Alexander Bain:
The Real Father of Television?

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Introduction

Alexander Bain (1810-76) is a virtually forgotten nineteenth century engineer. If he is ever mentioned, it is usually as inventor of the fax machine without any acknowledgement of his other inventions or his significance. He is also frequently confused with his near contemporary, Alexander Bain (1818-1903), the eminent philosopher and academic for whom Aberdeen was place of birth and death and the location of most of his illustrious career. Almost every aspect of the subject of this article could not be more different. He received little formal education, he was not an establishment figure, and he died in poverty and obscurity leaving few writings and apparently little influence. Yet as a young man, he went to London and found himself at the centre of the new electric clock and telegraph industries, filing patent applications and meeting and negotiating with important individuals. Within a few years, he was a self-employed businessman with offices at various times in Edinburgh, London and New York, but this phase of his life was short lived and he ended almost where he had started.

Background

By the middle of the nineteenth century, the electric telegraph had already revolutionised communication as the first and biggest step in the shrinking of the world that is so familiar today. Prior to this time, communication was limited by the speed of horses, ships and the railway. Communication at the speed of light had always been possible using some form of line-of-sight signalling, but it was not until the late eighteenth century that it was exploited in the semaphore telegraph. Driven by defence needs, systems were installed in many European countries including the United Kingdom, where the main routes radiated from London to various naval bases. A semaphore telegraph comprised towers placed on hills five to ten miles apart with their shutters or moveable arms visible in silhouette against the sky from a neighbouring tower. Unfortunately, the technique was only available for less than 20% of the time, and expensive to operate - more than £3,000 per annum for the London-Portsmouth route alone.[1] Messages could not be sent at night or in fog, and two to four operators were required in each tower. Once the electric telegraph became a practical device, the semaphore telegraph was doomed and eventually abandoned in the late 1840s.

The pace at which electric telegraphy progressed from initially crude ideas to very sophisticated systems capable of transmission rates of hundreds of words per minute, with punched tape input, alphanumeric printing and multiplexing, was astounding. From the first patents in the 1830s, its global expansion was rapid once the manufacture of submarine cables was perfected; for example, the English Channel was crossed in 1850, the Irish Sea in 1852 and then the biggest obstacle of all was overcome when the first successful Atlantic cable between Ireland and Newfoundland was laid in 1866. With telegraph mania being characterised by claims and counter-claims over patent infringement, it was not surprising that the issue of priority would eventually impact on Bain's activity in this and related fields.

Alexander Bain photographed in 1876 on behalf of the Society of Telegraph Engineers, the forerunner of the Institution of Electrical Engineers, which merged with the Institution of Incorporated Engineers in 2004 to form the Institution of Engineering and Technology. *IET photograph.*

The modern era in the understanding and exploitation of electromagnetism can be traced back to about 1800 when Alessandro Volta[2] demonstrated his voltaic pile or battery, enabling current-based electrical devices to be made in place of those using static electricity from the discharge of a Leyden jar - as capacitors were then referred to. This breakthrough was followed by two important discoveries which were the basis of Bain's work on clocks and the electric telegraph. In 1820 in the University of Copenhagen, Hans Christian Oersted[3] noticed that a current-carrying wire affected a nearby compass needle

- indicating that while the current was flowing the wire was producing a magnetic field. Then in 1831 at the Royal Institution of Great Britain, Michael Faraday[4] found that a potential difference or voltage was produced between the ends of a length of wire when moved relative to a magnet, a process now known as electromagnetic induction. These two phenomena led to the electromagnet and the dynamo respectively.

Alexander Bain's Early Life, 1810-37

Little is recorded of Alexander Bain's early life, even in his own writings. His parents John and Isabella (Tait) Bain rented a small farm at Backlass Hill, two miles to the west of Watten, almost mid-way between Thurso and Wick. There were already two sons and two daughters in the family before he and his twin sister were born in October 1810 and they were followed by another four sons and two daughters making a total of twelve.[5] According to the *New Statistical Account of Scotland*, in 1840 there were three schools in the parish of Watten: one parochial, one supported by fees and one endowed by the Church of Scotland General Assembly's Education Committee that Bain attended.[6] He was a very idle and day-dreaming scholar, but even as a boy he turned his hand to repairing clocks. After leaving school in 1822, he worked on the farm until he was apprenticed in January 1830 to John Sellar, a clock and watch maker in Stafford Place, Wick. To avoid the daily walk of sixteen miles round trip, he might have stayed in Wick with his eldest brother Peter, a teacher who had lost a hand in an explosion while serving as a soldier.[7]

Almost immediately after starting his apprenticeship, Bain attended a public lecture in Thurso that changed his life for ever. Its title was 'Light, Heat and the Electric Fluid' but the understanding of the three topics at this time was very limited. The wave character of light had only recently been demonstrated and explained by the experimental and theoretical work of Thomas Young[8] and Augustin-Jean Fresnel;[9] thermodynamics, the science of heat, was not properly quantified until later in century by Sir William Thomson (Lord Kelvin)[10] and others; while the first important observations on current electricity had just been made. Bain described the impact of the talk in the following terms:

> When the lecture was over, and the audience were leaving, a few gentlemen accompanied the lecturer, and conversed with him on the subjects of the lecture. There was a humble lad walking behind them, and listening attentively to what was said...he never forgot the lecture, nor the subsequent conversation.[11]

In 1837, he took the huge step for that time of moving to London. Before the creation of a national railway network, the logistics of travelling seven hundred miles overland were not insignificant but with coastal shipping well developed, he would probably have sailed first to the Forth and thence to the Thames. Local tradition maintains that he broke his period of apprenticeship to learn more about electricity than he could in Wick, and that his father and a neighbour had to pay compensation as guarantors but were later recompensed. This assertion is supported by the fact that he spent a short time in Edinburgh before moving to London and must have left Wick before the seven years were fully up. However, that he then worked as a journeyman in London suggests he somehow completed his apprenticeship before moving there.[12]

Bain's Electric Clock and Telegraph

Establishing himself in Clerkenwell, the centre of the London clock and watch industry, and with lodgings in Wigmore Street, Bain first set about self-improvement by attending lectures in the Adelaide Gallery[13] and the Polytechnic Institution,[14] two locations where new inventions were exhibited as popular entertainment. He then decided to make an impression in this exciting era in engineering by combining what he had learnt about the mysterious powers of electricity with his trade, in other words to construct clocks driven or controlled by electric currents and conversely to apply the principles of clockwork motors to the electric telegraph.

There were more than twenty different known but unpatented telegraphs, dating back to the 1770s, before the five-needle telegraph was patented in June 1837 by William Fothergill Cooke[15] and Charles Wheatstone.[16] This list of early telegraphs contains many impractical ideas, such as using a different wire for each alphanumeric character, using static electricity generated by friction, and observing the production of gas by electrolysis in a specific container of water to indicate the receipt of a specific letter. However, the list also pointed towards the future by including those using a single wire, those using the deflections of compass needles, those in which the deflections made a mark on a moving strip of paper, and those which printed characters.[17] Even earlier in 1753, 'C.M.' of Renfrew wrote a remarkable letter to the *Scots Magazine* describing the various components of a proposed static electric telegraph, but without any indication that it was ever constructed.[18]

From 1837, a bewildering array of new instruments and improvements to the telegraph were patented, but *not* the telegraph itself - the popular history that Cooke and Wheatstone or even Samuel Morse[19] invented the electric telegraph is simplistic. The situation concerning electric clocks was similar, in the sense that working but fundamentally impractical examples using the attractive and repulsive properties of static electricity to maintain the swing of a pendulum were also demonstrated in the first decades of the nineteenth century. It was only when Bain looked afresh at the problem that the modern concept of an electromagnetic clock powered by an electric current was established.

Fig.1: Sir Charles Wheatstone (1802-75) at the time of his encounter with Alexander Bain.

By July 1840, Bain had made rough models of an electric clock and a printing telegraph, but like all inventors he needed advice as to how to proceed. He contacted Mr W Baddeley, assistant editor of the *Mechanics' Magazine*, a journal that reported on the latest technical advances. Baddeley in turn suggested that Bain should meet Charles Wheatstone (Fig.1), Professor of Experimental Physics at the newly-founded King's College, London. The introduction was made on 1 August 1840 at the college, followed by a meeting at Wheatstone's home on the 18 August, when Bain brought along his models. Although this meeting seemingly provided a way to reach out to London's engineering establishment, in fact it was the first of a number of mistakes that ultimately blighted Bain's life.

Dispute with Charles Wheatstone

At the second meeting, Wheatstone gave Alexander Bain £5 for the model of the printing telegraph, ordered two working examples for £150 and promised a further £50 if he succeeded in selling a telegraph using this method of printing.[20] He demanded that the discussion should be kept confidential and that further activity on the electric clock be suspended, possibly to ensure progress on the telegraph instruments. Bain decided to ignore Wheatstone's admonition and together with John Barwise, a 'Chronometer Maker' of St Martin's Lane, applied on 10 October for what was to become the first United Kingdom patent for an electric clock. Unfortunately, because of one of Queen Victoria's confinements commencing on 24 November, Patent No.8783 was not signed until 8 January 1841. To Bain's dismay, Wheatstone meanwhile exhibited a similar electric clock at the Royal Society on 26 November 1840. Then just after the patent was granted, Wheatstone again attempted to exhibit an electric clock, this time at the Adelaide Gallery, but was prevented by an injunction secured by Barwise. Bain's own clock was eventually displayed at the rival Polytechnic Institution a few weeks later, on 28 March. These were not electric clocks in the accepted sense, but were 'slaves' in which a pulsing electric current drove the gear train and hence turned the hands. The pulsing current was produced by the swinging pendulum of a conventional weight or spring driven clock operating a switch.[21]

The telegraph instruments were duly completed and delivered to Wheatstone during the autumn of 1840, but Bain did not succeed in obtaining payment or even compensation for the materials used. Finally, in December he confronted Wheatstone at his home, but after a heated exchange he left without his money or his handiwork. In this way a bitter feud was born between the two men. During 1841 and 1842 the row became public. It was mainly fought in the pages of the *Literary Gazette* and the *Inventors' Advocate* with letters appearing in almost every issue, contesting each disputed point. Wheatstone disparagingly referred to Bain as a 'working mechanic who had been employed by me…' At one stage someone even tried to bribe the editor of the *Inventors' Advocate* by offering to place lucrative advertisements if he refused to publish further letters in support of Bain. The correspondence also featured testimonials from friends of the two protagonists confirming what had been said or done at each stage.

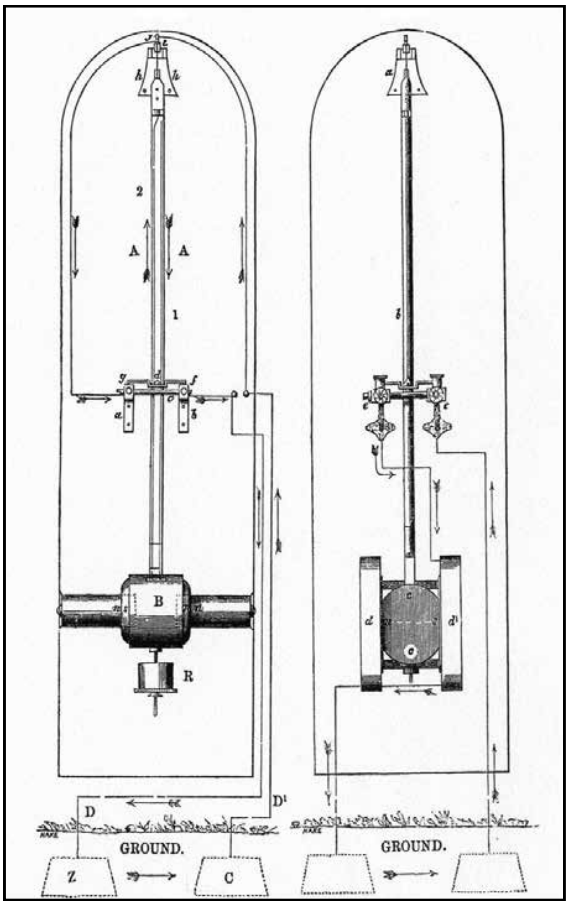
Bain's champion was Thurso-born John Finlaison (1783-1860), Actuary of the National Debt, first President of the Institute of Actuaries and a man sufficiently eminent to deserve an entry in the *Dictionary of National Biography*.[22] In 1843 he published a very detailed but probably biased account of the dispute which described his reaction to seeing Bain's printing telegraph at an exhibition in the following terms:

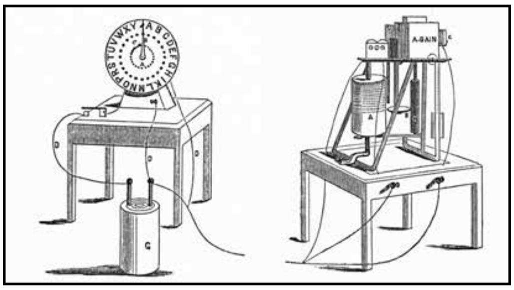
> On enquiring who was the inventor of this extraordinary apparatus, the writer found to his great surprise that he was a young man, by the name Alexander Bain; by trade a clock and watchmaker; a self-taught genius from the author's own spot in the extreme north of Scotland, totally unfriended and hitherto unknown to fame.[23]

Finlaison's intervention might well have back-fired because the book was not well received in the technical press. The *Electrical Magazine* condemned it by recording 'we cannot congratulate Mr. Bain on the manner in which his claims have been advocated; however much he may think himself wronged, and however deeply his feelings may have been wounded by the sense of his unmerited neglect, we are quite sure that the great want of courtesy displayed in every page of Mr. Finlaison's work will induce many to close the volume without doing justice to the young man, in whose behalf it is penned'. This review added that 'the tedium and constant repetition of the same charges, and the same evidence only weary the reader without strengthening the case', but surprisingly still recommended the book because it contained an early history of the electric telegraph.[24] In its review, the *Practical Mechanic and Engineers' Magazine* also commented on 'the reiteration and repetition of personal charges with which its pages are overlaid', but came down firmly on the side of Bain as the wronged individual.[25]

For the rest of his life, Bain maintained that meeting Wheatstone was the biggest mistake he had ever made. Here was someone with little formal education who found himself before one of the most eminent scientists in London. In contrast, Wheatstone was an experienced inventor, and with Cooke had already patented a telegraph and been involved in experimental installation of telegraphs on the railway. With Bain describing a possibly better telegraph and an electric clock, Wheatstone should have warned him about premature disclosure, especially to a potential rival. But at a distance of more than 170 years it is impossible to determine what actually happened at the meetings other than that the two men were working towards the same ends. Bain was certainly naïve in discussing his ideas, but Wheatstone might well have thought that he was buying the telegraph instruments and the rights to them. The electric clock is a different matter as it appears not to have been part of any contract. It is also worth noting that Wheatstone's dispute with Bain was not his only one. He later fell out with his business partner Cooke over patents and royalties to such an extent that they had to seek arbitration from Sir Isambard Kingdom Brunel and John Frederick Daniell;[26] nor did he object to his 1843 improved version of the resistance bridge - invented in 1833 by Samuel Christie - becoming known as the Wheatstone bridge.[27,28] Cooke's subsequent account of his experiences, *The electric telegraph: was it invented by Professor Wheatstone?*, is surprisingly reminiscent of Finlaison's effort on Bain's behalf.[29]

Despite Wheatstone and Cooke's turbulent history, in 1846 they formed with others the Electrical Telegraph Company. As the erection of telegraph lines would involve rights of way issues, they applied to Parliament for a Bill of Incorporation. Immediately, this was opposed by Bain on the grounds of patent infringement. The Bill was passed by the Commons but when it reached the committee stage in the Lords, the Duke of Beaufort, as chairman, decided to take evidence. Both parties were legally represented although Cooke and Bain also spoke for themselves. In contrast to Wheatstone's diffidence, the committee was so impressed by Bain's personal appeal that it hinted to Cooke and Wheatstone that they should come to some kind of settlement or risk the Bill being defeated. The deal was that in return for withdrawing his objection, Bain would receive £7,500 along with a further £2,500 for the use of his own 1845 patent on printing telegraphs, and the Electric Telegraph Company would make his electric clocks, provide





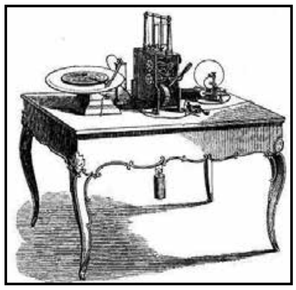


Fig.2 (left): Bain's electromagnetic clock of 1843, powered by the 'earth battery'. It shows the two arrangements of the electrically maintained pendulum: left, the pendulum bob is an electromagnet moving relative to fixed permanent magnets; right, the bob is a permanent magnet moving relative to two electromagnets. The sliding contact switch is located near the middle of the pendulum in each case. It was made of gold to prevent oxidisation and operated at just the correct point in the swing to allow the pendulum to be attracted in the opposite direction. From A Bain, *A short history of the electric clocks* (1852).

Fig.3 (above): A simplified version of Bain's printing telegraph. In the sender (left), the character to be sent and printed is selected by stopping a clockwork driven pointer at the appropriate location on a labelled disc. In the receiver (right), the printing type-wheel (B) is rotated into the correct position by an electric clock escapement released one tooth at a time by electrical pulses. These are produced by the pointer on the sender passing over electrical contacts. The type-wheel is inked by the roller (C) and prints the selected character on the drum (A) on which paper is wrapped. In both the sender and receiver, the pointer on the dial and the printing wheel are continually rotated by their respective clock mechanisms. From A Bain, *A treatise on numerous applications of electrical science to the useful arts* (c.1866).

Fig.4 (above right): Bain's chemical telegraph. It uses strips or discs of chemically treated paper on which a metal stylus connected to the telegraph line rests; in this example, the paper is on the turntable on the left. When the message is sent as dots and dashes, there is electrical conduction from the tip of the stylus through the paper to an earthed metal surface below. The electric current causes a blue mark to be made by decomposition of the salt in the paper's treatment, and as the disc is turning by clockwork a permanent record of the message is made. The weight powering the clockwork mechanism for rotating the turntable is visible below the table. From T P Schaffner, *The telegraph manual* (New York, 1859).

capital for their manufacture and market them. He would also receive half of the profits and the clock dials would be clearly marked 'A. Bain – inventor'. Wheatstone's response was to resign from the company - although he would continue to receive royalty payments.[30,31,32,33,34]

Patents and Discoveries, 1841-64

Alexander Bain's first patent of January 1841, No.8763, lodged in collaboration with John Barwise presumably for financial support, established him as the father of electrical horology despite a similar Bavarian patent being obtained unbeknown to him by Carl August Steinheil (1801-70) in October 1839. It was an extremely important and wide ranging patent as it anticipated many applications of electricity to time-keeping including the use of electricity and electromagnets to drive clocks in place of weights or springs, the use of a central clock to operate any number of clocks, and the distribution of time using a system of master and slave clocks. The principles behind the synchronisation of clocks were not only relevant to measuring and controlling time but were also vital to the synchronisation of printing telegraph instruments where the characters being printed must be the same as those being sent. The Antiquarian Horology Society has championed his cause and it marked the centenary of his death by organising an exhibition entitled 'Electrifying Time' at the Science Museum in 1976-77. Ironically, Wheatstone was absent from the timeline of pioneers on the catalogue's cover where Bain was in second place after Sir Francis Ronalds (1788-1873), a developer of the impractical electrostatic clock.[35]

Following on from his 1841 patent, he applied for a number of others during the next 23 years until his last in 1864. His equally important patent, No.9745 of 27 May 1843, lodged from an address in Oxford Street, extended his first and described a proper self-contained electric clock. It was powered by a pendulum attracted to and fro by electromagnets using the continually reversing current produced by a switch operated in turn by the swinging pendulum (Fig.2). It also included the 'earth battery' in which the electric current was obtained from zinc and copper plates imbedded in damp soil as an alternative to the expensive Daniell cells then in use. If used in a telegraph, the plates could be many miles apart at each end of the line thus dispensing with the second wire in a circuit. This discovery was made in a series of experiments performed in Hyde Park and the grounds and 'moat' of Finlaison's house in Essex, in collaboration with a Lieutenant Thomas Wright of the Royal Navy.[36]

Bain's contributions to the electric telegraph were many, as each patent covered a wide range of ideas as well as improvements to previous designs. On 7 December 1841, in collaboration with Wright, he patented a printing telegraph (Fig.3), although an unpatented example, possibly the one at the centre of the dispute with Wheatstone, had already been on display in the Polytechnic Institution.[37] A version was used in 1844 by the London and South Western Railway between its original terminus at Nine Elms and Wimbledon.[38]

Then in 1843 he patented the chemical telegraph (Fig.4) which became the basis of his short-lived commercial success.[39] His co-patentee on this occasion was a Robert Smith, 'lecturer in chemistry' of Blackford, Perthshire. This telegraph was silent, and when coupled with a punched tape reader at the sender, as also invented by Bain, exceptional speeds were obtainable; for example, more than 1500 characters per minute were sent and received in a demonstration in France in 1850.[40] Neither the phenomenon of marking paper by electricity nor the chemical telegraph itself were novel, but Bain's improved version was later used by the Electric Telegraph Company on its London-Manchester and Manchester-Liverpool circuits until replaced in the 1860s by a Wheatstone system. It suffered from the need for chemically treated paper to be available – at a time when the necessary infrastructure was primitive - and for it to be maintained in a damp state; but in the USA it was reported to be more reliable than Morse's telegraph in damp conditions and more sensitive to weak signals.[41]

But what of the fax machine referred to at the start of the article? It was part of Bain's 1843 patent and combined the separate principles of electrically-synchronised pendulums and electrical printing on chemically treated paper.[42] Its significance will be revisited later but its operation can be understood by reference to Fig.5. The idea was probably not pursued by Bain but he is nevertheless still recognised as the inventor of facsimile transmission (fax).[43] His approach was vindicated in 1865 when Abbé Caselli, using similar equipment, launched the first commercial facsimile service between Paris and Lyon.[44] By the 1920s the technology was mature enough to be adopted worldwide for sending copies of photographs and documents, while the 1980s digital revolution ensured that fax machines became part of office and domestic furniture.

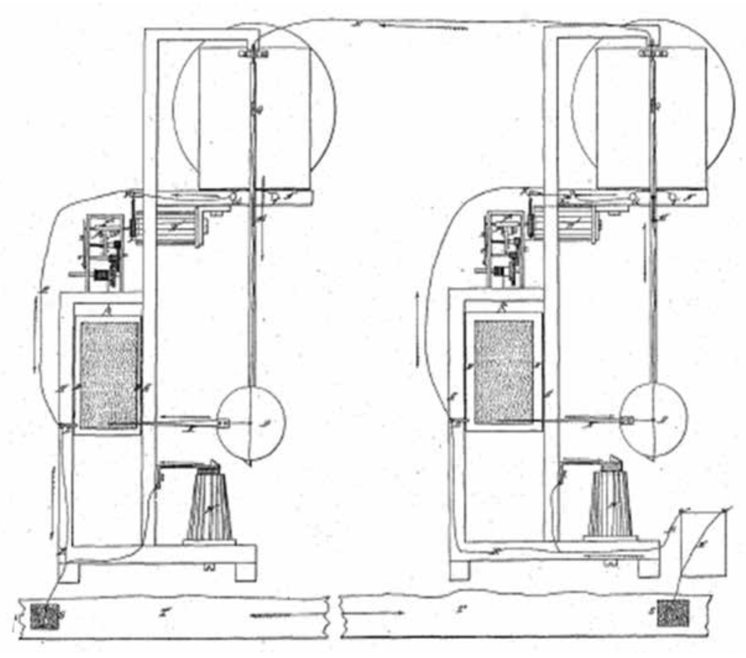


Fig.5: Bain's facsimile telegraph of 1843. The document to be sent comprises metal typeface characters in the left hand rectangular frame, while the printed copy will be on a sheet of chemically treated paper in the right hand rectangular frame. Each of the two pendulums has a stylus protruding from it that makes electrical contact with the raised surfaces in the original and makes a corresponding mark on the paper via electrical printing as in the chemical telegraph. The synchronised swinging pendulums scan and print lines respectively, while the original and the printed copy are steadily lowered after each swing. In this way every point on the original is transferred to a printed point on the paper. Illustration from US Patent No.5957: A Bain, *Improvement in copying surfaces by electricity,* December 1848.

Among Bain's other patented inventions was an ear attachment for listening to the clicks of the telegraph receiver to maintain confidentiality, a telegraph sending key, a device for producing punched tape, a telegraph with a dial similar to a telephone's for selecting characters, a 'voltaic governor' for ensuring that wet cells produce a constant current by controlling the immersion of the electrodes in the electrolyte, a device for drawing a measure of liquid from a container as in a bar optic for spirits, a water tap as found in drinking fountains where pressing a glass against a lever turns on the liquid, a typewriter ribbon, a fire alarm, a marine depth sounder with electrical recording of the amount of line required to reach the bottom, a ship's log for recording speed at sea, a ships chronometer using a 'sea battery' for power, a pre-loaded magazine for a rifle or pistol, and electrical control of a remote player- piano using punched tape.[45]

Edinburgh and London

Alexander Bain relocated his business from London to Edinburgh in 1844 and then back again within four years; but before undertaking the first of these journeys he married Finlaison's widowed sister-in-law, Matilda Bowie (née Davis), mother of a six year old daughter. Although they were a couple for only twelve years, they were also apart for extended periods during his visits to the United States. They eventually had five children - two daughters (Elizabeth, 1846 and Isabella, 1848), twin sons (Alexander and Henry, 1849) and a third daughter, Barbara.[46]

Bain and his new wife moved into rooms at 75 Princes Street, Edinburgh, and opened a workshop nearby at No.11 (now No.21) Hanover Street. He was listed under his own name in the 1845-46 Post Office Directory as an electric clock and telegraph manufacturer, but by 1847 - following the settlement with Cooke and Wheatstone - his business was named as the Electric Telegraph Company. The family probably returned to London late in 1847. Bain's address for a patent of that year was Upper Baker Street, but soon after they were at Beavor Lodge, Hammersmith - an important enough house to warrant a full description in the London County Council's 1915 Survey of London.[47] As was expected of a successful businessman, his household there in 1851 boasted a staff of five servants and a private tutor for his children.[48] Although demolished in the 1960s, Beavor Lodge was coincidentally occupied for a while by the International Time Recording Company Limited, a manufacturer of time register systems based on electric master and slave clocks. Bain seems to have been well aware of his upward mobility in society, referring to himself in his patent applications as a 'mechanist' in 1841, an 'electrical engineer' in 1847 but as a 'gentleman' in 1852.

Time Distribution

In 1846, during his stay in Edinburgh, Alexander Bain was involved in a very important demonstration of the potential impact of the electric telegraph and electric clock. Assisted by his brother John, he constructed a telegraph line alongside the forty-six mile route of the Edinburgh and Glasgow Railway, which had been opened between the two cities via Falkirk (High) in 1842. Despite being rewarded with a contract from the company and being able to restrict the cost of the telegraph line to £50 per mile[49,50] - in contrast to his rival Wheatstone who was charging the Great Western Railway at least £250 per mile - he still needed to borrow £3,000 from Finlaison.

Bain's personal interest in this project was the feasibility of time distribution over a significant distance. For example, the master clock in Edinburgh could be controlled by the Royal Observatory while slave clocks could be installed in each town along the route. He had the vision to realise that universal time was essential for modern life and that it could be distributed in the same way as any utility. Up to the coming of the railways there was little need for universal time as overland travel was slow. People just went by the time set by 'local noon'. With the expansion of the railway system over longer routes, trains had to run to timetables based on a single time zone - something that was then impossible for lines of east-west orientation. The railway companies and the early telegraph developers were natural partners; the former needed the services of the latter for sending company messages while the latter needed the formers' rights of way without having to negotiate with landowners. Later, the railway companies established their own telegraph departments to install and maintain the block method of signalling, based on telegraphy between adjacent signal boxes.[51]

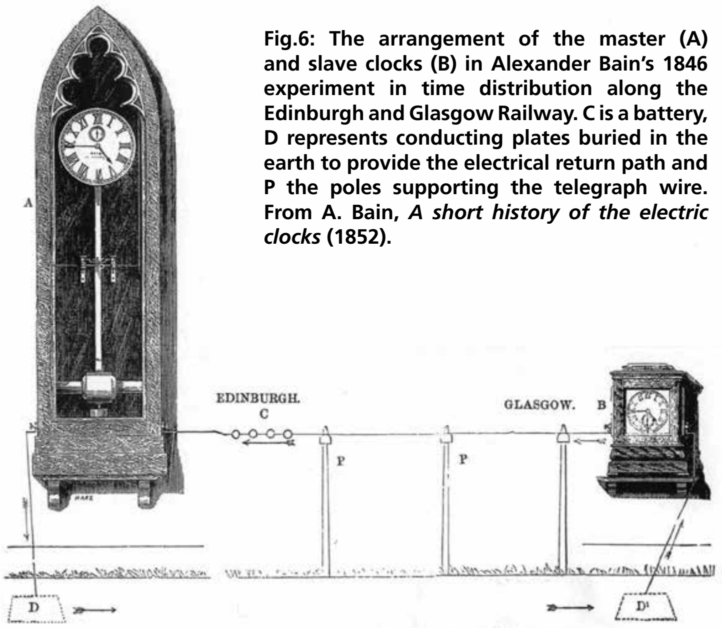


Fig.6: The arrangement of the master (A) and slave clocks (B) in Alexander Bain's 1846 experiment in time distribution along the Edinburgh and Glasgow Railway. C is a battery, D represents conducting plates buried in the earth to provide the electrical return path and P the poles supporting the telegraph wire. From A. Bain, *A short history of the electric clocks* (1852).

Fig.6 shows Bain's own diagram of the master and slave clock system. The master was an electric pendulum clock connected via a single wire to the slave in Glasgow. The plates (D), pushed into the earth, were only to provide the return path and not the electric potential, which in this case came from a battery (C). The electric current in the telegraph wire was continually reversed by the sliding contact operated by the pendulum in the master clock. This reversing current produced a reversing magnetic field in the electromagnet of the master clock, which kept its pendulum in motion, but at the same time operated the electromagnet in the slave clock - thus attracting its pendulum to and fro in a similar manner. He also described an alternative version of the master clock in which the pendulum carried a second coil which, due to its movement relative to fixed permanent magnets, generated the reversing electric current by electromagnetic induction. This arrangement avoided the use of the same circuit for both clocks and was also suitable for a conventional weight or spring driven master clock completely dispensing with batteries. Bain's approach to time distribution must be distinguished from the use of electric telegraphy to simply send a prearranged time signal for the manual adjustment of clocks at the receiving station, a method adopted by the Electric Telegraph Company from 1852, using a time signal from the Greenwich Observatory.[52]

Bain in the USA, 1848-51

Having only been in London for about a year after returning from Edinburgh, in 1848 Alexander Bain embarked on his next big adventure. Leaving his family behind for much of the next four years, he moved to the United States of America to attempt to break into the expanding telegraph business there. This was of course a much bigger country and the push to open up the territory west of the Mississippi was just about to start. Distances to be linked by wires were measured in thousands and not hundreds of miles and in the 1840s railways were being constructed which would provide rights of ways. The two industries were competing for investors at the same time, but this didn't prevent promoters with no knowledge of the telegraph from exploiting the country's craze to be connected.

Fig.7: Samuel Finley Breese Morse (1791-1872).

After visiting Europe in 1832, Samuel Morse (Fig.7), already a successful painter, developed an interest in the electric telegraph. Congress eventually awarded him a grant of $30,000, in 1842, to build a demonstration telegraph between Washington and Baltimore using the route of the Baltimore and Ohio Railway.[53] In contrast to his later approach to competitors, his view at this time was that the telegraph should be publicly owned. He offered his system to the US Government for $100,000 but the response by the Postmaster General of the time was that anticipated receipts would never cover the costs.

The other major personality in the early American telegraph industry was Henry O'Reilly (1806-86) from Carrickmacross, County Monaghan, Ireland. In 1845, while a newspaper editor in Rochester, he had a fortuitous meeting with a telegraph contractor on board a New York-Albany ferry on the Hudson River. As this man had been successful in obtaining contracts from the Morse syndicate he encouraged O'Reilly to do the same. In keeping with the rapidity with which the industry was expanding, two weeks later O'Reilly had a contract to connect Philadelphia with St Louis in the mid-west and principal towns on the Great Lakes. The probable intention was for O'Reilly simply to construct the line, but he decided that he had received a franchise to establish and run an independent telegraph company.[54] Although preferring to be independent, he had to use the Morse system as the only alternative American system was the quicker but more complicated printing telegraph of Royal Earl House.[55]

O'Reilly's possible salvation was Bain's chemical telegraph, but its introduction in the United States was not straightforward. In early 1848 Smith and Bain's first application for an American patent on the chemical telegraph was successfully opposed by Morse. This was on grounds of priority as he had also made an application earlier in the same year, notwithstanding Smith and Bain having already demonstrated priority in their United Kingdom patent of December 1846. Bain appealed to the District of Columbia Federal Court, which overruled the Commissioner of Patents, and they received their patent in October 1849.[56,57]

For a couple of years there was an explosion of telegraph building by O'Reilly and others, with Bain's chemical telegraph in licensed use on more than two thousand route miles at maximum, representing around 10% of the USA total.[58] There was severe competition along the Washington-New York-Boston-Buffalo axis, where most telegraph traffic was concentrated, with up to three different systems, including Morse's and Bain's, in operation on some routes. There was also competition for a route into Newfoundland, the destination of the shortest trans-Atlantic sea crossing where the future Atlantic cable would come ashore from Ireland. This Newfoundland circuit connected American cities almost directly with Europe and vice-versa.

Bain was now a major player in the world's biggest telegraph market but his good fortune was not to last, for Morse did not accept his earlier defeat easily. In 1851 he and his partners obtained an injunction in the Pennsylvania Federal Court on the grounds that O'Reilly's use of Bain's apparatus was infringing his original 1840 patent. Morse was in effect attempting to claim almost every aspect of electric telegraphy, including the principle of communicating by electricity and even some related properties of electromagnetism. The case reached the US Supreme Court in 1853, with resultant defeat for O'Reilly, and Morse being more or less declared inventor of the electric telegraph. Fortunately his broadest claim was rejected by the court because it would have given him the rights in almost every conceivable use of electric current in communication.[59] This landmark 1853 judgement is still cited in cases on patentable subject matter where a distinction is made between an idea and its implementation.

Before the final stage of Morse's dispute with O'Reilly was reached, consolidation of the telegraph companies had already commenced, as it was clearly advisable to sell out or convert to the Morse system or else be forced out of business. In the case of the Bain operated lines, this was almost complete by 1854.[60] Western Union continued the process from its foundation in 1851 until the 1890s, by which time it operated a virtual monopoly in the United Sates.

Return to London

Alexander Bain returned to London in 1851 and re-joined his family in Beavor Lodge. Fending off Morse had been expensive, but he would have received his share of the assets of his partnerships. With his involvement in the telegraph stalled, he severed his links with the Electric Telegraph Company and instead concentrated on developing the electric clock under his own name from a workshop and showroom in Old Bond Street. He exhibited electric clocks, the chemical telegraph and the 'electro-chemical copying telegraph' (fax machine) at the Great Exhibition of 1851[61] and was awarded the Exhibition Medal, Class X, for their novelty.[62] His stand was adjacent to that of Frederick Bakewell who had patented his own version of Bain's copying telegraph in 1848. Bakewell was claiming that his device had been tested by the Electric Telegraph Company while Bain was advertising that his was now able to copy and transmit handwriting and diagrams and not just raised typeface as in the 1843 patent.

In an attempt at self-publicity, Bain published the first of his two books in 1852: *A short history of the electric clocks, with explanations of their principles and mechanism, and instructions for their management and regulation*.[63] It described the time distribution trials on the Edinburgh and Glasgow Railway and electric clocks suitable for every room of the house. These were powered by earth batteries, but for use upstairs he described one in which the soil and metal plates were hidden in decorative vases for placing on either side of the clock on the mantelpiece (Fig.8). His suggestion that master and multiple slave clock systems were ideal for large houses or similar premises did eventually become reality.

Fig.8: The vases are the earth batteries containing the zinc and copper plates as an alternative to placing them in the ground. This arrangement was especially useful for clocks intended for use upstairs. From: A Bain, *A short history of the electric clocks* (1852).

In the 1850s, electric clocks were expensive luxuries that were not as reliable as their mechanical counterparts and, like many inventions that are marketed before their technology has properly matured, had little widespread impact until modern batteries or AC mains electricity became available in the early twentieth century. A near contemporary writer on clocks described them thus '…of the three pendulums which used to go in Mr Bain's window in Bond Street while his shop existed, some one [sic] was generally stopping, or going so feebly that it was evidently going to stop very soon'.[64]

Bain's second book,[65] *A treatise on numerous applications of electrical science to the useful arts, Part 1*, was published in 1866 for the purpose of ensuring that his role in telegraph engineering was documented, since it seemed unlikely that anyone else would do this on his behalf. He needed to set the record straight and to remind those readers with influence that he had made important contributions. This slim volume contains some valuable information on his early life and an alternative history of the development of telegraphy. Having

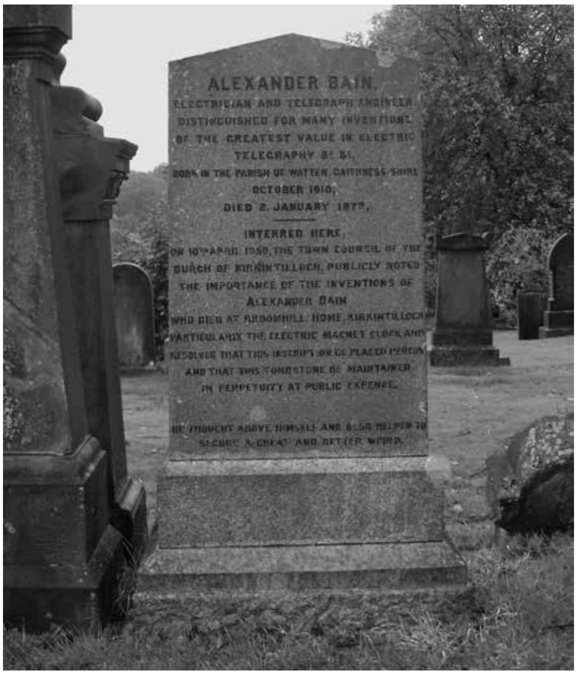


Fig.9: Left: Alexander Bain's headstone in the Old Aisle Cemetery, Kirkintilloch. *Photograph by I S Ruddock.* Right: The 1959 rededication with Isaac Black of Kirkintilloch & District Society of Antiquaries (left) and Hugh Gillies, a former provost of Kirkintilloch (right). *Courtesy of East Dunbartonshire Information and Archives.*

already experienced defeat in North American courts, he must have decided that he had little left to lose; for example, while it might not have been the best way to make friends in science and engineering, he described Wheatstone as 'one of the most accomplished plagiarists that ever existed in any age or country'. *Part 2* never materialised but it promised descriptions of his experiments on submarine telegraphy and the earth battery, and a further vindication of his claims for priority in the invention of the electric clock and the printing telegraph.

In 1856, Mrs Bain died at Finlaison's house in Richmond. According to her daughter Isabella, the only child of whom anything is known, Bain spent very little time with his family after this date, even though he had already been absent for most of the three years he spent in the United States. He made another visit there in 1860, possibly with a view to challenging Morse again or retrieving money still owed to him after the winding up of his interests, but either way he lost his remaining assets.[66] He then attempted to interest the United Kingdom government in his telegraph but was too late, as the by now well-engineered Cooke and Wheatstone system was in extensive use by the Electric Telegraph Company, which in 1868 was nationalised and later merged with the General Post Office.

Last Days

By 1872, Alexander Bain was working for a watchmaker at 96 Buchanan Street, Glasgow, effectively back to where he had started out in 1830. One of his customers was Sir William Thomson, Professor of Natural Philosophy at the University of Glasgow; even if they had not met previously, they would have known of each other's work. Thomson had been knighted for his contributions to the successful Atlantic cable of 1866 and would have immediately realised this was not a fitting end for such a pioneer. With others he petitioned the prime minister, William Gladstone, for a Civil List pension, and this resulted in £80 per year being granted in July 1872. In addition, a one-off grant of £150 was made in 1873 by the Royal Society, of which Thomson was a Fellow, medal winner and future President.[67,68]

Thus supported, Bain entered the final stages of his life. His known movements are unclear, but he visited Caithness again in 1874 before settling in Helensburgh. He was probably a broken man, like many other inventors who have felt cheated out of fortune and fame. He was an inventor and businessman who only had to look at Wheatstone or Cooke, both knighted, to see what might have been. When he suffered a stroke in 1876, Thomson again came to his assistance and secured him a place in the new Broomhill Home for Incurables in Kirkintilloch in December of that year. This establishment had recently been opened by the Scottish National Institution for the Relief of Incurables, following extensive fundraising by local philanthropist Beatrice Clugston. His stay there was very short as he died on 2 January 1877. His daughter Isabella was by this time in India as a schools inspector, the twin sons were already dead and nothing is known about the other two girls. It is possible that there were no grandchildren and hence no direct descendants.[69]

Alexander Bain was buried in Kirkintilloch's Old Aisle Cemetery, with a headstone erected by members of the Glasgow engineering community including Thomson. The original inscription was 'Alexander Bain, electrician and telegraph engineer, distinguished for many inventions of the greatest value in electric telegraphy. Born in the parish of Watten, Caithness-shire, 1810. Died 2nd January, 1877, interred here'. Even in death he did not escape misfortune - the year was originally engraved as 1876, requiring correction in 1901 by the Glasgow Caithness Literary Association.[70] In 1959, Kirkintilloch Burgh restored the headstone and undertook to maintain it, adding this additional inscription (Fig.9):

> On 10th April 1959, the Town Council of the Burgh of Kirkintilloch, publicly noted the importance of the inventions of Alexander Bain who died at Broomhill Home, Kirkintilloch, particularly the electric magnet [sic] clock and resolved that this inscription be placed hereon and that this tombstone be maintained in perpetuity at public expense. He thought above himself and also helped to secure a great and better world.

Fig.10: 21 Hanover Street, Edinburgh and the stone tablet unveiled on 11 January 1941. ***Photographs by I S Ruddock.***

Monuments

For someone who appears to most people as a relatively minor figure in the history of engineering, there are a surprisingly large number of locations where the name of Alexander Bain is perpetuated. To commemorate the centenary of his electric clock patent, the site of his Edinburgh workshop at 21 Hanover Place was marked by a stone tablet (Fig.10) on 11 January 1941, in a ceremony organised by the Royal Scottish Society of Arts. The unveiling was performed by the Deputy Regional Director of the GPO, the body then responsible for telegraphy as well as telephony, in the presence of one of Bain's great-grand-nieces and representatives of the Edinburgh Electrical Society, the Caithness Association and the Institution of Electrical Engineers. The unveiling was followed by the first Keith lecture of the Royal Scottish Society of Arts entitled 'Alexander Bain - his inventions and their influence on modern time distribution'. The speaker was Alexander Steuart, a past president of the Royal Scottish Society of Arts and a developer of the electric clock in his own right.[71]

Prompted by the centenary event in Edinburgh, a campaign then started in the *John O'Groat Journal* for the erection of some kind of memorial in Watten. The 1941 volume of this newspaper contains a number of contributions from individuals involved in the Edinburgh memorial which in turn prompted some local people to relate anecdotes concerning the Bain family. One correspondent described an occasion in 1887 when he was a telegraphist in Wick and Alexander Bain's nephew John came into the office to send a telegram. John Bain remarked that his uncle had invented the telegraph system, but the telegraphist recounted that he did not have the heart to tell him that unfortunately the Bain system was no longer in use. The same writer went on to describe how he had visited the 1893 Chicago World's Fair and noticed that on the wall of the Electricity Pavilion the names listed were - Edison, Morse, Siemens, Thomson, Faraday and Bain!

The result of the campaign was that the County Council formed a committee of representatives from various interested bodies. In addition to a plaque erected in Stafford Place, Wick (Fig.11), the original plan included another on the hall in Thurso where the 1830 lecture had been held, a cairn to be erected at the site of the farm, and the establishment of a commemorative bursary for school children. There were even calls for Bain's remains to be brought back to Caithness. The resulting monument in Watten was in the form of a large granite monolith in front of the village hall (Fig.12). Bain's name is also commemorated in Watten's Bain Place, Wick's 'Alexander Bain' public house on High Street and British Telecom's 'Alexander Bain House' (in both Thurso and Glasgow).

Fig.11: The building in Stafford Place, Wick, where Alexander Bain was apprenticed. The commemorative plaque was erected in 1943. ***Photographs by I S Ruddock.***

Legacy

Engineers tend to suffer more than most historical figures because their inventions usually only have a limited life and are replaced with something better; for example, the typewriter, the slide rule and the thermionic valve. In contrast, scientists, and in particular physicists, are commemorated by their names being associated with the phenomena they discovered or else being used for the names of SI units - James Joule and Lord Kelvin have been remembered together in the Joule-Kelvin effect in thermodynamics (the basis of refrigeration), and individually via 'joule' as the unit of energy and 'kelvin' as the unit of absolute temperature. Morse is now only an historical figure after the virtual abandonment of the telex network and the use of Morse code for marine communication via radio

Fig.12: Left: The memorial stone erected in 1943 in front of Watten village hall. Note the hour-glass superimposed on electrical flashes to represent how time has been electrified and the relief of the pendulum from a Bain electric clock. Right: The Bain clock inside the hall with a pendulum similar to that on the stone. It has a double set of contacts, indicating that it was used as a master clock in a time distribution set-up. *Photographs by I S Ruddock.*

and lamp, but Faraday's pioneering discoveries in electricity and magnetism have ensured his immortality, with the 'farad' as the unit of electrical capacitance.

Is Bain destined to be consigned to history along with the other pioneers of the electric telegraph? Possibly not, because he also established two important principles which will outlive him. The first is the distribution of time on a national and international scale, as already discussed. The second is not the fax machine itself, but its underlying principle. The idea that a two-dimensional picture can be represented by a large number of closely spaced lines which are each scanned in turn, converted into an electric current, sent along a wire and then reconstructed was a step of genius. It is not only the fundamental basis of all modern forms of digital image storage and transmission, but also that of television. Without this concept (of the raster scan), television could not have been developed. The Nipkow disc of 1885,[72] as used by John Logie Baird in the 1920s, was just a convenient method of mechanically scanning the focused image of a scene to produce a varying electric current representing the brightness along each line in turn. Similarly, the contemporaneous electronic television system of Philo Farnsworth[73] and others employed a scanning beam of electrons in both the camera and the receiver to deconstruct and to assemble the image respectively. It is thus not an exaggeration to claim that Alexander Bain is the real father of television.

Acknowledgement

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3 Hans Christian Oersted (1777-1851) was a Danish physicist and chemist who discovered the magnetic effects of a current-carrying wire and after whom the cgs unit of magnetic field is named.

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