

Prof. Charles WHEATSTONE AND HIS TELEGRAPHS

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PREFACE.



In the past I have written articles about the companies of Louis BREGUET and Werner SIEMENS, their activities in the field of telegraphy and their instruments. So it is high time that I now devote one to Charles WHEATSTONE.... Let it be clear from the beginning: I did not do any research about the life and work of Prof. Ch. Wheatstone. First, I am not in the position to do that, and second, some talented people have already done this thoroughly and with success. That has resulted in splendid books and there are several of them in my library. See the bibliography at the end of this article.

SUMMARY [2].

Wheatstone began his life-long involvement with electrical engineering in the days when it was still at the stage of “philosophical toys”. Yet, after having done tests in order to measure the speed of electricity in cables, he had a vision of telecommunications that could deliver printed messages around the world. Working with William F. Cooke he developed the first practical electric telegraph; he also made contributions in the fields of optics and acoustics as well as electrical engineering. He had an encyclopaedic knowledge of the scientific literature in several languages, and made connections which benefited not only his own work but also that of others. His research aided the development of the new King’s College in London into a centre of scientific excellence. Amongst his many inventions were the concertina and the stereoscope, both very popular in the nineteenth century. He is usually remembered by electricians and engineers for the ‘Wheatstone bridge’, which he did not invent but published the details of in the course of a lecture on measurements. He tried to measure the speed of electricity, made electric motors, laid the base for a linear motor, and so much more. Yes, Wheatstone was certainly a major figure in Victorian science.

PART I HISTORY.

1.1. SOME PRECURSORS. [1]

I think it is worth describing in chronological order how technology lead to the invention of the telegraph. I will not go all the way back, but will only highlight briefly some interesting facts and people, starting at the beginning of the 19-th century.



*Around the year 1800 **Allessandro Volta** (1745-1827) noticed that he could generate an electric current by bringing two different metals into contact with one another. Further research resulted in the ‘voltaic pile’, which comprised a stack of discs in the recurring sequence of copper, zinc and felt soaked in sulphuric acid. That was the start of the development of further research for continuous current sources: the batteries.

*In 1816 **Francis Ronalds** (1788-1873) erected in his garden (just above Hammersmith Bridge in London) a complex wooden structure that carried nearly 8 miles of metallic wire. On applying an electric charge to one end of the long wire, a spark would jump from the other end. He thus showed that electricity would travel a long distance in an imperceptible interval of time and without any apparent diminution. Then he used the line to carry out some simple signalling experiments.

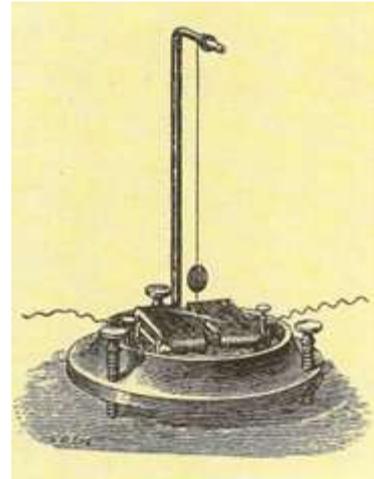
*In 1820, the Danish physicist **Hans Christian Ørsted** (1777-1851) published a paper in which he showed that a magnetic needle could be deflected by a wire carrying an electric current, and that the direction of the deflection depended on the direction of the current and on whether the wire was above or below the needle. Less than two months later **André-Marie Ampere** (1775-1836) published his theoretical explanation of the effect and that was the start of electromagnetism. I can add here that Ørsted was in London in May 1823 where he became acquainted with Wheatstone’s work.

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*At around the same time **Johann Schweigger** (1779-1857) of Halle (Germany, not my hometown here in Belgium...) announced the invention which became known as *Schweigger's multiplier*, an invention of great importance in the history of the telegraph. He had concluded from Ørsted's experiments that if a current was made to flow through a wire wound in a coil, a needle placed inside the coil and parallel to its turns, would experience a force multiplied in proportion to the numbers of turns of wire.

*Schweigger's idea was successfully applied in 1832 by the scientists **Karl F. Gauss** (1777-1855) and **Wilhelm E. Weber** (1804-1891) of Göttingen (Germ.) to the private single line telegraph system (2.5 km) between the observatory and Weber's laboratory. Their system may be regarded as the world's first effective telegraph link. It was mainly used to transmit the results of their measurements related to Ohm's law and the earth's magnetic field. During the mid-eighteen thirties, they handed their system over to prof. **Carl A. Steinheil** (1801-1870) of Munich. He made improvements in the electromagnetic system for generating the current (by a magneto), and also devised a simple but ingenious receiver. He published a description in 1838 but did not develop it any further. Steinheil also discovered in the mid 1830's, during his experiments concerning the use of railway rails as conductors, that he could use the earth just as well as a wire

*At about the same time there was a Russian diplomat in Germany, Baron **Schilling von Canstatt** (1786-1837), who was, with the help of professor **Georg W. Muncke** (1772-1847) of Heidelberg (Germ.), working on a telegraph based upon five electrical circuits controlling five needles. Each magnetic needle was suspended by a silk thread and hung horizontally within a coil of wire. Fixed on the suspended thread was a vertical disc of cardboard carrying a horizontal black line on one side and a vertical line on the other. Below the needle and the coil was a horizontal paddle which moved in a small bath of mercury in order to limit the fluctuation of the needle. As each disc could take two positions, depending on the sense of the electrical current sent by the transmitter, there were 32 possible positions. In the next few years Schilling simplified his telegraph to use only one needle. In 1837, at the order of the Russian Tsar, he installed the first line between Kronstadt and Peterhof. Sadly, he died before the project could be completed and it was discontinued. Pity, he could have been the father of the telegraph...



*Professor Muncke showed such a single needle system in his lectures. It was in March 1836 when one of his audience, a young man called **William Fothergill Cooke**, was extremely captivated by the telegraph and immediately saw its money-making potential. He soon asked Wheatstone to help him. (Will be continued in the next chapters...).

1.2. Professor Charles WHEATSTONE (1802-1875) [1] & [2]

Charles Wheatstone was born on 6 February 1802 in Barnwood (Gloucester). His father was a musician, and in the early 1820's we find Charles engaged in the manufacture and sale of musical instruments in London. Quite how the young musical instrument maker turned to serious scientific enquiry is not clear. His work was directed towards the improvement of the instruments his firm made, but instead of trying one alteration after another he chose to conduct systematic experiments on the nature of sound. He read widely, particularly the published work of Continental scientists. Then he began his life-long involvement with electrical engineering. He obtained his first patent in 1829 for a special music instrument, the "symphonium". In 1833 he published two great papers. One was labelled 'On Acoustic Figures,' and the other 'An Account of some experiments to measure the velocity of electricity and the duration of electric light'. This latter paper on electricity marks a definite departure from the work he had previously done on acoustics. His experiment is known as the one with the rotating mirror. The result of his experiment was 288,000 miles a second, although more precise experiments in the 1860s showed that this was markedly higher than the actual speed of light. Even so, those two great papers so enhanced his scientific reputation that in 1834 he was appointed to the post of Professor of Experimental Philosophy at King's College, London. His early attempts to measure the speed of electrical current using long lines (1833-1834) were inconclusive, but these experiments gave him the idea to transmit signals over great distances. In other words, he was already thinking of how he could convert his apparatus into a telegraph! His later studies of signals in submarine cables contributed to the understanding of the effects of capacitance and inductance in undersea

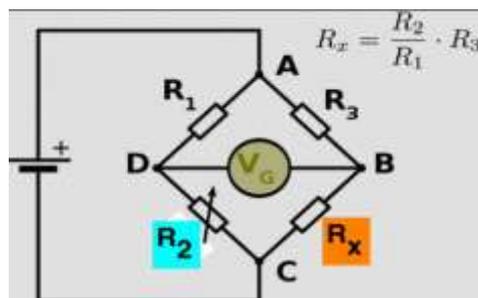
conductors. As a consequence, he devoted himself in the following years (especially during 1836 and 1837) to the making of a telegraph. By early 1837 he had invented several versions. Important to note are relationships with two men who had a considerable influence on him and who helped a lot in that period. These were his friend Joseph DANIELL (1790-1845), who was also a Professor at King's College, and Professor Joseph Henry (1797-1878), Professor of Mathematics and Natural Philosophy at the Albany Academy, New York, an authority on electromagnetism. The fact that Wheatstone alone had the necessary understanding of electric circuit theory to design a telegraph system which would work through several miles of wire put him in a strong position for what followed. Together with William F. Cooke, who knocked on his door on 27 February 1837, he developed in that year the first practical electric telegraph. Both men were interested in it, but their approaches were quite different: Wheatstone was pursuing scientific research while Cooke was embarking on a business venture. Cooke told Wheatstone that his intention was to take out a patent; Wheatstone told Cooke that his own intention was the advancement of scientific theory and that he had no plans to exploit the telegraph commercially. More on this in the next pages. For Belgian readers I can add here that the Belgian scientist (and director of the Royal Observatory) Adolphe Quetelet and Wheatstone were very good friends. In 1840 Quetelet wrote about Wheatstone's telegraph in the Bulletin of the Royal Academy of Brussels, and Belgium was the only European country (outside the UK) to have installed Cooke & Wheatstone needle telegraphs (1845/1846). This was certainly highly influenced by their friendship. Amongst others, Quetelet helped Wheatstone to gain a patent in Belgium.

A few more words about the WHEATSTONE BRIDGE.

Prof. Wheatstone is usually remembered by electricians and engineers for the 'Wheatstone bridge'. He did not invent this instrument, but published details of it in the course of a lecture in 1843 on electrical measurements. It was actually a device first put forward by one of his assistants, Mr. S.H. Christie. But despite all that, the arrangement of resistors (in the form of a bridge?) has been known ever since as 'Wheatstone's Bridge'. He himself called it 'the differential resistance measurer'. And now for the technicians among us...Why is it called a 'bridge'. I think that Brian Bowers is right when he presented this idea in his book on Wheatstone [1] "This term relates not to the whole circuit, but to the detector, which 'bridges' points of equal potential". A last and sad comment here: Charles Wheatstone died almost a hundred and fifty years ago, and while he made a number of significant inventions, he is only remembered, if at all, for this 'Bridge', which he did not invent...

Here she is, "The Bridge"...

The aim is to calculate the resistance value (R_x) of an unknown conductor (e.g. the resistance of a long wire). The equation in the figure becomes valid when no current flows through the galvanometer (R_2 is a variable resistor).



1.3. William Fothergill COOKE (1806-1879). [2]



William Cooke was born at Ealing in 1806. His father was a surgeon who was later appointed to the post of Professor of Anatomy at Durham University. William was educated at Edinburgh University, but that education was not continued beyond the age of nineteen, when he joined the Army. He resigned in 1833 on grounds of ill health. During that year he started to model anatomical sections in wax, and in 1834 he accompanied his parents on a tour of Switzerland and Germany. At Heidelberg he met the director of the Anatomical Institute, and there he returned, in November 1834, to study anatomy. One day early in 1836 he went to a lecture by Professor Muncke at which the professor demonstrated his copy of Schilling's single needle telegraph (see 1.1.). The demonstration was so simple that it appealed to Cooke's untutored imagination. The wires ran across the room and the

needle moved at the other side. Later on, William said that he was thinking at that moment: 'if it could work across a room, why not across a continent'. While still in Germany he made his first instrument during the month of March 1836, corresponding in most ways to Muncke's. In April 1836 he travelled back to London, where he applied himself with his accustomed energy to the development of a telegraph. An important question came up: 'will the telegraph work at the end of a long line?'. He was able to pose this question, through the agency of a friend, to the great scientist Michael Faraday. Faraday, however, who was well known for his discoveries in electromagnetic induction (made in 1831), did not have a definite answer at that time, although he spoke positively as to the general aspects of his plans. That was in November 1836. Then Cooke was directed by Peter Mark Roget, Secretary of the Royal Society, to Prof Wheatstone. He called on Wheatstone on 27 February 1837, and Wheatstone, to Cooke's great satisfaction, told him that he had four miles of wire in readiness. But then Cooke learned that Wheatstone had been employed for months in the construction of a telegraph, and had actually invented several with a view to bring them to a practical use. A positive result of the meeting was that Cooke was invited to come back the next day to discuss a proposal to unite their plans and carry them out together.

1.4. VIA A PARTNERSHIP TOWARDS A PRACTICAL ELECTRIC TELEGRAPH. [2] [3] [4]

In March 1837 the partnership was agreed in principle between the scientist and the entrepreneur, and the current ideas of both inventors could be united; Cooke was more 'the businessman' and Wheatstone on the other hand the 'scientific man'. The full title of the patent is 'Improvements in Giving Signals and Sounding Alarums in Distant Place by means of Electric Current transmitted through metallic Circuits'. It received the 'Great Seal' on 12 June 1837. By December, the 'Specification', for which they were allowed six months under the existing patent law to submit, had a different tale to tell through its eighteen pages of text and its three sheets of drawings; it focused on a five needle telegraph. This patent reflected mostly ideas from Wheatstone and only a few from Cooke. It was a point in time at which Cooke turned from experiments to practical affairs. Subsequent to the grant of the patent in 1837, the first of many that Cooke and Wheatstone obtained together and separately, the partnership constructed lines of telegraph in its own name and granted licences to others to use its instruments and materials. The business had a very slow start, not least because the seed capital used to build the lines had to be borrowed from individuals and banks, as the partners had only limited means. The first 'public' trial was held on 25 July 1837 over a distance of 2.4 km. between Euston Square and Camden Town (North London) for the London & Birmingham Railway. For this trial Wheatstone had made telegraph instruments with four needles suspended vertically (arranged in such a way that twelve characters could be transmitted), and the line was required to be laid at the expense of Cooke and Wheatstone. In September two other demonstrations were given, now with five-needle instruments (twenty characters). Alas, it did not lead to a contract. The first permanent line of electric telegraph in England was completed on 9 July 1839 between the Paddington and West Drayton stations of the Great Western Railway (part of the London to Bristol line), a distance of thirteen miles, having taken a year to make. It used another model of the four-needle instrument which allowed the transmission of twenty characters. On 6 July 1840 a telegraph system was opened on the London and Blackwall Railway. One can say that this was the first successful commercial application of the electric telegraph in the world.

In 1838 Morse was in England seeking an English patent, but the application was opposed by Cooke and Wheatstone, among others, on the grounds that he was seeking to patent ideas which were already

published. In 1840 Cooke and Wheatstone wrote to Morse suggesting that they join forces but after consulting friends Morse rejected the proposal.[2]

The purchase and installation of the wires for all the upcoming projects was very expensive. The only way to raise the necessary capital for further expansion was to form a company, and so “The Electric Telegraph Company” was founded in 1846. Soon after, Wheatstone was bought out by Cooke. He kept rather loose contacts as ‘scientific adviser’ and as ‘assistant’. The establishment of the ET Co was the final parting of the ways for Cooke and Wheatstone. Cooke was a director of the company for most of the rest of his life, although he made no more inventions in connection with the telegraph. Belgium was the only foreign customer (as from 1845). The contact was signed between the Belgian government and the “Compagnie du Télégraphe Électrique”; the English name translated in French. In 1850 the Belgian government took over the operations.

Wheatstone was very successful with his ABC telegraph, patented in 1858 (see Part 2). In order to enforce the success he established the “Universal Private Telegraph Company” in June 1861. The company proved profitable, and when the telegraphs were taken over by the General Post Office (GPO) in 1870 the shareholders, and Wheatstone additionally for his patents, got a huge compensation. In that year the company had over 2,500 miles (4,000 km) of wire and 1,700 instruments in use. Wheatstone also had his own manufacturing establishment, “the British Telegraph Manufactory”. It was first established in about 1858, became a limited company in January 1874, and was wound up voluntarily in 1882.

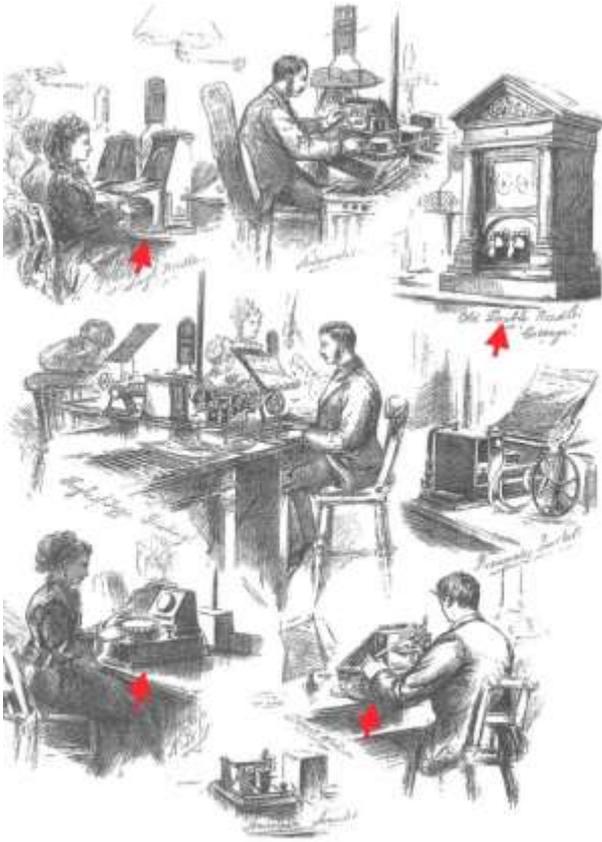
Without going into the tangled complications of the story of Samuel Morse and Alfred Vail in America, it can be fairly claimed that Wheatstone and Cooke were first in the field, with a margin of several years in their favour (sorry, American friends!). And from this point on, slowly but inexorably, the telegraph went ahead.

1.5. TOWARDS A DISCORD [1] [2]

Towards the end of 1840 there was one prospect which disquieted Cooke: the state of his relationship with Wheatstone, which had never been an easy partnership. The cause of the difficulty was their fundamental difference of approach. Wheatstone wanted scientific glory, with, if possible, monetary rewards as well. Cooke wanted commercial success with, naturally, a fair proportion of the scientific glory. It would have been so much easier if Wheatstone had been less astute about money and/or Cooke less hungry for reputation. The tension became more acute the longer they worked together. (Didn't we see later exactly the same happen between Samuel Morse and Alfred Vail...). The divergence continued. Cooke was engaging in building short lines for signalling purposes and therefore in developing and using simple needle instruments, whereas Wheatstone was developing new ideas of less immediate application. In 1841 he made a printing telegraph based on his ‘alphabetic’ (ABC) telegraph of the previous year. However, it was very slow, and the whole idea of telegraphy was too new for there to be any demand for a printer. His main activity in pure science during the next year or so was to establish a sound basis for the measurement of electrical properties such as voltage, current and resistance. Later on, Wheatstone continued with his scientific work, and this resulted in many inventions, papers, instruments, theories and technologies. But an important part of that was still in the field of telegraphy. In Part 2 I will give some details of his ABC telegraph (patented in 1858) and his ‘high speed’ telegraphic system (for which he received, also in 1858, a first patent). He never retired, but continued working to within a few days of his death at the age of 73. It was while attending meetings of the Academy of Science in Paris that he became ill with bronchitis and he died there on 19 October 1875.

Cooke made a great deal of money from the telegraph, though he ended his days in poverty. He invested his money in a quarry in North Wales, and in 1865 he obtained a patent for slate-cutting machinery. But the business failed and he lost all his money. He received his Knighthood in 1869 (the year that the telegraph companies were nationalized), and died in 1879. **End of Part 1**

PART 2: THE TELEGRAPHS.



Here we will have a close look, via short descriptions and photographs, at the most important telegraphs that were first made by Cooke & Wheatstone in the earlier period, and by Wheatstone alone in the later period. The illustrations show instruments in my collection (with a few exceptions, which will be mentioned when applicable). For a detailed description I refer the reader to the bibliography at the end of this Part 2 .

The engraving on the left comes from “*The Illustrated London News*”, 29 November 1874. The four telegraphs marked with a red arrow are part of the Cooke & Wheatstone telegraphs instruments that are described below.

2.1. THE VERY FIRST PRACTICAL ABC TELEGRAPH



The three photos here show an original instrument in the Science Museum in Kensington/London: above the receiver and on the left the transmitter (photos courtesy of The Science and Society Picture Library). It is the oldest practical ABC from the inventors, but it had only a short lifetime because they were concentrating more on their needle telegraphs (see further). It is described in Cooke and Wheatstone’s Patent N°. 8345 of 1840. Obviously it is extremely rare. But on Saturday 22 February 2003 there was one on offer. That was at the ‘famous’ BT auction in the period when they decided to stop the activities of their museum. I was lucky to be there, but the price went up above my means.



Fortunately I was able to acquire several other -but not as historical-rare telegraphs at reasonable prices. Less than a year later (June 3, 2004) the buyer put it on sales at Bonhams for about 3 times his buying price. It didn't sell...

The working principle is rather simple and is somewhat based on that of a clock. The letters of the alphabet are arranged on the circumference of the dial of the receiver like the seconds on a watch. Here, in this early model, the dial was made out of cardboard... This dial turns around, step by step, so as to show character after character through the small front window that can

be seen in the photo. It turns one character, thanks to the action of an electromagnet, each time an electrical pulse is received. The transmitter is sending electric pulses; one pulse with every single move of its dial, driven by the sending operator. At the receiver the dial moves forward by one step, i.e. one letter, for each pulse received. This movement is caused by the action of an electromagnet. Suppose that at the start of a word the sender dial is positioned on the letter A and the little window in the front of the receiver shows the letter A. Then suppose that the next letter to be transmitted is F. That means that the sender has to move its dial by 5 steps. The dial at the receiver will do the same movements and will turn from A to F. The person receiving the message notes the letters at which the needle stops.

It is worth saying that in the same patent another form of telegraph, probably designed by Cooke, was described. Here the receiver dial was fixed and it was a turning needle that pointed to the respective characters. It is this principle that was taken over by later inventors like Werner Siemens, Louis Breguet and many others.)

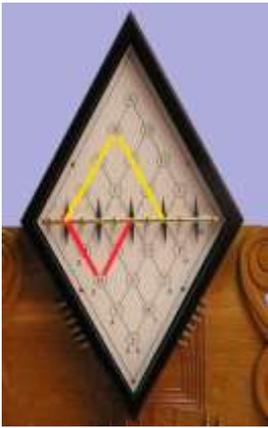


2.2. THE FIVE-NEEDLE TELEGRAPH.[4]



I refer to part 1 which explains how William Cooke came into contact with Prof. Wheatstone and their cooperation that led to their patent 7390 in June 1837. The image below [see Note 1 at the end] is one page of the patent (I have a copy of all figures as well as from the accompanying text). The two photos are from my working replica and will help to understand how this telegraph operated. One can see the five needles (receiver) and needs to know that behind each, in the back, five coils are mounted. The receiving electrical current passes through these coils, creating a magnetic field that then deflects the needles (C̈ersted's principle). Obviously the keyboard is the sender, with two rows of six keys. Let us forget here the two additional right-hand keys, as they are only used when figures must be transmitted. The position of the five other keys (left to right) corresponds with the position of the five needles. By pushing one key of the upper row the corresponding needle deflects to the left; by pushing one key of the lower row the needle deflects to the right. This is because the keys in the upper row connect the battery from + to - whereas the lower ones do it from - to +. Both keys have to be pushed at the same time in

order to close the electrical circuit. The deflection of a needle, either to its left or its right, depending on the current received by the coil, is limited here by a pin on each side, which stops the needle when it reaches a diagonal line on the panel. Suppose now that we push the upper key 1 (turn left action) and the lower key 3 (turn right action); then the diagonal lines on which the needles are crossing point to the letter R > red lines in the next image. Had we pushed the lower 1 (right) and the upper 4 (left), then we point to the B > yellow line. Another example: 2 left and 5 right gives us a W. So this is a "visual" coding and therefore easy to learn.



One of the drawbacks is that only twenty letters could be used; the letters C, J, Q, U, X and Z were not used (and when needed were replaced by others > a V for a U &c.) In order to have all 26 letters there would be a need for a 6th needle, therefore a 6th wire, making the high cost of the lines even higher. Until recently it was generally accepted that (only) three such models of the five-needle telegraphs were used on the Great Western Railway in London. Three of these instruments are known today, of which one is in the 'Science museum' in London, one in the 'Powerhouse Museum' in Sydney (Australia) and one in the 'Deutsches Technikmuseum' in Berlin. But in November 2005, at the Cross "ConneXion" Telecommunications Conference on "The History of Telecommunications" (where I was present), the then Curator Communications (now Emeritus Curator) of the London Science Museum, Mr. John Liffen, after several years of in-depth research, presented an astonishing study. In this he proved that there were many misunderstandings in *all* old literature of the

19th and 20th century about the five-needle telegraphs by Cooke & Wheatstone (so also in my book "Classics of Communication" from 1999...) Here is a summary of the findings which John kindly sent me at that time.

"My research 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 emphasise 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) 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 College 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 but four-needle ones."

So the first pair of five-needle instruments in use were exceptionally large versions with a lozenge-shaped open "dial" about twenty-four inches wide (64 cm) and forty-two inches (107 cm) tall , on a mahogany board

about thirty inches (76 cm) by forty-eight inches (122 cm), with the row of electro-magnetic coils for the five needles protected by a box on the back. These instruments still exist. The transmitter was a separate brass and mahogany desktop 'permutating' keyboard to work the needles on the dial board. Later on, John Liffen's study was fully completed and came out under the title "The Introduction of the Electric Telegraph in Britain, a Reappraisal of the Work of Cooke and Wheatstone" It might be sufficient for most readers to have read John's quote above. But for those who want indeed to read the full report (31 pages) I refer you to the details in my 'Bibliography' [4] at the end of this Part 2.

Here are two interesting images of the 'big' receiver

taken from John's study, showing the front and the back (with the coils that drive the needles) of the original model of the five-needle instrument. This big board was hanging on the wall. The keyboards were separated from them and standing on a desk. (Photos courtesy of The Science and Society Picture Library)



2.2. THE TWO-NEEDLE TELEGRAPH.



In order to avoid the high cost of the lines, two-needle instruments using coded signals replaced the existing ones. But now as the characters had to be coded, this made learning to manipulate the sender, as well as decoding at the receiving side, much more difficult. Here are two models from my collection. Both were probably used in Belgium in the early days, and the left one is the older of the two. The transmitter is formed by the two 'drop-handles', each of which operates the needle above it. The operator commands the needles at the remote site but the signals also pass via the needles of his own instrument, allowing some control. Each character is defined by a combination of the deflection of the left-hand needle to the left or the right and the same from the right-hand needle. Some examples: the letter A is coded by two deviations to the left of the left needle, L by a simultaneous deviation of the two needles to the left followed by a simultaneous deviation of the two needles to the right. Not simple at all... In Belgium the first telegraph network was given in concession (23 December 1845) to the private telegraph company of Cooke & Wheatstone, the Electric Telegraph Co. The first (public) line, interconnecting Brussels with Antwerp via Mechelen, was put in operation on 9 September 1846. The instruments were two-needle telegraphs.

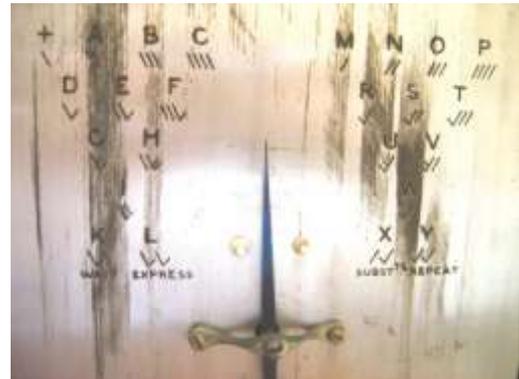
2.3. THE SINGLE-NEEDLE TELEGRAPHS.[5]



After 1845, when Cooke & Wheatstone felt the competition of the single-wire system from Morse, most of the telegraphs in the UK became single-needle ones. In Belgium they came into use beginning in 1850 (photo left, my collection). Until then there was only the line Brussels-Mechelen-Antwerp, but the government took it over in that year and the network expanded rapidly. However, the Morse telegraph had the big advantage that it delivered a written message (dots and dashes on a paper tape) whereas the signals of the needle telegraphs were volatile... The code here with one needle was a lot simpler than with the two-needle instrument. The photo below shows in somewhat more detail the dial with the code. With one needle you can make deflection combinations to the left and the right. You can see that A is marked as two inverted slash (\), B as three, C as four, M as a normal slash (/), N as two, D as an inverted one followed by a normal one (V) &c. An inverted slash means that you have to deflect the needle with the handle to the left, a normal slash that you have to do it to the right. The movement of the handle to the left sends a 'positive' current through the coil behind the needle and a movement to the right a 'negative' current.

(Positive means sending the current in one way through the coil and negative means doing it the other way).

The needle reacts, according to Ørsted's principle, by moving to the left or the right. In the other photo (left) you can see on the bottom the switch mechanism (operated by the front handle) as well as the coil that creates the magnetic field when the electric current is flowing through it. You can compare this code with



the two states of the Morse code: associate a dot with the inverted slash and a dash with the normal slash. But then you will see in the dial of the above instrument that Cooke /

Wheatstone did not follow the Morse code as, for instance, an A is here not the equivalent of 'dot dash' but of 'two dots'. We all know that the Morse code was a well-known optimised code (shortest signals for the most frequent letters). It was not until years later, when Wheatstone was no longer directly involved, that Morse code was used. To my knowledge the needle telegraphs from Cooke & Wheatstone were only installed in the UK and in Belgium. Here in Belgium, as in most countries, we soon moved towards Morse telegraphs and other technologies (all described in my second book [11] and many also in my www.telegraphy.eu [12]). And as of 1865 the International Telegraph Union (later the International Telecommunications Union, part of the U.N.O.) imposed Morse telegraphs (also Hughes telegraphs) for traffic *between* all 20 member states.

The housings of the early single needle instruments were somewhat 'sophisticated'. Most of them looked like chapels and some of them even had gothic ornamentations in the fashion of the time (photo Fondazione Scienza e Technica, Florence). Later models were made cheaper but also much more solid.



Main users were the railroads and later also the Post Office. Here at the left is a picture of a typical one that was in use at the GER, the Great Eastern Railway. One can see, via the \ and / symbols on the dial, that this time the Morse code was used. For example, the letter A is now \ i.e. the equivalent of a dot and a dash. In 1887 about 16,000 of these instruments were in use in the UK! For many years, and well into the 20th century, this type of telegraph was used by British Railways (later British Rail), mostly for signalling purposes. In the photo showing the dial you can see the white 'stop' pins at both sides of the needle, their purpose being to arrest the movement of the needle. It is perhaps hard to believe, but the last pair of instruments, operational between the 'Newark South Cabin' and the 'Doncaster Telegraph Office', were not taken out of service until October 1976 (a hundred years after the invention of the telephone...). And the last telegraph instrument on a Post Office line was not withdrawn from service until 1950! The customary speed was about 25 words per minute. The next eleven images show different instruments based upon the single-needle principle.

As they were used to transmit messages they were called "speaking telegraphs ...". The first photo below shows three different models; the one on the right is an 'acoustic' one (see further), and the other photo, obviously, shows the inside.



The five photos below show models that were in use as railway signalling instruments.



The basic principle of a needle activated by the magnetism created by an electric current in a coil in its vicinity is also used in what were then called 'galvanometers' (we now call them Ampère meters or ammeters). Indeed, the stronger the current the more the needle will deflect. The next photo shows a big galvanometer, probably in the housing that was first intended for a 'chapel' single-needle telegraph. The instruments in the next two photos have the same housing, but in the left one it is a small single needle telegraph (2 little pins limit the deflection) whereas in the right one it is used as a galvanometer: therefore the scale. The last photo shows again a small needle telegraph.





The basic needle telegraph used on all early lines had the great disadvantage that someone had to watch the receiving instruments continuously while a message was being received. Usually the person watching would dictate the message to a colleague who would write it down. A further feature was that the deflection of the needle should produce a sound, the sound being different for the left- and right-hand deflections. The advantage of this would be that the person receiving the message could hear the signals, rather than see them, and could therefore also write down the message as it was received (no need any more for a second person). For that purpose the pins were replaced with a metal pin on which a small metal plate was fixed, e.g. a tin one on one side and a brass one on the other side. In that way the needle would make a different sound when hitting either pin. To end

this chapter I will show a very special application of a single needle telegraph in my collection. When I first



acquired it (thank you AE!), I could not find what the purpose was. One could see in the front that the needle acts as a switch, but what was its function? Later on, during my first visit to the Science Museum in London, I noticed that the same instrument was on display there. A bit remarkable: why was this one displayed, as there were only very few other telegraphs on show? So I thought that it had to be something really special. It is still on display in the gallery "Making the Modern World" in order to show another use of the telegraph as well as conventional person-to-person communication. I got the explanation from John Liffen. Its description is "Bright's patent Relay and Switch for indicating stations where fire-alarm is sounded, 1878". The following text is a copy of the exhibition label; it gives the explanation (courtesy of J. Liffen). One will learn that this alarm set-up is based upon the Wheatstone bridge and that



it uses a single needle instrument invented by Cooke & Wheatstone!

FIRE ALARM, c. 1878

By means of this apparatus, which was patented in 1878 by Mr. E. B. Bright, it is possible at a central station to determine from which of a number of places an alarm has been given.

The various places are connected together by a line wire, and at each place there is a definite resistance as well as a switch whereby the line can be connected with earth. At the central station there are a rheostat, a battery, and a relay controlling a separate bell circuit. The various parts are so connected that the line and the rheostat form adjacent arms of a Wheatstone bridge, of which the relay forms the galvanometer arm and two resistance coils attached to the relay form the ratio arms. If the line at any place be connected with earth the alarm bell rings and continues to do so until the resistance of the rheostat, which can be varied by means of a handle, is made to correspond with that of the line. The position of the handle then indicates the place from which the alarm was given.

The rheostat consists of a series of insulated sectors between which varying resistances are arranged, and each sector bears a number corresponding with one of the outside places. The relay has a coil surrounding a magnetised needle, and mounted on the axis of the latter there are tongues which close the bell circuit when the needle is deflected in either direction.

The relay and the rheostat only are exhibited, and the latter has been partly sectioned.

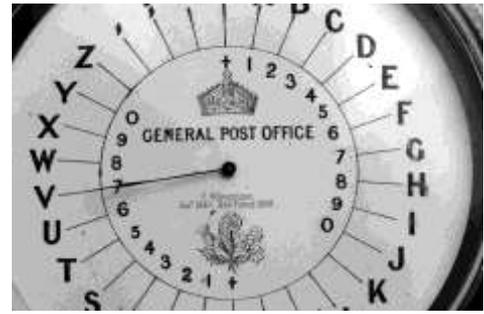
References : Brit. Pat. Spec. Nos. 596 and 3801 of 1878.



The photo on the left (courtesy of J. Liffen) shows the setup in the Science Museum. One can see the rheostat at the left hand site. My model bears the maker's name: "Telegraph Works Silvertown".

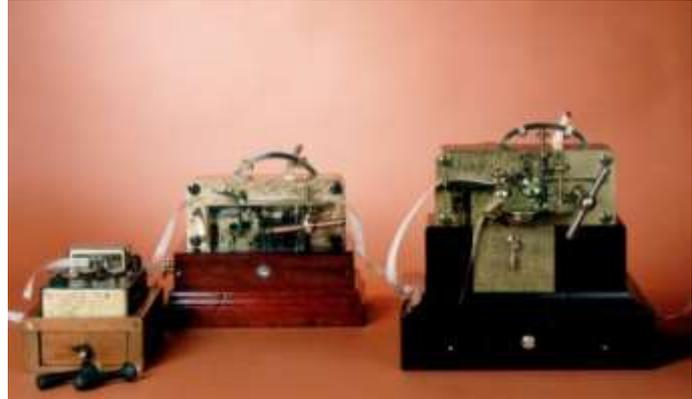


2.3. THE ABC TELEGRAPH FROM 1858 [1]



We have seen in Part 1 that the first working ABC telegraphs were developed around 1840, without commercial success. It was only in 1858 that Charles Wheatstone received a further patent on a much-improved model, which was successful at the time and for many years to follow (another patent for it was obtained in 1860). This model has a built-in dynamo producing alternating current (it generates an 'AC' voltage); i.e. it produces alternate positive and negative electric pulses by turning the crank handle mounted in the front of the base (the base being the transmitter). This was a big advantage as there was no need for a battery, and it converted the ABC telegraph from a curiosity in 1840 into a practical telegraph usable by anyone who could read (no code to learn). The "communicator", as Wheatstone called it, has a dial pointer similar to that on the receiver (see the photos of my model). The dial is surrounded by buttons, one opposite each symbol on the dial. The buttons are linked by a chain in a way that only one can be pressed at a time; when a second button is pressed the first is released. Furthermore, the design is such that signals are only transmitted while the pointer is in motion towards the next symbol. This instrument was very robust and required little or no maintenance. Among early orders there was one for the ABC telegraphs, which were installed in September 1860 between police stations in the City of London. In 1870 the number of installed Wheatstone ABC telegraphs was 1,200 and in 1880 more than 5,000 were in use (where have they all gone? ;o). The speed was from 5 to 10 words a minute.

2.3. THE HIGH-SPEED AUTOMATIC SYSTEM. [10]



This one is also called the 'High Speed' system. It had been patented in 1858 but I learned that it was only put into service in 1867. The basic idea was to prepare the message "off line" at a 'human' speed and then transmit it automatically at high speed by mechanical means. This Wheatstone apparatus comprises three separate and distinct parts. Firstly, the perforator, which is employed to prepare a punched paper tape ("slip" as it is termed), which contains the signals that should be sent out. Secondly, the transmitter - the paper tape reader - which serves to send out signals in accordance with the perforations of the slip. And thirdly, the receiver, which is a very sensitive form of polarized direct ink writer. About the *perforator*. The tape has three lines of holes; the central line is for driving and guiding while the outer lines are punched or not, according to the Morse code. A 'dot' is created by pushing the left hand button; it makes a pair of holes on both sides of the centre hole at the same



M O R S E



position. Pushing the right hand button for a 'dash' there are also two holes but they are staggered. The button in the middle is used to create the 'space' between the words. The drawing hereby will make this clear. The



tape is drawn through a paper tape reader (the *transmitter*), by the central line of holes, one hole-spacing at a time. At each position two light metal rods are pressed successively against the paper. The rods operate contacts whenever they pass through a hole, producing positive and negative pulses respectively. When a dot is read two pulses occur in quick succession. When a dash is read their



separation is somewhat increased. In the photo at the right one of the rods (hiding here the other one) is indicated by a red arrow.



The *receiver* is a sophisticated Morse writer. The dot and dash signals are printed in ink. In the early days, both the transmitter and receiver were driven by a weight, later by a spring motor, and in the end by an electric motor.

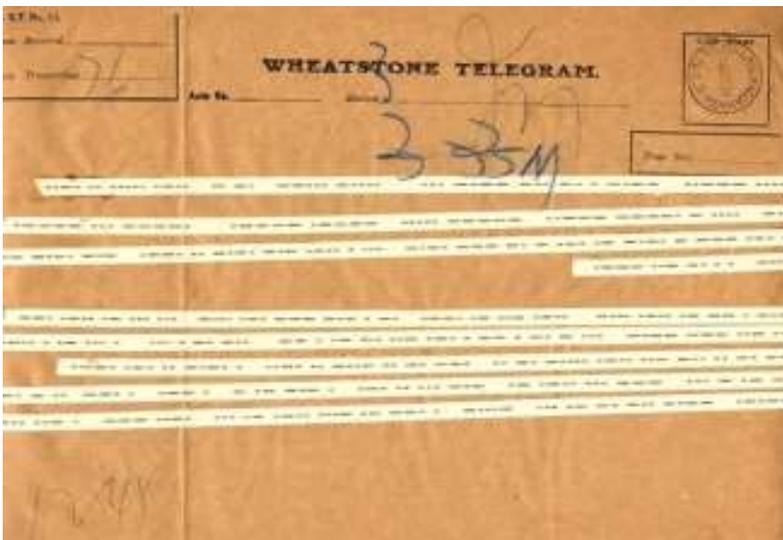


Both the transmitter and the receiver have a speed regulator: see the bow on top of them and the marks SLOW and FAST.

Explaining how the transmitter and receiver are doing their job is far out of the aim of this article. See for instance TELEGRAPHY, a reference work by T.E. Herbert [10]. Speed was important because it enabled more messages to be sent over one circuit, and the provision of the telegraph circuits was the major part of the capital cost of a telegraph system. Several clerks could now prepare message tapes simultaneously, and the tapes would then be fed into a single transmitter. In 1880 W.H. Preece (later Sir William Preece), Engineer-in-Chief of the Post Office, gave his assessment in a lecture at the Royal Institution on the subject of Wheatstone's telegraphic achievements. He referred to the speed of Wheatstone's automatic apparatus, and stated that when it was invented it was "only" working at an average of 70 or 80 words a minute, but that after improvements it was working at a rate of 180 or 190 words a minute. In 1870 there were eight such high-speed telegraph systems in use, and in 1880 the number had already increased to 151.



The basic principle of the Wheatstone transmitter was still alive up to the middle of the 19th century. Companies like G.N.T. (Denmark) used it. The photo shows one of its popular transmitters.



FROM MY LIBRARY

I used/copied information out of the following books:

- [1] **"COOKE AND WHEATSTONE and the Invention of the Electric Telegraph".** *Geoffrey HUBBARD*, 1965
- [2] **"Sir Charles WHEATSTONE FRS 1802-1875".** *Brian BOWERS* The first edition appeared in 1975, the second in 2001. It is published by the IEE and © by the Science Museum in London
- [3] **"DISTANT WRITING".** *Steven ROBERTS*, 2012 It has never been published as a book but the 340 pages can be downloaded > <http://distantwriting.co.uk/>
- [4] **"THE INTRODUCTION OF THE ELECTRIC TELEGRAPH IN BRITAIN, A REAPPRAISAL OF THE WORK OF COOKE AND WHEATSTONE".** *John LIFFEN*, 2010. Published by the International Journal for the History of Engineering & Technik, Vol. 80 No. 2, July, 2010, 268–99
- [5] **"THE SINGLE NEEDLE TELEGRAPH".** *Andrew EMMERSON*, A (not published) study from 1984

I recommend the following ones:

- [6] **"THE ELECTRIC TELEGRAPH: WAS IT INVENTED BY PROFESSOR WHEATSTONE?".** *William Fothergill COOKE*, 1854.
- [7] **"HISTORY, THEORY AND PRACTICE OF THE ELECTRIC TELEGRAPH".** *George B. PRESCOTT*, 1866.
- [8] **"THE VICTORIAN INTERNET".** *Tom STANDAGE*, 1998.
- [9] **"HISTORY OF TELEGRAPHY".** *Ken BEAUCHAMP*, 2001.
- [10] **"TELEGRAPHY".** *T.E. HERBERT*, 1907 (sec. ed.)
- [11] **"HET INTERNET VAN DE 19-de EEUW".** *Fons VANDEN BERGHEN*, 2012 > 434 pages. For the moment only in Dutch, but with 650 images. Only downloadable via:
<http://www.telegraphy.eu/pagina/boek/TELEGRAFIE%2025%20APRIL%20Fons.pdf>
- [12] My www.telegraphy.eu and www.telegraphsofeurope.net

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- * **Bill Burns**, for revising and correcting my 'Flemish English'... Bill is the leading world authority regarding submarine cables and everything related to it > see his <http://atlantic-cable.com/>

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