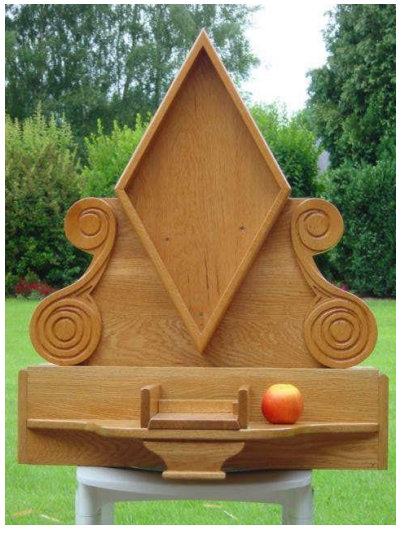
JOHN LIFFEN TALKS ABOUT THE 5-NEEDLE

INTRODUCTION
William Fothergill Cooke and Charles Wheatstone patented the first practical electric telegraph system in 1837. Demonstrations using multi-needle instruments were given to the Directors of the London and Birmingham Railway (L&BR) at Euston and Camden Town later in 1837, but the electric telegraph was not adopted by the L&BR at this time. In 1839 Cooke installed a demonstration line alongside the Great Western Railway (GWR) between London Paddington and West Drayton using four-needle instruments.
This was the very first electric telegraph in the public domain in the world (and thus 5 years before Samuel Morse did so in America between Baltimore and Washington in 1844).
The idea then occurred to me to make (or have made) a replica of the 5-needle model, also because of its attractive shape.
To this end, I contacted the then curator of the Science Museum in London, Mr. John Liffen. After all, the museum had an extensive range of apparatus by Cooke and Wheatstone, including variants of the 5 needle telegraph. I was invited in the Museum and then we went to the 'Reserves' building to look, measure and photograph the 5-needle telegraph.
From there on the work could begin. In a" Provincial Technical School", the attractive piece of furniture was made: it was the "final work" of two students of the carpentry department. And together with a friend, I then made the metalwork and wiring.



I have had further good contacts with John Liffen. During that period he did a lot of research on this type of telegraph. He then honored me by sending the result of his study for review. And his final -and very important- document, **with startling conclusions**, can be found here further below in pdf form (22 pages).
But before this study was completed he had already emailed me the most important conclusion for me.

"For the last year I've been researching the paper I am delivering on Saturday. This concerns the very first British electric telegraphs and attempts a re-identification of the multi-needle telegraphs held in museums in the UK. I have to tell you that I have come to some rather startling conclusions about the date of manufacture of the particular Cooke and Wheatstone five-needle that you are having copied. I must emphasize that this has emerged only recently, and as a result of some concentrated research among Cooke's correspondence and various records of patent infringement cases brought by the Electric Telegraph Company between 1846 and 1850. As a consequence, however, ***I believe that the five-needle we have on show here (and its exact counterparts in Berlin and Sydney (Australia)) are not original 1837 instruments, but half-size copies made by the ETC in 1849 to demonstrate at a court case.*** *I also believe that the original 1837 instruments (which are much larger) still survive and are the two dials still belonging to King's College London, one of which is displayed in a modified form in the Royal Museum of Scotland, and the other, hitherto unidentified, having been held on loan in store by the Science Museum from King's since 1963.* ***I am also satisfied that five-needle instruments did not form part of the equipment supplied by Cooke on contract for the Great Western Railway in 1839.*** *For the last few months I have been worried about telling you this because of your own initiative to commission the copy of the five-needle. However, at the time of your visit I had not started the research and had no reason to express any reservations. I await your response with some apprehension."*

If you would like to read the full final report (30 pages) see the pages below.

int. j. for the history of eng. & tech., Vol. 80 No. 2, July, 2010, 268–99

The Introduction of the Electric Telegraph in Britain, a Reappraisal of the Work of Cooke and Wheatstone

John Liffen
Science Museum, London, UK

William Fothergill Cooke and Charles Wheatstone patented the first practical electric telegraph system in 1837. Demonstrations using multi-needle instruments were given to the Directors of the London and Birmingham Railway (L&BR) at Euston and Camden Town later in 1837 but the electric telegraph was not adopted by the L&BR at this time. In 1839 Cooke installed a demonstration line alongside the Great Western Railway (GWR) between London Paddington and West Drayton using four-needle instruments. Although trials were successful the telegraph line was afterwards little used by the GWR and was abandoned within a year or so. Precise details of the equipment used on these demonstrations have always been unclear, leading to ambiguity in the identification of surviving instruments preserved in the Science Museum, London, and elsewhere. Recent close examination of these along with a new interpretation of contemporary documents shows that the widely held belief that five-needle instruments were used on the 1839 GWR installation is incorrect. It is also argued that the small five-needle instrument displayed at the Science Museum, London, and two similar specimens held elsewhere, are not the original instruments demonstrated in 1837 but working models made for a patent infringement trial in 1850. Conversely another five-needle dial owned by King's College London and on loan to the Science Museum can now be identified as almost certainly one of the original 1837 instruments.

keywords Cooke, Wheatstone, Farey, electric telegraph, patents, London and Birmingham Railway, Great Western Railway, Science Museum, King's College London, Court of Common Pleas

Introduction

The introduction of the practical electric telegraph stemmed from Hans Oersted's demonstration in 1820 that a current of electricity passing through a wire exerts a

DOI 10.1179/175812110X12714133353911

turning effect on a magnetic needle placed near it. The essential elements of a telegraph based on this principle were developed over the next twenty years. Carl Friedrich Gauss and Wilhelm Weber in Gottingen in 1833, Pavel Schilling in St Petersburg at about the same time, and Carl Steinheil in Munich in 1836, all showed apparatus made in this way. Samuel Morse, in the USA, began to consider an electric telegraph, on different principles, in 1832 but his ideas did not culminate in a work- able system until 1844. The Morse telegraph was the one to be ultimately adopted in most parts of the world. In the 1830s, however, all these systems were little more than lecture-theatre demonstrations.

In order to break out into the wider world the electric telegraph needed to have strong commercial applications. Morse saw this, and so too, crucially, did William Fothergill Cooke (1806–1879), a British ex-army officer. In March 1836 Cooke was in Heidelberg studying anatomical modelling. Almost by chance he attended a demonstration by Professor G. W. Muncke, Professor of Natural Philosophy at the Anatomical Institute in Heidelberg, of an experimental electric telegraph of the type developed by Schilling. Cooke was immediately struck by the practical uses of such equipment and set to work to make his own copies. He brought these to London and in 1837 teamed up with Professor Charles Wheatstone of King's College London. Over the next few years this partnership developed equipment which was demon- strated to several British railway companies, Cooke having determined that railways were an ideal customer for sending messages many miles almost instantaneously. After three years of campaigning and demonstrations to several companies an electric telegraph was installed in 1840 on the London and Blackwall Railway. When it opened on 6 July 1840, it was the first successful commercial application of an electric telegraph anywhere in the world.

The London and Blackwall installation was preceded by demonstration telegraphs along short lengths of the London and Birmingham Railway (L&BR) in 1837 and the Great Western Railway (GWR) in 1839. Contemporary published accounts give a reasonable amount of general information on these installations but precise details are sparse. A description by Wheatstone of the 1839 GWR installation given to a House of Commons committee in 1840 is almost the sole source of technical informa- tion about it. Wheatstone provided a description and illustration of his 1837 telegraph instrument, implying that this design was used. The Parliamentary report received wide circulation in the technical press at the time and has been accepted uncritically by historians ever since. However, a comparison with almost all other contemporary sources suggests that Wheatstone was being economical with the truth. It is the pur- pose of this paper to examine the reasons for this and to attempt a new identification of the apparatus used in these pioneer British installations. Crucially, it will argue that an instrument described by the Science Museum, London, as Cooke and Wheatstone's earliest needle telegraph and one that was used on both the L&BR and GWR telegraphs is in fact a demonstration model not made until 1849.

The Cooke–Wheatstone partnership

Schilling's telegraph comprised instruments each with five-needle galvanometers with suspended needles, working with six wires, one being a common return. Mounted on

each suspension was a paper disc with a vertical line on one side and a horizontal line on the other. As the galvanometer needle rotated it would make one side of the disc visible, then the other. Messages would be sent using some kind of code. Muncke's version was two instruments, each with a single needle, placed in different rooms.[1] Cooke's copies had three needles and six wires, and he worked out a code giving an alphabet of twenty-six signals. He also devised an electrically operated clockwork alarm bell, and within six weeks he felt he had the makings of a practical electric telegraph system.

Cooke returned to London in April 1836 and worked hard on making further instruments for demonstration, including a synchronous dial telegraph he described as a 'mechanical telegraph'. He showed this to the directors of the Liverpool and Manchester Railway in January 1837, suggesting its use at each end of tunnels, but they thought it too complex for sending the few signals required. Cooke began to design a simpler version, and at the same time experimented to find out the farthest distance that he could operate an electro-magnet. He erected a mile of wire in a friend's room with unsuccessful results. Having little scientific training himself, Cooke sought advice from Michael Faraday of the Royal Institution and Peter Mark Roget (1779–1869), Secretary of the Royal Society. Roget advised Cooke that Professor Wheatstone of King's College had a large quantity of wire and gave him an introduc- tion to him. Cooke called on Wheatstone on 27 February 1837. Charles Wheatstone (1802–1875) had been appointed Professor of Experimental Philosophy at King's College in 1834. He told a crestfallen Cooke that he too had been considering an electric telegraph for several years as part of his work studying the velocity of electric- ity. In particular he had devised a 'permutating keyboard' which enabled the number of wires needed for a multi-needle telegraph to be reduced, an important considera- tion before the earth return had been discovered. Nevertheless, over the next few weeks they tried many experiments on the electro-magnet over long distances, but Wheatstone had no better success than Cooke. It was possibly only when Wheatstone was paid a visit on 11 April by Professor Joseph Henry, Professor of Mathematics and Natural Philosophy at the Albany Academy, New York, that this difficulty was solved.[2] Henry told Wheatstone of his research on the relationship between the resist- ance of wire and the relative number of cells in a battery, and his description of what is now known as the relay.[3] With these revelations Wheatstone then understood the difficulties under which he and Cooke had been labouring.

With the technical problems receding, Cooke and Wheatstone agreed to enter into a partnership to promote the electric telegraph commercially. They applied for a patent which was granted on 12 June 1837.[4] Under the existing patent law they had six months from that date to submit the specification. Freed from secrecy Cooke was ready to exploit the invention. He recorded his progress in a series of detailed letters to his mother. While in part they represent a natural wish to recount his activities to a close relative, there is no doubt that the letters were also intended to stand as dated and postmarked evidence of the state of Cooke's innovations at any particular time in case of later disputes over priority.

The telegraph on the London and Birmingham Railway

In May 1837 Cooke and Wheatstone were planning a demonstration of the telegraph from one side of the River Thames to the other and had arranged with Enderby

Brothers, a sailcloth- and rope-maker in Greenwich, to cover sufficient wire with yarn to make a 'rope'. It is unclear whether or not the demonstration took place. Cooke had also heard that some form of communication was needed on the extension of the London & Birmingham Railway (L&BR) from Camden Town to Euston, which was almost ready for opening. Owing to the steepness of Camden Bank trains were to be hauled as far as Camden Town by an endless rope driven by winding engines located there. The winding house would need some kind of indication from Euston that a train was ready to start. On Friday 23 June Cooke was introduced to George Carr Glyn, the Chairman, and Richard Creed, the Secretary of the L&BR.[5] On 27 June he was introduced to Robert Stephenson, the L&BR's engineer, and was given permis- sion to use the carriage shed at Euston for his experiments. On Tuesday 4 July Cooke, by working flat out, had installed a 13-mile circuit inside the carriage shed. That morning about twenty of the L&BR's directors, together with Stephenson, witnessed a demonstration given by Cooke alone, as Wheatstone for some reason could not be present.[6] The instruments used were the two 'mechanical telegraphs' Cooke had made for the Liverpool & Manchester Railway, and his 'Heidelberg' (Schilling) pattern instruments with the horizontal coils and suspended needles.[7] The demonstra- tion went well and another was arranged for Monday 10 July for Stephenson, Creed and John Prevost, a director of the L&BR. Cooke wrote to his mother that night:

> Mr Stevenson [*sic*] and Mr Creed have both been with us today, and took the deepest interest in our experiments. They wish, however, to see the effect in greater distances still, and I have received orders to get more wire and extend along the road.[8]

Cooke had extended the circuit to Camden Town by Monday 17 July, but this was evidently vulnerable to damage, as a letter he wrote to Creed that day shows:

> As it is possible that you may have appointed this morning for Mr Stevenson's inspection of our telegraphic experiments I lose no time in informing you that the four wires which I have extended from Euston Station to the Engine House Camden Town are disarranged. From their exposed situation along the road they are necessarily beyond my entire control and are subject at any moment to injury either from wantonness or accident. The one broken connection may be restored presently, but if not I shall not have time later in the day to give you notice. [. . .] An accident of the present description is liable to happen when 4 great lengths of wires are stretched along a road frequented by numerous workmen. I will take every precaution to prevent its recurrence. Beyond a doubt every- thing will be in good order before the train returns in the evening. The wires have been extended to the Engine House (where one of our telegraphs is placed) in accordance with Mr Stevenson's wishes making a circuit of nearly 19 miles.[9]

The following Thursday, 20 July, public services began on the L&BR from Euston as far as Boxmoor, about 25 miles away. The winding engines at Camden Town were not, however, ready for use and until 14 October steam locomotives were used to haul trains up the bank out of Euston.[10] This would explain Prevost's encounter with one, described in a letter from him to Cooke dated Monday 24 July:

> As I was walking yesterday down the extension line, an engine unexpectedly overtook me under the lower tunnel, and I crossed to the other side, between two of the square pillars.

figure 1 Thomas Talbot Bury, 'View taken from under the Hampstead Road Bridge, looking towards the Station at Euston Square', an aquatint published by Ackermann & Co. on 18 September 1837. The viewpoint is the 'lower tunnel' mentioned by Prevost in his letter to Cooke of 24 July 1837. ScM Inv. 1906-18, ScM/SSPL 10419925.

> If this had happened in the upper tunnel, I might have run against your wires, and perhaps unfastened some of the nails which secure them to the arch, where they cross the line. The result might be that the wires hanging across would catch and cut the first passengers of a train coming down.[11]

The 'lower tunnel' was the covered way under the Hampstead Road (Figure 1), the 'upper tunnel' the similar covered way under Park Street (now Parkway). The use by Prevost of 'wires' and 'the nails which secure them', also Cooke's reference to '4 great lengths of wires', suggest that the circuit comprised four separate wires, each presum- ably covered in silk or yarn for insulation, separately fixed to the brick-lined side wall of the railway cutting using nails or possibly iron staples. However, Cooke in 1875 responding to a query by Latimer Clark concerning Prevost's letter, referred to 'the wire rope', which suggests that the insulated wires were gathered together and enclosed within cloth wrapping as described in the 1837 patent specification.[12] According to Cooke, the Enderby rope intended for the cross-Thames experiment was tried at the L&BR but the insulation failed when it received a soaking from rain.[13] It will probably now be impossible to confirm which configuration was used, but perhaps more weight should be given to the contemporary descriptions than to a recollection thirty-seven years after the event.

On Tuesday 25 July another demonstration took place.[14] This time Cooke was at Camden Town and Wheatstone at Euston. Recalling the occasion for Latimer Clark in 1875, Cooke said that 'At the second experiment Wheatstone had arranged a hastily-made telegraph with 4 needles suspended vertically'.[15] This represented one of the most fundamental innovations Wheatstone made towards the successful intro- duction of the electric telegraph. By tipping up the Schilling design through 90 degrees and placing a board behind it, it became possible to make the telegraph self-indicating if letters were written on the board. Wheatstone weighted the needles so that they would remain vertical when no current was flowing, and he added stops on either side of them to limit their movement and make their action more positive. He arranged twelve letters in a diamond formation so that the movement of any two needles simultaneously pointed to the appropriate letter. Consequently no knowledge of a code was needed, an important point when trying to persuade non-technical clients of the telegraph's value. It seems likely that Wheatstone would have used the permutating keyboards that he had made before he met Cooke. The set-up would need four wires to operate it, which is the number Cooke had erected to Camden Town. The haste would arise if the decision to have these four-needle instruments made was only taken after Cooke had been requested only a fortnight before to extend the line to Camden Town. All the evidence points to this being the 'second experiment' Cooke referred to.

Again the demonstration was successful. Cooke wrote to his mother late the same night:

> Yesterday Mr Stevenson witnessed our experiments through 19 miles of wire, extended from Euston Square to Camden Town, and declared himself so satisfied with result [*sic*] that he begged me to lay down my wires permanently between those two points on my best plan, with a view to extending the communication hereafter, if the Directors approved. He wishes us also to have all our instruments on the most approved construc- tion, and I have consequently put several new ones in hand, to be ready, if possible, in a fortnight. [. . .] I have just given orders for 5,000 ft of wood to be sawn in a particular manner, with grooves for the wires, which I am going to have boiled in coal tar previously to laying down. Our wire is all ready.[16]

The conduit was a wooden block of trapezoidal section (Figure 2), in the top and two sides of which five copper wires were inserted, in grooves containing a resinous material. The grooves were capped with strips of wood, the whole being afterwards coated with a protective compound. The work of making and laying down this fir conduit was contracted to Sir Charles Fox, Stephenson's resident engineer on the L&BR.[17] Cooke arranged for two new telegraph instruments to be made. Like the four-needle instruments, the dials were in the shape of a diamond, reminiscent of the hatchment used for exhibiting armorial bearings. Consequently these instruments were often described as having 'hatchment dials'. Each was by a different maker: 'I got these made for five wires, one by Kirby, and one by Moore, the clock maker, Clerkenwell', recalled Cooke in 1875.[18] It has not yet been possible to identify Kirby precisely, but he was possibly associated with the firm of Kirby, Beard & Kirby, needle and pin makers of Cannon Street in the City of London. John Moore and Sons was a clock- and watch-making firm with a factory at 38 Clerkenwell Close, in the

figure 2 Portion of the 'fossil telegraph', the five-wire wooden conduit laid down by W. F. Cooke between Euston and Camden Town in August 1837. ScM Inv. 1867–37, ScM/SSPL 10313540.

heart of London's clock-making district. Cooke dealt with Josiah Moore, who also made the keyboards for the instruments. These were first made for four wires but were later altered for five wires. It seems that there were not ten buttons, arranged in two rows of five, with two to be depressed for each letter, but twenty buttons, one for each letter.[19] This was an arrangement suggested by Robert Stephenson.[20]

It was, however, not the fortnight that Cooke had hoped, but six weeks before the next demonstration took place. At 8 o'clock in the evening of Wednesday 6 Septem- ber Stephenson and Creed joined Cooke in his 'den underground' at the winding engine house, Camden Town, while Wheatstone was at Euston accompanied by Cooke's brother Tom.[21] Messages passed to and fro on the new twenty-letter five- needle instruments for more than an hour without a hitch. Stephenson was deeply impressed and said he would recommend to the L&BR's directors the general adop- tion of the electric telegraph on the railway. A demonstration to the Chairman and some of the directors of the L&BR took place a fortnight later, on the morning of Friday 22 September.[22] Though no contemporary description has been found of this occasion it was presumably as successful as the previous one. The following Tuesday the L&BR Station Sub-committee discussed the matter:

> The Secretary reported that the Chairman having authorized Mr Cooke and Professor Wheatstone to make a trial on the Extension Line under the superintendence of the Engineer of their system of Telegraphic communication by the means of Galvanic Electricity the result of repeated experiments at different times and under various circum- stances had been so satisfactory as to decide the Engineer strongly to recommend to the Company a Trial on a more extended scale and to secure for this object the services of Mr Cooke.[23]

On Tuesday 3 October the Chairman reported back that Cooke was full of enthusi- asm for extending the telegraph to Birmingham with an immediate extension of the trial to Harrow. The Station Sub-committee requested Stephenson to obtain an estimate from Cooke for this extension, but a few days later a terminal blow was delivered. The non- resident directors of the L&BR, based in the Liverpool area, had received a report on the works in the London area from two of their number on 30 September. They recommended no extension of the telegraph beyond Camden Town until 'further experience shall have tested its practical utility'.[24] The following week, with the Station Sub-committee's minute in front of them, the non-resident

directors made it very clear that they were not prepared to enter into further expenditure on trials of the telegraph without clear evidence of its usefulness.[25] The news was broken to Cooke on 12 October.[26] Despite his remonstrations the L&BR directors proved immoveable.

During this time Cooke and Wheatstone were negotiating the terms of their partnership agreement, which were proving difficult to resolve. On 19 November they had, however, reached agreement and were now working hard on the text of the patent specification, which had to be submitted by the second week of December.[27] In this they were assisted by John Farey, a patent agent who drew up the specification and prepared the accompanying sheets of drawings. There was a great deal to do (when printed in 1857 the specification occupied forty-two pages) and it seemed to Cooke that Wheatstone was concentrating on his own innovations, leaving little time for Cooke's to be included. On the last available day, assumed to be 12 December, much that Cooke wished to be included had still not been prepared, but he was very anxious to get in a reference to 'the return wire' — a common return enabling any needle to be operated singly, rather than in pairs as Wheatstone's hatchment dial required. In Cooke's words, 'a very warm discussion arose upon this point; I urging the great practical importance of the simpler arrangement, and Mr Wheatstone objecting that it would spoil the symmetry of his dial'. In the end Farey sided with Cooke and, using red ink and pecked lines, added a sixth wire and an extended keyboard on to his drawing of Wheatstone's five-needle instrument. After a last- minute scramble the specification and drawings were handed in at the Rolls Chapel a few minutes before midnight.[28] A separate Scottish patent was also granted on 12 December, a rival inventor, William Alexander, having waived his opposition.[29] A week later Cooke sent off the specifications, drawings and models in application for a United States patent,[30] though for some reason this was not granted until 1840.[31]

Meanwhile Cooke was negotiating with the L&BR to purchase the five-needle instruments now that that railway no further use for them.[32] He attended a meeting of the railway's Committee of Management on 14 December and they agreed to return them on payment to the Company of £31, about half their cost.[33] Having done so,[34] Cooke sold the instruments to Wheatstone, who had them removed to King's College on 16 January 1838.[35]

The telegraph on the Great Western Railway

The loss of further business with the L&BR was a setback but there was a glimmer of hope from another direction. The same day as the 22 September demonstration Cooke received a note from Isambard Kingdom Brunel, inviting him to call on either the following Sunday or Monday. Brunel was Engineer of the Great Western Railway (GWR), whose line between London and Bristol was still under construction. Presum- ably Brunel had been present at the demonstration.[36] Though no business resulted immediately from this meeting, Brunel remained in touch with Cooke and on 4 January 1838 took him on a trip out to Maidenhead in his carriage to view the GWR construction works.[37] Cooke remained in suspense until February when the GWR London Committee formally opened negotiations with him regarding the installation of an experimental line of telegraph.[38]

While these negotiations were in progress the specification of Cooke and Wheat- stone's Scottish patent was enrolled at Edinburgh on 10 April.[39] This was not just a duplicate of the English patent but contained much new material of Cooke's design, including items which had had to be left out of the English specification owing to the lack of time. Among these was a development of the four-needle telegraph which had been shown as a hatchment dial instrument in the December 1837 drawings. This incorporated the 'return wire' and operated both by converging pairs of needles for some letters and by indications of a single needle for others. In these new drawings it was shown in a more practical-looking rectangular case with a ten-button permu- tating keyboard integrally mounted below the dial, and developed into a communica- tion system comprising 'terminal' and 'intermediate' instruments. The intermediate instrument incorporated a 'current director' at the right-hand side of the dial, essen- tially a multi-point switch for cutting the instrument into or out of circuit. Also described was a portable double-needle instrument which was intended to be carried in trains and, when necessary, taken out and plugged into one of the junction boxes incorporated at intervals in the tubular line-side conduit. A switch at the side of the case connected the instrument to stations either up or down the line, or allowed through communication between them with the portable instrument switched out though still plugged in. The hybrid nature of the specification is borne out by the inclusion of the 'sixth wire' arrangement of the five-needle hatchment dial with the additions shown by pecked lines as before. The completeness of the four-needle system described shows that by the end of March 1838 Cooke had already worked out a practical telegraph system for railway application. A week later, on 18 April, a second English patent for these new designs was granted in Cooke's name only; the specification was enrolled six months later, on 18 October.[40]

Cooke took a strong line with the GWR negotiations, at one point withdrawing altogether. This strength of will apparently impressed the GWR and discussions were quickly taken up again.[41] They reached a successful conclusion in May 1838. Possibly taking warning from the ad hoc arrangements on the L&BR the previous year, the GWR directors negotiated a written agreement with Cooke and Wheatstone covering their respective responsibilities and obligations and the way the work would be fund- ed. The agreement was signed by all parties on 28 May 1838.[42] 'Now comes the proof of the patent', wrote Cooke that day to his mother.

The agreement was for the GWR to construct a line of six wires between Padding- ton and West Drayton, which was the first intermediate station from London, just over 13 miles away. If this proved successful there was an option to continue the telegraph to Maidenhead. It was to be used for railway purposes only and not for general commercial business. The equipment which Cooke intended to provide, to be described in detail later, showed that his plans had already moved on from using Wheatstone's hatchment dial telegraphs.

The terms of the GWR agreement suggest that it was expected that construction of the telegraph to West Drayton would take six months, but in fact it was not until 9 July 1839, over a year later, that Cooke could report to the GWR Directors that the telegraph to West Drayton was complete and ready for inspection.[43] In the mean- time, the first portion of the railway had opened from Paddington to Maidenhead on 4 June 1838 and additional stations at Ealing (5.75 miles out) and Hanwell (7.25 miles) had opened on 1 December 1838. Initially two terminal instruments, two

intermediate instruments and two portable instruments were provided.[44] Given the experimental nature of the installation, it appears that additional instruments were soon acquired. By December 1839 there were intermediate telegraph stations at the Ealing and Hanwell passenger stations and another at the GWR's stores depot at Bulls Bridge (10.5 miles).[45]

For about two months during October and November 1839 the installation was worked intensively for several hours each day. The passing times of trains at Hanwell and West Drayton were telegraphed back to Paddington and a record kept by a clerk.[46] This may have been inconvenient for the Superintendent at Paddington, in whose office the instrument was located, because Cooke was requested to remove it. On 2 December 1839 he reported to Charles Saunders, Secretary of the GWR, 'I have consigned the instrument at Paddington to its humble destination in the washing room, with such precautions as will I hope protect it against moisture'.[47] This was a rather perverse move, for in the same letter Cooke went on to comment on the difficulties that dampness had caused elsewhere:

> Three instruments which have succeeded each other at Hanwell, are so much injured by the damp, that I strongly recommend Hanwell being given up as a telegraph station 'till a dryer season of the year, there is a telegraph at Ealing and another at Bull's Bridge which will perhaps be as useful a post as Hanwell. On receiving your instructions I will have the instruments at those stations again examined, and the instrument removed. Should the Company hereafter proceed with the telegraph I shall recommend more simple instruments for intermediate stations, which might even be kept out of doors under charge of a policeman.[48]

Cooke also asked for the GWR directors' opinion on the usefulness of the telegraph, as the 'retirement' (Cooke's own word) of the Paddington instrument had caused some public comment. Saunders replied that the directors considered it a practical success and it was only the considerations of cost and a profitable return that weighed in any extension beyond West Drayton. He requested that the line be made direct between Paddington and West Drayton, with the instruments at Ealing and Hanwell being retained for use only in an emergency.[49]

Early in 1840 the House of Commons Select Committee on Railway Communica- tion turned their attention to the electric telegraph. On Tuesday 6 February the com- mittee interviewed Wheatstone and Saunders on the subject. The Minutes of Evidence of this interview have ever since provided historians with the principal and most readily accessible source of technical information on the original GWR installation.[50]

However, Cooke, who waited outside the committee room, was not called in to give evidence and unfortunately Wheatstone's evidence is sometimes inconsistent with other records.[51] The implications of this will be discussed later in this paper. Just over a week later, on Saturday 15 February, members of the Select Committee visited Paddington to see the installation, where both Cooke and Wheatstone were present to demonstrate it.[52] It is to be hoped that the instrument was moved to somewhere more suitable than the washing room.

The GWR's telegraph played no part in the regulation of train services, being used only for messages of a more general nature and not at all by the public. Cooke was released from day-to-day involvement with it in December 1839,[53] and after the Select Committee visit it was probably little used. It was described as still working in a short

article in *The Times* on 26 August 1840, but in another twelve months, if not earlier, it was defunct. Cooke wrote to Saunders on 21 September 1841 offering to install an electric telegraph for the GWR through Box tunnel. If they objected to the fresh expense, he suggested that 'a portion of the tube now lying useless between Padding- ton and Drayton might be removed and turned to account in the Box tunnel'.[54] The GWR did not take up this suggestion.

The reason for Cooke's withdrawal was that he was now hard at work installing an electric telegraph system for the 3½ mile cable-worked London and Blackwall Railway, which was in operation from the line's opening in July 1840. The equipment comprised single-needle instruments at each station which communicated with repeater instruments in the winding-engine houses at each end of the line. Using these instruments, signals were sent indicating when the engines were to be started and stopped. The equipment worked without major breakdown until 1849 when the line converted to conventional steam locomotive operation. By this time the electric telegraph was fast becoming an essential adjunct for business and commerce.

The arbitration dispute

During the first half of 1840 Cooke and Wheatstone were working on the specifica- tion of their third English patent, which had been granted on 21 January.[55] The specification was enrolled on 21 July. Included in it are two designs of alphabetical, or 'ABC', telegraphs. In each the letters were arranged on a circular dial. In one the dial rotated and successive letters appeared in a small window, while in the other the dial was stationary and selected letters were indicated by a rotating pointer. The former is a design particularly associated with Wheatstone; the latter seems to be Cooke's. There appears to be little suggestion of collaboration on the two designs and in fact as 1840 progressed Cooke became increasingly dissatisfied with the public perception of his standing within the partnership. The tenor of Wheatstone's printed evidence to the Commons Select Committee, published on 2 July, gave scant credit to Cooke, and the first question put to Charles Saunders referred to 'Mr Wheatstone's magnetic telegraph'. On 25 July *Chambers' Edinburgh Journal* included a long feature article on Wheatstone's research at King's College into the electric telegraph, including a description of the GWR installation, without mentioning Cooke's name at all. Cooke made representations to Wheatstone that his equality in the invention of the electric telegraph should be publicly acknowledged, but Wheatstone's respons- es were not acceptable to him. Following an exchange of letters they agreed in November to arbitration as a means of settling their differences, the arbitrators being Sir Marc Isambard Brunel (for Cooke) and John Frederick Daniell (for Wheatstone).

The arbitrators had a great mass of evidence to work through, most of it prepared by Cooke. As Marc Brunel put it, 'Mr Daniell was quite dispirited at the sight of the papers that were produced', and at his suggestion Cooke had them printed for con- venient reference.[56] In effect, however, the arbitration was not proceeded with. Brunel and Daniell were mindful of the financial interests at stake by both parties and decided not to examine the originality of the telegraph. Instead they compiled a care- fully worded brief statement of facts concerning the partners' work which studiously
avoided partiality. Cooke was 'entitled to stand alone […] for having practically

introduced and carried out the Electric Telegraph as a useful undertaking', while Wheatstone was 'acknowledged as the scientific man'. It was to their 'united labours' that the rapid progress of the electric telegraph was due.[57] This statement, dated 27 April 1841, was gratefully accepted by both partners and appears to have patched up their differences, at least for the next two years.

Cooke continued energetically to promote the electric telegraph to railway com- panies and during 1841 wrote a short book, *Telegraphic Railways*, describing how a single-track railway controlled by the telegraph would be safer and cheaper to construct than a double-track railway without it.[58] This was published in January 1842. Later that year Cooke patented his system of suspending bare conducting wires from ceramic insulators mounted on posts.[59] Together with the adoption of the earth return this brought down construction costs significantly and the telegraph was taken up by an increasing number of railways. Among these was a revival of the GWR telegraph, extending it to Slough using double-needle instruments. This was brought into use on 17 May 1843.[60] Wheatstone continued his work at King's College, and in 1845 the last patent of the partnership was granted. This was largely concerned with modifications to needle telegraphs, including a description of a single-needle system.[61]

It is not the purpose of this paper to undertake a further reassessment of who invented the electric telegraph. This depends on the interpretation of the words 'invention' and 'telegraph' and is not straightforward. On the other hand, the claims and counter-claims arising from the arbitration process have caused a fog of con- fusion to settle over the identity of the equipment used in the pioneer British instal- lations. A number of needle-indicating telegraphs survive in public and private collections in Britain and elsewhere. Unfortunately their provenance has been for the most part poorly recorded, leading museum curators and historians of the electric telegraph to make contradictory assumptions about the use of these preserved instru- ments in the pioneer installations. It is proposed now to attempt a more positive identification of the instruments used on the L&BR and GWR, based on an examina- tion of contemporary records and correspondence, and determine from this evidence where, if at all, the preserved instruments fit in.

The London and Birmingham Railway

The first demonstrations in early July 1837 were entirely inside the carriage shed at Euston station. As detailed above, Cooke arranged a 13-mile circuit on frames, using his 'two mechanical telegraphs made for the Liverpool incline'[62] and his copies of the Schilling telegraph with the needles suspended on silk wires. The Liverpool incline was the freight tunnel on the Liverpool and Manchester Railway between Edge Hill and Liverpool Docks. It is not clear from Cooke's account whether these were the instruments actually shown to the Liverpool and Manchester Railway directors in January 1837 but declined as being too complicated for their needs, or the simplified design of February 1837 of which four were made.[63] By 17 July Cooke had erected four wires to the winding house at Camden Town and, for the demonstration on 25 July, telegraphs with four needles suspended vertically were used, these being 'hastily-made' by Wheatstone. It is assumed the dials were in the diamond, or

hatchment, shape. As far as is known none of this equipment is now extant.

figure 3 Small five-needle electric telegraph instrument probably made in 1849, acquired by the Science Museum from the GPO in 1876. ScM Inv. 1876-1272, ScM/SSPL 10213638.

As a result of this successful demonstration Robert Stephenson authorized laying down the Euston — Camden Town telegraph more permanently. Two new five- needle instruments were made, one for Euston and one for Camden Town, joined by five-wire wooden conduit. A successful demonstration followed on 6 September. The identification of the conduit is certain, as portions of it were later dug up and preserved at the Science Museum, London, and elsewhere.[64] The identity of the five- needle instruments is far less clear. The Science Museum has a small five-needle telegraph which was received from the General Post Office (GPO) in 1876 (Figure 3). It has come to be described by the Museum as one of the original instruments used in 1837 in the London and Birmingham Railway experiments.[65] However, various details of its construction raise considerable doubts, as Brian Bowers discovered when he made a detailed examination in 1978.[66] The hatchment dial has six terminals and the built-in permutating keyboard has twelve buttons. As the original line had five wires, only ten buttons would be needed to operate the dial as Wheatstone intended, with pairs of needles indicating individual letters. The sixth wire would only be needed to indicate a letter by the movement of a single needle. This facility is described in Cooke and Wheatstone's first patent (1837) but, as mentioned above, the 'return wire' feature was only added hastily by John Farey on the drawings just before the specifications were handed in on 12 December.

The drawings for the 1837 patent show strong evidence of being drawn from actual specimens already made. Most of the component parts — coils, keyboards, alarums, and so on — are drawn full size, but the main drawing of the five-needle hatchment dial (Figure 4, top right) is drawn 'one fourth of the real size'. By com- parison with the drawing (Figure 4, middle left) showing a horizontal plan of part of the dial, where the needle pivots are exactly 4 inches (102 mm) apart, the dial is actu- ally drawn to a slightly smaller scale than one-fourth.[67] However, making allowance for this, scaling up would make the original dial 46.74 inches (1187 mm) high by 27.36
inches (695 mm) wide. The Science Museum instrument's dial is only 23.75 inches

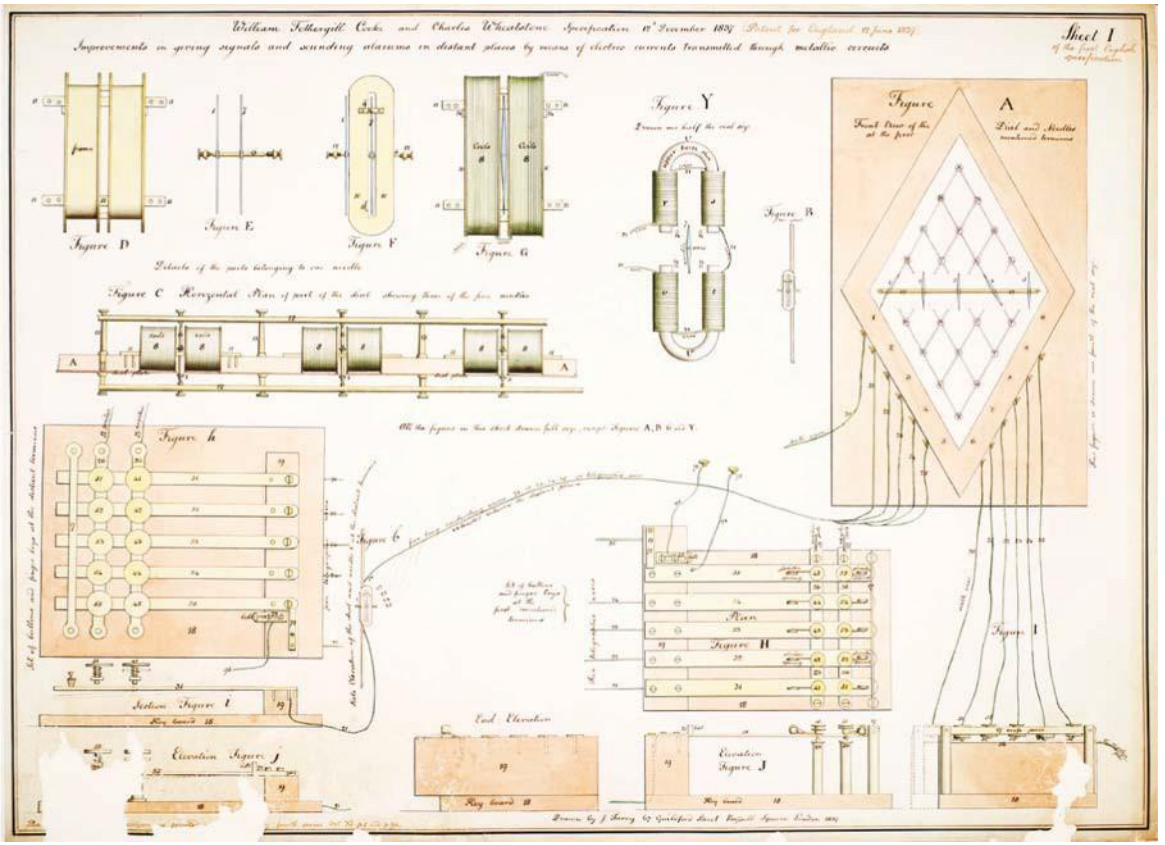


figure 4 An almost exact copy on paper by John Farey of Sheet I of his drawings for the specification of of Cooke and Wheatstone's English patent number 7390, 12 June 1837. The only difference from Farey's original drawing on vellum is the addition of the rectangular colour-wash surround to the five-needle hatchment dial. ScM Inv. 1999-960 (part), ScM/SSPL 10257162.

(603 mm) high by 14.00 inches (356 mm) wide, with the needle pivots just over 2.10 inches (53 mm) apart, so its size alone would appear to eliminate it from being one of the originals.

As stated above, the instruments used on the Euston–Camden Town trials were removed to King's College on 16 January 1838. Two large five-needle hatchment dials were in the historical collection at King's for many years but have since been placed on loan elsewhere. One (Figure 5) was borrowed initially by the Science Museum in 1949 but passed, still on loan, to the Royal Scottish Museum (now National Museums Scotland (NMS)) in 1951.[68] This is a large hatchment dial without mounting or keyboard, and is 46.50 inches (1155 mm) high by 26 inches (662 mm) wide.[69] The size suggests it is one of the originals, but interestingly the needles and coils are not mounted on a common bar but are fitted individually. This was a modification Cooke patented in 1838 to make for easier adjustment. The needle pivots are not at 4 inch centres but slightly closer, at 3.85 inches (97 mm). The dial is an enamelled plate with the coils and needles positioned within elliptical cut-outs. The other five-needle hatchment dial at King's College came to the Science Museum on loan in 1963 (Figure 6).[70] This is of different construction to the NMS instrument, with the dial painted on a rectangular wooden backboard, with a rectan- gular cover board hinged at one side with a cut-out diamond-shaped dial aperture (originally glazed). The overall dimensions are 47.75 inches (1213 mm) by 28.50 inches (724 mm). The needles and coils are mounted on a common bar, with the needle pivots exactly 4 inches apart, as on the drawings on Sheet 1 of the 1837 patent. Farey's original drawing submitted with the specification shows the five-needle dial as a simple diamond, but a copy made by Farey and now in the 'Wheatstone Collec- tion' of papers and drawings associated with Sir Charles Wheatstone, held in the Science Museum, shows the diamond-shaped dial within a rectangular panel, colour- washed brown.[71] As such it closely resembles the instrument now held by the Science Museum. (This appears to be the only variation between the filed drawing and this copy. The drawing made by Farey for the Scottish specification is as for the English specification, including the sixth wire and with the keyboard extension shown by pecked lines.) Among the drawings prepared by Cooke in late 1840 or early 1841 for the arbitration proceedings is one showing a pair of four-needle hatchment dial instruments to represent the 1837 patent.[72] These are depicted in rectangular cases very similar to the King's College instrument now at the Science Museum.

The constructional differences between the two King's College instruments can be explained if, as Cooke recounted, they were by two makers, Moore and Kirby. Unfortunately, despite a careful examination, no maker's names or marks have been found on either. Though conclusive documentary proof is still lacking, their size and other evidence point to them being those used for the L&BR September 1837 demonstrations.

The Great Western Railway

Cooke's negotiations with the GWR began early in 1838. On 3 April he informed Robert Wilson, his solicitor, of the prices he had contracted with the Company.[73] These were:

figure 5 Large five-needle Cooke and Wheatstone electric telegraph dial with individual needle mountings, probably one of the instruments demonstrated at Euston and Camden Town in 1837. On loan to National Museums Scotland from King's College London. NMS T.1951.L23.
Photo J. Liffen

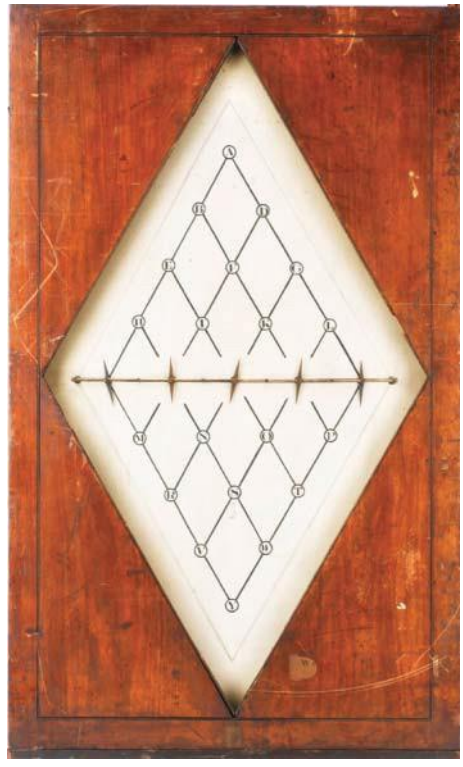


figure 6 Large five-needle Cooke and Wheatstone electric telegraph dial, almost certainly one of the two demonstrated at Euston and Camden Town in 1837. On loan to the Science Museum from King's College London. ScM Inv. 1963-215, ScM Photo Studio 1963-0215_(0001).

Completing the Telegraphic line per mile	£165 0. 0.
Each station	£ 10 0. 0.
For each Telegraphic apparatus with alarums and Batteries	£ 48 0. 0.
For each intermediate apparatus &c &c	£ 54 0. 0.
For each portable apparatus	£ 28 0. 0.

The references to 'intermediate' and 'portable' apparatus can leave little doubt that the instruments intended to use were those described and illustrated in Cooke and Wheatstone's Scottish patent, the specification of which was to be enrolled at Edin- burgh on 10 April.[74] Construction work began in June 1838. The agreement between Cooke and Wheatstone and the GWR stated that six wires were to be laid down.[75] Cooke originally intended to use wooden conduit similar to that used the previous autumn between Euston and Camden Town, but Brunel decided that the wires should

be carried in iron tubes, an alternative method described in Cooke and Wheatstone's 1837 specification.[76] It gave better protection to the wires but was more expensive to install. The provision of six wires is not in itself an indication that five-needle twelve- button instruments were used, with the sixth wire being the return wire. As stated in the specification of the 1838 English patent, five wires were needed to work the four- needle instruments, and the sixth was a spare, to be connected if any of the others failed owing to defective insulation or breakage.[77]

In July 1839, when the initial installation was ready for use, Cooke placed his state- ment of account for constructing the telegraph before the GWR directors. It confirms that he had provided two terminal instruments, two intermediate instruments and two portable instruments, all at the contracted prices.[78]

As mentioned above, few contemporary descriptions survive of the original GWR installation. One that does is an item that appeared in *The Observer* on Sunday 1 September 1839 and reprinted in *The Times* the following day:

> The space occupied by the case containing the machinery (which simply stands upon a table, and can be removed at pleasure to any part of the room) is little more than that required for a gentleman's hat box. The telegraph is worked by merely pressing small brass keys (similar to those on a keyed bugle), which acting (by means of galvanic power) upon various hands placed upon a dial-plate at the other end of the telegraphic line, as far as now opened, point not only to each letter of the alphabet (as each key may be struck or pressed), but the numericals are indicated by the same means, as well as the various points, from a comma to a colon, with notes of admiration and interjection. There is likewise a cross (X) upon the dial, which indicates that when this key is struck, a mistake has been made in some part of the sentence telegraphed, and that an 'erasure' is intended. [. . .] There are wires (as may be imagined) communicating with each end, thus far completed, passing through a hollow iron tube, not more than an inch and a half in diameter, which is fixed about six inches above the ground, running parallel with the railway, and about two or three feet distant from it.

It is a great pity that newspapers at that time did not include illustrations; it would have saved historians of the electric telegraph a great deal of trouble over the years. It has been assumed by virtually all such writers that hatchment-dial five-needle telegraphs were used on the original GWR installation, at least to begin with. It is just possible that such dials are being described by *The Observer*'s reporter, but his references to the keys on a keyed bugle, or of a cross on the dial, raise doubts. The Maltese cross became an important feature on needle-telegraph dials for many years, as the indications of the needles were by no means always as clear and unambiguous as Cooke maintained. Termed the 'stop' symbol, it was used by the sender of a message at the end of every word, and by the reader when he did not understand any particular word.[79] It is not shown on any of the drawings of the 1837 or 1838 speci- fications, but its need must have become obvious as soon as regular communications on the electric telegraph began. Just where it would have been sited on the dial the reporter was describing is still a matter of speculation. X was not one of the letters

on Cooke's four-needle dial, so was the journalist looking at a double-needle dial? That shown in the Scottish patent drawing (dated 7 April 1838) has no numbers or letters marked, while that in the English patent drawing (specification filed

18 October 1838) bears only the numbers 0 to 7. Cooke's *Telegraphic Railways* was published on 1 January 1842, and therefore in preparation during 1841. It includes a drawing of a double-needle telegraph used on the Edinburgh and Glasgow Railway. This is likewise marked with the numbers 1 to 8, in the same layout as the 1838 drawings. The earliest illustration I have found of a double-needle dial with both letters and figures is that published in *The Railway Times* for 27 May 1843.[80] In this the Maltese cross 'stop' symbol is at the bottom, not at top left which became the normal position within another year or so. It is reasonable to suppose that the com- bined letters/numbers layout might have been devised some while before 1843, but whether it could have been as early as August 1839 awaits confirmation.

The 'small brass keys' mentioned by *The Observer*'s reporter might conceivably refer to buttons on a permutating keyboard, but describe much more closely the centrally pivoted 'finger keys' shown in the drawings of the portable double-needle instrument described in Cooke's 1838 English specification. In these drawings the four-needle instruments are shown with permutating keyboards, but in the descrip- tion Cooke stated that they might also be fitted with finger keys.[81] Cooke referred to these as 'Heidelberg keys', because they functioned in the same way as similar ones he had fitted to the copy of Schilling's telegraph he had made in Heidelberg in March 1836. In another of Cooke's arbitration drawings the 1838 patent is represented by three of the rectangular-case four-needle instruments each with a set of five finger keys.[82] In Cooke's *Telegraphic Railways* is a drawing of the telegraph used on the Great Western Railway. The two four-needle instruments depicted each have finger keys rather than buttons. The keys on a keyed bugle appear to me to resemble much more closely the finger keys on the telegraph than they do a set of buttons on a permutating keyboard. Wheatstone, in his case against Cooke, said that 'he made a different disposition of the keys' on the instruments made for the GWR.[83] From the context it is clear he was referring to 'Heidelberg keys'.

What amounts to a set of Cooke's 1838 four-needle instruments still exists. The Science Museum has an intermediate instrument, received from the GPO in 1876 (Figure 7).[84] A terminal instrument is owned by the Museum of London, this having been in the ownership of the GPO (later BT) for many years until 2003.[85] Another terminal instrument is at Newcastle Discovery, having been donated in 1937 by Armstrong College, Newcastle upon Tyne (but at that time part of the University of Durham).[86] Its earlier history is unknown. All these have ten-button permutating keyboards similar to those illustrated in the 1837 patent. The Science Museum has an example, possibly the only one extant, of the portable double-needle instrument (Figure 8).[87] This one has brass finger keys, not buttons. This instrument, too, was owned by the Post Office and then BT until transferred in 2003.

It is hard to be certain, but none of the four instruments appears to have seen service, but instead suggest some kind of demonstration set. There is little direct evi- dence for this except that on all of them certain components, particularly the coils, bear small circular labels with printed numbers on them. These numbers are the same as the key numbers for the components illustrated in the patent drawings. The key- boards on all three four-needle instruments are separately made units which slide into a compartment at the base of the dial. Apart from their baseboards having bevelled edges they are otherwise exactly similar to a pair of ten-button permutating

figure 7 A prototype, fitted with Wheatstone's ten-button permutating keyboard, of the four-needle electric telegraph instruments patented by W. F. Cooke in 1838 and installed on the Great Western Railway between Paddington and West Drayton in 1839. ScM Inv. 1876-1274, ScM Photo Studio 1876-1274_(0001).

figure 8 W. F. Cooke's double-needle portable telegraph instrument of 1838, fitted with Cooke's centrally pivoted operating keys ('Heidelberg keys'). ScM Inv. 2004-105, ScM/SSPL 10459328.

keyboards held in the King's College collection now on loan to the Science Museum.[88] In a letter to his mother dated 9 November 1837, Cooke stated, 'I have just completed a perfect set of instruments for exhibition before the members of Government, if they are inclined to take it up'.[89] This might refer to the instruments under discussion, though November 1837 seems rather early for them, even if they were described and illustrated in finished form in the Scottish specification of 7 April 1838.

It is now relevant to examine the evidence for the use of five-needle hatchment dials on the GWR 1839 installation. There appears to be only one contemporary source: Wheatstone's evidence to the House of Commons Select Committee on Railway Communication, which was published in July 1840. An engraving of the five-needle dial and keyboard forms the frontispiece of the report containing the minutes of evidence. In response to a request to describe the electric telegraph, Wheatstone replied:

> I have here a copy of the drawing of the specification to the first patent taken out by myself and Mr Cooke; in all essential particulars the instrument here represented resembles the one at the Great Western Railway.[90]

In Wheatstone's ensuing explanation, it is clear that he is referring to the drawing reproduced in the report. These minutes, and the drawing, received wide circulation at the time. They were reproduced verbatim in the *Mechanics' Magazine* (1 August

1840), while extensive extracts were published in, for example, *The Inventor's Advo- cate and Journal of Industry* (8 August 1840); *The Railway Magazine and Commer- cial Journal* (8 August 1840); *The Penny Magazine* (31 October 1840); and *The Railway Times* (12 June 1841). These sources, apparently definitive, would seem to leave little room for doubt for later commentators. Early technical works on the electric telegraph stated that the first GWR system was based on the five-needle dial[91] and more modern historians have taken the same view.[92]

But what did Wheatstone actually say? According to Cooke, he had the opportu- nity to check his evidence as transcribed before it was published, so it cannot be certain what he actually said in the interview room.[93] However, the words as printed say '*in all essential particulars* the instrument here represented resembles the one at the Great Western Railway' (my emphasis). This is exactly true. The four-needle dial worked by means of the coils, wires and switches described and illustrated in the 1837 English patent. Twelve of the twenty letters on the dial were indicated by the con- vergence of a pair of needles, even if the other eight were indicated by the movement of a single needle only. Indeed, the working of a four-needle telegraph, indicating by both multiple and single needle movements within a hatchment-shaped dial, was described and illustrated in that patent. Yet the drawing that Wheatstone chose to produce on the day of the interview, and allowed to be copied for publication, was of his own five-needle dial, which indicated only by the convergence of pairs of needles. The dial is shown as having terminals for five wires only and is connected to a ten-button permutating keyboard.

At this point, Cooke's evidence in the arbitration papers has again to be adduced, but with some reservation. Cooke held a grievance against Wheatstone in the way that he considered that Wheatstone had excluded him from his share of credit in the invention of the electric telegraph. It was Cooke who initiated the proceedings and caused the arbitration hearing to be organized. The mass of material he produced for the arbitrators to consider sometimes has a strident tone of trying too hard, particu- larly in the speech of his solicitor Robert Wilson at the arbitration meeting, which makes it displeasing to read even where one considers Cooke to be in the right. Yet I believe that Cooke was an essentially honest man. His statements have the ring of truth about them, even if they are expressed in an over-emphatic way. With that premise, Cooke's statements in the arbitration evidence, albeit given with the benefit of hindsight, need to be considered:

> One important principle, which, like other inventions of mine, Mr Wheatstone once claimed, but which he now leaves to me without contest — 'the return wire' — I was most anxious to get into the [1837] specification. Mr Wheatstone's 'hatchment' form of dial, according to the drawing of it which he had cause to be prepared, only gave signals by the combined movements of two needles, not by the separate movement of the needles singly, as in my Heidleberg telegraph. I always felt, as experience has proved, that single- needle movements must, from their simplicity, supersede in practice any form of appara- tus which would increase unnecessarily the number of needles employed, and double the resistance of the coils. A very warm discussion arose on this point; I urging the great practical importance of the simpler arrangement, and Mr Wheatstone objecting that it would spoil the symmetry of his dial.[94]

> Now Mr Wheatstone's 'hatchment' instrument and the permutating key-board, to be seen at King's College and only there, have never come into practical use. Mr Wheatstone reluctantly admits this.[95]

Leaving aside the tone of these statements, it is clear that Cooke, having defended his return wire in a 'very warm discussion' in late 1837, was unlikely to have used Wheatstone's five-needle principle in any of the systems he himself was to be respon- sible for. He could not have employed the large instruments demonstrated at Euston and Camden Town, as these were sold on to Wheatstone and taken to King's College in January 1838. It will be argued later that for another reason he could not have used, even if he wished to, the small five-needle instrument now owned by the Science Museum.

So why, when describing the GWR telegraph, did Wheatstone produce the hatchment-dial drawing to show to the parliamentary committee? It was probably because he wanted to draw attention to an arrangement that was unequivocally his, and one that, over two years later, he remained proud of. Despite their working agreement, the partnership with Cooke remained an uneasy one and he would be unlikely to want to draw attention to technical developments by his partner to the detriment of his own. The move succeeded brilliantly. Wheatstone's name has remained associated with the introduction of the practical electric telegraph into Britain to the present day, and his elegant but impractical five-needle hatchment dial has been given a prominence that belies its importance. At the same time, Cooke's contribution has been subtly downgraded, as he himself feared it would. Even though the mountain of words he produced to defend his position has provided historians with much information that would otherwise be lost, it has been used reluctantly by them as it is perceived to be one-sided and therefore unreliable.

It is just possible, of course, that Wheatstone took advantage of the existence of the GWR telegraph to take his five-needle instruments out of King's College to try them out temporarily under real-life conditions. There is no contemporary evidence of this, but in any event such instruments formed no part of the equipment installed by Cooke under contract to the GWR.

Meanwhile, what of the small five-needle telegraph claimed by the Science Museum to be one of the instruments used on both the L&BR and GWR installations? There are actually three examples of this design extant. As well as the Science Museum's, a second is in the collection of the Museum fur Kommunikation in Berlin, while a third is held in the Powerhouse Museum in Sydney. I have not yet inspected the other two, but from photographs their construction seems identical and contemporary with the Science Museum specimen. Neither of these has any better provenance than the Science Museum's. The Berlin example is known to have been in their collection since the 1890s, but its earlier history is unrecorded. The Powerhouse instrument can be traced back no earlier than 1936, when it was donated to the Powerhouse's predecessor museum by a Mr A. C. Webb, an *émigré* British engineer.

As stated earlier, the Science Museum instrument originally came to South Kensington on loan from the GPO, along with a number of other historical items, for the 'Special Loan Collection of Scientific Apparatus', an exhibition which took place between May and December 1876. In the exhibition catalogue it was described as 'Cooke and Wheatstone's earliest needle telegraph, 1837'.[96] Unfortunately no records

have been traced which describe how this historical collection was originally brought together, but it was previously in the possession of the Electric Telegraph Company (ETC) and taken over by the GPO when the British inland telegraph companies were nationalized in 1870. At the Great Exhibition, held in London in 1851, the large ETC display included several items which were already of historic interest. One was described as 'Original five-needle telegraph invented by Cooke and Wheatstone in 1837, and worked on the Great Western Railway'.[97] This was written only fourteen years after the event, when Cooke was still active in the ETC and a major share- holder. If, as has been argued above, five-needle telegraphs were not used on the GWR, how was it that the misunderstanding had already taken root? In the absence of any illustrations of the ETC display, it is assumed that the small instrument was shown, not one of the large five-needle dials taken to King's College in 1838. Where had it come from? To attempt to answer this question it is necessary to move forward a few years to the late 1840s.

The Electric Telegraph Company and patent disputes

During 1845 the number of new contracts being taken out for telegraph installations moved the scale of the business beyond the ability of Cooke and Wheatstone to deal with as a partnership. The threat of competition, too, required that their interests be protected by the formation of a company. Following negotiations with George Parker Bidder and John Lewis Ricardo, a prominent businessman, the Electric Tele- graph Company (ETC) was incorporated by Act of Parliament in 1846.[98] The pro- gress of the bill in Parliament proved difficult. It was opposed by Alexander Bain, a rival inventor of an electric telegraph system and of electric clocks. The substance of his arguments cannot be recounted in detail here, except to say that they did not reflect well on Wheatstone's reputation as a man of honour in his business and per- sonal dealings. The result was that Bain had to be bought off before the bill could be
given Royal Assent.[99] Wheatstone ceased his official involvement in the ETC, though he continued to provide technical advice to the company for several years.[100]
The ETC had not been incorporated for many months before its patent monopoly was tested. During the summer of 1846 an ABC pointer telegraph patented by John Nott and John Gamble was installed on the London and North Western Railway between Northampton and Blisworth. The ETC considered that it violated its patents and applied for an injunction to restrain Nott and Gamble. The motion was
heard in the Vice-Chancellor's Court in December 1846 and January 1847.[101] Both
sides entered affidavits from many prominent scientists and engineers, together with examples of apparatus built in accordance with the various patents.[102]
The subsequent progress of the case is outside the scope of this paper, but the exhibits entered by the ETC are of particular relevance. They were listed and described by William Henry Hatcher, the ETC's Engineer in Chief, in his affidavit dated 14 November 1846. Part of his statement read as follows:

> I further say that the two telegraph dials with the fittings thereof now shewn to me and numbered respectively 1 and 2 and the two keyboards now shewn to me and numbered respectively 3 and 4 are old telegraphic instruments made by the said William Fothergill Cooke and Charles Wheatstone or one of them in or previously to the year One thousand

> eight hundred and thirty nine (the same having been at Kings College since October in that year) And I say that the said Dials and the fittings thereof and the said Keyboards are of a construction similar to that of the corresponding instruments represented in the drawings of the specification of Cooke and Wheatstone's first English patent.[103]

As stated above, among the telegraph items taken on loan by the Science Museum from King's College in 1963 were two ten-button permutating keyboards.[104] These are both very similar in construction to the keyboard illustrated in Figures **h**, **i** and **j** on Sheet 1 of the 1837 patent drawings (Figure 4). The front-to-back dimension of the baseboard corresponds exactly, though they are slightly wider. On the base of one of the keyboards is pasted a label on which is written:

> 4 / Electric Telegraph Co v Nott & others / This is the key board mentioned or referred to in the affidavit of William Henry Hatcher as numbered 4 sworn before me this 14 day of November 1846. / [signed] S Anderson

There is no trace of a similar label under the other keyboard, but there can be virtu- ally no doubt that both are indeed the keyboards produced in evidence in 1846. Hatcher only accounted for them at King's back to October 1839, but this probably reflects the earliest date that he himself could swear to. Hatcher, born in about 1821, was educated at King's College School.[105] After matriculation he graduated into the College and worked as a pupil for, among others, Daniell, Cowper and Wheatstone, assisting the latter in some of his electric telegraph experiments. This would have been from 1839, assuming he matriculated at the age of eighteen.

Cooke entered two affidavits in the case. In the second, dated 5 February 1847, he referred to the London and Birmingham Railway installation, and continued:

> I say that the Diamond Shaped telegraphic instruments which have been exhibited in this Cause on behalf of the Plaintiffs are part of the identical telegraph which was so erected on the London and Birmingham Railway in the year one thousand eight hundred and thirty seven.[106]

Having discovered the label on the keyboard, I carefully examined the two King's College five-needle telegraphs now on loan to the Science Museum and National Museums Scotland respectively, but found no traces of any similar labels on either. However, the telegraphs' provenance lends weight to the probability that they were exhibits 1 and 2 in the 1846/47 injunction hearing, even accepting that the dial now in Scotland was modified at some time after its purchase by Wheatstone. If so, the possibility that either was represented by the small instrument with the twelve-button integral keyboard can be discounted. 'ETC v Nott and others' dragged on through several hearings but ended without clear-cut victory to either side.

In 1847, therefore, a hearing took place at which the original 1837 instruments were produced as evidence. Within a short time the 1837 patent was to be challenged again and this time it was necessary to demonstrate the operation of the equipment. In 1847 Alfred Brett and George Little patented what they regarded as a novel design of telegraph indicator.[107] The ETC felt it infringed their patents and in 1849 brought an action in the Court of Common Pleas against Brett and Little. The ETC Board of Directors discussed the forthcoming trial at a meeting held on 30 January 1850 at which their solicitors were present. After discussing barristers' fees,

The solicitors also mentioned that the opinion of the scientific witnesses were very favour- able to the Company and that considerable expenses had already been incurred for
models and printing and witnesses fees and the Board after discussion sanctioned the councils fees recommended.[108]

The hearings took place at the Guildhall on 21, 22, 23 and 25 February before Lord Chief Justice Wilde and a special jury.[109] The specific ETC patent at issue was Cooke and Wheatstone's 1837 English patent. According to a report of the case in *The Patent Journal and Inventor's Magazine*

The defendants in a great number of pleas denied [. . .] that the invention claimed by the plaintiffs was new, or that the defendants had infringed it. The instruments severally patented by the parties were placed on the floor of the court, and were referred to and explained to the jury by the counsel and witnesses.[110]

The same report then summarized the opening speech for the ETC by the Attorney General, during which he said

The plaintiffs' telegraph has a lozenge-shaped dial, on which is placed twenty letters of the alphabet, and five magnetic needles so disposed, that, by the convergence of one or two needles, any letter might be pointed out. [. . .] Another advantage of the plaintiff's patent was, that at every station was placed a duplicate of the dial-plate with the magnetic needles upon it, so that the operator might see what signals he was communicat- ing, and the like signals might, if necessary, be shown upon the dial-plates at all the intermediate stations at the same time.

At the conclusion of his speech

Mr William Carpmael, the patent agent, was then called, and stated that prior to the invention patented by Messrs Cooke and Wheatstone, there was nothing that could be properly called an electric telegraph. He then explained the discovery of Oerstead [*sic*], and the suggestions of Ampere, Ronalds and Schweigger, and also explained to the jury from the instruments in the court, the invention claimed by the plaintiffs, and the mode of using it.

According to another report of the case, in summarizing witnesses' evidence for the plaintiffs

The mode of conveying signals, according to the plaintiffs' patent, was, by causing two or more magnetic needles to deflect or point to letters or figures on a dial-plate, with stops to control the oscillation of the needles, — the person to be communicated with at the distant point having before him a similar dial-plate with similar magnetic needles; five wires and five needles being used to convey the signals, and a sixth wire for the purpose of completing the circuit, by returning the electric current to the negative pole of the battery whence it started.[111]

The following points can be inferred from the above extracts:

- in preparing for the case, the ETC incurred expense in obtaining 'models';
- instruments representing the two patents at issue were brought into court and used for explanatory purposes;

- the instrument representing the Cooke and Wheatstone 1837 patent was a hatchment-dial telegraph with five needles and twenty letters;
- this instrument had six wires and could therefore indicate letters or figures by the movement of a single needle as well as in pairs;
- the principle of intermediate instruments, exactly similar to the terminal instruments, was also explained;
- more than one instrument was brought into court, and they were probably demonstrated in working order.

If these inferences are correct, there is a possibility that at as many as three 1837-style instruments were shown. If so, they could not include the pair demonstrated at the London and Birmingham Railway in 1837, as these operated with five wires only. In any case the ETC Board minutes suggest that new instruments ('models') were purchased. This would be a sensible move if they were required to operate reliably in court.

At this point it is worth returning to the Cooke–Wheatstone dispute of 1841, the aftermath of which continued to simmer for many years, occasionally flaring up. As late as 1868, the Revd Thomas Fothergill Cooke, W. F. Cooke's brother, compiled a book reiterating his brother's claims to priority in the invention of the electric telegraph.[112] The book incorporates long extracts from the arbitration evidence of 1841 and is itself far from impartial. It is, in fact, very one-sided and is wearisome to read. However, Tom Cooke was a witness of some of the 1837 experiments and maintained a close interest in the progress of the telegraph. The partiality of the book turns on the selection and presentation of the facts, rather than their veracity. In summarizing a discussion of the development of the needle telegraph in a previous 'letter' (chapter) in the book, T. F. Cooke wrote

> With respect to this perfected Hatchment Dial with Key-board, I pointed out that it has never come into practical use; — that it is now to be seen at King's College, in the only two specimens ever constructed, and nowhere else.[113]

To this statement, a paraphrase of Cooke's statement in the arbitration papers, he added a footnote:

> I will here mention, that both the 'Hatchment Dial' instruments were made entirely under my brother's direction; one by Messrs Moore, the well-known clock makers of Clerken- well, the other, by a mechanician named Kirby. Mr Wheatstone, I believe, never saw them, till they were produced complete at Euston Square. Since the text was in type it has been brought to my knowledge that besides these two specimens of the Hatchment Dial, two working models of the same were afterwards made for the trial in Guildhall, mentioned in a following note. These models have since remained, *for show only*, [emphasis in original] in the Board-room of the Electric Telegraph Company.[114]

The 'following note' confirmed that the trial was ETC v Brett and Little.

In the W. F. Cooke papers preserved at the Institution of Engineering and Technol- ogy is an extract from the minutes of the London and Birmingham Railway Commit- tee of Management for 14 December 1837 recording their decision to return the telegraph instruments used in the demonstrations to Cooke on payment of half the cost of them. On the back of the sheet is a manuscript note by Cooke dated 11 January 1875:

> Professor Wheatstone purchased these instruments from me at cost price £50 or £60, and moved them at once to Kings College. They were the only ones ever made on that principle except a pair to exhibit at a trial or before a Committee.[115]

The description of the small hatchment dial instrument at the Science Museum, and its counterparts in Berlin and Sydney, strongly suggest that these are the instruments made for the ETC in about 1849 for demonstration at the trial at Guildhall. Being half-size, they could conveniently be placed on tables for showing to the court; their construction makes them freestanding; the dials have terminals for six wires; and they have integral twelve-button keyboards. It would explain why the dial is exactly similar in looks and construction, though smaller, than the dial represented in the patent drawing, and why terminals are fitted on the dial to connect parts that are permanently fixed together. It looks as if it was made to be as alike the patent drawing as possible, not the other way round. An aphorism constantly to be borne in mind when making analyses of this kind is 'absence of evidence is not evidence of absence'. However, the design of the dial mounting and base is not to be found in any patent drawing, nor in any of the many contemporary drawings held in the Wheatstone Collection at the Science Museum, nor in any contemporary periodical of the many that have been consulted in the research for this paper. Whether a third instrument (assuming all three are contemporary with each other) was shown in court, or, if not, why it was made, remains to be discovered.

Leaving aside the question of the third instrument, there seems no reason to dis- believe T. F. Cooke's statement that two instruments used in the trial in 1850 were later displayed in the ETC's board room. As ETC property they would have come into the possession of the GPO when the inland telegraph companies were national- ized in 1870. As their property, it would be perfectly in order for the GPO to lend one of the instruments for display at the Special Loan Collection at South Kensington Museum in 1876, and to continue the loan afterwards.

The provenance of the Berlin instrument is unclear, and what is so far known is contained in a letter from what was then called the Postal Museum to the Science Museum in 1964:

> The Cooke and Wheatstone 5-needle telegraph mentioned in your letter is still being exhibited in the postal museum of Berlin. The instrument has been referred to and described for the first time in the catalogue of our museum edited in 1897 also saying that it was designed in 1837. The editions of this catalogue published earlier than 1897 do not yet mention any 5-needle telegraph.
>
> The instrument we own does not contain any distinguishing marks of the producer. The 1897 catalogue indicates that the original instrument is in the possession of the General Post Office in London so that ours is obviously an imitation. Unfortunately, there are no file-marks left on this subject. We are enclosing a photograph of our instrument.[116]

The Berlin photograph bears a typed caption on the reverse: 'Funfnadeltelegraph von Cooke & Wheatstone, 1849'. The date has been crossed through and amended to '1837' by hand. However, the caption is highly suggestive of being copied from the Postal Museum's original accession record and innocently 'giving the game away' as to when the instrument was actually made. To what else could the date refer?

Recent correspondence with the Museum fur Kommunikation has revealed no new information to confirm or negate this speculation.

As to the Sydney instrument, there can only be speculation. Assuming it is not a more recent copy of the Science Museum's instrument but contemporary with it, as also appears to be the case with the Berlin example, information on how it came into the ownership of Mr Webb is still to be uncovered.

Conclusion

The needle-indicating electric telegraph was a peculiarly British innovation. It required an operator to read the movements of the needles and another to write down the received message. Atmospheric disturbances could cause the needles to indicate spurious signals, or to become demagnetized. The simple Morse key and sounder system developed a few years later in the USA was cheap and practical and its adop- tion there was swift. Yet because the needle telegraph was the first practical system in the world and was ideally suited to the regulation of railway movements on a congested network, it became an established method of communication in Britain. Indeed, its descendants, in the guise of the three-position block telegraph, are still in fairly extensive use for signalling on Britain's railways. However, the history of its introduction and development has not been well told. Successive historians have tended to copy what previous books have said, rather than carry out new research. For reasons hinted at above, there has been a tendency to believe all Wheatstone's statements unquestioningly, while treating Cooke's version of events with suspicion. Contradictions in the evidence have been allowed to go unchallenged. Where original instruments have been preserved, there has been a tendency to try to make the his- tory fit the surviving artefacts, rather than research the history afresh and determine where (or if) the surviving instruments fit in.

In this regard the Science Museum in London, where many examples of needle telegraphs have been preserved, is not blameless. In 1876 its predecessor the South Kensington Museum became the home of some of the earliest practical electric tele- graph instruments to be made. Another large collection was received in 1884 and in more recent times it has become the repository for a large portion of the historical collection owned by King's College London. In the nineteenth century the Museum's overt approach was that of technical education. The exhibits were there principally to illustrate the design and development of particular technologies, and for this purpose a specially constructed explanatory model would do just as well if an original were not available. The historical provenance, or heritage aspect, of an artefact was largely irrelevant except where it helped elucidate the functioning of a device. Consequently little effort needed to be made at the time of acquisition to record what was actually used where. This approach has dogged the history of the small Cooke and Wheatstone five-needle telegraph. As each new version of the exhibit label has been written for successive displays, the text, in 'Chinese whispers' fashion, has moved from describing an object which illustrates the working of the system to cred- iting it with being the original artefact itself. As such its image has been constantly reproduced all over the world and identified as the original 1837 telegraph. The Science Museum's approach to preservation and display has changed over time to

reflect the requirements of its users, and much more emphasis is now placed on 'real objects'. This involves submitting artefacts to the kind of scrutiny which a museum's own documentation might not be able to sustain. The considerable amount of research needed to construct the alternative histories recounted above would have been unnecessary if full details of provenance had been recorded at the time of acqui- sition. Yet no doubt the requirements of future generations will be different again from those which seem so important today. Because we cannot easily predict these changes, the recording of historical provenance in as full and unbiased a manner as possible must be accepted as a cornerstone of the work of museums of science and industry.

Acknowledgements

I am extremely grateful to many friends and colleagues in the museum world and elsewhere for their help, advice and encouragement in the preparation of this paper. It is invidious to single out individuals, but I should specially like to mention the fol- lowing: John Clayson (Newcastle Discovery); Mary Godwin (Porthcurno Telegraph Museum); Vanessa Salter (Hull Museums); Alison Taubman (National Museums of Scotland); Alex Werner (Museum of London); Jenny Wetton (Museum of Science and Industry in Manchester); and David Wright (National Railway Museum), all of whom went to some trouble to make objects from the collections in their care available for me to study; colleagues in the Science Museum Photographic Studio, who took such excellent photographs; and Matthew Connell (Powerhouse Museum, Sydney). Neil Johannessen (freelance researcher) read an early draft of the paper and made many helpful comments. My thanks also go to staff at the following locations, all of whom were unvaryingly helpful and courteous: The British Library, St Pancras, and the British Library Newspaper Library, Colindale; Family Records Centre, Islington; Guildhall Library; Probate Registry; British Telecom Archives; British Library of Political and Economic Science; The National Archives (Public Record Office), Kew; Science Museum Documentation Centre; Science Museum Library; National Archives of Scotland; King's College Library; Institution of Engineering and Technology Archives; Tower Hamlets Local History Library.

Notes

1 W. F. Cooke, *The Electric Telegraph, Was it Invented by Professor Wheatstone?*, 2 vols (London, 1856 [part II], 1857 [part I]), part II, p. 14. The author consulted the copies held in the Science Museum Library, London (SML).

2 E. A. Marland, *Early Electrical Communi-cation* (London/New York/Toronto, 1964), p. 83, gives the date of the visit, citing an 1857 report of the lawsuit Morse v O'Reilly, 1849. G. Hubbard, *Cooke and Wheatstone and the Invention of the Electric Telegraph* (London, 1965), p. 42, also gives this date but he does not identify his source. There are no citations at all in this book, which limits its value to the historian. Copies in SML.

3 W. B. Taylor, *An Historical Sketch of Hen- ry's Contribution to the Electro-Magnetic Telegraph* (Washington, 1879), pp. 81–84 (reprinted in facsimile in *The Electric Tele- graph, an Historical Anthology*, ed. by G. Shiers (New York, 1977). Copy in SML).

4 English patent 7390 of 1837.

5 Date inferred from letter from Cooke to his mother, 2 July 1837. Original held in

Institution of Engineering and Technology (IET) Archives; printed as Letter XXIV in *Extracts from the Private Letters of the Late Sir William Fothergill Cooke* [etc.], ed. by F. H. Webb (London, 1895). Copy in SML.

6 Letter, Cooke to his mother, 4 July 1837, IET Archives and Letter XXV.

7 These details were recollected by Cooke in a letter to Latimer Clark, 12 January 1875, IET Archives, Sir W. F. Cooke Papers, ref. UK0108 SC MSS 007/1/099.

8 Letter, Cooke to his mother, dated 9 July 1837 but including a subscript dated the following night (IET Archives and Letter XXVI).

9 Letter, Cooke to Creed, 17 July 1837. The original has not been located but a typed transcript is in The National Archives (TNA): Public Record Office (PRO) RAIL 1008/95.

10 D. S. Barrie, 'The Story of Euston-1', *The Railway Magazine* (July 1938), pp. 43–52.

11 Letter, Prevost to Cooke, 24 July 1837, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/009.

12 Letter, Cooke to Clark, 12 January 1875, IET Archives, Cooke Papers, UK0108 SC MSS 007/I/099.

13 Cooke, *Electric Telegraph*, part II, p. 132.

14 Cooke described this demonstration in a letter to his mother dated 'Midnight, twenty-fifth July, 1837' but referred to the events as taking place 'yesterday', which could also mean Monday 24 July. However, a description published in the *Quarterly Review* in June 1854, using information supplied by Wheatstone, stated 'Late in the evening of the twenty-fifth' and there seems no reason to doubt this.

15 Letter, Cooke to Clark, 12 January 1875, IET Archives, Cooke Papers, UK0108 SC MSS 007/I/099.

16 Letter, Cooke to his mother, 25 July 1837, IET Archives and Letter XXVII.

17 W. H. Preece, Communication, *IEE Journal*, xxvi (1897), pp. 633–35. This includes a reprint of Fox's invoice for the work.

18 Letter, Cooke to Clark, 12 January 1875, IET Archives, Cooke Papers, UK0108 SC MSS 007/I/099.

19 A sketch of this layout is shown in a letter from Cooke to Josiah Moore, 17 February 1841, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/080.

20 Cooke, *Electric Telegraph*, part II, pp. 170–71.

21 Letter, Cooke to his mother, 8 September 1837, IET Archives and Letter XXIX.

22 Letter, Creed to Cooke, 20 September 1837, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/015.

23 L&BR meeting of Station Sub-committee, 26 September 1837, TNA: PRO RAIL 384/35, f. 244.

24 London & Birmingham Railway, meeting of Non-Resident Directors, 30 September 1837, TNA: PRO RAIL 384/62.

25 London & Birmingham Railway, meeting of Non-Resident Directors, 7 October 1837, TNA: PRO RAIL 384/62.

26 Letter, Cooke to Creed, 6 December 1837, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/034.

27 10 December is the date given by Cooke in a letter dated 9 November 1837 (Letter XXXII), but this was a Sunday, when the Rolls Chapel was unlikely to be open to receive specifications. Six calendar months from 12 June would be Tuesday 12 December and this is the date the specification was sealed.

28 Cooke, *Electric Telegraph*, part I, p. 183.

29 Letter, Cooke to his mother, 20 December 1837, IET Archives and Letter XXXIV.

30 Ibid.

31 Charles Wheatstone and William Fothergill Cooke, 'Improvement in the Electro-Magnetic Telegraph', US Patent No. 1622, dated 10 June 1840.

32 Letter, Cooke to Creed, 6 December 1837, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/034.

33 The L&BR paid Moore & Co. £39 9s 6d for 'apparatus' on 16 October 1837 and J. Kirby £22 15s for 'needles' on 22 October 1837, together coming to £62 4s 6d. (Letter, Creed to L&BR, 6 January 1838, TNA: PRO RAIL 1008/95.)

34 Meeting of the L&BR Committee of Management, 17 January 1838, TNA: PRO RAIL 384/85, f. 120.

35 MS note by Cooke on reverse of L&BR, extract from the Minutes of the Committee of Management of 14 December 1837, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/041. The date of removal is that

given by Robert Wilson in his Arbitration Address; Cooke, *Electric Telegraph*, part II, p. 170.

36 Letter, Brunel to Cooke, 22 September 1837, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/017.

37 Letter, Cooke to his mother, 12 January 1838 (nd, but date deduced from internal evidence), IET Archives and Letter XXXV. Cooke referred to 'Maidstone' in the letter, but Maidenhead must be intended.

38 GWR London Committee. Abstract of Minutes September 1833 to August 1839, TNA: PRO RAIL 250/83, entry for 22 February.

39 National Archives of Scotland, C 30/38/27.

40 English patent 7614 of 1838.

41 Letters, Cooke to his mother, 10 March and 13 March 1838, IET Archives and Letters XXXVI and XXXVII.

42 A typewritten copy of the agreement is in TNA: PRO RAIL 1005/39.

43 Letter, Cooke to GWR directors, 9 July 1839, TNA: PRO RAIL 1005/9.

44 TNA: PRO RAIL 1005/9.

45 Letter, Cooke to Saunders (GWR), 2 December 1839, TNA: PRO RAIL 1005/9.

46 Letter, Cooke to GWR directors, 21 October 1839, TNA: PRO RAIL 1005/9.

47 Letter, Cooke to Saunders (GWR), 2 December 1839, TNA: PRO RAIL 1005/9.

48 Ibid.

49 Letter, Saunders to Cooke, 16 December 1839. Typewritten copy in TNA: PRO RAIL 1005/9.

50 *Parliamentary Papers*, 1840, xiii: Select Committee on Railway Communication, Fourth Report (House of Commons, 9 July 1840); Fifth Report, with Minutes of Evidence (House of Commons, 6 February 1840).

51 Cooke, *Electric Telegraph*, part I, pp. 37– 38.

52 *The Inventor's Advocate and Journal of Industry*, ii, 22 February 1840, p. 120. Copy in the British Library, St Pancras, London (BL).

53 Letter, Saunders to Cooke, 16 December 1839. Typewritten copy in TNA: PRO RAIL 1005/9.

54 Letter, Cooke to Saunders, 21 September 1841, TNA: PRO RAIL 1005/9.

55 English patent 8345 of 1840.

56 Cooke, *Electric Telegraph*, Part I, p. 207.

57 Cooke, *Electric Telegraph*, Part II, pp. 265–68.

58 W. F. Cooke, *Telegraphic Railways; or the single way recommended by safety, economy and efficiency, under the safeguard and control of the electric telegraph: with particular reference to railway communication with Scotland, and to Irish railways* (London, 1842). Copy in the British Library of Political and Economic Science, London (BLPES).

59 English patent 9465, 8 September 1842, specification enrolled 8 March 1843.

60 *The Railway Times*, 20 May 1843, p. 568. Copy in SML.

61 English patent 10,655, 6 May 1845, specification enrolled 6 November 1845.

62 Letter, Cooke to Clark, 12 January 1875, IEE Archives, Cooke Papers, UK0108 SC MSS 007/1/099.

63 Cooke, *Electric Telegraph*, part II, pp. 22–24.

64 ScM Inv. 1867-37 and 1968-658.

65 ScM Inv. 1876-1272.

66 B. Bowers, 'The Case of the Missing Wire — A New Look at the Five Needle Telegraph', *The History of Electrical Engineering: Papers Presented at the Sixth IEE Weekend Meeting, Nottingham, 7–9 July 1978*, pp. 50–51. Copy lodged in SML.

67 These dimensions were checked on the original drawings filed with the specification and which are now kept at TNA: PRO C 73/81/2, but the engravings made when the specifications were printed in 1857 are in exact accordance with them.

68 NMS T.1951.L23.

69 I am indebted to Alison Taubman of the National Museums of Scotland for access to this and other objects in the NMS collection.

70 ScM Inv. 1963-215.

71 ScM Archives Collection ARCH:WHE Folder 1, drawing 1/2. The Wheatstone Collection, comprising over two hundred pieces, mostly drawings, has been held by the museum for many years but unfortunately its provenance is unknown.

72 Cooke, *Electric Telegraph*, part II, Drawing X.

73 Letter, Cooke to Wilson, 3 April 1838, IET Archives, Cooke Papers, UK0108 SC MSS 007/II/044.
74 National Archives of Scotland, C 30/38/27.
75 TNA: PRO RAIL 1005/9.
76 Letter, Cooke to GWR Directors, 25 April 1839, TNA: PRO RAIL 1005/9.
77 English patent 7614 (1838), printed specification, p. 33, line 38.
78 TNA: PRO RAIL 1005/9.
79 C. V. Walker, *Electric Telegraph Manipulation* (London, 1850), p. 74. Copy in SML.
80 F. Whishaw, 'Mr Cooke's Electric Telegraph', *The Railway Times*, vi, 27 May 1843, 594–97 (the text of the Paper read before the Society of Arts, 17 May 1843). Copy in SML.
81 English patent no. 7614, 18 April 1838; printed specification, pp. 25–27.
82 Cooke, *Electric Telegraph*, part II, Drawing VI.
83 Cooke, *Electric Telegraph*, part II, p. 98.
84 ScM Inv. 1876-1274.
85 Museum of London, accession L329/21. I am indebted to Alex Werner for making this object available for inspection.
86 Newcastle Discovery, accession TWCMS:1997.3755 (old acc. no. SE 5999). I am indebted to John Clayson for making this object available for inspection.
87 ScM Inv. 2004-105.
88 ScM Inv. 1963-214.
89 Letter, Cooke to his mother, 9 November 1837, IET Archives and letter XXXII.
90 *Parliamentary Papers*, 1840, p. xiii: Select Committee on Railway Communication: Fifth Report, with Minutes of Evidence (House of Commons, 6 February 1840).
91 For example, L. Turnbull, *The Electro-Magnetic Telegraph: With an Historical Account* [etc.] (Philadelphia, 1853); T. P. Shaffner, *The Telegraph Manual* (New York, 1859); R. Sabine, *The Electric Telegraph* (London, 1867).
92 For example, C. Mackechnie Jarvis, 'The Origin and Development of the Electric Telegraph: Part 2', *Journal of the Institution of Electrical Engineers* (London, October 1956), pp. 584–92; Marland; Hubbard; J. Kieve, *The Electric Telegraph: A Social and Economic History* (Newton Abbot, 1973); B. Bowers, *Sir Charles Wheatstone FRS, 1802–1875*, 2nd ed. (London, 2001).
93 Cooke, *Electric Telegraph*, part II, pp. 69–70.
94 Cooke, *Electric Telegraph*, part I, pp. 182–83.
95 Cooke, *Electric Telegraph*, part I, p. 186.
96 Science and Art Department of the Committee of Council on Education, *Catalogue of the Special Loan Collection of Scientific Apparatus. MDCCCLXXVI*, 3rd ed. (London, 1877), 349, cat. no. 1508e. Copy in SML.
97 *Great Exhibition of the Works of Industry of all Nations, 1851. Official Descriptive and Illustrated Catalogue*, 3 vols (London, 1851), vol. 1, pp. 477–78. Copy in SML.
98 The ETC bill received Royal Assent on 18 June 1846.
99 R. W. Burns, 'Alexander Bain, 1810–1877 (Some Aspects of his Life)', *Papers Presented at the Seventeenth IEE Weekend Meeting on the History of Electrical Engineering, Swansea, 7–9 July 1989*. Copy in SML.
100 Further details of the ETC's formation and Bain's opposition can be found in Kieve, pp. 42–45, and Bowers, pp. 151–56.
101 A compilation of legal reports is in *Hayward's Patent Cases 1600–1883*, ed. by P. A. Hayward, 5 (1845–1849) (Abingdon, 1988), pp. 421–42. Copy in BL.
102 The manuscript originals of the affidavits are preserved in The National Archives (TNA: PRO C 31/722 and C 31/728) but for convenience in court they were printed and bound. The volume consulted by the author is in King's College Library, Foyle Special Collections, callmark ESCI FOL HE8110. E4 AFF. It bears the name Nathaniel J. Holmes, who was an engineer with the ETC.
103 TNA: PRO C 31/722.
104 ScM Inv. 1963-214.
105 Hatcher died on 2 August 1879 at the age of fifty-eight, but the precise date of his birth has not yet been identified. A biographical memoir by C. Robertson FRS is in *English Mechanic and World of Science*, no. 757, 26 September 1879, 64. Copy in SML.
106 TNA: PRO C 31/728.
107 11 February 1847.

108 BT Archives, POST 81/15, ETC Board Minutes 1846–50.
109 A compilation of legal reports is in Hayward (see note 101), 6 (1850–1853), pp. 285–317. Copy in BL.
110 *The Patent Journal and Inventor's Magazine*, 8, 2 March 1850, pp. 264–66. Copy in BL.
111 *The English Reports, vol. CXXXVIII, Common Pleas XVI, containing Common Bench Reports, Vols 10 to 13* (Edinburgh and London, 1913), pp. 331–50 (reprinted in Hayward).
112 Thomas Fothergill Cooke, *Authorship of the Practical Electric Telegraph of Great Britain; or, the Brunel Award Vindicated; in VII Letters, Containing Extracts from the Arbitration Evidence of 1841, Edited in Assertion of his Brother's Rights* (Bath and London, 1868). Copy in SML.
113 T. F. Cooke, *Authorship* (1868), p. 38.
114 Ibid.
115 IET Archives, Cooke Papers, UK0108 SC MSS 007/II/041.
116 Science Museum Documentation Centre, Technical Object File T/1876-1272.

Notes on contributor

John Liffen is Curator of Communications at the Science Museum, London. He joined as a Museum Assistant, the most junior grade, in 1969. He had a long spell between 1975 and 1984 as assistant to Keith Geddes on the Telecommunications collections, contributing to several major exhibitions. A promotion to the transport collections followed, involving among other things the logistics of the movement of various full-size railway locomotives in and out of the museum building. In 1998 he joined the project team brought together to devise the new permanent exhibition *Making the Modern World*. Opened in June 2000, this is a major synoptic gallery displaying many of the museum's most important historic objects set in the context of their times. Between 2002 and 2004 he was on the project team writing and building an online version of *Making the Modern World*, which used Flash technology to provide multi-media narratives, an innovative technique at the time. He was appointed to his present post in 2003. Alongside his professional responsibilities he has researched and written on other areas of the history of technology such as cash-handling equipment, pneumatic dispatch tubes and early railways. A particular aspect he enjoys is the forensic re-examination of historical evidence to confirm or reject the accepted stories surrounding some of the Science Museum's most important exhibits.

Correspondence to: John Liffen. Email: john.liffen@sciencemuseum.org.uk