by the North of England Institute of Mining and Mechanical Engineers in Newcastle upon Tyne. The railway was also visited by the Prussian engineers von Oeynhausen and von Dechen about July 1827 – their report was published in translation by the Newcomen Society in 1971 - and again in January 1829 by John Rastrick, one of two nationally-known engineers commissioned by the directors of the Liverpool & Manchester Railway to report on the 'comparative merits of steam locomotives and stationary engines'; his report is deposited in the Special Collections section of the Senate House Library of the University of London, sadly not published. The earliest known plan of the railway is undated but probably drawn between 1836 and 1840 at the scale of forty inches to the mile. The original is now missing, but the speaker has a photocopy.

The original railway was changed very radically in the first five years of its operation and so it is very helpful to have Dodds' description of it at the beginning. Dodds gives complete details of every incline rope, its length, weight, diameter, initial cost, the precise number of chaldron waggons which it hauled, the cost per chaldron per rope and the exact dates when it was fitted and removed.

The 1½ miles between the colliery and the foot of Copt Hill bank was worked by Stephenson's locomotive(s). This had been built with a gently declining gradient, but had been raised by four feet, using 6,000 chaldrons of coal, by 1824 to 'equalise the way for the Locomotive Engines' (14). This section was single line with one passing loop, in other words, an identical system to that which Stephenson used for the Stockton & Darlington Railway Given that there were only three locomotives up to the latter months of 1823, there was perhaps one on this southern end and two on the northern end. From here the Byer/Byre Engine worked fulls and empties simultaneously up the 882-yard Byer Engine bank, also known as the Copt Hill Incline. The next incline, operated by what Dodds calls the Mill Engine but which is universally known as the Warden Law Engine, comprised two equal sections of 775 yards and used a form of direct rope haulage almost certainly unique. The first section had a gradient averaging 1 in 90 and the second a gradient of 1 in 22, the two sections being linked by a meetings. As the engine hauled a set of eight fulls up from the meetings, a tail rope attached to the rear of the waggons hauled up a second set of eight from the Byer Engine 775 yards behind it (15). This completed, both ropes were transferred to sets of empties, which were then lowered, a procedure which must have required great operational care. So both of the powered inclines up to Warden Law were able to run fulls and empties simultaneously, and had the 'rope barrel' (possibly two rope barrels) mounted over the track. Both of the haulers were 60 h.p. condensing engines, but their builders are unknown.

From Warden Law four consecutive self-acting inclines took the waggons down to the outskirts of Sunderland. These respectively were 1302, 1224, 716 and 902 yards, and four in succession is believed to be unique. Self-acting inclines by definition must run fulls and empties simultaneously; the apparently triangular gantries shown on the lithograph at the top of each of these inclines are a mystery, as Oeynhausen and Dechen state clearly that the brake wheel around which the rope went at the top of each incline lay beneath the rails (16).

Then followed 2½ miles worked by locomotives, which brought the waggons almost to the river. This section was also single line, with varying gradients and apparently with only one passing place. At the end of this section, near what became Hylton Road in Sunderland, a fifth self-acting incline of 325 yards took them down to the staith. Its design seems to be unique; whether Stephenson designed it is not known. The site was far from ideal, as the railway ended at the edge of a cliff with a drop of about 75 feet between waggon and the bottom of a ship's hold. The staith comprised two shipping points, but it was also intended as a store for coal awaiting shipping. To accommodate these uses a large wooden building was erected, and to permit the loading of coal from stock two chutes were provided. To accommodate the chutes the chaldron waggons were, uniquely to my knowledge, built with end doors; upon entering the building, they ran down on canted rails to discharge their load. How they were retrieved from this position is not known, but presumably horses were used.

Within months the Railway and its staith were giving the company's directors cause for serious concern and they looked round for a reputable and independent engineer to inspect them and comment. There was perhaps only one such man, William Chapman, now 74 years old. Between June and September 1823 Chapman wrote three reports (17), which were critical of much of the detail, but also stated that in his opinion the railway as he saw it was not capable of carrying any higher tonnage. This was a critical question. The company was already planning to sink two more collieries, at Elemore, about a mile to the south of Hetton, where sinking began on 25th March 1825, and at Eppleton, a mile to the north east of Hetton, where sinking began on 23rd May 1825, and as early as April 1823 the directors were seeking the implications of the Railway's tonnage being raised to 100,000 chaldrons per year (265,000 tons)(18). Eppleton, its sinking delayed by severe water problems, did not produce coal until 1833, but Elemore, like Eppleton, connected to the railway by a self-acting incline, began production in February 1827 and clearly this was a major factor in the railway's increasing difficulties.

Hardly had Chapman completed his investigation than Robert Stephenson was dismissed. His replacement, within months, was Joseph Smith, who had been foreman enginewright at Heaton Colliery near Newcastle upon Tyne, where he had supervised both the maintenance and construction of 'travelling engines'. Chapman's reports were followed by almost a plethora of valuations and reports on Hetton and its railway, produced at the request of the anxious directors. Of these, the most important are 'An Investigation into Hetton Colliery affairs' by Messrs Easton and Dunn, two notable colliery viewers, dated 27th September 1827 (19), and a report for the directors on the condition and capacity of the railway by Charles Robinson, Joseph Smith's successor, undated but probably written about 1829-30 (20), while Oeynhausen & Dechen's report is also very informative.

Virtually everything comprising the Railway was criticised. The line was constructed from Stephenson & Losh's patent cast iron rails (21), laid on stone blocks. Despite Losh's claims elsewhere that his rails gave few problems (22), the foundry at Hetton replaced nearly 21 tons of rails between November 1823 and October 1824 at a cost of £114 (23). The problem scarcely diminishes in subsequent years, and a review of the foundry in 1827 suggested that malleable iron rails should be introduced, at a saving of £200 per year (24). One is left to wonder whether Stephenson's experiences here lay behind his recommendation that malleable iron rails should be adopted on the Stockton & Darlington Railway. Nor were the chaldron waggons much better. The originals cost about £20 each, but Robinson criticises them as being 'very defective' and subject to accidental damage; their replacements, costing £28 10s each (25) were giving better service. These problems apart, the Railway's equipment seems generally to have been in good condition; the more critical problems lay in its fundamental design.

Top of the directors' problems was the staith. Chapman records that the ships' captains reported that the coal lost half of its value between leaving the waggons and arriving in the hold, due to damage in the chutes (where it fell a vertical distance of 50 feet) and the hold (a final vertical drop of 12-14 feet) (26). Even by the time Chapman was writing his report on the staith in June 1823, a second self-acting incline was being constructed 'to bring the waggons immediately over the ship's decks', presumably by cantilevering the final section of the incline out from the bank, a most unusual arrangement. Cradle loading involved running one waggon at a time out on to a platform, which because of the extra weight then went out over the ship's hold. Here a man on the platform released the bottom doors to discharge the coal. The platform and its waggon were now lighter than the counterbalance, which then swung them back to their starting point. Chapman accepted that damage would still occur, but it would be less. This system of course needed waggons with bottom, rather than end doors, and the need for these was obviously another reason behind the waggon replacement programme mentioned above. There would clearly be an increase in shipments when Elemore Colliery began production, and in February 1826 Mowbray and Smith advertised for two high-pressure steam engines, one of 30 hp and one of 12 hp, 'to be fixed on the Hetton Company's railroad' (27). It would seem reasonable to assume that the smaller engine was for use at the staiths. By the time of Easton & Dunn's report in September 1827, there were two stationary engines working at the staiths. Robinson reports only one, the Bell Engine, working staiths (or 'drops') Nos.4-6, although the "Staith Engine" was also helping out, as we shall see, and he also reports only one self-acting incline, still called the 5th Inclined Plane, which was serving drops Nos. 2 and 3 (28).

The Warden Law Incline was also giving rise to serious concern. Undoubtedly this was because of the time taken to operate the complicated and difficult method described earlier, which would clearly be aggravated by the lower 775 yard section down to the Byer Engine, where the gradients reduced from 1 in 22 to an average of 1 in 91. The problems of similar inclines elsewhere would suggest that it may well have proved difficult to get a set of only eight empties, lacking both springs and lubrication, to complete its run. So the company decided to divide the incline in two and to install a new stationary engine, to be known as the Flat Engine, at the former 'meetings'. The advertisement of 1826 mentioned above included a 30 hp high pressure engine, and the only 30 hp engine on the line when Oeynhausen & Dechen walked along it was here, so clearly the two are the same. The engine operated the section between the Byer Engine and itself, but the number of waggons in a set was increased to 16, with fulls and empties being run alternately as the original single line here was retained. The installation of this new engine meant that a new 'meetings' for the Warden Law Incline also had to be built.

Chapman was also critical of the Warden Law Engine itself (29). It was identical with the Byer Engine, and almost certainly very similar to the stationary engines used at the colliery, which were based on 'Mr.Stephenson's design' (George or Robert?). The Warden Law and Byer Engines were condensing engines served by three boilers 14ft in diameter and had two 30in x 60in 'engines' (cylinders) (30) driving on to a single drum (31). Twin vertical cylinder engines driving one drum or rope wheel were were quite common in the 1820s, and were used on the Stockton & Darlington Railway in 1825 and the Cromford & High Peak Railway in 1829-30. Despite this, Chapman had reservations about the use of two cylinders; he criticised both the elevation and the siting of the engine house, which lay 150 yards from the bank head instead of the usual 50 or 60 yards, the absence of a hump, or 'kip' at the bank head, which he showed could be installed without the necessity of the ropes crossing, and he recommended that the boiler house walls should be completed up to the roofs in order to prevent tiles from being blown off. Unfortunately, none of the surviving documents reveal the identity of the two engines' manufacturer(s). Given the criticism of it, it is perhaps not surprising that a new and more powerful engine was installed at Warden Law in 1836, almost certainly installed with the rebuilding of the incline to run fulls and empties simultaneously. This was a 97½ hp beam engine made by Thomas Murray of Chester-le-Street, with a single cylinder 39in x 74in (32). Almost certainly this was a condensing engine as built, although latterly it was non-condensing, albeit fitted with an economiser. It was clearly fitted with two drums as built, though whether the building that housed them latterly was contemporary with the engine house building itself is open to question. The beam drove a flywheel 24½ft in diameter, whose shaft operated pinions which in turn drove the drums. To reverse the engine the driver depressed a foot pedal, which disengaged the gab, allowing the slide valve to be worked by hand to rotate the engine back 180 degrees, at which point the gab was re-engaged. Whether the Byer Engine was also replaced about this time is unknown.

Following the installation of the Flat Engine in 1826-27, the directors' next problem was the section between the foot of the 4th self-acting incline and the top of the 5th self-acting incline, near the staiths, the other section worked by locomotives. Chapman had seen the problem as early as July 1823:

> 'The Travelling Engines go with great facility both ways at the rate of about 5 miles an hour [between the top of the 5th Incline and a point known as Pemberton's Cut, a distance of about 2,700 yards], but then upwards for a distance of about 1,533 yards to the foot of the 4th Inclined Plane.... the ascent is so much steeper so when combined with the various curvatures on the line to cause the Engine with the return waggons to move only at the rate of 2½ or 3 miles an hour, which is of little moment under your present Vend; but when it comes to be much increased, you must either have an additional Travelling Engine or cause the ascent westward from Pemberton's Cut....to be more gentle, viz., to ascend at 5in per chain instead of 7in.' (33).

As at the southern end, the locomotives were hauling sets of 16 waggons, here making ten round trips totalling fifty miles in 14 hours. This was a stiffer task than Stephenson's locomotives at Killingworth, where they were hauling trains of only 12 waggons for a distance of two miles each way, the fulls comprising 33 tons and the waggons themselves a further 14 tons, a train load of 47 tons (34). At Sunderland the gradients on the section identified by Chapman were between 1 in 109 and 1 in 139, and if these, combined with the curves and the longer train, were greater than the locomotives could manage effectively, then the responsibility has to lie with the designer of them all, George Stephenson.

Chapman's prediction was correct: the addition of Elemore Colliery traffic would clearly be more than the 'travellers' could manage, and plans were put in hand to replace them with three more stationary engines. The first, situated at the foot of No.4 Incline and thus known as the Fourth Incline Engine, worked the first 2,602 yards, lowering 16 fulls down and then hauling 16 empties back. The next two, the Winter's Lane Engine and the Staith Engine (40 hp), worked the remaining 1,748 yards on the 'reciprocating system', that is, operated waggons by main-and-tail haulage. The new rope haulage commenced work at the end of May 1827 (41). The increased capacity was dramatic; Oeynhausen and Dechen, visiting only a few weeks after the introduction of the new system, recorded the Fourth Incline Engine working sets of 16, the same as the locomotive, but at 10 mph, while on the main-and-tail section sets of 24 were run, and sometimes 28 or 30, again at 10 mph (42), and of course both sections were working simultaneously. Yet even after this, more change was still needed. This sketch from Rastrick's notebook in January 1829 shows that a main-and-tail system was also introduced between the Fourth Incline Engine and the Winter's Lane Engine, perhaps used as necessary. Against this background it is possible now to understand why there were doubts about the continued use of locomotives on the Stockton & Darlington Railway, and about their adoption on the Liverpool & Manchester Railway. The three now-redundant locomotives were taken down to Hetton. The two locomotives here were already in daily use, so the arrivals from Sunderland no doubt provided much-needed relief for the locomotive foreman, who now could have one spare and one or two under repair as required.

Even the self-acting inclines do not escape criticism of detail. Other than Oeynhausen and Dechen's description above, we know nothing of how the sets of waggons on these inclines were braked. In his report Robinson repeated his call for the installation of larger return wheels fitted with friction brakes. On all the other self-acting inclines still operating in the North East in the second half of the twentieth century the brake on the return wheel was applied by a hand-operated wheel, in a two-storey brake cabin. But in Sunderland lives a gentleman whose father and grandfather were the brakesman on No.3 Incline from 1882 onwards, and he was able to describe the braking system used here, which was very different. As the diagram shows, here two brake shoes, made originally of lignum vitae, clasped both the top and bottom of the return wheel to slow the set; but instead of being operated by a wheel, the Hetton brakes were attached by wires to a pivoted crank, which in turn was linked to a wire attached to a bar about 14 feet long, also pivoted and angled upwards above a slot in the cabin floor. At the opposite end of the bar was a seat, and behind the seat was a vertical pivoted rachet bar with dog teeth. To apply the brake the brakesman sat on the seat and forced it down the rachet bar, using simple 'mechanical advantage', then pulling the bar back when he wanted to release the brake. This arrangement seems very simple, and one wonders whether it could even have gone back to the very early days of the railway. Note too the design of the bank head cabins provided for the brakesman, a single storey building complete with an improvised bedroom, with, only a few yards away, the very simple cottages provided for the men working on the Railway.

Another long-standing feature may also date back to the early days of the Railway. Given that some inclines here were nearly a mile long (and were to be made longer still elsewhere), have you ever wondered how the men at the bottom communicated with the men at the top? It was clearly essential that the men at the bottom communicate to the men at the top that work at the bottom had been completed satisfactorily before those at the top released their wagons. Various methods were adopted across Britain for doing this, the method here being for the bottom to pull on a large iron lever to pull a wire and hoist a large wooden disc at the top. Could this simple mechanical system also date back to George Stephenson's time?

Combining information from Easton & Dunn's analysis of 1827 and Robinson's report from about 1830 produces rare information both very detailed and extremely interesting:

Statistical and operational information, Hetton Railway, 1827-30
based on Messrs. Easton & Dunn's report of 1827 (NRO 3410/Wks/10, doc.2) for columns 1-5
and Robinson's report dated about 1830 (NRO 725/F/17, 282) for column 6

Section	Length	Power	Cylinders	Boilers	Details of railway operation
Hetton to Rough Dene	2541 yards	2 traveling engines	2 @ 9in x 24in	50 psi	1 loco takes 12 mins to haul a full set of 16 waggons, then13 mins to haul empties, 4 mins for coal & water and is ready to take another set in 1 min = 30 mins = 4 keels, 2 engines at work = 8 keels per hour = 168 tons
Byer Plane	882 yards	Byer Engine	2 @ 30in x 60in	3 @ 14ft diam	Hauls 8 full waggons [and lets 8 empties down], ready to haul another set in 8 mins = 7½ keels per hour = 157½ tons
Flat Plane	775 yards	Flat Engine	[one] 22in x 56in	2 @ 17ft diam	Draws 16 loaded in 7½ mins, runs 16 empties back in 3½ mins, ready to draw another set in 3 mins = 14 mins = 8½ keels per hour = 178½ tons
Warden Law Plane	775 yards	Warden Law Engine	2 @ 30in x 60in	3 @ 14ft diam	Draws 8 full waggons [and lets 8 empties down], ready to draw another set in 6½ mins = 9½ keels (nearly) per hour = 199½ tons
1st Incline Plane	1302 yards	self-acting	-	-	Runs sets of 8 in 5½ mins, ready to run again in ½ min, = 6 mins = 10 keels per hour = 210 tons
2nd Incline Plane	1224 yards	self-acting	-	-	Runs sets of 8 and is ready to run again in 5¾ mins = 10¼ keels per hour = 215¼ tons
3rd Incline Plane	716 yards	self-acting	-	-	Runs sets of 8, ready to run again in 3¾ mins = 16 keels per hour = 336 tons
4th Incline Plane	902 yards	self-acting	-		Runs sets of 8, ready to run again in 5¼ mins = 11½ keels per hour = 241½ tons
4th Engine Plane	2602 yards	Fourth Incline(d) Engine	[one] 22in x 60in	2 HP @ 30ft long 6ft diam	Lowers 24 fulls in 11½ mins, ready to draw 24 empties in 2½ mins, which it draws in 10 mins= 3 keels in 24 mins = 7½ keels per hour = 157½ tons
Winters Lane to Staith Engine	1748 yards	Winters Lane Engine Staith Engine	[one] 16in x 48in [one] 22in x 72in	1 @ 26ft long 6ft diam 2 HP @ 30ft long 6ft diam	Takes 2½ mins to give signals to Staith Engine, which then runs 24 full waggons in 7 mins, takes 1 min to give signal and then the Winters Lane Engine draws 24 empties in 7 mins = 18½ mins for complete sequence = 9½ keels per hour = 199½ tons [The Staith Engine was also being used to haul "timber and other goods from the Quay", which Robinson says reduced its ability to handle coal traffic by one-third]
5th Incline Plane	325 yards	self-acting	-	-	Runs sets of 4, ready for another set in 3½ mins = 8½ keels per hour = 178½ tons. This served Nos. 2 and 3 drops
The 1827 report lists a '1st Staith Engine' (the one above being the '2nd Staith Engine'), which is assumed to be the 'Bell Engine' listed by Robinson			[one] 16in x 48in	1 @ 16ft long 5½ft diam	Runs 2 full waggons in 1 min, draws up 2 empties and is ready to run another set in 1½ mins = 2½ mins = 6 keels per hour = 126 tons

In studying this, remember that 1 chaldron = 2.65 tons; 8 chaldrons = 1 keel = 21 tons. Robinson's analysis of his survey is equally revealing. In such a fragmented system operationally, its capacity is limited to that of the slowest section – the 4th Engine Plane, at 7½ keels per hour. He expands this to equal "90 keels for 12 hours, which is as much working time as should be calculated daily. But as stoppages altogether cannot be avoided, it will frequently happen that these men will be detained for 14 or 15 hours for the above quantity. If we suppose that there are 10 working days per fortnight and 25 fortnights per year, that gives 250 working days at 90 keels, or 180,000 chaldrons per year" [which equals 477,000 tons per year]. He continues "the principal breakages arise from the breakages of chains or ropes and from the mistakes of men and boys in dark nights and mornings and in stormy weather", which he says are unavoidable. Interestingly, yet another valuation of Hetton Colliery, by the viewers Matthias Dunn and George Hunter as at 31st December 1830 (35) lists the total of men and boys employed on the Railway as 83, with 52 labourers, including waggon riders and greasers; 16 others employed on inclines, 9 at the staiths and 6 locomotive enginemen, with the drivers being paid 21 shillings per week and their firemen 13 shillings per week. So far as is known, all of these men worked one shift a day, which was obviously as long as was needed (and accounts for the beds in the incline cabins).

But Robinson's brief from the company's directors was not only to analyse the current operation and capacity of the Railway, but to examine what would be required to increase its capacity to 125 keels per day, that is, 250,000 chaldrons, or 656, 250 tons annually, which must surely be a staggering figure for 1830. To achieve this he says extra power would be needed, by utilising another locomotive and increasing the power of the engine houses, by altering the track layout and thus the operation on the inclines, by adding a further 84 waggons and by adding a further drop at Sunderland. The cost of these alterations he estimates as £12,091. The company had spent a huge amount of money in sinking first Hetton and then Elemore Collieries and in building the railway; its indebtedness to its bankers is shown as £92,690 on 31st December

1826, though this had fallen to £55,879 a year later, and was helpfully re-adjusted to £36,810 by a downward valuation of its stock (44). But Eppleton Colliery was still sinking and the prospect of having to spend yet more on the Railway can hardly have pleased the directors. In the event the Warden Law Engine was replaced, as we have seen, but currently no evidence has come to light to indicate that the other changes that Robinson advocated were carried out.

In the 1850s locomotive haulage was restored on the northern section and was eventually extended through to the staiths. To the south, the Flat Engine was replaced in 1876 by a new Byer Engine. Its design was almost certainly unique, and I thought a description of it might be of interest.

This new engine, said to have been 350 hp, may well have been unique in that it was designed to work two uphill gradients on either side of it. It was also provided with four drums, which again may well be unique. It was built in 1876, Works No. 125, by The Grange Iron Co of Belmont, near Durham City. This was a firm of general engineers, of which there were several in North-East England, building stationary engines and a handful of steam locomotives, as well as handling a wide range of smaller engineering work. Its records do not survive, and there is no full contemporary description of the engine. However, a series of excellent photographs of both its exterior and interior were taken in the 1950s and from them it has been possible to produce the following understanding of how it was driven and how its design enabled it to carry out the operation of the two inclines simultaneously.

The first view shows the front of the engine house, facing Hetton. The boiler house on the left is believed to have housed three, or possibly four, Lancashire boilers. To the right of the engine house is the bank foot for the section up to the Flat, sometimes called the Flatts, with fulls on the left and the kip for empties on the right. The rope for the western side of the Engine bank can be seen emerging through an aperture at ground level below the window; the rope for the eastern side is not visible, but was carried from the engine house underground to emerge near to the kip. Looking through the open door of the engine house, it may be observed that the drums were in pits below ground level. The second picture shows the view looking in exactly the opposite direction, with a set of fulls just coming over the kip.

The full page interior view illustrates the engine from immediately behind the driver's platform, but with his wooden chair removed, normally positioned centrally on the platform. Immediately in front of him is the steam control valve - the throttle or regulator – for admitting or reducing the steam to the horizontal cylinders which flank the engine. Fixed to the steam pipe serving the left hand cylinder is the circular steam pressure gauge. To his right but located slightly higher is the forward/reverse lever, capable of being slid up and down in its quadrant but here in neutral. At a higher level again, only operable by the driver standing up, are the two long cranked handles which operated the brakes on the two drums at the front of the engine. Note that the guide that the left hand handle slid down in has been filled with a wooden block to prevent it being operated, as by this time the front left hand drum was no longer in use. On the right hand guide there is a chain with a pin, so that the handle could be pulled down and the pin inserted to keep it in position. Immediately to the left of the missing driver's chair is the electric bell signal apparatus for receiving and giving signals to the bankhead man. Between this and the main steam pipe to the left hand cylinder, lagged to insulate the heat, can be seen the Engine Bank indicator, which by means of a moving pointer, here near the bottom, showed the driver the position of the sets on the incline. Note that this pointer is wired to a bell, which it rang when passing certain points. Below the 'X', about half way up the indicator, are two horizontal white bars, with the words MEET INGS above them, indicating the places where the sets passed.

The two wheels immediately in front of the platform are the clutch wheels for the two rear drums, enabling them to be wound in and out of mesh with the drive pinions via the long shaft running across the back of the engine. These could only be operated at floor level and may have been the responsibility of the second man in the engine house. The large lever on the right, angled at 45 degrees and kept in position by another pin is the brake lever for the right hand rear drum and is mounted on a sleeve on the clutch shaft; the brackets for the ends of the semi-circular underslung band brakes can be seen on the same sleeve, either side of the brake lever. The lever for the left hand rear drum is hidden behind the mounting for the electric bell apparatus, although the top of the handle and the bottom section of the guide can just be seen. The rims of the drums – the brake paths - are shiny because of the band brakes tightening on them. Each drum can be braked separately, but in practice most of the braking would have been almost certainly done by using the engine itself. As this view shows, the two cylinders were located slightly backward of the rear drums. Unfortunately, the size of the cylinders is not known.

The drums followed the traditional nineteenth century Durham practice, being probably not more than 3ft wide. As viewed from the driver's position in back to Illustration 31, the left hand rear and right hand front drums carry the ropes for the Engine Bank. To make their work possible, both drums had to be the same diameter and to revolve in the same direction, so that as one rope on one drum wound on, the rope on the other wound off. On the front drum the rope came off the top, while on the rear drum the rope came off the bottom and passed under the drum in front of it, remaining underground until outside the engine house and coming to the surface to reach the bank head. Because on the Flat side the engine had still to haul uphill, the basic design here was direct haulage over a single track. The main rope on the rear right hand drum came off the bottom and out of the engine house underground, passing round two sheaves to bring it through two right-angles and so enable it to run in a covered gulley alongside the track up to the Flat bank head. Here there was a return wheel in a pit between the tracks at the northern end of the pass-bye, which brought the rope round 180 degrees and out again, to run down between the rails back to the bank foot, where its fulls were waiting. This layout kept the outward and inward ropes from fouling each other.

For normal working just three drums were used, the right hand front (RHF) and left hand rear (LHR) for the 882-yard Engine bank, both the same diameter but with the rope coming off the top of the former and off the bottom of the latter, and also the right hand rear drum (RHR) for the 775-yard Flat side, with the rope also coming off the bottom. Latterly sets of five 10-12½ ton wooden hopper wagons were run on the Engine and Warden Law inclines, and also four self-acting inclines north of Warden Law. To avoid the single-line Copt Hill-Flat section becoming a bottleneck, sets of ten were run here.

With a set of ten fulls on the west side of the Flat bank foot, ten empties on the kip next to them divided into two sets of five, and all four drums were out of gear, the operational sequence would begin with :

1. The rope from the RHR drum, running up to the return wheel at the Flat and then back down, is attached to the set of ten fulls. The first of the two sets of five empties is run by gravity from the Flat bank foot to the Engine bank bank head and the rope from the LHR drum attached. The rope from the RHF drum at the bottom of the Engine bank is attached to a set of five fulls. While this was being done the engine house men were putting all three drums into gear. Then

2. Simultaneously:
(i) on the Engine bank the empties descend from the bank head (LHR drum) and the engine hauls the fulls from the bank foot using the RHF drum. On arrival these fulls are run by gravity to the Flat bank foot;
(ii) the engine hauls the set of ten fulls up to the Flat. Both rear drums are rotating in the same direction.
(iii) the second set of five empties from the Flat bank foot is run by gravity down to the opposite side of the Engine bank bank head kip.
(iv) Meanwhile the Warden Law Engine to the north has completed the running of two sequences of five fulls up and five empties down, so that there are now ten empties waiting at the Flat ready to descend.

3. On the arrival of all three rope-worked sets, the rope from the LHR drum is attached to the next set of fulls at the bank foot, the rope from the RHF drum is attached to the set of empties now arrived by gravity at the opposite side of the bank head kip, while at the Flat the rope end is attached to the set of ten empties. While all this was happening, the haulerman reversed the engine and the RHR drum taken out of gear. Then simultaneously :
(i) on the Engine bank the empties descend from the bank head (RHF drum) and the engine hauls the fulls from the bank foot using the LHR drum. On arrival they are run by gravity to the Flat bank foot to join the five already there;
(ii) on the Flat side the ten empties descend by gravity, controlled by braking the RHR drum.

At the end of this sequence the position of fulls and empties on the Flat was as at the beginning above.

However, the nineteenth century engineers knew from experience that there were occasions when the power of the wind made it difficult to bring the ten empties down from the Flat. So the Byer Engine was provided with a fourth drum, the left hand front drum. This was the same size at the RHR drum and the rope also came off the bottom, but going forward, emerging from the engine house underground and then going round a sheave to change its direction to reach the Flat bank bank foot.When the wind was strong, this 4th drum rope was attached to the rear of an ascending set of fulls to convert the operation of the Flat bank from direct haulage to main-and-tail haulage. The sequence was the same as above for 1 and 2, except that the ascending set of fulls to the Flat was now hauling the LHF drum's rope as a tail rope, with this drum out of gear. On arriving at the Flat this rope was attached to the front of the fulls waiting to descend, while the rope from the RHR drum was attached to the back of the set and the drum taken out of gear. Now both the LHF and RHF drums had to haul, rotating in the same direction, while the RHR drum was braked and the LHR drum was in gear, again with both rotating in the same direction. Using the engine in this way, to haul and brake on both inclines simultaneously, meant that the two operations had to be completely synchronised, achieved presumably by having marks on the drum. Almost certainly the engine was unique in Britain in having this facility.

However, by the 1950s the LHF drum had had its rope removed, so clearly main-and-tail working had been abandoned. In one visitor's notes he mentions that roller bearings had been fitted to the rollers between the engine house and the Flat, enabling them to run more freely, and perhaps because of this, when the rope on the front drum became due for renewal, it was decided that it was no longer needed.

Changes and minor improvements continued after 1876, but in this basic form it continued in operation until 9th September1959.

The Hetton Railway occupies a unique place in the international history of railways. Although horses were considered, it was the first new railway to incorporate the use of locomotives. It was George Stephenson's first essay in railway design, and it is thus hardly surprising that it gave its owners problems. Even though it is clear that much of the detail was left to others, the route of the line, with its curves and the overall design of the rope inclines and the innovative design of staith would all appear likely to have been his direct responsibility. A combination of the curves and the increasing quantities of coal carried stretched his locomotives on the northern section beyond their ability to work economically. Indeed, as the capacity of 60,000 chaldrons per year upon which Stephenson had based his design rose to three times that figure in only eight years, the company and the engineers it employed were compelled to appraise the line and do what they could to change that design. With such detailed documentation now available, the Hetton Railway's first ten years are a fascinating study of a new railway struggling with the technology of the day to cope with the ever-increasing demands placed upon it.

(1) A Guy and J Rees (eds), *Early Railways* (London, 2001).
(2) M J T Lewis (ed), *Early Railways 2* (London, 2003).
(3) For example, L T C Rolt, *George and Robert Stephenson* (London, 1960)
(4) C E Mountford, *The Private Railways of County Durham* (Melton Mowbray, 2004).
(5) For example, C E Lee's (ed) note in *Railways in England in 1826 and 1827* (Cambridge, 1971, p.34), English translation of the German text of C von Oeynhausen and H von Dechen, *Concerning Railways in England : Observations collected during a Journey in the Years 1826 and 1827* in *Archive fürBergbau und Hattenwesen, XIX (1829).*
(6) Durham County Record Office (DCRO), Londonderry Collection (D/Lo), C/142/1/3 (2).
(7) DCRO, D/Lo, Acc. 1750(D), 24/4.
(8) DCRO, D/Lo, Acc. 1750(D), 24/4.
(9) North of England Institute of Mining & Mechanical Engineers (NEIMME), Newcastle upon Tyne, 3410/Wat/3/59/2, doc.3.
(10) Northumberland Archives (NA), 725/F/17, 222.
(11) The one-storey house in Hetton in which Robert Stephenson lived can still be seen, now marked with a plaque.

(12) Liverpool Record Office, 385/JAM/1/5/1, letter from George Stephenson to William James, 7 October 1821.

(13) G.Dodds, *Observations on Railways.............*, written in December 1824 and now in private ownership, p.10.

(14) Dodds, p.15.

(15) Dodds, p.4.

(16) von Oeynhausen and von Dechen, translation in 1971, p.39.

(17) NA, 725/F, pp. 57-61, 62-67, 68-72. This volume is a Viewbook of Nicholas Wood (1795-1865).

(18) NEIMME, 3410/Bud/32, 110. Dodds records that between 18 November 1822 and 30 November 1823 the number of chaldrons led from Hetton Colliery was 53,823, and that by 26 September 1824 this total had risen to 109,279. All of this was by one, then two locomotives, at a cost of 'one penny and three farthings & 4/5 of a farthing nearly per chaldron' (Dodds, 17).

(19) NEIMME, 3410/Wks/10, doc. 2.

(20) NA, 725/F/17, 279-86.

(21) Dodds, 19, states that on the sections where locomotives were used the rail, which was three feet long, and its chair weighed 73 pounds @ 9s/6d per hundredweight, totalling £871 16d 6d and that in one mile of way [track] there were 2,816 rails and chairs, supported by 2,816 blocks of stone or wood @ 6d each, totalling £70 8s 0d.

(22) Newcastle Library & Information Service (NL&IS), Tomlinson Collection, 6749-5, Vol.1, 57, letter of William Losh to Edward Pease, 3 November 1821.

(23) NA, 725/F/17, 294. This is confirmed by Dodds, who gives the annual replacement cost as £120, excluding accidents (Dodds, p.19).

(24) NA, 725/F/17, 260.

(25) NA, 725/F/17, 271.

(26) NA, 725/F/17, 57-8.

(27) British Geological Survey, 923, Vol.24, doc. 313.

(28) NA, 725/F/17, 282-3.

(29) NA, 725/F/17, 64.

(30) NEIMME, 3410/Wks/10, doc.2.

(31) von Oeynhausen and von Dechen, 1829, translation in 1971, p.36.

(32) A major survey and analysis of this Engine was undertaken by J.Free for his dissertation towards a degree in Mechanical Engineering at King's College, Newcastle, then part of the University of Durham, and published by the university in the *Journal of the Stephenson Engineering Society,* 1955-56, 98-118. This is now held by the Special Collections Section of the Robinson Library in Newcastle University.

(33) NA, 725/F/17, 62.

(34) NL&IS, L.920/S836. Dodds gives meticulous detail of the working of the locomotives, including 'On Friday 27 June 1823 this engine [at Hetton] led 388 chaldrons the above distance [1½ miles], and travelled the ground 23 times backward and forward, which was upward of 66 miles in 16 hours – it would have taken 12 horses to do the work. The same day two of the Locomotive Engines on the lower [northern] part of the way took 336 chaldrons 4350 yards.....each engine travelled 47½ miles in 16 hours....[the cost], including every item of charge for labour, keep of engine, repairs, etc., is about 5/6 of a farthing per ton per mile, including the weight of both waggons and coals' (Dodds, p.24).

(35) NA, 725/F/17, 259.

Colin E. Mountford
9th March 2012.