2 Wildman Whitehouse, William Thomson, and the First Atlantic Cable

The first serious effort to span the Atlantic with a telegraph cable was launched in 1856 by a group of entrepreneurs led by Cyrus Field in the United States and John Watkins Brett in England. Theirs was an audacious, not to say foolhardy, enterprise. The nearly 2000-mile-long cable they proposed to lay between Ireland and Newfoundland would be more than six times longer than any yet laid and would lie in waters deeper than any previously attempted. That such an ambitious undertaking was nonetheless launched and quickly drew financial backers is testimony to the technological enthusiasm of the mid-Victorian era, as well as to the prospects for large profits if it should succeed.

The first Atlantic cable proved, however, to be a spectacular failure. It snapped during the first two attempts to lay it in August 1857 and during three more the following June, dashing the hopes of all but its most ardent backers. The success of a final attempt, completed on August 5, 1858, caught almost everyone by surprise and set off rapturous celebrations on both sides of the Atlantic. Troubles soon arose, however, and after just a few weeks of fitful service the cable sputtered to its demise.[1]

Even before the 1858 cable had fallen completely silent, much of the blame for its failure came to be laid at the feet of Edward Orange Wildman Whitehouse, the "electrician-projector" of the Atlantic Telegraph Company and the man in charge of its electrical department. Less than two weeks after the cable was laid and its first messages transmitted, he was summarily dismissed by the board of the company he had helped to found and denounced by its officials as a fool, a fraud, or both. The board dispatched one of its own members, the young University of Glasgow professor of natural philosophy William Thomson (later Lord Kelvin), to

[1] On the first Atlantic cable, see the accounts in Charles Bright, *Submarine Telegraphs, Their History, Construction, and Working* (London: Lockwood, 1898), 38–54; Charles Bright, *The Story of the Atlantic Cable* (New York: Appleton, 1903); Thompson, *Kelvin*, *1*: 325–96; Bern Dibner, *The Atlantic Cable* (Norwalk, CT: Burndy Library, 1959), 5–45; Crosbie Smith and M. Norton Wise, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: Cambridge University Press, 1989), 667–75; and Gillian Cookson, *The Cable: The Wire That Changed the World* (Port Stroud: Tempus, 2003).

take Whitehouse's place at the Irish end of the cable and supervise electrical operations there. Thomson, who had advised on electrical arrangements for the project from its early days and sailed on all of its laying expeditions, nursed the cable along for two more weeks but in the end could not keep its insulation from giving way. By early September the cable was effectively dead.

There were many reasons why the first Atlantic cable failed and many reasons why blame for its failure came to be apportioned as it was. Whitehouse certainly deserved to shoulder a substantial share of that blame, but why in the end was almost all of it heaped on him while others who arguably bore comparable responsibility, particularly Field and the young chief engineer Charles Tilston Bright, escaped virtually unscathed? And how did Thomson, who presided over the actual death of the cable, manage to emerge from the debacle with his reputation not just untarnished but substantially enhanced, and to go on to become perhaps the most revered figure in the Victorian cable industry (Figure 2.1)? An important but often overlooked factor in the differing fates of Whitehouse and Thomson, and in the subsequent development of cable telegraphy as a whole, centers on *measurement*. Thomson strongly emphasized the precision measurement of electrical quantities, particularly resistance, and the exercise of strict quality control. He devised important new instruments and measuring techniques and helped lay the foundation for a connected system of electrical units and standards. The measurement practices he pursued and advocated in his work on the first Atlantic cable converged with and reinforced many of those being developed at the same time by leading telegraph engineers. The result by the mid-1860s was the development of a cohesive and effective system for understanding and managing the operation of submarine cables, the main features of which would continue to be followed well into the twentieth century.

Whitehouse was also an avid measurer, but it was not always clear quite what he was actually measuring. He too developed new techniques and instruments, some of considerable delicacy and precision, but his instruments remained his alone, and many of his measurements could not be readily related to those made by more mainstream scientists and engineers. He was thus left isolated and vulnerable, and when things began to go wrong, others on the project were able to throw him overboard with little risk he would take them down with him. Thereafter the technical aspects of cable telegraphy were left in the hands of a group of scientists and engineers whose shared attitudes and practices, particularly concerning electrical measurement, would set much of the direction of British work in electrical science and technology for decades to come.

Figure 2.1 The four "projectors" of the Atlantic Telegraph Company: a: Cyrus W. Field, b: John Watkins Brett, c: Charles Tilston Bright, and d: E. O. Wildman Whitehouse.
(Field, Brett, and Whitehouse from Louis Figuier, *Merveilles de la Science*, Vol. 2: 248, 208, and 253, 1868; Bright from Charles Bright, *Life of Sir Charles Tilston Bright*, frontispiece, 1908.)

Field's Dream

Cyrus Field had barely heard of submarine telegraphy before January 1854, when he first encountered Frederic Gisborne. Gisborne, a British-born telegraph engineer, had been working for years to promote a scheme to speed up transatlantic communication via Newfoundland. He had made some headway by mid-1853 when his financing abruptly collapsed. Facing bankruptcy, he headed to New York to seek new backing and there chanced to meet Matthew Field, a civil engineer, who suggested he speak with his brother Cyrus. Though only 34, Cyrus Field had already made a fortune in the paper business and was now looking for a new outlet for his wealth and restless energies. Gisborne's scheme intrigued him. In the 1850s, it took about ten days for even the most urgent news from England to reach New York by steamship. A ship could beat that by a day or two by putting in at Halifax, Nova Scotia, and sending its messages ahead by overland telegraph – and many businesses and news agencies were willing to pay handsomely for a day's head start on their competitors. Gisborne proposed to shave off another day or more by extending this telegraphic shortcut eastward to St. John's, Newfoundland, using overland lines across the island and a short cable across Cabot Strait from Cape Ray to Cape Breton Island in Nova Scotia. Buoyed by hopes of making Newfoundland a transatlantic communications hub, the colonial legislature in St. John's granted Gisborne valuable concessions, including a thirty-year monopoly on all telegraphs on the island.[2]

Field listened closely to Gisborne's pitch but was not immediately won over. When he later consulted his globe to check the proposed route, however, he was struck by a far grander idea: why stop at Newfoundland? St. John's was about a third of the way from New York to London; why not extend a cable clear across the Atlantic to Ireland, and so link the New World directly to the Old?[3] A cable spanning nearly 2000 miles of open ocean would be an enormous leap over anything yet accomplished or even attempted in submarine telegraphy, but Field knew too little about the technical obstacles to be put off by them. Not long after meeting with Gisborne, he wrote to the pioneering oceanographer Matthew Fontaine Maury of the US Naval Observatory, who told him that recent soundings showed the bed of the North Atlantic would provide an ideal resting place for a submarine cable – Maury even dubbed it the "Telegraphic Plateau." Field also wrote to the telegraph entrepreneur Samuel F. B. Morse, who assured him that an electric current could indeed be made to pass through

[2] On Gisborne's Newfoundland plan, see Donald Tarrant, *Atlantic Sentinel: Newfoundland's Role in Transatlantic Cable Communications* (St. John's, NL: Flanker Press, 1999), 7–17.
[3] Henry M. Field, *The Story of the Atlantic Telegraph* (New York: Scribner's, 1893), 16.

an insulated wire long enough to span an ocean.[4] Neither Maury nor Morse had any real experience with submarine cables, but their assurances were enough for Field, and he pushed ahead at full speed. Backed by Peter Cooper, Moses Taylor, and other New York capitalists, Field quickly organized the ambitiously named New York, Newfoundland, and London Telegraph Company – an American firm aiming to lay a cable to link two parts of the British Empire. By April 1854 the new group had bought up the assets of Gisborne's bankrupt operation and secured more concessions from the government of Newfoundland, including a fifty-year monopoly on landing telegraph cables on the island.[5] This, along with Field himself, would prove to be the New York company's most valuable asset.

Running a telegraph wire across Newfoundland was, Field later said, "a very pretty plan on paper"; one simply drew a line on the map and the job was done.[6] He expected the task to take just a few months and to cost a small fraction of his company's capital. In fact it took his brother Matthew and a crew of workers more than two years to hack a route through the rugged interior of the island, and erecting and maintaining the overhead line from St. John's to Cape Ray, as well as a new overhead line across Cape Breton Island, proved far more costly than Field and his partners had anticipated (Figure 2.2).

While that work was going forward, Field set about securing the cable that was to span Cabot Strait and connect Newfoundland to the North American telegraph network. He could obtain wires and equipment for the landline in the United States and Canada, but a cable was a different matter; for that, he would have to go to Britain, then and for long to come virtually the sole home of submarine telegraph technology.[7] Armed with an introduction from Gisborne, Field arrived in London early in 1855 and called on John Watkins Brett, whose Submarine Telegraph Company had laid the first cable across the English Channel a few years before. Already an enthusiast for oceanic telegraphy, Brett invested $10,000 in the New York company and joined whole-heartedly in its efforts to span the Atlantic.[8] On his advice,

[4] Field, *Atlantic Telegraph*, 18–22. [5] Tarrant, *Atlantic Sentinel*, 20–22.

[6] Field made this remark at a banquet in 1866; see *The Atlantic Telegraph: Report of the Proceedings of a Banquet Given to Mr. Cyrus W. Field by the Chamber of Commerce of New-York, at the Metropolitan Hotel, November 15th, 1866* (New York: privately printed, 1866), 19.

[7] Samuel Bishop of New York reportedly began supplying wires insulated with gutta-percha in 1851, but while his Bishop Gutta Percha Works long remained the chief American cable maker, it produced only short cables for use in rivers and harbors rather than longer ones suitable for sea crossings; see "The Bishop Gutta Percha Works," *The Telegrapher* (January 1, 1870) *6*: 145–47.

[8] John W. Brett, *On the Origin and Progress of the Oceanic Electric Telegraph* (London: W. S. Johnson, 1858), 47.

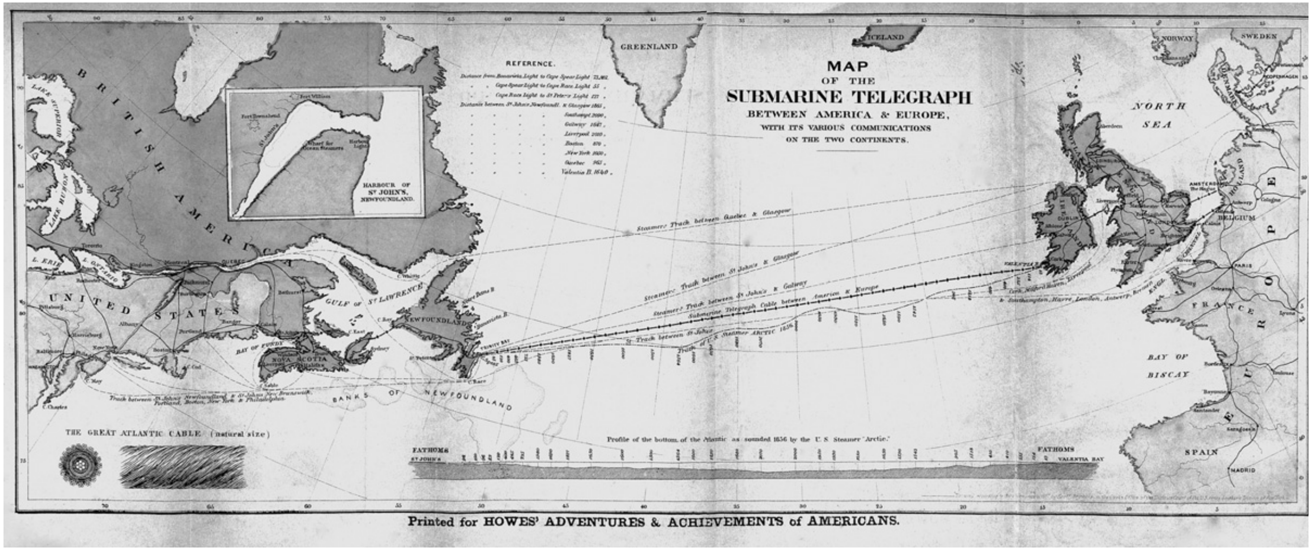

Figure 2.2 Map showing the route of the 1858 Atlantic cable, including its connections from London to Ireland and from Newfoundland to New York.
(From Henry Howe, *Adventures and Achievements of Americans*, frontispiece, 1858.)

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Field ordered seventy-five miles of multiconductor cable from Küper and Company (later to become Glass, Elliot and Company) and arranged to have it shipped to Newfoundland in a sailing bark. While in England, Field also first met Charles Tilston Bright, then just 22 but already chief engineer of the Magnetic Telegraph Company. Impressed by the young engineer's drive, Field took steps to enlist him in the Atlantic cable project.[9]

Always attuned to the value of publicity but with little grasp of the practicalities of cable-laying, Field chartered a steamer in New York in August 1855 and invited more than fifty guests, including Morse, Cooper, and their families, on what he expected would be a pleasant summer excursion to Newfoundland.[10] There they were to watch as their vessel towed the bark from which the cable would be uncoiled across Cabot Strait. It all turned into an embarrassing fiasco, however, as the towing arrangement proved unwieldy and a fierce gale blew the vessels off course. After some tense moments when it seemed the bark might be swamped, the cable had to be cut and the attempt to lay it abandoned.[11] The chastened party slunk back to New York, but Field treated the whole episode as simply a lesson learned: he soon ordered a new length of cable from England and had a properly equipped steamship lay it the following summer, this time with little fanfare. By then the landline across Newfoundland was finally complete and Field was ready to tackle the next and far bigger step: spanning the Atlantic.

Field and his New York partners had initially hoped to finance the entire Atlantic telegraph project on their own, but after exhausting so much of their capital extending their lines just to St. John's, they realized the task would be beyond their means. In July 1856 Field sailed again to England, authorized by his partners to take whatever steps he thought would best advance the project. After consulting with Brett, he decided to launch a new company in London, and the two began sounding out potential investors. Field also sought to bolster the credibility of the project by enlisting engineers and scientific men willing to lend it their skills and reputations. He had a particular eye on Bright, "strenuously urging," as Brett later put it, that the young engineer be included as one of the initial "projectors" of the new company.[12] On September 29, 1856, Field, Brett, and Bright signed a document mutually pledging to do all in

[9] Edward Brailsford Bright and Charles Bright, *The Life Story of the Late Sir Charles Tilston Bright, Civil Engineer*, 2 vols. (London: Archibald Constable, 1899), *1*: 109–10.
[10] For a list of the many guests on this excursion, see John Mullaly, *The Laying of the Cable, or The Ocean Telegraph* (New York: Appleton, 1858), 51.
[11] Mullaly, *Laying of the Cable*, 52–75.
[12] John W. Brett, "The Atlantic Telegraph" (letter), *Morning Post* (September 23, 1858), 2.

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their power to advance the formation and success of what they proposed to call the Atlantic Telegraph Company.[13]

Field was by all accounts a whirlwind of activity in these months, meeting with cable makers to examine sample designs and discuss costs, pressing the British government to supply ships to assist with the laying of the cable and to guarantee a substantial amount of official business for the cable once it was successfully completed, and constantly touting the merits of the proposed cable to the press and potential investors. Morse came over from America to lend his support, and Field saw to it that a lavish dinner was mounted in his honor, thus winning further publicity for the project.[14]

Field and Brett formally registered the Atlantic Telegraph Company on October 20, 1856, and issued a prospectus a few weeks later. They initially set its capital at £300,000, soon raised to £350,000, to be offered in shares of £1000 each; Field and Brett started by taking twenty-five shares each.[15] Stressing both the grandeur and utility of a cable spanning the Atlantic, the prospectus sought to allay concerns about the practicability of the project by citing Morse and Maury's endorsements, as well as recent experiments on signaling through long underground wires. "It is considered," the prospectus went on, "that little requires to be said in favour of the undertaking," as "the benefits which it will confer upon all classes are too obvious to need mention, and its proved practicability renders its accomplishment a duty." Nor did the prospectus ignore financial practicalities, reporting that cable manufacturers had given assurances that £350,000 would be more than enough to cover all of the costs of making and laying the cable, and stating that "upon a very moderate computation of the probable amount of traffic, and a consideration of the comparatively small working expenses (which are necessarily limited to those of the terminal stations), the net receipts will yield an annual return exceeding 40 per cent. upon the capital" – a truly enticing rate of profit.[16] The pitch was evidently persuasive, as the shares were all subscribed within a few weeks. Liverpool merchants were especially avid to invest;

[13] George Saward, *The Trans-Atlantic Submarine Telegraph: A Brief Narrative of the Principal Incidents in the History of the Atlantic Telegraph Company* (London: privately printed, 1878), 7–8. Saward was for many years the secretary of the Atlantic Telegraph Company.

[14] On the October 1856 London banquet for Morse, see Samuel Irenaeus Prime, *The Life of Samuel F. B. Morse* (New York: Appleton, 1875), 646; on Field's activities, see Field, *Atlantic Telegraph*, 69–71.

[15] Brett, *Origin and Progress*, 48; on the increase in the capitalization of the company, see ATC Minute Book, entry for October 31, 1856, 5. This Minute Book is held by the BICC Archive at the Merseyside Maritime Museum, Liverpool. I thank Allan Green for his generous loan of a copy of it.

[16] "Prospectus of the Atlantic Telegraph Company," November 6, 1856, reprinted in Brett, *Origin and Progress*, 49–51.

many of them were active in the transatlantic trade in cotton and other commodities and were attracted by the prospect of quicker access to American market information. According to the *Times,* when Field showed a sample of the proposed cable to a group of Liverpool businessmen, "a broker admiringly exclaimed, 'There's the thing to tell the price of cotton!'"[17] Most of the rest of the shares were sold in London, with a scattering to investors in Manchester, Glasgow, and other British cities. Americans, however, evinced little enthusiasm; although Field had reserved eighty-eight shares, a quarter of the total, to sell in the United States, he could only find buyers there for twenty-seven and was forced to carry the rest himself.[18] He would remain the largest single investor in the Atlantic Telegraph Company.

Although it quickly drew financial backers, the project met with considerable skepticism in Britain. Many observers doubted that a cable could be successfully laid in such deep waters, while others thought the capital had been set too low. The eminent engineer Isambard Kingdom Brunel, whose ship the *Great Eastern* would later lay the 1865 and 1866 Atlantic cables, reportedly estimated it would cost about £2,000,000 to do the job properly – very close to what, after many reverses, proved to be the eventual total.[19] Field and Brett judged, however, that £350,000 was the most they could raise in 1856 and so set out to do what they could with that amount.

Beyond its relatively low estimate of costs, perhaps the most striking point in the prospectus was the statement that "it is determined to complete and have the Telegraph in operation during the ensuing summer."[20] That is, the Atlantic cable was to be designed, manufactured, tested, loaded, shipped, laid, and put into service, with all of its associated apparatus and personnel, within just ten months after the company was first launched. It was a stupendously ambitious, not to say wildly unrealistic, timetable. Brett later said it was Field, with "the go-ahead character of an American," who had insisted on aiming to lay the cable in 1857, and while Brett conceded that promising such quick completion had been necessary, "as a matter of policy," to attract investors when the company

[17] "The Atlantic Telegraph Company," *Times* (November 14, 1856), 12. On how telegraphy, and particularly the Atlantic cables, affected the global cotton trade, see Harold D. Woodman, *King Cotton and His Retainers: Financing and Marketing the Cotton Crop of the South, 1800–1925* (Lexington: University of Kentucky Press, 1968), 267, 273, 292–93, and Sven Beckert, *Empire of Cotton: A Global History* (New York: Vintage, 2014), 320, 336.
[18] Saward, *Trans-Atlantic Submarine Telegraph*, 8–9.
[19] Saward, *Trans-Atlantic Submarine Telegraph*, 9.
[20] "Prospectus," in Brett, *Origin and Progress*, 49.

was first floated, he also admitted that the ensuing rush lay behind many of the problems that would bedevil the project.[21]

Even if a cable could be successfully laid beneath the Atlantic, critics doubted it could be made to carry signals at a commercially viable rate. The great obstacle was retardation, as discovered by Latimer Clark in 1852 and brought before the public by Michael Faraday in 1854. Induction effects had already been found to interfere with signaling on some shorter cables, and Thomson had given theoretical grounds for expecting the retardation on a cable of any given thickness to increase with the square of its length. If Thomson was right, the retardation on a cable long enough to span the Atlantic might be so severe as to render it almost useless.

Here was a serious threat to the viability of the whole Atlantic cable project, and in 1856 Field latched onto a new and seemingly unlikely ally to combat it. Wildman Whitehouse proceeded to take up the task with remarkable vigor and soon emerged as one of the most active and controversial figures in the story of the first Atlantic cable.

Wildman Whitehouse

By training and background, Wildman Whitehouse was neither an engineer nor a scientist, but a surgeon. He had built up a thriving practice at Brighton when, in the early 1850s, at the age of about thirty five, he began to experiment with electricity.[22] His efforts to devise a new system of multi-wire telegraphy soon brought him into contact with John Watkins Brett, who later said he saw in Whitehouse "most patient qualities of investigation." Here was just the man, Brett thought, to tackle the threat posed by retardation, and in the spring of 1855 he began providing Whitehouse with hundreds of pounds for equipment and experimental expenses as well as the assistance of James Banks, an experienced technician from Brett's staff.[23] Crucially, Brett also gave Whitehouse access to

[21] Testimony of J. W. Brett, December 10, 1859, in *Joint Committee Report*, 58.

[22] The fullest collection of biographical information on Whitehouse, compiled by Bill Burns, Allan Green, and others, can be found on the "Atlantic Cable" website at http://atlantic-cable.com/Books/Whitehouse/eoww.htm. Whitehouse did not confine his electrical studies to telegraphy; in 1852–53 he devised a sensitive galvanometer that his fellow Brighton resident John O. N. Rutter used to investigate electrical phenomena in muscle tissue. See Richard Noakes, *Physics and Psychics: The Occult and the Sciences in Modern Britain* (Cambridge: Cambridge University Press, 2019), 32, and John O. N. Rutter, *Human Electricity: The Means of Its Development, Illustrated by Experiments* (London: John W. Parker and Son, 1854), 117 and frontispiece.

[23] Brett later reported that he supplied Whitehouse with "several hundred pounds" for his experiments; see Brett, "Atlantic Telegraph" (letter), *Morning Post* (September 23, 1858), 2.

two multiconductor cables then being readied for shipment from Küper's works in East Greenwich: a 150-mile-long cable destined for the Mediterranean containing six separately insulated conductors, and the 75-mile-ong cable with three conductors that Field would soon try and fail to lay from Newfoundland to Nova Scotia.[24] Whitehouse proceeded to spend several weeks performing virtually every test he could think of on this total of 1125 miles of insulated wire, hoping, as he later said, to demonstrate the practicability of oceanic submarine telegraphy or, failing that, at least to "make us better acquainted with the electrical difficulties to be encountered, and so place us in a position to meet the enemy with the true indomitable English spirit, – determined to conquer."[25]

Whitehouse presented a very full account of his experiments to the Mathematical and Physical Section of the British Association at its September 1855 meeting in Glasgow. It was his first scientific paper and he took great pains with it, even having it printed as a pamphlet; he also sent a shorter version to the *Illustrated London News*.[26] He opened by seeking to justify himself before his audience – to explain why he, a surgeon with neither scientific credentials nor practical engineering experience, should be taken seriously when speaking on cable telegraphy. "The study of the varied phenomena of Electricity," he declared, "is no longer the exclusive privilege of the philosopher"; the recent spread of telegraphy had opened the subject far more widely, so that even one like himself, "unknown in the world of science," might now venture to record his electrical experiments and observations, justifying his intervention in the field by citing its great practical importance.[27]

[24] See Whitehouse's testimony, December 15, 1859, in *Joint Committee Report*, 69; J. W. Brett, "Atlantic Telegraph" (letter), *Engineer* (October 8, 1858), *6*: 267; and Wildman Whitehouse, *The Atlantic Telegraph: The Rise, Progress, and Development of Its Electrical Department* (London: Bradley and Evans, 1858), 6, also published in *Engineer* (September 24, 1858) *6*: 230–32.

[25] Wildman Whitehouse, *Report on a Series of Experimental Observations on two lengths of Submarine Electric Cable, containing, in the aggregate, 1,125 miles of wire, being the substance of a paper read before the British Association for the Advancement of Science, at Glasgow, September 14, 1855* (Brighton: privately printed, 1855), 6.

[26] "Mediterranean Telegraph," *Illustrated London News* (October 6, 1855) *27*: 423. Although it was published after the Glasgow meeting, this article was written well before it. An account of Whitehouse's British Association paper appeared in *Athenæum* (September 22, 1855), 1091–92, and a brief abstract appeared under the title "Experimental Observations on an Electric Cable" in the 1855 *BA Report*, Section A, 23–24; extensive excerpts were later published as "The Atlantic Telegraph," *Engineer* (January 30, 1857), *3*: 82–83.

[27] Whitehouse, *Report* (1855), 3.

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Whitehouse was unknown, however, not just in the world of science but in the world of practice as well. With no experience on lines or cables in actual use, he had no real standing among the emerging community of telegraph engineers. The facts he could present for consideration were the products of special experiments, not of practical field experience. He evidently concluded that in such circumstances his best hope of achieving some standing in the electrical world and of contributing to the advancement of submarine telegraphy lay in presenting himself as neither a "philosopher" nor a practical engineer but as a Baconian experimenter whose findings might aid practical progress. In his 1855 paper Whitehouse explicitly disavowed the role of the disinterested natural philosopher, asking that, in light of the importance of cable telegraphy, he be "pardoned" for having "investigated the phenomena exhibited by electrical currents in subterranean and submarine wires, as a speciality, and with a direct leaning towards their practical application, rather than in their more general and more extended theoretical aspects."[28]

The basic experimental technique Whitehouse described in his Glasgow paper was straightforward: he sent trains of electrical pulses into an insulated wire and, at its far end, recorded the arriving currents electrochemically on a moving paper tape. This yielded what he called "the handwriting, the autograph, of the current itself" and enabled him to "observe its habits and behaviour," particularly the delay and stretching of signals due to retardation, as he varied the length of wire used and the strength and nature of the pulses sent[29] (Figure 2.3). He found, among much else, that strong alternating pulses from a magneto-electric generator showed much less retardation than did the usual battery currents – indeed, with such magneto pulses, signaling speeds "ample for commercial success" could, he said, be achieved through the full 1125 miles of wire.[30] Notably, Whitehouse made these tests using simple reversals rather than the irregularly spaced pulses that would be needed to spell out actual words. He also reported that "doubling or trebling the mass of conducting metals" carrying the current (which he did by sending it simultaneously along two or three of the separately insulated wires within the cable, *not* by using a single larger conductor) did not reduce the retardation, so that "no adequate advantage would be gained by any considerable increase in the

[28] Whitehouse, *Report* (1855), 5.

[29] Whitehouse, *Report* (1855), 10–11. Whitehouse gave a fuller account of his methods (with illustrations) in "Experiments on the Retardation of Electric Signals, Observed in Submarine Conductors," *Engineer* (January 23, 1857) *3*: 62–63.

[30] Whitehouse, *Report* (1855), 21.

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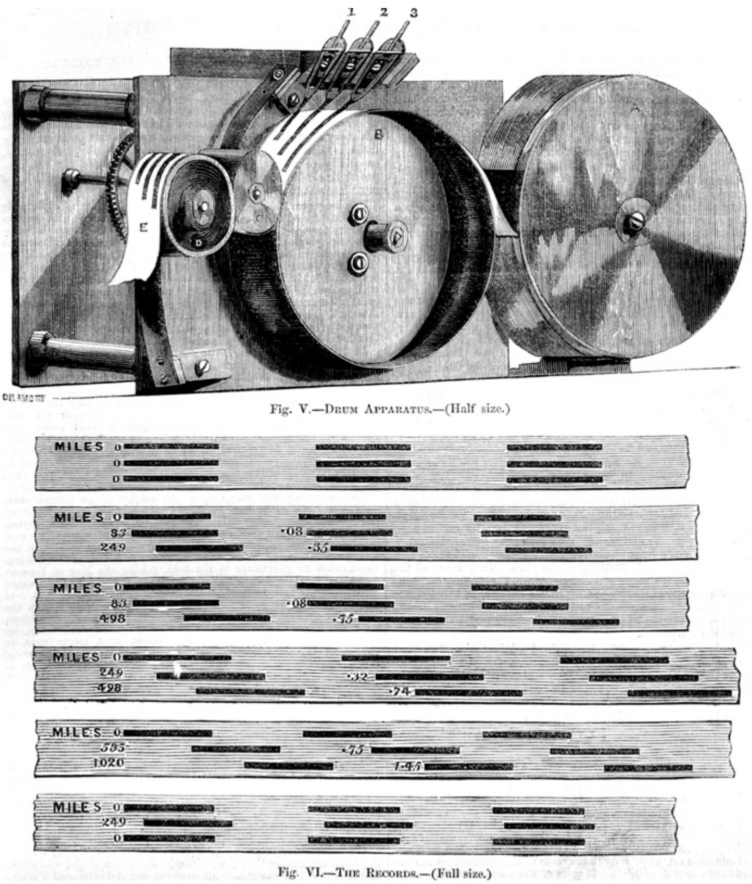

Figure 2.3 Wildman Whitehouse's telegraphic recording apparatus and marked paper tapes, showing the degree of retardation experienced by signals passing through different lengths of cable.
(From *Engineer*, Vol. 3: 63, January 23, 1857; courtesy University of Texas Libraries.)

size of the wire" – a claim that would later become the focus of sharp controversy.[31] In short, Whitehouse claimed to have shown that retardation did not pose nearly as serious an obstacle to submarine telegraphy as many had feared, and he was happy to be able to conclude "that India, Australia, and America are readily accessible by telegraph without the

[31] Whitehouse, "Experimental Observations," 24; Whitehouse, *Report* (1855), 20.

use of wires larger than those now commonly employed in submarine cables."[32]

This was just what the promoters of an Atlantic cable wanted to hear, of course, and they were no doubt delighted when the Duke of Argyll, the president of the Glasgow meeting, said in his closing remarks that Whitehouse's paper "deserved especial notice" for its demonstration that "there remained no practical difficulty" to overcoming the ill effects of retardation, even on a cable long enough to span the Atlantic.[33] Brett and Field would later tout Whitehouse's results to potential backers, and Field thought enough of Whitehouse's Glasgow paper to send a copy of it to Morse in March 1856.[34]

Not all of the response to Whitehouse's paper was positive, however. Thomson voiced doubts on hearing it delivered at the Glasgow meeting, and in fact presented a paper of his own at the same session that undercut many of Whitehouse's main claims[35] (Figure 2.4). In "On Peristaltic Induction of Electric Currents in Submarine Telegraph Wires," Thomson examined theoretically how signals would move along parallel insulated wires like those in the multiconductor cables Whitehouse had used in his experiments.[36] Drawing on the mathematical analysis of induction in telegraph wires he had published a few months earlier in the *Proceedings of the Royal Society*, he concluded that electrostatic action between neighboring wires might skew the results of tests like those Whitehouse had performed on multiconductor cables, and warned that "expectations as to the working of a submarine telegraph between Britain and America, founded on such experiments, may prove fallacious."[37] It was a serious shot across Whitehouse's bow.

Reverting to a suggestion he had first made in his Royal Society paper, Thomson said that "to avoid the chance of prodigious losses," those proposing to lay a cable across the Atlantic should look not to flawed experiments like Whitehouse's but instead to the actual performance of existing cables, particularly the single-conductor line recently laid beneath the Black

[32] Whitehouse, *Report* (1855), 22.
[33] The Duke of Argyll was quoted in "General Concluding Remarks," *Glasgow Herald* (September 21, 1855), 5; John Tyndall was quoted in "Meetings of the British Association," *Glasgow Sentinel* (September 15, 1855), 4.
[34] The copy of Whitehouse's *Report* (1855) held by the Olin Library at Cornell University is inscribed "March 4, 1856 Sam. F. B. Morse from Cyrus W. Field, Esq."
[35] Thomson's remarks about Whitehouse's paper are quoted in "The British Association," *The Globe* (September 17, 1855).
[36] William Thomson, "On Peristaltic Induction of Electric Currents in Submarine Telegraph Wires," *BA Report* (1855), Section A, 21–22, repr. in Thomson, *MPP 2*: 77–78.
[37] Thomson, "Peristaltic Induction," 22.

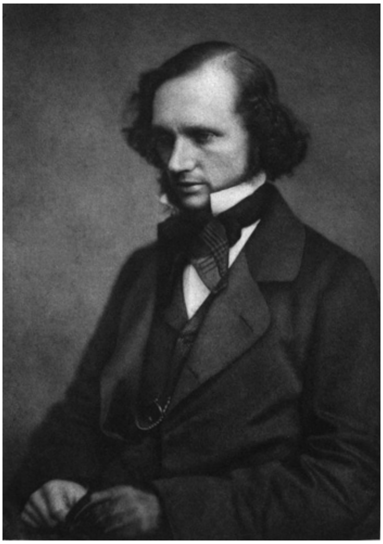

Figure 2.4 William Thomson in 1852, at age 28.
(From Silvanus P. Thompson, *Kelvin,* Vol. 1: 232, 1910.)

Sea from Varna to Balaklava to speed communications during the Crimean War. Signaling on this 300-mile-long cable was known to be slow, no more than five words per minute, because of effects its operators ascribed to induction.[38] Citing his mathematical demonstration that, for a given thickness of wire and insulation, the retardation on a cable is proportional to the square of its length, Thomson said that a cable across the Atlantic – six times the distance from Varna to Balaklava – could be expected to suffer thirty-six times the retardation. "If the distinctness of utterance and rapidity of action practicable with the Varna and Balaklava wire are only such as not to be inconvenient," he said, transmission rates on an Atlantic cable of similar gauge would thus be far too slow to be commercially useful. The only solution appeared to be to make the cable six times as thick, thus requiring thirty-six times as much copper and gutta-percha per mile, while still achieving no more than the slow speed of the Black Sea line.[39]

[38] Thomson, "Peristaltic Induction," 22. Thomson had first suggested looking to the Black Sea cable in "On the Theory of the Electric Telegraph," *Proc. RS* (May 1855) *7*: 382–99, on 99, repr. in Thomson, *MPP 2*: 75. On signaling rates, see Alfred Varley to Douglas Galton, May 4, 1861, in *Joint Committee Report*, 506. The Black Sea line lacked external armoring except at its shore ends and so was not a true "cable."
[39] Thomson, "Peristaltic Induction," 22.

Few engineers or investors could follow the intricacies of Thomson's differential equations, but they could multiply by six – or by thirty-six. If Thomson's analysis was correct, the dream of spanning the Atlantic would be dashed; the required cable would either be too expensive and unwieldy to make and lay, or too slow to pay its way. Unless some answer to Thomson could be found, Field and Brett's project appeared doomed.

Whitehouse was convinced – justifiably, as it turned out – that Thomson had erred on some major points, but he did not rush to offer a public response. He spent much of the year after the Glasgow meeting devising new instruments and securing a patent on "Improvements in Electro-Telegraphic Apparatus," particularly a new form of induction coil that would later play an important part in the short life of the Atlantic cable. With Brett's backing, he also undertook a series of new experiments on transmission rates along lengths of multiconductor cables being readied for shipment to the Mediterranean. Encouraged by the physicist John Tyndall to focus entirely on his electrical researches, Whitehouse took steps that summer to wrap up his medical practice and, as a Brighton newspaper put it, free himself to "direct his talents to the perfection and extension of the Electric Telegraph."[40] From mid-1856 on, Whitehouse would no longer be a surgeon who dabbled in electricity but a full-time telegraphic experimenter.

By early August 1856, when the British Association met at Cheltenham, Whitehouse was ready to answer Thomson, and he hit back hard. In a paper provocatively titled "The Law of Squares – Is It Applicable or Not to the Transmission of Signals in Submarine Circuits?," published in the *Athenæum* at the end of August, he announced that his experiments pointed to an unequivocal answer: no. Indeed, he declared Thomson's "law" to be no more than "a fiction of the schools," fine in its place but wholly irrelevant to the proper design and operation of submarine cables.[41]

Whitehouse began by defending his use of multiconductor cables, saying that careful measurements showed the effects of mutual induction between the wires to be negligibly small, a point Thomson would soon

[40] Whitehouse, *Atlantic Telegraph*, 7–8; Whitehouse's patents are listed and annotated by Allan Green at http://atlantic-cable.com/Books/Whitehouse/Patents/patents.htm. A note in the *Brighton Gazette* (August 21, 1856), 5, reported that Whitehouse, "for many years a distinguished member of the medical profession of Brighton," had "given up the practice of medicine, and left Brighton" to focus on telegraphy. Whitehouse later said Tyndall had encouraged him to turn from medicine to electrical experimentation; see Whitehouse, *Atlantic Telegraph* (1858), 8.

[41] Wildman Whitehouse, "The Law of Squares – Is It Applicable or Not to the Transmission of Signals in Submarine Circuits?," *BA Report* (1856), 21–23, also published in the *Athenæum* (August 30, 1856) 1092.

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concede.[42] He next turned to Thomson's telegraphic theory itself, distinguishing three aspects of it, all of which he called the "law of squares." First, there was retardation itself, which Whitehouse defined as the delay before a detectable current first appeared at the far end of a cable. Using sensitive magnetic relays and a paper tape arrangement similar to the one he had employed the year before, he found retardations of 0.08 seconds through 83 miles of wire, 0.79 seconds through 498 miles, and 1.42 seconds through 1020 miles. Far from increasing with the square of the length, he said, the retardation evidently increased "very little beyond the simple arithmetical ratio."[43] Next he took up what he called the *experimentum crucis*, measuring the maximum rate at which distinct signals could be made to pass along a cable. He found that when he doubled the length of an insulated conductor from 500 to just more than 1000 miles, the number of pulses of current it could carry per unit time indeed fell, but only from 350 to 270, not, as the law of squares would imply, to fewer than 90. Long cables were indeed a bit slower than short ones, he said, but not by nearly as much as Thomson's theory had suggested. Finally, Whitehouse reported that increasing the size of the conductor (he again used multiple separately insulated wires rather than a single thicker one) not only did not reduce the retardation but actually increased it: "trebling the size of the conductor augmented the amount of retardation to nearly double that observed in the single wire." As Whitehouse observed, his results were "strikingly opposed" to Thomson's theory; they virtually demanded a response.[44]

Whitehouse later said he had hoped to see Thomson at the Cheltenham meeting so they could hash out their differences in person, but Thomson was then visiting spas on the Continent with his ailing wife and did not learn of Whitehouse's paper until late September, when he happened across the account of it that appeared in the August 30 issue of the *Athenæum*.[45] Concerned that silence might be taken as acquiescence to Whitehouse's criticisms, he dashed off a letter defending his earlier claims and boldly asserting that "all Mr. Whitehouse's experimental results are perfectly consistent with my theory." He admitted, however, that he based this claim simply on his own confidence in his theory, "which, like every *theory*, is merely a combination of established truths"; he could not yet say quite *how* to square it with Whitehouse's seemingly contrary results, just that he was sure there must be a way. Conscious of

[42] William Thomson, "Telegraph to America" (letter), *Athenæum* (November 1, 1856) 1338–39, repr. in Thomson, *MPP 2*: 94–102.
[43] Whitehouse, "Law of Squares," 21–23. [44] Whitehouse, "Law of Squares," 23.
[45] Wildman Whitehouse, "The Atlantic Telegraph" (letter), *Athenæum* (October 11, 1856) 1247; on Thomson's travels from July to September 1856, see Thompson, *Kelvin*, *1*: 320–24.

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the weakness of his response and with an eye on the plans then brewing to lay a cable across the ocean, Thomson said he hoped to have more to offer soon, for "capitalists ought to require a very 'matter-of-fact' proof of the attainability of a sufficient rapidity of communication of actual messages … before sinking so large an amount of property in the Atlantic."[46]

Whitehouse replied in the next issue of the *Athenæum*, thanking Thomson for his published response and also for a "long and friendly communication" (now lost) from him. In return, he sent Thomson a detailed account of his experiments and offered to meet him "as far northward as Liverpool any day next week" to explain them more fully. But while confessing that he could not "follow the learned Professor into fine distinctions upon the nature of theory," he said he was at a loss to see how the results of his experiments could possibly be reconciled with Thomson's law of squares. He repeated and extended his claim that "by any considerable increase in the size of a long *submarine conductor*, we positively increase the difficulty of giving telegraphic signals and diminish the speed of their transmission," and declared that if anyone still wished to argue that the maximum rate of signaling attainable on a submarine cable falls off with the square of its length, "I will undertake to prove experimentally the fallacy of that idea."[47]

After closely studying Whitehouse's account of his experiments, Thomson sent the *Athenæum* a long letter in which he sought to explain away the apparent conflicts with his theory. The basic problem, he said, was that Whitehouse had not applied the theory correctly, so that what he had so meticulously measured turned out to be not quite what Thomson had been talking about. In particular, Whitehouse had jumped too quickly from Thomson's full mathematical theory of telegraphic transmission to the simple "law of squares" – though it must be said that Thomson had opened the way when he had asserted that "a wire six times the length of the Varna and Balaklava wire, if of the same lateral dimensions, would give thirty-six times the retardation and thirty-six times the slowness of action."[48] He now backed off from such sweeping statements and stressed that "it depends on the nature of the electric operation performed at one extremity of the wire, and on the nature of the test afforded by the indicating instrument at the other extremity, whether or not any *approach to the law of squares is to be expected* in the observed

[46] William Thomson, "Telegraphs to America" (letter), *Athenæum* (October 4, 1856) 1219, repr. in Thomson, *MPP 2*: 92–93.

[47] Whitehouse, "Atlantic Telegraph," *Athenæum* (October 11, 1856) 1247. Whitehouse and Thomson did not meet at that time.

[48] Thomson, "Peristaltic Induction," 21–22.

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results."[49] According to Thomson, when we take into account the varying power of the batteries, the limited sensitivity of the instruments, and the effects of electromagnetic induction in the coils of the receivers, Whitehouse's careful measurements of retardation and signaling rates were actually well in line with what Thomson's theory predicted; indeed, Thomson later said that "nothing can be more perfect that the agreement of these experimental results with the theory" – when that theory was properly applied.[50]

As for the claim that increasing the size of the conductor led to more, not less, retardation, Thomson said Whitehouse had erred in treating the three separately insulated wires of his cable as equivalent to a single thicker conductor. The key to reducing retardation lay not just in reducing the total resistance of a circuit but also in reducing its associated induction (or capacitance). Since the latter depended crucially on the surface area of the conductor and the thickness and arrangement of the surrounding insulation, the experiments in which Whitehouse sent currents simultaneously along all three wires of his cable were not a proper test of the retardation to be expected along a single thicker conductor. Though he drily said it was "not my part" to explain the increase in retardation Whitehouse had seen when using all three wires, Thomson suggested that the more rapid depletion of the battery when acting through a smaller resistance might have produced the effect.[51]

Amid these defenses of his theory, however, Thomson made a major concession: he had been too hasty, he said, in ascribing the poor performance of the Black Sea cable simply to retardation, and his estimates of the signaling rates achievable on longer cables were therefore mistaken. Drawing on new measurements of the ratio of electromagnetic to electrostatic units by "that most profound and accurate of all experimenters, Wilhelm Weber," Thomson now calculated that the Black Sea line, if pushed to its utmost, should have been able to carry nine letters per second, or about 100 words per minute. That in practice it achieved only a small fraction of that speed was evidently due to the use of sending and receiving instruments that were poorly chosen and badly adjusted. Thomson now calculated that with properly designed apparatus, operated "so as to clear a wire rapidly of residual electricity," a cable of ordinary thickness should be able to carry a distinct letter across the Atlantic every 3.5 seconds. "This, amounting to 17 letters a minute,

[49] Thomson, "Telegraphs to America," 1338–39.
[50] William Thomson to Auguste de la Rive, December 17, 1856, in Paul Tunbridge, *Lord Kelvin: His Influence on Electrical Measurements and Units* (London: Peter Peregrinus, 1992), 97.
[51] Thomson, "Telegraphs to America," 1339.

would give 200 messages of 20 words each in the 24 hours," he observed, "and at 30*s*. a message would be not a bad return for 1,000,000 *l* of capital expended."[52] Indeed, it would come to about a 10 percent annual return on a capital of £1 million, and not far short of the 40 percent return Field would soon be touting for the Atlantic Telegraph Company's actual capital of £350,000. The prospects for a successful Atlantic cable had evidently brightened considerably from the dark picture Thomson had drawn just a year earlier.

Whitehouse practically crowed over this response from Thomson. In a letter published in the *Athenæum* on November 8, he said he was happy to let Thomson go on "maintaining the correctness of his theory – as theory," since, as he saw it, "the whole position for which I originally contended is conceded by Prof. Thomson." Whitehouse particularly prized Thomson's admission that a cable not much thicker than those already in use could be expected to carry several words per minute across the Atlantic, and that with carefully contrived techniques and apparatus even higher rates might be possible. This, Whitehouse said, opened up "a field of research, rich, promising, intensely interesting, and practical," and devising such improved signaling methods, based mainly on using pulses of current from induction coils, had already become the focus of his own work.[53]

The whole exchange with Thomson, from Whitehouse's British Association paper in early August to his final letter in the *Athenæum* in early November, played out just as Field, Brett, and Bright were rushing to launch the Atlantic Telegraph Company – and drawing Whitehouse more closely into it. He and Bright had experimented together on Magnetic Telegraph Company lines as early as November 1855 and had even formed a loose partnership at that time.[54] When in late September 1856 Bright joined Field and Brett in pledging to work together to promote an Atlantic telegraph, Whitehouse was not far behind. A key step came on the night of October 2–3, when he and Bright performed a series of transmission tests on a 2000-mile circuit of the Magnetic Telegraph Company's underground lines. Morse came along to observe the experiments and the next morning sent Field an enthusiastic letter – promptly forwarded to the *Daily News* – filled with praise for the "active and agreeable" Bright and "that clear-sighted investigator of electrical phenomena, Dr. Whitehouse." Using Whitehouse's induction coils and magnetic receivers, Morse reported, they had transmitted up to 270 pulses per minute through the full length of the lines, a result that "most satisfactorily resolved all doubts

[52] Thomson, "Telegraphs to America," 1338–39.
[53] Wildman Whitehouse, "Atlantic Telegraph" (letter), *Athenæum* (November 8, 1856) 1371.
[54] Whitehouse, *Atlantic Telegraph* (1858), 8.

of the practicability . . . of operating the telegraph from Newfoundland to Ireland."[55]

Morse's letter drew wide attention. Though Whitehouse later said it had been "incontinently published" and that his experiments with Bright should have been carefully verified before being made public, Morse's report had served its purpose, as Field no doubt intended when he forwarded it to the press: by putting the weight of a famous name behind the Atlantic cable project, it had helped calm the fears of investors worried that retardation might render the cable too slow to pay.[56] Field himself was so impressed by Whitehouse, and so intent on securing access to his patents, that in early October he took steps to add him as the fourth "projector" of the nascent company.[57] From then on Whitehouse would occupy a central position in the Atlantic cable project.

The prospectus for the Atlantic Telegraph Company – issued in early November 1856, just as Whitehouse's last reply to Thomson was appearing in the *Athenæum* – went out of its way to praise Whitehouse and Bright's recent "conclusive experiments" on underground circuits and to call their patented instruments "the most perfect mode at present known" for signaling through long submarine cables.[58] To secure the rights to their patents, as well as their future services to the company, the prospectus called for granting Whitehouse and Bright, jointly with Field and Brett, half of all profits the company earned once it had successfully laid its cable and was paying a 10 percent dividend to its shareholders. Whitehouse thus had a substantial financial interest in the success of the venture, as well as in the use of his instruments, and would also earn a handsome salary of £1000 per year as the company's electrician, as Bright would as its chief engineer.[59]

Whitehouse soon went on the road with his fellow projectors, traveling to Liverpool and Glasgow to pitch shares in the company to potential

55 Samuel Morse to Cyrus Field, October 3, 1856, in Field, *Atlantic Telegraph*, 76–78; also published as "Telegraphic Experiments" in the *Daily News* (October 10, 1856). Morse wrote again to Field on October 10, 1856 to say he believed a cable across the Atlantic could carry at least ten words per minute and was sure to be profitable; see Field, *Atlantic Telegraph*, 78–80.

56 Whitehouse, *Atlantic Telegraph* (1858), 9–10.

57 Brett, "Atlantic Telegraph" (letter), *Morning Post* (September 23, 1858), 2.

58 "Prospectus," in Brett, *Origin and Progress*, 49.

59 On the appointment of Whitehouse as electrician of the Atlantic Telegraph Company, see ATC Minute Book entry for October 29, 1856, 3; Morse was also named as a company electrician but his title was essentially honorary. On Whitehouse and Bright's salaries, see ATC Minute Book, entry for c. January 10, 1857, 47. In February 1858, after the reverses of the previous summer had tempered their expectations, the four projectors agreed to give up their claim to half of the company's future profits in return for £75,000 in additional shares (just over £28,000 each for Brett and Field, £12,500 for Whitehouse, and £6240 for Bright); see Saward, *Trans-Atlantic Submarine Telegraph*, 11, and ATC Minute Book, entry for February 17, 1858, 293.

investors.[60] On the swing through Glasgow in late November he met with Thomson and explained his experiments to him. Thomson was impressed with Whitehouse's techniques and apparatus, and though the two continued to differ on how to interpret some of Whitehouse's results, Thomson became a warm supporter of the cable project and of Whitehouse himself.[61] After Whitehouse told the assembled group at Glasgow that the proposed cable would be able to carry about seven words per minute, Thomson volunteered that he was now "satisfied that for long distances communication could be much more speedily made than was obtained on the line betwixt Varna and Balaklava, and that the pecuniary return in this speculation would be ample."[62] In early December he joined the project himself when the Glasgow shareholders elected him to the board of directors of the Atlantic Telegraph Company.[63] By January Thomson was publicly declaring that his previous theoretical objections had now been met and that Whitehouse's signaling system promised to give excellent results on the Atlantic cable; by the following September he was praising Whitehouse's patented relays and induction coils in glowing terms at the annual meeting of the British Association; and by November he was asking how he might go about proposing Whitehouse for election to the Royal Society of London.[64] To say that Whitehouse and Thomson had patched up their differences would evidently be an understatement; but that was not quite the end of the story.

Thick or Thin

As the Atlantic Telegraph Company was being formed in the fall of 1856, its leaders faced a crucial decision: what kind of cable should they lay down? What should be the size and composition of its conductor,

[60] On visits by Field, Brett, and Whitehouse to groups of potential investors in Liverpool, see *Times* (November 14, 1856), 12; in Glasgow, see *Glasgow Herald* (November 24, 1856); and in Manchester, though apparently without Whitehouse, see *Times* (November 22, 1856), 6.

[61] On Thomson's meeting with Whitehouse, see Thomson to de la Rive, December 17, 1856, in Tunbridge, *Kelvin,* 97. Thomson later wrote on his copy of Whitehouse's "Experiments on the Retardation of Electric Signals" that it gave "The best account of what is good in Whitehouse's experiments and apparatus. The conclusions, however, are fallacious in almost every point"; see Thompson, *Kelvin*, *1*: 330n.

[62] "The Atlantic Telegraph," *Glasgow Herald* (November 24, 1856).

[63] ATC Minute Book, entries for December 3 and December 9, 1856, 25 and 34.

[64] William Thomson, in discussion of F. R. Window, "On Submarine Electric Telegraphs," *Proc. ICE* (January 1857), *16*: 188–202, discussion 203–25, on 210–11; William Thomson, "On Mr. Whitehouse's Relay and Induction Coils in action on Short Circuit," *BA Report* (1857), 21; William Thomson to G. G. Stokes, November 7, 1857, in David B. Wilson, ed., *Correspondence between Sir George Gabriel Stokes and Sir William Thomson, Baron Kelvin of Largs*, 2 vols. (Cambridge: Cambridge University Press, 1990), *1*: 226.

insulation, and protective outer armoring? In particular, should their cable be thick or thin? It was a question on which Thomson's theory and Whitehouse's experiments pointed in opposite directions, and the answer the company gave would have far-reaching consequences.

In choosing a design for their cable, the company faced several constraints. The first was cost: the company had no more than £350,000 to spend on the entire project. Another was time: Field's promise to lay the cable by the summer of 1857 ruled out adoption of any design that could not be executed quickly. The cable would also have to meet a long list of mechanical requirements for strength, flexibility, and specific gravity, and its total bulk could not exceed the capacity of the two ships that were to carry and lay it. Finally, the cable had to have the requisite electrical qualities to enable it to convey signals across the Atlantic at a commercially viable rate. As Field later observed, this last consideration ought properly to have come first, since solving the mechanical problem of laying a cable across the Atlantic would count for nothing if it proved unable to carry readable signals.[65] In practice, however, more attention was devoted to the mechanical than the electrical needs of the first Atlantic cable.

Immediately after registering their new company on October 20, Field and Brett recruited several business associates to join them on its provisional board of directors, including Samuel Statham of the Gutta Percha Company and George Carr and Charles Tupper, galvanized iron dealers who had worked with Brett on his Mediterranean cables. They soon took up the task of choosing a design for the cable, for as Carr, the chair of the provisional board, told the permanent directors when they took over on December 9, "If it was intended to attempt the enterprise next year, no time was to be lost in deciding upon the cable to be used, and in concluding arrangements for its manufacture."[66]

Whitehouse later said that when he asked for three more months to test sample cables before choosing a final design, Field replied "Pooh, nonsense"; three months of testing, followed by the time needed to manufacture 2500 miles of cable, would have pushed them past the summer laying season recommended by Maury and so put the project back a full year.[67] Unwilling to yield on the 1857 deadline, the provisional board pressed

[65] Cyrus Field, in discussion of J. A. Longridge and C. H. Brooks, "On Submerging Telegraphic Cables," *Proc. ICE* (February 23, 1858) *17*: 221–61, discussion 298–366, on 326.

[66] ATC Minute Book, entries for October 23, 1856, 2, and December 9, 1856, 31–32.

[67] Testimony of Wildman Whitehouse, December 15, 1859, in *Joint Committee Report*, 75. On Maury's advice on when best to lay the cable, see his March 28, 1857, letter to Field, in M. F. Maury, *Explanations and Sailing Directions to Accompany the Wind and Current Charts*, 2 vols. (Washington, DC: William A. Harris, 1858), *1*: 182–89, on 189.

ahead with only hurried testing of cable designs. Field had already received samples of several types of cores from Statham and of outer coverings from Richard Glass of Küper and Company. He soon came to favor a core consisting of seven number 22 gauge copper wires (each about 0.028 inches in diameter) twisted together to form a single conductor, all covered with three layers of gutta-percha.[68] Such a stranded conductor had first been used on Field's Cabot Strait cable; it was more flexible than a single wire of the same thickness and also more secure against a loss of continuity, since a break in any one wire would not stop the flow of current.

Field next took up what kind of outer covering to use. Since the Channel cable of 1851, almost all submarine conductors had been protected by an outer armoring of iron wires laid on with a slight spiral, as in a wire rope. While traveling by train in the late summer of 1856, Field happened to encounter Isambard Brunel and showed him some samples of cable designs. Impressed by the stranded conductor, Brunel reportedly suggested that stranded wire be used for the outer covering as well; it would be at least as strong as thicker single wires, he said, and much more flexible.[69] The stranded cable also had the advantage of looking good, and Field later had Glass make thousands of short lengths of it to hand out as marketing props when promoting shares in the new company. The company later paid Glass £1000 to cover the "preliminary expenses" he had incurred in this way.[70]

On October 29, 1856, just nine days after the company was registered and before it had issued a prospectus, the provisional board of the Atlantic Telegraph Company requested tenders from the Gutta Percha Company for the core of the planned cable and from Küper and Company for its outer armoring. Two days later the board appointed Field, Brett, and Tupper to a committee to consider the tenders and recommend which design to adopt. Notably, none of the three were cable engineers or experts on either the mechanical or electrical aspects of cable design. They reported back just ten days later, unanimously recommending that the company adopt essentially the design Field already favored: a stranded copper conductor weighing 107 pounds per nautical mile and "insulated in Gutta Percha of the best quality," applied in three layers

68 Charles F. Briggs and Augustus Maverick, *The Story of the Telegraph, and a History of the Great Atlantic Cable* (New York: Rudd & Carleton, 1858), 59–60.
69 Mulally, *The Laying of the Cable*, 29.
70 Saward, *Trans-Atlantic Submarine Telegraph*, 9. Willoughby Smith, *The Rise and Extension of Submarine Telegraphy* (London: J. S. Virtue, 1891), 45, said the samples "looked very pretty, and were used as decoys to obtain the capital required." On the later payments to Glass, see ATC Minute Book, entries for April 1, 1857, 102, and June 25, 1857, 177.

to bring the diameter of the core up to three-eighths of an inch. This would then be covered with a layer of jute yarn saturated with tar and beeswax, and finally by an outer armoring consisting of "eighteen strands, seven wires each, of No. 22 gauge Best Charcoal Iron bright wire."[71] The report made no mention of the electrical qualities of either the copper or the gutta-percha, nor did it call for any electrical tests on any part of the cable.

Although many later assumed that Whitehouse had chosen this design, he in fact favored a somewhat different one.[72] While assuring the provisional board that he believed the design it had recommended was "well adapted" to its purpose and that he did not at all oppose its adoption, he argued in his "Electrician's Report" that another of the samples the company had been offered, with a slightly thicker covering of gutta-percha and with its outer iron wires embedded in hempen cords, offered several advantages. Such a cable would, he said, be just as strong and nearly as flexible as the design the committee favored, while its lower specific gravity would help buoy it up during laying and so reduce the strain to which it would be subjected. In addition, he said, "in consequence of the greater thickness of the Gutta Percha it will certainly have less induction and retardation, and hence admit of the attainment of higher working speed" than the other design.[73] Whitehouse did not address whether to use a thicker copper conductor, which Thomson had said would also reduce the retardation.[74]

Whitehouse's objections were quickly overruled. Brett flatly rejected the use of hemp-covered armoring, declaring that such a cable would be so weak he "would not have it if it were laid."[75] Bright later said he had favored a much thicker cable, with nearly four times as much copper and half again as much gutta-percha per mile as the core recommended by the committee, but this proposal, if it was ever officially made, was also rejected, largely, he said, because of its greater

[71] ATC Minute Book, entries for October 29, October 31, and November 10, 1856, 3–8.

[72] Douglas Galton and George Saward were among those who assumed Whitehouse had designed the cable; see their questioning of him, December 15, 1859, *Joint Committee Report*, 74.

[73] Wildman Whitehouse to Atlantic Telegraph Company, November 5 and November 8, 1856, in ATC Minute Book, entry for November 10, 1856, 8–9.

[74] Thomson, "Telegraphs to America," *Athenæum* (November 1, 1856), 1339. Thomson later said that while a thicker cable would have shown less retardation, he believed the design adopted by the Atlantic Telegraph Company was a good choice for a first attempt, given the cost constraints; see "Banquet to Professor William Thomson," *Glasgow Herald* (January 21, 1859), and Thomson's December 17, 1859, testimony in *Joint Committee Report*, 111.

[75] Whitehouse, *Atlantic Telegraph* (1858), 13, and Brett, "Atlantic Telegraph" (letter), *Morning Post* (September 23, 1858).

expense.[76] Focusing mainly on the mechanical strength of the outer armoring, the provisional board quickly voted to adopt the design recommended by its committee and to invite tenders from manufacturers.[77]

In their choice of conductor, Field and Brett had relied heavily on Whitehouse and Morse's assurances that a wire of ordinary thickness would be able to carry signals at a commercially viable rate across the Atlantic. In fact the Atlantic Telegraph Company soon began to assert not just that a thin conductor would work well enough, but that it would actually be *better* than a thicker one. When Whitehouse had first suggested this in 1856, based on his experiments with three separately insulated wires, Thomson had pointed out that such an arrangement was not at all equivalent to a single thicker conductor, but Whitehouse did not back down, and the idea that thin conductors produce less retardation came to be closely identified with him.[78] In January 1857 it received influential support when Michael Faraday rose during discussion of a paper at the Institution of Civil Engineers to declare that "the larger the wire, the more electricity was required to charge it, and the greater was the retardation of that electric impulse, which should be occupied in sending the charge forward."[79] The leaders of the Atlantic Telegraph Company were delighted to hear the leading electrical authority of the day, and the man who had first brought the problem of retardation to public notice, state that for a submarine cable like theirs, a thin conductor would show less retardation than a thick one. As S. A. Varley and others later pointed out, however, Faraday had erred badly: although the larger surface area of a thick conductor would indeed give rise to more induction, this would be more than offset by its lower resistance, which would result in *less* overall retardation than with a thin wire.[80] Such niceties were lost on most observers, however, and Field later happily quoted Faraday's remark as a direct and authoritative endorsement of the relatively thin conductor the company had already adopted.[81]

[76] In a January 1862 discussion at the Institution of Civil Engineers, Bright said that in 1856 he had called for the Atlantic cable to be made with 392 pounds of copper and a like weight of gutta-percha per nautical mile, but "owing to financial and other considerations," this advice was not taken; Bright, in discussion of H. C. Forde, "The Malta and Alexandria Submarine Telegraph Cable," *Proc. ICE* (May 1862) *21*: 493–514, discussion 531–40, on 531.

[77] ATC Minute Book, entry for November 10, 1856, 9.

[78] Whitehouse, "Law of Squares," 23.

[79] Faraday, in discussion of Window, "Submarine Electric Telegraphs," 221.

[80] S. A. Varley, in discussion of Frederick Charles Webb, "On the Practical Operations Connected with Paying Out and Repairing Submarine Telegraph Cables," *Proc. ICE* (February 1858) *17*: 262–297, discussion 298–366, on 330–31.

[81] Field, in discussion of Webb, "Practical Operations," 326.

The Atlantic Telegraph Company committed itself most explicitly to the supposed superiority of thin conductors in an "official manifesto" it issued in the summer of 1857.[82] Stung by criticisms of the project in the press, in April the board of directors ordered the company's engineer, electrician, and secretary (Bright, Whitehouse, and George Saward) to prepare a response.[83] The resulting sixty-nine-page booklet, *The Atlantic Telegraph: A History of Preliminary Experimental Proceedings*, *and a Descriptive Account of the Present State & Prospects of the Undertaking*, appeared in mid-July, just weeks before the ships carrying the cable were to begin laying it across the ocean.[84] Widely advertised and distributed, the little book heaped so much praise on Whitehouse that many believed he had written it himself.[85] In fact it issued from the pen of R. J. Mann, a physician turned popular scientific writer, though Whitehouse later said that Mann had based it on materials "chiefly furnished by me." Some surviving copies bear the initials "R. J. M." at the end, but Mann later said that after the printing was completed the Atlantic Telegraph Company insisted on paying him fifty guineas and blotting out his initials with a "black lozenge" (as seen in most surviving copies) so that the publication would appear "with the authority of an official document."[86] Similar praise for Whitehouse also appeared in an anonymous piece Mann wrote for the July number of the *Edinburgh Review*, as well as in an article on "The Atlantic Telegraph" in the June 27 issue of *Chambers's Journal*; the latter went so far as to dub the "indefatigable and sagacious" Whitehouse the "lightning-king."[87]

[82] The phrase "official manifesto" appears in Briggs and Maverick, *Story of the Telegraph*, 72.

[83] ATC Minute Book, entry for April 22, 1857, 119, evidently in response to "The Great Atlantic Submarine Telegraph Cable," *Times* (April 22, 1857), 9.

[84] [R. J. Mann], *The Atlantic Telegraph: A History of Preliminary Experimental Proceedings, and a Descriptive Account of the Present State & Prospects of the Undertaking, Published by Order of the Directors of the Company* (London: Jarrold and Sons, 1857).

[85] See, for example, "The Atlantic Telegraph" (letter), *Engineer* (November 5, 1858) *6*: 355, which says it was widely understood that the booklet "was written by Mr. Whitehouse himself." Signed "A Telegraph Engineer and Practical Electrician," this letter had been written by W. H. Preece; see the manuscript of it, NAEST 17/12.8, IET Archives, London. Whitehouse responded in "The Atlantic Telegraph" (letter), *Engineer* (November 26, 1858) *6*: 410, disclaiming authorship and saying the booklet had instead been written by "a talented popular writer."

[86] R. J. Mann to Latimer Clark, November 12, 1880, WC-NYPL; see also Wildman Whitehouse to J. J. Fahie, September 18, 1879, SC/MSS 009/2/151/1, IET Archives, London. No "black lozenge" covers the initials "R. J. M." at the end of the copy held by the University of California at Berkeley, a scan of which is available through Google Books. On the payment of fifty guineas to Mann, see ATC Minute Book, entry for June 25, 1857, 175.

[87] [R. J. Mann], "De la Rive on Electrical Science," *Edinburgh Review* (July 1857) *106*: 26–62; on Whitehouse, see 40–44. Mann is identified as the author in Walter E. Houghton et al., eds., *Wellesley Index to Victorian Periodicals, 1824–1900*, 5 vols. (Toronto: University of Toronto Press, 1966–1989). Mann almost certainly also wrote

In his booklet, Mann gave a full and adulatory account of Whitehouse's various devices and experiments, and after briefly noting the "counsel" provided by "Professor W. Thompson [*sic*] of Glasgow," devoted several pages to recounting Whitehouse's supposed refutations of the law of squares.[88] He then boiled Whitehouse's results down into a set of succinct principles, including the unequivocal statement "that large coated wires used beneath the water or the earth are worse conductors, so far as velocity of transmission is concerned, than small ones, and therefore are not so well suited as small ones for the purposes of submarine transmission of telegraphic signals."[89] Widely quoted in the press, this passage was universally taken to express the official view of the Atlantic Telegraph Company on the question of thick versus thin conductors. It was also widely criticized by experienced cable engineers, including S. A. Varley, F. C. Webb, and Latimer Clark.[90] By the time Mann's booklet appeared in July 1857, however, such criticisms were beside the point: the cable had already been made and would soon be laid, and the size of its conductor was a fait accompli. Thomson, himself by then a director of the company and deeply engaged in its activities, knew that a thicker conductor would give a faster working speed, but he recognized that this would cost more than it might be possible to raise at the time, and in any case he thought he saw a way to make even a relatively thin cable work well enough to pay.[91] Although in the end the signaling method by which he proposed to accomplish this was not carried into practice, it would have important consequences, as we shall see.

"The Atlantic Telegraph," *Chambers's Journal* (June 27, 1857) *7*: 401–4, which includes many of the same passages about Whitehouse.

88 [Mann], *Atlantic Telegraph*, 21. 89 [Mann], *Atlantic Telegraph*, 26.

90 Among the many quotations of this passage in the press, see "The Atlantic Telegraph," *Morning Chronicle* (August 22, 1857); "Secrets of the Atlantic Cable," *Morning Chronicle* (September 10, 1858), where it is cited as the reason the Atlantic Telegraph Company adopted a thin conductor for its cable; and [David Brewster], "The Atlantic Telegraph," *North British Review* (November 1858) *29*: 519–55, on 533. Brewster is identified as the author in Houghton et al., eds., *Wellesley Index*. The passage also appears in Briggs and Maverick, *Story of the Telegraph*, 81, and in Tal. P. Shaffner, *The Telegraph Manual* (New York: Pudney and Russell, 1859), 624, but was strongly criticized by S. A. Varley in "On the Electrical Qualifications Requisite in Long Submarine Telegraph Cables," *Proc. ICE* (February 1858) *17*: 368–85, on 369, and by both Varley and Webb in the discussion of Webb, "Practical Operations," 330–31 and 357. Latimer Clark made penciled exclamation marks beside this passage in his own copy of Mann's pamphlet, WC-NYPL. Note, however, that C. V. Walker endorsed using very thin conductors; *Joint Committee Report*, December 16, 1859, 103.

91 William Thomson, "On Practical Methods for Rapid Signalling by the Electric Telegraph," *Proc. RS* (November 1856) *8*: 299–303, and (December 1856) *8*: 303–7, repr. in Thomson, *MPP 2*: 103; see also Thomson's remarks in "Banquet to Professor William Thomson," *Glasgow Herald* (January 21, 1859), and his December 17, 1859, testimony in *Joint Committee Report*, 111 and 124.

Making and Laying the Cable – the First Attempt

As Cyrus Field rushed to launch the Atlantic Telegraph Company in the fall of 1856, he dealt directly with Richard Glass of Küper and Company as the prospective manufacturer of the cable. As word got out that a large contract might be in the offing, however, Glass's rival R. S. Newall began angling for a piece of it. Known as a bold and aggressive businessman, Newall had made and laid several important early cables but had also presided over some embarrassing failures. He was also known to be litigious, particularly about his patent rights, and in November 1856, as the competition to secure the order to armor the cable became, in Saward's later words, "the subject of intrigues," the provisional board of the Atlantic Telegraph Company decided "as an act of policy rather than prudence" to split the contract between the two manufacturers.[92] The Gutta Percha Company of London was to produce 2500 miles of insulated core; half would then be armored by Glass at the Küper works in East Greenwich and half by Newall at his works in Birkenhead near Liverpool, all to be delivered, coiled, stowed, and "ready for sea" by June 1857.[93]

The splitting of the cable contract led to several problems. One came to be seen as emblematic of bungling on the project: after the armoring was complete, it was found that Glass had given the outer wires of his half of the cable a left-handed "lay," or twist, while Newall had given his half a right-handed one. Had the two halves been spliced directly together, they would have unwound each other, exposing the underlying core. This could be prevented only by inserting a heavy frame at the splice, but while the mismatched lays were embarrassing, they had little real effect on the integrity of the cable.[94] More serious was the fact that quality control measures had to be split between two sites more than 200 miles apart, and that no tests could be conducted through the full length of the cable until both halves had been completed and shipped out for laying, a failure that Whitehouse later said he particularly regretted.[95]

While the cable was being manufactured, Whitehouse set about assembling the instruments and apparatus he would use to test and operate it. The expense was substantial; in April 1857 the board authorized spending more than £3200 to acquire sets of Whitehouse's patented batteries, induction

[92] Saward, *Trans-Atlantic Submarine Telegraph*, 9; on Newall's litigiousness, see Smith, *Rise*, 15–16.
[93] ATC Minute Book, entry for November 18, 1856, 16–18.
[94] Bright, *Submarine Telegraphs*, 35n, 44–45; Cookson, *Cable*, 73.
[95] ATC Minute Book, entries for January 13, 1857, 50; c. March 1857, 91, 96; Whitehouse, "Electrician's Report," January 4, 1858, WC-NYPL; Whitehouse, *Atlantic Telegraph* (1858), 11.

coils, and relays, and Saward later reported that in all the company spent some £13,000 on Whitehouse's electrical department.[96] The "perpetual maintenance batteries" Whitehouse used to power his huge induction coils were a particularly lavish item; the company reportedly spent £2000 just on their enormous silver plates, though these were later scrapped when graphite plates proved more effective. Perhaps not surprisingly, the board of directors repeatedly grumbled about Whitehouse's spending, leading to tensions that occasionally threatened to boil over.[97]

No ship afloat was big enough to hold the entire cable (the *Great Eastern* was then still under construction), so half was to be carried by the *Niagara*, a steam frigate on loan from the US Navy, and half by the Royal Navy's HMS *Agamemnon* (Figure 2.5). After various complications and delays, Newall's half of the cable was loaded onto the *Niagara* and Glass's onto the *Agamemnon*, a task that took up much of July. While waiting to be loaded, Glass's half of the cable sat in direct sun on some unusually hot days at Greenwich – topping out at 88°F on Sunday, June 28, the hottest day in eleven years – "melting out the gutta percha in many miles of cable," which had to be cut out and replaced.[98]

Once the loading was completed, the two ships, accompanied by several smaller vessels, rendezvoused on July 30 at Queenstown (now Cobh) in southern Ireland, where for the first time the two halves of the cable could be linked together. Conditions were far from ideal, but Whitehouse and Thomson – aided, according to one report, by Whitehouse's wife, Emma – managed to rig connecting wires between the two ships and successfully passed currents through the entire 2500 miles of cable.[99] The link was broken at the turn of the tide, but after reconnecting the wires the next day, Whitehouse began using his induction coils and relays to check signaling rates. He told the press the tests were "most satisfactory," but they in fact raised serious concerns.

[96] ATC Minute Book, entries for April 16, 1857, p. 116, and April 22, 1857, p. 119; "The Atlantic Telegraph," *Engineer* (October 8, 1858) *6*: 268.

[97] J. N. Hearder, "On the Atlantic Cable," *Phil.Mag*. (January 1859) *17*: 27–42, on 40. Most of the cost of the silver plates could be recovered when they were scrapped; see C. V. Walker in *Joint Committee Report*, 102. On Whitehouse's patented battery, see [Mann], *Atlantic Telegraph*, 58–62. For attempts to rein in Whitehouse's spending, see ATC Minute Book, entries for c. June 1857, 168; September 17, 1857, 231; and October 8, 1857, 242.

[98] "Atlantic Submarine Telegraph," *Times* (July 24, 1857), 5; Whitehouse, *Atlantic Telegraph* (1858) 12 and 16; Whitehouse, December 15, 1859, *Joint Committee Report*, 76. On the temperature, see James Glaisher, "On the Meteorology of England, during the Quarter ended June 30th, 1857," *Journal of the Statistical Society of London* (December 1857) *20*: 441–42.

[99] Whitehouse, "Electrician's Report," January 4, 1858, WC-NYPL; on Mrs. Whitehouse, "a lady of great skill and experience in electric telegraphic operation," see "The Atlantic Cable – Arrival of the *Agamemnon*," *The Constitution, or Cork Advertiser* (August 1, 1857).

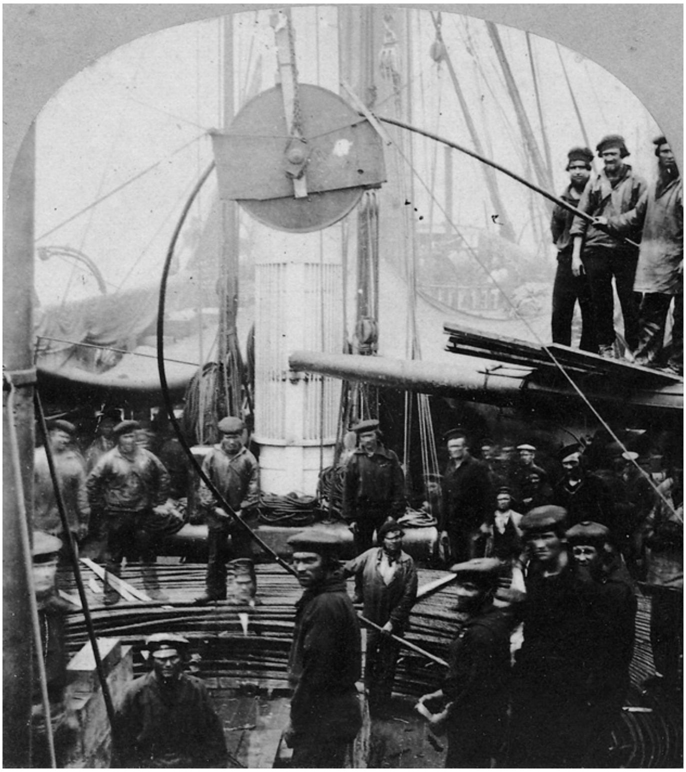

Figure 2.5 Crewmen coiling the first Atlantic cable on the US warship *Niagara* in 1857 or 1858, from a series of stereoscopic views produced by the London Stereoscopic Company.
(Photograph courtesy of and copyright © 2007 Page and Bryan Ginns, www.stereographica.com.)

Morse, who had come over on the *Niagara*, observed the tests and wrote to his wife that while he still believed the project would eventually succeed, he was troubled by how slowly readable signals could be sent: "twenty words in sixteen minutes is now the rate," he said, far below the ten words per minute he had promised when the company was launched.[100] As Whitehouse euphemistically later put it, the Queenstown tests "rendered

[100] "The Atlantic Telegraph," *Daily News* (August 6, 1857), 5, particularly the section marked "(Official Intelligence)," the style and content of which suggest it was written by Whitehouse; "The Atlantic Telegraph," *Times* (August 3, 1857), 7; Whitehouse, *Atlantic Telegraph* (1858), 17; Morse to his wife, August 4, 1857, in Prime, *Morse*, 657.

it sufficiently evident that much time and attention might judiciously be bestowed on . . . the details and peculiar arrangements required for signaling through so vast and untried a distance, in order to attain a thoroughly certain and commercially satisfactory rate of communication."[101] In other words, his system did not yet work at all well. As the ships carrying the cable steamed out of Queenstown, outward confidence masked nagging doubts.

The original plan had called for the two ships to meet at mid-ocean, splice their cables together, and steam off in opposite directions, the *Niagara* laying its half to Valentia Island on the southwest coast of Ireland and the *Agamemnon* its half to Trinity Bay in Newfoundland. Starting in mid-ocean had the advantage of ensuring that a calm day could be chosen for the risky splicing operation, while also cutting the total laying time in half and so reducing the chance the ships would encounter bad weather. Whitehouse, however, had been forbidden by his physician from sailing beyond Ireland, and wishing to be able to monitor the progress of the expedition from his base at Valentia, he proposed that the *Niagara* instead start directly from there and, after laying its half of the cable, hand over to the *Agamemnon* to complete the route to Newfoundland. The engineers and naval officers strongly opposed this plan – Henry Woodhouse, Bright's assistant, later called it "suicidal" – but the board of directors, perhaps intrigued by the prospect of being able to "speak" through their cable with ships at sea, backed Whitehouse. Thomson, at that point one of Whitehouse's strongest supporters on the board, seconded the motion; he also agreed to take Whitehouse's place on the *Agamemnon*, and in fact would sail on all of the Atlantic cable-laying expeditions.[102]

On August 5, amid speeches and celebrations, the *Niagara* landed its end of the cable at Valentia and began steaming west. In a foretaste of troubles to come, the cable jammed and snapped before the flotilla had left sight of land. Little time or cable was lost, however, and the *Niagara* set out again three days later. Bright's paying-out machinery was of a novel design and not well tested; Woodhouse later said that in the rush to start the laying, "the machines were literally being put together" as the ships made their way to Valentia.[103] The heavy machinery required constant and careful supervision to keep it from putting too much strain on the cable as it was being payed out, and three days out, after the *Niagara* had laid 335 miles and entered deeper waters, the inevitable

[101] Whitehouse, "Electrician's Report" (January 4, 1858), 26, WC-NYPL.
[102] Henry Woodhouse, *Joint Committee Report*, December 9, 1859, 39; ATC Minute Book, entry for c. July 1857, 190; Thompson, *Kelvin*, *1*: 343.
[103] Woodhouse, *Joint Committee Report*, December 9, 1859, 42.

occurred: a workman did not ease the brake at a crucial moment, and the cable parted.[104]

By then it was August 11, too late in the laying season to start another attempt, and too much cable had been lost to be confident that the remaining length would suffice to reach Newfoundland. After gathering reports from Bright, Whitehouse, and the commanders of the *Niagara* and the *Agamemnon*, the board of directors concluded that the failure had resulted from a series of avoidable accidents, and at its September 9 meeting resolved to try again a year later.[105] There was talk for a time of selling the cable stowed in the *Agamemnon* and the *Niagara* to a company that proposed to lay it down the Red Sea to speed communications with India, then in the throes of the Indian Rebellion, with the Atlantic company then using the proceeds to buy a fresh length of cable for its own use the next summer. But the deal fell through, in part because of fears the Atlantic cable would not stand up to the heat of the tropics.[106] The directors decided instead to store their remaining 2000 miles of cable over the winter at the Keyham naval dockyards at Devonport near Plymouth and, after raising some additional capital and securing renewed promises of support from the British and American governments, ordered 900 miles of new cable to replace the length lost and cover any future exigencies.[107] No longer driven by the mad rush to meet Field's original deadline, Whitehouse settled in at Devonport to perform the tests on the full cable that he had long called for.

Credible Measures

From his first involvement with cable telegraphy, Whitehouse had been an active though unorthodox measurer, meticulously recording data produced by instruments of his own design. Thomson later observed that Whitehouse "had his own system" of electrical measurement that he "considered satisfactory," but it remained unique to him; his measurement practices did not link up with those then becoming standard among both laboratory scientists and practical telegraph engineers.[108] As a result, when things began to go wrong, Whitehouse would find himself

[104] Bright's report is reproduced in Bright, *Atlantic Cable*, 68–73.
[105] ATC Minute Book, entry for September 9, 1857, 220; see also the entries for August 19 and August 20, 1857, 207–12, and Saward, *Trans-Atlantic Submarine Telegraph*, 21.
[106] "Money-Market and City Intelligence," *Times* (August 22, 1857), 11, and *Times* (September 4, 1857), 8.
[107] Saward, *Trans-Atlantic Submarine Telegraph*, 24. The company raised £31,000 by selling new cheaper shares; see "Money-Market and City Intelligence," *Times* (August 6, 1858), 7.
[108] Thomson, *Joint Committee*, December 17, 1859, 115.

isolated and vulnerable to attacks on the credibility of his methods, instruments, and results.

As the Atlantic Telegraph Company regrouped in the wake of its 1857 failure, Whitehouse and his assistants began an extensive series of tests and measurements on the now land-bound cable. The company had spent more than £3000 to build tanks at Devonport, planning to store the coiled cable underwater to protect its iron armoring and gutta-percha insulation from oxidation. But the tanks leaked, so the company instead coated the cable with tar to stave off rusting and coiled it in open sheds.[109] The time the cable had spent sitting in the sun at Greenwich had already compromised the soundness of its gutta-percha; now, as it was subjected to repeated handling and exposed to heat and air, its insulation no doubt suffered further. In particular, it was later found that where heat had softened the gutta-percha, the copper conductor often settled into an off-center position, sometimes leaving only a thin layer of insulation separating it from the outer covering. In addition, Whitehouse's experiments required frequent cutting and splicing of the cable, risking the introduction of additional faults, and there was no opportunity to test the cable under water, where such faults could be more readily detected.[110]

Whitehouse used several measuring instruments in his work at Plymouth, but the most significant and distinctive was his "magneto-electrometer," or electromagnetic steelyard (Figure 2.6). Whitehouse was very proud of this little device; James Burn Russell, a former student of Thomson's who worked as an assistant on the project, said it was known as Whitehouse's "pet child" – a phrase that also appeared in an article in *Chambers's Journal* in June 1857 – and it served as the touchstone for many of his most important measurements.[111] Whitehouse described it briefly at the 1855 British Association meeting and more fully the

[109] Whitehouse, December 15, 1859, *Joint Committee Report*, 77–78; Saward, *Trans-Atlantic Submarine Telegraph*, 24.

[110] Whitehouse, December 15, 1859, *Joint Committee Report*, 76–77; Donard de Cogan, "Dr. E. O. W. Whitehouse and the 1858 Trans-Atlantic Telegraph Cable," *History of Technology* (1985) *10*: 1–15; Saward, January 12, 1860, *Joint Committee Report*, 175.

[111] [James Burn Russell], "Paying-Out the Atlantic Cable," *Sydney Morning Herald* (February 8, 1859), 5; excerpt in Thompson, *Kelvin*, *1*: 360–64. The texts of both Russell's *Sydney Morning Herald* article and a fuller three-part account ("Atlantic Cable: Leaves from the Journal of an Amateur Telegrapher") he wrote for the *West of Scotland Magazine and Review* in 1859 can be found at http://atlantic-cable.com/Article/1858JBRussell/index.htm, along with a transcription of much of the detailed journal, "Notes of my connection with the Atlantic Telegraph," he kept during his time on the cable project, the original of which is now in the Glasgow City Archives. This transcription is hereinafter cited as Russell, "Notes." See also Donard de Cogan, *They Talk Along the Deep: A Global History of the Valentia Island Telegraph Cables* (Norwich: Dosanda Publications, 2016), 55–59. Russell later became a physician and a leading public health figure in Glasgow; see Edna Robertson, *Glasgow's Doctor: James Burn Russell, MOH, 1837–1904* (East Linton:

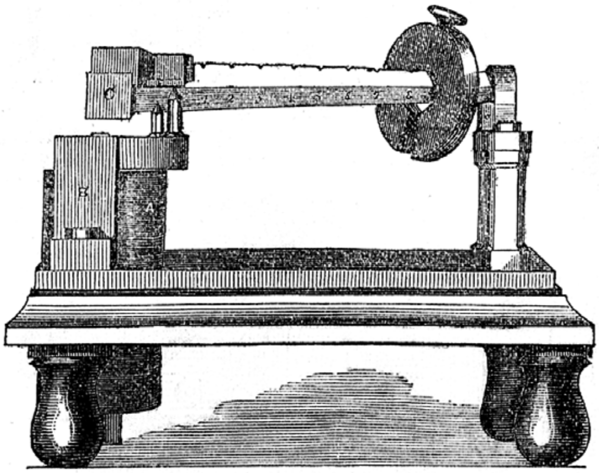

Figure 2.6 Wildman Whitehouse used his "magneto-electrometer" or electromagnetic steelyard to weigh the "value" of pulses of electric current. The little instrument stood about five inches high.
(From *Engineer*, Vol. 2: 523, September 26, 1856; courtesy University of Texas Libraries.)

following year.[112] Designed to measure pulses of current too brief to produce a steady deflection on a galvanometer, the magneto-electrometer consisted of an electromagnet set in a sturdy frame on which was poised a lever, with a soft iron keeper on one end and a movable weight on the other. When a pulse of current entered the coils of the electromagnet, the resulting magnetic force pulled down on the iron keeper and, if strong enough, lifted the weight at the other end of the lever. Whitehouse regarded the maximum weight a pulse of current could lift as the best measure of what he called "its 'value' in telegraphy." He claimed that his magnetic steelyard was so delicate that it could measure the value of a current "too feeble in its energy, too brief in its

Tuckwell, 1998). For an earlier description of the magneto-electrometer as Whitehouse's "pet child," see [Mann], "Atlantic Telegraph" (*Chambers's Journal*), 401.

112 Whitehouse, "Experimental Observations" (1855), 22; Wildman Whitehouse, "On the Construction and Use of an Instrument for determining the Value of Intermittent or Alternating Electric Currents for purposes of Practical Telegraphy," *BA Report* (1856), 19–21; a fuller account appeared under the same title in *Engineer* (September 26, 1856) *2*: 523. Allan Green emphasizes the merits of Whitehouse's device in "Dr. Wildman Whitehouse and his 'Iron Oscillograph'; Electrical Measurements Relating to the First Atlantic Cable," *International Journal for the History of Engineering and Technology* (2012) *82*: 68–92.

duration, to give the slightest indication" on a sensitive galvanometer, yet so robust that, with proper adjustments, it could accurately "weigh" currents over a range from less than one grain to more than half a million (i.e., from just over a thousandth of an ounce to nearly one hundred pounds).[113]

Whitehouse's instrument closely resembled one J. N. Hearder had introduced in 1842, though Whitehouse evidently hit on the idea independently.[114] Known as "the blind electrician of Plymouth," Hearder had lost his sight in a chemical accident as a young man but continued to perform experiments, devising ingenious ways to detect electric and magnetic effects by touch or with his tongue. He took a strong interest in the Atlantic cable project and, after Whitehouse arrived in Plymouth, met with him for "frequent friendly discussions," though they found they differed on many points.[115]

One of Hearder's most serious criticisms concerned the operation of Whitehouse's magneto-electrometer. Whitehouse had said that each pulse of current produced a magnetic force "strictly proportioned to its own proper energy," registered by his device as its "value" in grains.[116] He presented no evidence to back up this claim, however, and Hearder said his own long experience with similar devices had convinced him it was not true, or at least depended on what one meant by "its own proper energy." The force generated in the iron core of the electromagnet was not "strictly proportioned" to the strength of the applied current, Hearder said, but instead varied in "a most extraordinary and apparently incongruous" way. Thus, a current that registered a value of ten grains might not really be twice as strong as one that showed a value of five grains. The magnetic steelyard had its uses, Hearder said, but its "relative indications cannot be compared with each other, as expressing corresponding variations in the exciting currents"; one simply could not reliably compare measurements made with it under different conditions.[117] Whitehouse's magneto-electrometer might be his "pet child," but others had serious doubts about adopting it as a tool for electrical measurement.

Whitehouse nonetheless tried hard to convince other electricians of the merits of his device, contrasting its "definiteness and accuracy" with the wandering readings of the "far from reliable" galvanometer.[118] Taking his

[113] Whitehouse, "Construction and Use" (*Engineer*), 523.
[114] Hearder, "Atlantic Cable," 29; J. N. Hearder, "Description of a Magnetometer and Appendages," *Annual Report of the Cornwall Polytechnic Society*, (1844) *12*: 98–100.
[115] Hearder, "Atlantic Cable," 33; see also Ian G. Hearder, "Jonathan Nash Hearder," *ODNB*.
[116] Whitehouse, "Construction and Use" (*Engineer*), 523.
[117] Hearder, "The Atlantic Cable" (letter), *Engineer* (April 1, 1859) *7*: 224.
[118] Whitehouse, "Construction and Use" (*Engineer*), 523.

lead from Whitehouse, Mann painted the contrast even more strongly – and in strikingly gendered terms – in the manifesto the Atlantic Telegraph Company issued in 1857. A galvanometer was "of no value whatever" for measuring brief pulses of current, Mann said; "the needle . . . commonly turns somersets, and jerks backwards and forwards in the most hysterical and passionate way, instead of maintaining the steady divergence which alone could be accepted by the eye of science as a satisfactory indication of strength." Whitehouse's magneto-electrometer, on the other hand, was simple, direct, and reliable:

It is only necessary to see this staid and business-like instrument at work by the side of the old ecstatic, as well as astatic needle, to comprehend its superiority at a glance. The one piece of apparatus tossing so wildly and crazily about, that for minutes at a time the most patient and skilful observer can make neither head nor tail of its bewildering movements; the other piece quietly tilting up its weight on the end of the steelyard, and refusing in the most self-possessed way to lift another grain under any inducement that can be brought to bear, and then sending in its refusal as the exact estimate of the force it has been commissioned to determine.[119]

Where the galvanometer was "hysterical," Whitehouse's magneto-electrometer was "staid"; where the galvanometer was "ecstatic," his little steelyard was "business-like." Mann presented Whitehouse's device as embodying all of the virtues – manly ones, at that – likely to appeal to either a scientist or a practical man, and as the perfect instrument for producing solid experimental facts. Others were not so convinced.

Besides being more "business-like" than a galvanometer, Whitehouse's magneto-electrometer had the advantage, as he saw it, of operating in a way that more closely resembled the workings of actual telegraph receivers, including his patented relays. "Unlike the degrees upon the galvanometer," he declared, the grains lifted on his steelyard were "units of real value and of practical utility." He boasted that by measuring the "value" of pulses of current passing through different lengths of cable, he could "ascertain with certainty and minute accuracy the loss due to the combined effect of resistance, induction, and defective insulation." He could not, however, readily disentangle those different effects, nor could he directly measure resistance, current ("quantity"), or electromotive force ("intensity") as those were ordinarily defined. Whitehouse knew that to build up the credibility of his magneto-electrometer and the "values" it measured, he would need to extend it beyond the limits of his own testing room and make it the shared property of the broader electrical community; in particular, it would be "necessary to have one

[119] [Mann], *Atlantic Telegraph*, 18.

common standard of comparison, to which all instruments so made may be adjusted." Toward that end, he offered "to set aside for this special purpose the most accurately-finished and perfect instrument I can obtain, with which I will be most happy at all times to compare those of any of my fellow-labourers in the field."[120] But the offer was not taken up, and Whitehouse's instruments and measuring practices would remain his alone.

At the same time Whitehouse was devising his magnetic steelyard, Thomson was conducting an extensive series of electrical measurements in his Glasgow laboratory, as detailed in the Bakerian Lecture "On the Electro-dynamic Qualities of Metals" he delivered to the Royal Society of London in February 1856.[121] This project grew out of his pioneering work in thermodynamics, particularly on the transformations of energy in thermoelectric phenomena, and it required enormous numbers of meticulous measurements. To carry these out, Thomson began to recruit student volunteers from his natural philosophy classes. The work in the 1850s of this Glasgow "experimental corps" marked the beginnings of the laboratory teaching of physics in Britain, and its focus on precision electrical measurement set the pattern for most of the other physics laboratories that were to spring up in British universities over the next two decades.[122]

Many of Thomson's experiments concerned the way magnetization or mechanical strain affected the electrical resistance of iron or copper wires or plates. To measure these effects, he (or his assistant Donald MacFarlane, or one of the students) typically used the differential arrangement known as a Wheatstone bridge to compare the resistance of a "reference conductor" to that of the wire or plate being tested. Telegraph engineers had been using similar techniques for years, but in the mid-1850s these were all new to Thomson. He was in fact so unfamiliar with the usual practices of electrical measurement when he started this

[120] Whitehouse, "Construction and Use" (*Engineer*), 523. On standardization, replication, and networks of credibility, see Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 1987), 247–57, and Joseph O'Connell, "Metrology: The Creation of Universality by the Circulation of Particulars," *Social Studies of Science* (1993) *23*: 129–73.

[121] William Thomson, "On the Electro-dynamic Qualities of Metals," *Phil. Trans.* (1856) *146*: 649–751, repr. with additions in Thomson, *MPP 2*: 189–407.

[122] Crosbie Smith, "'Nowhere But in a Great Town': William Thomson's Spiral of Classroom Credibility," in Crosbie Smith and John Agar, eds., *Making Space for Science: Territorial Themes in the Shaping of Knowledge* (London: Macmillan, 1998), 118–46, on 131–36; Graeme Gooday, "Precision Measurement and the Genesis of Physics Teaching Laboratories in Victorian Britain," *British Journal for the History of Science* (1990) *23*: 25–51. James Clerk Maxwell praised Thomson's "experimental corps" in a 15 February 1871 draft letter to E. W. Blore, in Maxwell, *SLP 2*: 613.

project that he had to work out the principle of the Wheatstone bridge for himself, not realizing until just before his lecture to the Royal Society that Charles Wheatstone had described it in his own Bakerian Lecture in 1843, or that Samuel Hunter Christie had in fact first devised the technique as long ago as 1833.[123]

"On the Electro-dynamic Qualities of Metals" was by far the longest paper Thomson would ever write. The original version ran to more than one hundred pages in the *Philosophical Transactions*, and Thomson kept adding new sections to it as late as 1878; when reprinted in his *Mathematical and Physical Papers* in 1884, the paper filled most of the second volume. Together with the brief preliminary reports that led up to it, "Electro-dynamic Qualities" marked Thomson's initiation into the practice of precision electrical measurement, a field in which he would take a leading role for the rest of his long career. It also marked an important step in his exploration of the *theory* of electrical measurement. Drawing on Wilhelm Weber's recent demonstration that electrical resistance could be expressed in "absolute" units of length, mass, and time, Thomson had shown in 1851 how to extend this approach to include "mechanical effect," or energy, as seen, for instance, in the heat generated when a current flows through a resistance. Using others' published measurements, he calculated (in British units of feet, grains, and seconds) the absolute resistance of several wires, as well as the "specific resistance," or resistivity, of copper, silver, and mercury.[124] Around this time he also sent a piece of wire to Weber at Göttingen, asking him to determine its resistance in absolute units so that Thomson might use it as a standard. Weber finally returned the wire in 1855 (apparently after some prodding from Hermann Helmholtz) along with a note stating its measured resistance; thereafter Thomson used it to link together his growing chain of electrical measurements.[125]

Thomson made an especially important series of measurements in early 1857, not long after he joined the board of the Atlantic Telegraph Company. "In measuring the resistances of wires manufactured for

[123] Thomson, "Electro-dynamic Qualities," 732n; Charles Wheatstone, "An Account of Several New Instruments and Processes for Determining the Constants of a Voltaic Circuit," *Phil. Transa.* (1843) *133*: 303–27, on 325; Samuel Hunter Christie, "Experimental Determination of the Laws of Magneto-Electric Induction in Different Masses of the Same Metal, and of its Intensity in Different Metals" *Phil. Trans.* (1833) *123*: 95–142, on 99.

[124] William Thomson, "Applications of the Principle of Mechanical Effect to the Measurement of Electro-motive Forces, and of Galvanic Resistances, in Absolute Units," *Phil. Mag.* (December 1851) *2*: 551–62, repr. in Thomson, *MPP 1*: 490–502.

[125] William Thomson to Hermann Helmholtz, July 30, 1856, in Thompson, *Kelvin*, *1*: 321–22, on 322; see also Helmholtz to Thomson, August 11, 1855, H14, Kelvin Papers, GB 247 Kelvin, Glasgow.

submarine telegraphs," he said, "I was surprised to find differences between different specimens so great as most materially to affect their value in the electrical operations for which they are designed."[126] Like almost everyone else, he had assumed that copper was copper and that any reasonably pure wire would conduct a current about as well as any other.[127] He knew that mechanical strains of the kind he had investigated for his Bakerian Lecture could reduce the conductivity of a wire only to a slight degree, and he thought the larger variations in conductivity Weber had found in different copper wires probably just reflected differences in purity.[128] Thomson now found, however, that even ostensibly very pure samples of copper from different suppliers could differ markedly in their conductivity: wires from the manufacturer he labeled "A" conducted nearly twice as well as those from the one he labeled "D." Whatever the source of this difference, it had serious practical implications. As Thomson pointed out in a paper he presented to the Royal Society in June (the italics are his),

> It has only to be remarked, that *a submarine telegraph constructed with copper wire of the quality of the manufactory* A *of only* $^{1}/_{21}$ *of an inch in diameter, covered with gutta-percha to a diameter of a quarter of an inch, would, with the same electrical power, and the same instruments, do more telegraphic work than one constructed with copper wire of the quality* D, *of* $^{1}/_{16}$ *of an inch diameter, covered with gutta-percha to a diameter of a third of an inch*, to see how important it is to shareholders in submarine telegraph companies that only the best copper wire should be admitted for their use.[129]

In short, unknowingly using copper of low conductivity could cost a company dearly.

Two months before he published his findings, Thomson wrote to alert the other directors of the Atlantic Telegraph Company to the problem. They referred the matter to Whitehouse and Bright "for their information," and in July authorized Thomson to spend up to £15 to test more samples of wire.[130] By then, of course, it was too late to do anything about the 2500 miles of cable that had already been manufactured. When the company prepared to order more cable to replace the length lost in the August failure, however, Thomson launched a determined campaign to ensure that it would be made with wire of high conductivity. He wrote to

[126] William Thomson, "On the Electrical Conductivity of Commercial Copper of Various Kinds," *Proc. RS* (June 1857) *8*: 550–55, on 550, repr. in Thomson, *MPP 2*: 112–17.
[127] As Willoughby Smith later noted, in the early days of cable telegraphy "no attention was given" to the electrical qualities of the conductors "for the simple reason that all copper wire was credited with equal value in these respects"; Smith, *Rise and Extension*, 2.
[128] Thomson, "Commercial Copper," 550; Thomson, "Applications," 561.
[129] Thomson, "Commercial Copper," 551–52.
[130] ATC Minute Book, entries for c. April 1857, 125, and c. July 1857, 194.

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the board stressing the "great economical and scientific advantage" of using only the best copper, and after what he later said was "much perseverance" managed to secure passage of a resolution requiring that in the specification for the new length of cable, "provision is made for the chemical purity and conductivity of the copper core."[131] This marked a milestone in submarine telegraphy: for the first time a contract would specify the *electrical* qualities of a cable, not just its mechanical properties and material composition.

At first the Gutta Percha Company balked, claiming it could not possibly test the conductivity of so much copper wire in the short time available. On further inquiry, however, the company said it could do the job for £42 per mile, rather than the previous £40, and it soon began testing conductivity at its north London works.[132] In his January 1858 "Electrician's Report," Whitehouse said that though the process was "somewhat tedious and obstructive," now "every hank of wire to be used for our conductor is tested, and all whose conducting power falls below a certain standard is rejected." The result was "a conductor of the highest value, ranging in conductivity from 28 to 30 percent. above the average standard of unselected copper wire."[133] Of course, the more than 2000 miles of old cable then being stored at Devonport had all been made with "unselected" wire, some no doubt of poor conductivity, but the company would simply have to live with it.

Through the fall and winter, Whitehouse continued to tinker with his coils and relays, hoping to improve on the slow transmission speeds he had achieved in his tests at Queenstown.[134] In the meantime, Thomson was working on a new signaling system of his own that, while it never really panned out, led him to the most important device to emerge from the Atlantic cable project: his mirror galvanometer. In his exchange with Whitehouse in the *Athenæum* the previous fall, Thomson had remarked

[131] ATC Minute Book, entries for August 27, 1857, 218, and September 4, 1857, 221–22; Thomson, *MPP 2*: 125n, noted added 1883; Thompson, *Kelvin*, *1*: 350–51.

[132] William Thomson, "Analytical and Synthetical Attempts to Ascertain the Cause of the Differences of Electrical Conductivity Discovered in Wires of Nearly Pure Copper," *Proc. RS* (February 1860), *10*: 300–9, repr. in Thomson, *MPP 2*: 118–28, note added June 27, 1883, 125n; see also James M. Curley to William Thomson, September 30, 1857, and George Saward to William Thomson, October 6, 1857, Thomson Family Papers, Glasgow.

[133] Whitehouse, "Electrician's Report," January 4, 1858, WC-NYPL; see also Whitehouse, *Atlantic Telegraph* (1858), 12–13.

[134] In September 1857 the directors voted to offer a premium of £500 "for the best and most suitable form of telegraphic instrument for working through the Atlantic Cable," terms of the competition to be set by Whitehouse and Thomson, but Thomson declined to take part and the board soon dropped the idea; ATC Minute Book, entries for September 10, 1857, 225–26; October 8, 1857, 243; and December 5, 1857, 262.

that signaling rates depended on exactly how the current was applied at one end of the conductor and detected at the other. It soon occurred to him that by carefully calibrating the current entering a cable, one could contrive to make the first term of its Fourier expansion be zero; as the pulse decayed in transit, the remaining induced charges would then largely cancel each other out, reducing the retardation and speeding the transmission rate. Whitehouse's induction coils accomplished this to some extent by accident: the negative pulse that immediately followed each positive one helped clear the induced charge from the line and so prepared the way for the next signal. Thomson now proposed to speed this up further by using his transmission theory to guide exactly how much "curbing" to apply after each pulse, and by receiving the resulting signal on a refined version of a Helmholtz galvanometer. By carefully controlling the size and shape of each pulse, it would be possible, he said, to make each swing of the receiving galvanometer indicate a distinct letter: "The observer will watch through a telescope the image of a scale reflected from the polished side of the magnet, or from a small mirror carried by the magnet, and will note the letter or number which each maximum deflection brings into the middle of his field of view."[135] Instead of needing several dots and dashes to form each letter, a single swing would do the job, speeding up signaling rates by a factor of four or five.

Thomson presented this plan to the Royal Society on November 14, 1856, in a paper entitled "On Practical Methods for Rapid Signalling by the Electric Telegraph," but despite some promising early results, it eventually became clear that his method, at least in its strong form, was not really practical.[136] Too many extraneous factors – earth currents, atmospheric electricity, and other vagaries – came into play for one to be able to control the swing of the galvanometer precisely enough to distinguish different letters in a reliable way. Even as Thomson was forced to abandon his original plan, however, it led him to devise an extraordinarily sensitive galvanometer, able to respond nimbly to very small currents. The key step, foreshadowed in his remark about viewing a scale reflected from the polished side of the magnet, was to replace the needle of an ordinary galvanometer with a beam of light reflected from a tiny mirror. This beam would provide a weightless pointer of enormous length, greatly reducing the mass and moment of the moving parts of the galvanometer and so increasing its sensitivity. Working closely with

[135] Thomson, "Practical Methods," 301.

[136] Thomson, "Practical Methods," followed by a "Second Communication," *Proc. RS* (December 1856) *8*: 303–7, repr. in Thomson, *MPP 2*: 107–11, in which he proposed further refinements for use on both cables and overhead landlines.

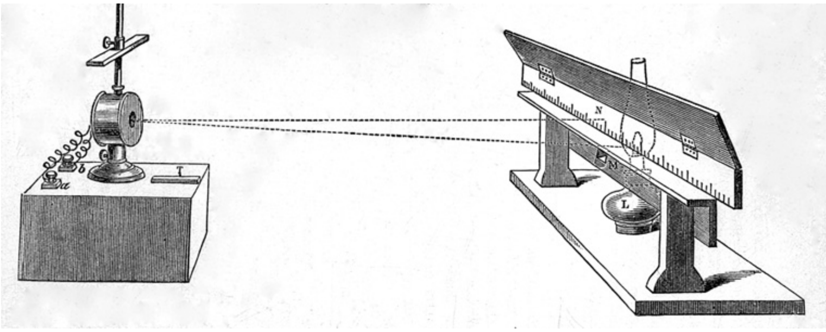

Figure 2.7 William Thomson's mirror galvanometer. Light from the lamp on the right passed through a hole in the screen and was reflected from a tiny mirror within the galvanometer on the left; the operator then read deflections by following the moving spot of light on the screen. (From Fleeming Jenkin, *Electricity and Magnetism*, p. 64, 1873.)

the Glasgow instrument maker James White, later his partner in a substantial business, Thomson refined his design and filed for a patent on his mirror galvanometer in February 1858[137] (Figure 2.7). He also designed a more robust "marine" version suitable for use on the ships that would try again to lay the cable that summer. The costs of this work were substantial, and in April he asked the board of the Atlantic Telegraph Company to grant him £2000 to complete the work. Having already spent thousands on Whitehouse's instruments, the board turned Thomson down, though it later granted him £500.[138] Thomson covered the difference from his own pocket, an investment that would later pay off handsomely.

Whitehouse and Thomson remained on good terms through the spring and summer of 1858, but their work was increasingly headed in opposite directions. Whitehouse continued to develop his huge induction coils and magnetic relays while relying on methods of electrical measurement, founded on his magneto-electrometer, that remained peculiarly his own. Thomson, on the other hand, focused on refining his sensitive

[137] Giuliano Pancaldi, "The Web of Knowing, Doing, and Patenting: William Thomson's Apparatus Room and the History of Electricity," in Mario Biagioli and Jessica Riskin, eds., *Nature Engaged: Science in Practice from the Renaissance to the Present* (New York: Palgrave Macmillan, 2012), 263–85. In a note added April 3, 1883, to the reprint of his "Practical Methods" paper (Thomson, *MPP 2*: 105n), Thomson said that the plan he described there, "modified and simplified, became developed a year later into the method of reading telegraphic signals by my form of mirror galvanometer."

[138] Smith, "Great Town," 135–36; Thompson, *Kelvin*, *1*: 353–54.

mirror galvanometer and on building up a network of electrical standards and practices that could be widely shared and so become widely credible, and that meshed well with the growing body of established electrical theory. Whitehouse was still the head of the Atlantic Telegraph Company electrical department, but Thomson's was the approach that was destined to prevail.

Success . . .

As the Atlantic Telegraph Company prepared to try again to lay its cable, frictions between Whitehouse and the board of directors repeatedly threatened to erupt into open warfare. Whitehouse's spending was a particular sore point. In his January 1858 "Electrician's Report," he admitted that the work of his electrical department had "naturally involved a somewhat considerable outlay" but insisted that none "had been entered into without the most careful consideration" and asserted that his expenditures on equipment and personnel had been "fully justified" by the positive results they had enabled him to achieve.[139] Nonetheless, the directors repeatedly reminded Whitehouse not to spend so much, and in late January they refused his request to hire additional skilled assistants. Evidently looking to keep him focused on the task at hand, the board also ordered him not to publish his findings in scientific journals or show off his workshop at Devonport to outside experts.[140] Incensed, Whitehouse threatened to resign. He was soon talked out of it, but serious concerns remained, including about the performance of his apparatus.[141] In his January report he had claimed that, by using his improved instruments and adopting "such an amount of abbreviation or code signals as we find safe to use," he and his operators had been able to transmit four words per minute through the full length of the cable. Hearder, who witnessed many of these trials, later said this was an exaggeration, and that the real rate was closer to one word per minute.[142] Moreover, though the board had instructed Whitehouse to focus on training the operators in the use of the signaling apparatus, he reportedly instead kept tinkering with the instruments and directing his staff to conduct new experiments.[143]

139 Whitehouse, "Electrician's Report," January 4, 1858, 25, WC-NYPL.
140 ATC Minute Book, entry for January 29, 1858, 289.
141 ATC Minute Book, entry for February 18, 1858, 297–98; see also Whitehouse, *Atlantic Telegraph* (1858), 20.
142 Whitehouse, "Electrician's Report," January 4, 1858, 28, WC-NYPL; Hearder, "Atlantic Cable," 36.
143 Saward, *Trans-Atlantic Submarine Telegraph*, 28.

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Work at Devonport ramped up in the spring, and Whitehouse got permission from the directors to invite the "eminent electricians" C. V. Walker and W. T. Henley to visit and see the progress being made.[144] Thomson, too, spent much of April and May there, working mainly on his "size of swing" signaling technique. As the difficulty of controlling the swing became evident, he shifted toward using his mirror receiver as simply a very sensitive galvanometer, a role at which it excelled. Looking ahead to the upcoming laying expedition, he asked White, his instrument maker in Glasgow, to deliver one of the new "marine" versions to Devonport as soon as possible.[145]

In late May, shortly before the *Agamemnon* and the *Niagara* were to sail to the Bay of Biscay to test new paying-out machinery, the board of directors gathered at Plymouth to see for themselves how the work was coming along. They were not reassured. In particular, Saward later said, "the condition of the Electrical Department was found to be such as to cause great anxiety to the Directors": not only had the operators not been properly drilled in the use of the equipment, but Whitehouse's "instruments were not in a state nor of a nature calculated to work the cable to a commercial profit." There were also troubling reports of poor insulation in some of the cable already stowed on the ships, and concerns that Whitehouse's testing methods were inadequate.[146] Whitehouse further irritated the board by announcing at the last minute that his physician had forbidden him from sailing on the trial run. As in 1857, Thomson stepped in to take his place on the *Agamemnon*. Thomson was in fact almost the last man to board, as his assistant Donald MacFarlane rushed to the quay to hand over the very first marine galvanometer, brought by express from Glasgow. Looking like "a small brass pot sitting on four legs," it perched amid Whitehouse's array of apparatus in the ship's instrument room, where it would soon take over much of the electrical work of the expedition[147] (Figure 2.8).

The trial run went well, and on June 10 the flotilla set out from Plymouth to lay the cable. Unlike the year before, this time they would

[144] ATC Minute Book, entries for March 13 and March 17, 1858, 332 and 352; Whitehouse, *Atlantic Telegraph* (1858), 20. The board also invited Faraday, Wheatstone, William Robert Grove, and J. P. Gassiot to visit Devonport, but there is no evidence they made the trip. Walker was at Devonport from March 27 to April 14, 1858, and Henley apparently a somewhat shorter time; see *Joint Committee Report*, 101, 105.

[145] William Thomson to James Thomson, April 19, 1858, in Thompson, *Kelvin*, *1*: 352. William Thomson was then in Glasgow, having just come from Devonport, to which he would return in May. See also Thomson to J. D. Forbes, April 24, 1858, in Smith, "Great Town," 135.

[146] Saward, *Trans-Atlantic Submarine Telegraph*, 28; ATC Minute Book, entry for April 5, 1858, 365; Whitehouse, *Joint Committee Report*, December 15, 1859, 78.

[147] Thompson, *Kelvin*, *1*: 354–55; [Russell], "Paying-Out the Atlantic Cable," 5.

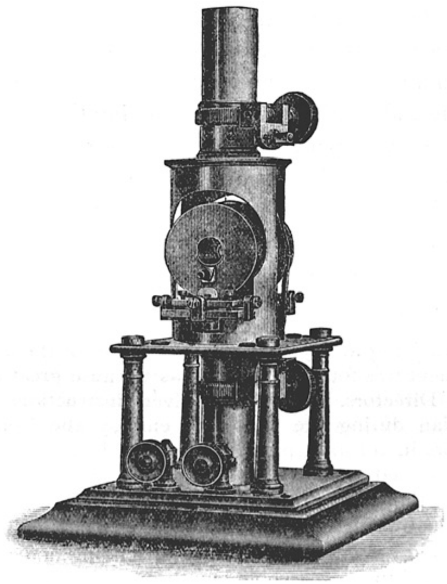

Figure 2.8 A more robust version of Thomson's mirror galvanometer, the marine galvanometer was designed for use aboard ships. (From Silvanus P. Thompson, *Kelvin*, Vol. 1: 355, 1910.)

start from mid-ocean, as Whitehouse now admitted that sending actual messages through the cable from ship to shore had proved unworkable. The most that could be reliably exchanged on shipboard were simple battery currents to check the continuity of the conductor and reveal any faults. The board strongly urged Whitehouse to join the voyage, but he again pleaded "indisposition" and went instead to Valentia to await the landing of the completed cable. Equipment for the Newfoundland end, including Whitehouse's coils and relays, was loaded onto the *Niagara* and its escort, HMS *Gorgon*. This apparatus – some of which, according to Hearder, had never been properly tested or adjusted – was entrusted to Whitehouse's assistant C. V. de Sauty, who would serve as chief electrician on the *Niagara*, while Thomson once again filled in for Whitehouse on the *Agamemnon*.[148]

[148] On de Sauty, see his obituary in *Elec.* (April 14, 1893) *30*: 685; on the lack of testing of Whitehouse's coils and relays, see Hearder, "Atlantic Cable," 39. The only known image of one of Whitehouse's five-foot induction coils appears in a painting by Theodor Linde, an operator at the Newfoundland station; see Figure 2.10.

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The health concerns that kept Whitehouse ashore may have been legitimate, but his absence from the voyage inevitably undercut his scientific credibility and personal standing: he was not the man on the spot, seeing and doing things for himself, and he was not out there braving the dangers of the North Atlantic.[149] The latter point became especially salient after the ships were hit by a severe storm three days out of Plymouth. Experienced sailors said it was the worst gale they had ever encountered, and the *Agamemnon*, with more than a thousand tons of cable stowed awkwardly in her hold and on her foredeck, suffered especially badly. Ten men were badly injured as the ship rolled violently and nearly capsized; tons of coal broke loose and tumbled across the deck, cabins were flooded, and the cable itself was tossed about and badly kinked.[150] Some of the electrical equipment was also damaged, but Thomson himself bore the ordeal well, winning the respect of the officers and engineers. The experience did not seem to put him off life at sea: he went on to become an avid sailor and later used his earnings from the cable business to buy a much-loved sailing yacht, the *Lalla Rookh*.[151]

After a perilous week the storm finally blew itself out and the ships were able to rendezvous at their appointed spot. They made their splice on June 26 and began paying out, but the cable almost immediately jammed and snapped. After another splice, they managed to pay out eighty miles before Thomson's galvanometer showed a break in the conductor; once again, the ships had to backtrack and make another splice. They made a third attempt but on June 29, after the ships had laid about 250 miles, the cable snapped yet again. Disheartened, the *Niagara* and *Agamemnon* made their way to Queenstown and Field headed to London to meet with the directors. William Brown, the hard-headed Liverpool banker who has served as the first chairman of the permanent board, said they should admit defeat, sell the remaining cable for whatever they could get, and wind up the company. Others called for waiting to make another attempt the next summer. But Field, backed by Brett, Thomson, and the American-born board member Curtis Lampson, pushed to try again at once. It was now or never, they said: the cable could not survive another winter in storage, nor were the British and American navies likely to agree to lend their ships for a third summer.[152] After heated debates, Field and Lampson carried the day and the board voted to make one last try to lay its

149 On the value of being the scientific man on the spot, see Bruce W. Hevly, "The Heroic Science of Glacier Motion," *Osiris* (1996) *11*: 66–86.

150 [Nicholas Woods], "The Atlantic Telegraph Expedition," *Times* (July 15, 1858), 10. This vivid account of the gale was reprinted in Bright, *Atlantic Cable*, 91–105.

151 On Thomson and the *Lalla Rookh*, see Smith and Wise, *Energy and Empire*, 733–40.

152 Saward, *Trans-Atlantic Telegraph*, 30–31.

cable. Success seemed so little assured, however, that to save the expense of chartering a vessel, the company held off on shipping its heavy shore end cable from Devonport to Valentia until after the main cable had been laid.[153] It was a decision that would lead to sharp controversies.

With none of the pomp that had marked the launching of the earlier attempts and with little real expectation of success, the ships slipped out of Queenstown harbor on July 17. After making their mid-ocean splice on July 29, the *Agamemnon* steamed again toward Ireland and the *Niagara* toward Newfoundland, with Thomson and de Sauty closely watching their galvanometers to gauge the state of the cable. Apart from a mysterious loss of current the first night, and signs of a possible fault in the insulation a couple of days later, things went more smoothly this time and the *Niagara* arrived at Trinity Bay, and the *Agamemnon* at Valentia, on August 5. To the surprise of all, this last forlorn hope had succeeded. Word quickly went out over the wires that the Old and New Worlds were now connected by telegraph, and the celebrations began.

The success was widely acclaimed in the British press and arrangements were soon made to award Bright a knighthood. The hoopla was far greater in the United States, where to the amusement of those who knew the real role British capital and expertise had played in the project, the laying of the cable was widely depicted as a purely American achievement. Field was hailed as the hero of the age, the man who had single-handedly spanned the Atlantic in what a Philadelphia paper called "the greatest triumph of scientific and mechanical *genius* that has been achieved for centuries."[154] Amid an outpouring of press speculation about how the cable would transform global trade and international relations, markets were flooded with ephemera – prints, broadsides, sheet music, and geegaws of all kinds. Once the *Niagara* arrived in New York, Field turned its miles of surplus cable to account by having Tiffany and Company make it up into four-inch lengths to sell as souvenirs[155] (Figure 2.9).

Shares in the Atlantic Telegraph Company had risen and fallen with the fortunes of the laying attempts, dipping to a low of £300 in the wake of the June failure. They now jumped overnight from £340 to over £900, though

[153] "The Atlantic Telegraph," *Times* (September 10, 1858), 7.

[154] "Newspaper Comments," *New York Times* (September 6, 1858), 1, citing the *Philadelphia Evening Journal*. Bright was knighted in Dublin on September 5, 1858; see "The Engineer of the Atlantic Telegraph," *Freeman's Journal* (September 6, 1858).

[155] For a collection of cable-related ephemera, see Robert Dalton Harris and Diane DeBlois, *An Atlantic Telegraph: The Transcendental Cable* (Cazenovia, NY: Ephemera Society of America, 1994); on Tiffany's sale of short lengths of the cable, see John Steele Gordon, *A Thread Across the Ocean: The Heroic Story of the Transatlantic Cable* (New York: Walker and Co., 2002), 137.

Figure 2.9 After the first Atlantic cable was completed in August 1858, Cyrus Field had the surplus length cut into short pieces, which Tiffany & Co. then sold as souvenirs. The band around this one reads "Atlantic Telegraph Cable – Guaranteed by Tiffany & Co. – Broadway • New York • 1858."

few shareholders appeared willing to sell.[156] Merchants and the public waited eagerly for market orders and news reports to begin flashing back and forth across the Atlantic, and for a new age of oceanic telegraphy to begin.

… and Failure

On arriving in the virtual wilderness of Trinity Bay, de Sauty and his assistants set about assembling Whitehouse's collection of batteries, induction coils, and relays, a task that would take them several days. In the meantime they kept up a steady battery current, with slow reversals, to show Valentia they had arrived and that the conductor was intact. In Ireland, Thomson handed his end of the cable over to Whitehouse and stayed on for several days to help get the station up and running in borrowed rooms at the Knightstown slate works. The prospects looked promising, but they would soon darken.

The plan, touted even before the Atlantic Telegraph Company had been formed, called for using Whitehouse's patented induction coils to send the signals and his relays to receive and record them on paper tapes. The relays, however, never worked as intended; when the Newfoundland operators connected theirs to the cable, they found the coil currents from

[156] "Money-Market and City Intelligence," *Times* (August 6, 1858), 7.

Valentia were too weak to trip it, while Thomson later reported that the longest complete word ever received at the Irish end entirely on a relay was "be."[157] After a few frustrating days the operators at Valentia put Whitehouse's relay aside and tried to receive signals on Thomson's mirror galvanometer instead. They were soon rewarded: at 1:45 a.m. on August 10, the swinging spot of light spelled out the first readable words from Trinity Bay: "Repeat, please." It was not the most profound of messages, but Whitehouse and Thomson were delighted; the latter reportedly skipped around the instrument room with joy and treated the staff to a round of porter from the nearby hotel.[158] The Valentia station soon adopted a system in which one operator would watch the spot of light and call out its motions to another, who would then use a local battery and Morse key to record the message on a paper tape. Whitehouse mailed some of these slips of paper to the directors in London, describing them as the "signals first transmitted and received across the Atlantic by the Company's instruments."[159] The directors took these to be just what they looked like: messages recorded directly by Whitehouse's relays. Whitehouse did not mention that they had in fact been received on Thomson's galvanometer.[160]

By then Thomson had already left Valentia. Thinking operations were on track and that Whitehouse would soon have his relays working properly, he had departed on the morning of August 10 for London, Glasgow, and, as he thought, a well-deserved rest. But events at Valentia soon took a turn, and within a week and a half he would be back. Those events centered on three interlocking issues: the possible existence of faults in the insulation of the cable; the effects the use of Whitehouse's induction coils might have on those faults; and Whitehouse's treatment of J. R. France, an experienced telegrapher the directors had sent to assist and, as

157 Newfoundland sent the message "coil signals too weak work relay" on August 12, 1858; see *Joint Committee Report*, 230. For Thomson's December 17, 1859 testimony on the length of words received at Valentia on relays, see *Joint Committee Report,* 121.

158 Russell, "Notes," August 10, 1858, 7–9. Thomson later testified that "a little single needle instrument of Mr. Henley's" was also in the circuit and received the first message simultaneously with his mirror galvanometer, but the more sensitive mirror device soon came to be used exclusively; Thomson, December 17, 1859, *Joint Committee Report*, 119.

159 Whitehouse to Directors Atlantic, London, August 10, 1858, in Wildman Whitehouse, *Recent Correspondence between Mr. Wildman Whitehouse and the Atlantic Telegraph Company* (London: Bradbury & Evans, 1858), 17.

160 On the directors in London assuming that the paper tapes Whitehouse sent from Valentia had been marked directly by his relays, see William Thomson to Board of the Atlantic Telegraph Company, August 21, 1858, Alcatel Archive, Porthcurno, doc. ref. 74/1. This important letter was found in the archive by Allan Green; for his transcription of it, see: http://atlantic-cable.com/Books/Whitehouse/AG/WTLetter.htm.

Whitehouse thought, report on him. All combined to make Whitehouse's relations with the directors in London increasingly fraught.

From early on, Whitehouse suspected the insulation of the cable might have suffered an injury near its Valentia end. It was a plausible idea: since the company had left the heavily armored shore end cable, weighing eight tons per mile, at Devonport to save on immediate costs, the *Agamemnon* had been forced to run its light cable, designed for use only in the deep sea and weighing just one ton per mile, right up to the shore at Knightstown, where it was continually buffeted by waves and risked being snagged by ships' anchors. As early as August 9, Whitehouse had wired London to say it was "absolutely essential" that the company act immediately to protect the light cable in the harbor or risk its destruction. He did not mention, however, that he was already hatching a plan to fix the problem himself.[161]

In the meantime, both Whitehouse and de Sauty were using their induction coils to send huge pulses of current into the cable. Whitehouse's coils were five feet long, with solid iron cores wrapped with miles of wire. Fed by his enormous batteries, such coils could, Whitehouse later said, produce sparks able to jump nearly a quarter inch air gap, implying potentials of thousands of volts. None of Whitehouse five-foot coils appear to have survived and we do not know the exact characteristics of the ones actually used at Valentia and Trinity Bay, but it is clear they could deliver very powerful jolts, enough to give an operator a nasty shock – or worse – if he touched one the wrong way[162] (Figure 2.10).

Whitehouse recognized that if there was indeed a fault in the cable near the Valentia end, shocks from his induction coils could worsen it. As he wrote to de Sauty on August 11 (in a letter that could have reached Newfoundland only much later), with most of the intense current produced by a coil discharge "forcing its way to earth" through such a fault, little would be left to continue on to Newfoundland. This was echoed in the journal kept by James Burn Russell, who had assisted Thomson on the *Agamemnon* and then joined the staff at the Valentia station. Remarking

[161] Whitehouse to Directors Atlantic Telegraph Company, London, August 9, 1858, *Recent Correspondence*, 16; Russell, "Notes," August 9, 1858, 7.

[162] Many secondary sources (e.g., Thompson, *Kelvin*, *1*: 385) say Whitehouse's induction coils produced tensions of 2000 volts, but cite no basis for this estimate. In his January 5, 1860 testimony (*Joint Committee Report*, 159), C. F. Varley, who had tested the coils at Valentia, noted that their quarter-inch sparking distance implied a tension equivalent to 10,000 to 15,000 Daniell's cells, or in modern units, just over 10,000 to 15,000 volts. Hearder said that while he believed defects of design or workmanship made Whitehouse's coils less powerful than their size would suggest, they could nonetheless produce jolts sufficient "to destroy life in an instant"; Hearder, "Atlantic Cable," 36, 39–40.

Figure 2.10 Theodor Linde, an operator at the Newfoundland end of the first Atlantic cable, painted this watercolor of the station's telegraph room in 1858. On the floor to the right is the only known depiction of a pair of Whitehouse's five-foot induction coils.
(Courtesy Bill Burns.)

on the evidence of "leakage at this end," he wrote that "coils therefore which we have used hitherto are very unsuitable since they give great intensity" and so "force through" the fault.[163] Around this time Whitehouse set his coils aside, except for occasional tests, and shifted to using much less intense currents from a set of Daniell's "quantity" batteries Thomson had provided. At the Trinity Bay end, however, de Sauty continued to use induction coils; indeed, Whitehouse later said that for the first few days after the cable was landed, the coil currents reaching Valentia were so strong "they made the relay speak out loud, so you could hear it across the room."[164] It is not clear if the company officials in London understood quite what was being done, or grasped the difference between the intense currents from the coils and milder ones from batteries, but they cautioned Whitehouse that "application of too much battery power" might injure the cable and asked him to send a full report.[165]

[163] Whitehouse to de Sauty and Laws, August 11, 1858, *Recent Correspondence*, 17; Russell, "Notes," August 11, 1858, 9–10.
[164] Whitehouse, December 15, 1859, *Joint Committee Report*, 78.
[165] Saward to Whitehouse, August 10, 1858, *Recent Correspondence,* 17. Saward, who was no electrician, sometimes used "battery power" as a synonym for electromotive force, whether its actual source was batteries or induction coils like Whitehouse's; see, for

Whitehouse used his induction coils steadily for only a few days at Valentia, but the intense jolts of current they produced most likely further damaged an already faulty cable; indeed, Whitehouse himself later said that, on encountering an existing flaw in the insulation, strong currents like those from his coils would tend to "augment the mischief."[166]

Concerned by delays in opening the cable to traffic and by a lack of reports from Whitehouse, the directors arranged to send J. R. France, a well-regarded telegrapher with Brett's Mediterranean Telegraph Company, to Valentia to help get the instruments there working properly. He left London on August 13, carrying a letter directing Whitehouse to give him "every encouragement and assistance," while Saward wired ahead to let Whitehouse know that France was on his way.[167] Whitehouse was incensed: "Advise the Directors to recall France," he wired back. "They have made a great mistake."[168] France might be an able operator, Whitehouse said, but it would not be right to put him above more senior staff already at Valentia. Nor would France's experience with other cable apparatus be of any help at Valentia, where he would encounter "instruments which he has never seen, and of whose nature and construction he can have, from their novelty, the most superficial knowledge."[169] Of course, by the time Whitehouse wrote this, the staff at Valentia had already stopped using his coils and relays, and while France might not have had any earlier experience with Thomson's mirror galvanometer, neither did Whitehouse or anyone else. Whitehouse real objection was that France had evidently been sent to "advise, direct, and, I presume, report on" his work at Valentia, and he resented what he took to be an effort by the directors to check up on him. He said he could use another instrument clerk, however, and told Saward he would be willing to take France on in that capacity, adding archly "I cannot

example, George Saward, "The Atlantic Telegraph," *Times* (September 24, 1858), 7, and Saward's questioning of J. W. Brett, December 10, 1859, *Joint Committee Report*, 58.

166 Whitehouse, December 15, 1859, *Joint Committee Report,* 79. See also Whitehouse's comments in *Letter from a Shareholder to Mr. Whitehouse, and His Reply* (London: Bradbury & Evans, 1858), published in December 1858, about the damage either strong battery power or currents from his "gigantic induction coils" could do to an already faulty cable, though he denied that his own use of the coils had caused any problems. A transcription of the pamphlet can be found at http://atlantic-cable.com/Books/Whitehouse/1858-FM/index.htm.

167 Samuel Gurney and George Saward, Atlantic Telegraph Company, London, to Whitehouse, August 12, 1858, *Recent Correspondence*, 20. France presented this letter to Whitehouse on arriving at Valentia on August 15, 1858.

168 Saward to Whitehouse, August 13, 1858, and Whitehouse to Saward, August 13, 1858, *Recent Correspondence*, 21.

169 Whitehouse to Saward, August 16, 1858, *Recent Correspondence*, 26–29, on 29.

recognise him in any other."[170] Tensions with London continued to mount, along with suspicions that Whitehouse was trying to hide something.

Amid all this, a hopeful sign emerged on August 13: the Newfoundland station, having put a mirror galvanometer in circuit for some tests, managed to receive its first full word: "Atlantic." But the Trinity Bay operators then immediately went back to their relay – and were unable to read anything more. The staff at Valentia regarded this an another example of "an extra proportion of obtuseness" at the Newfoundland end, but the Trinity Bay operators were simply following established protocols while waiting for their Valentia counterparts to sort out their equipment and procedures.[171] Fruitless efforts to get de Sauty and his staff to give up their relay continued for another day until they finally caught on and switched to using an ordinary needle galvanometer. The result was not great – the needle only moved about half a degree with each pulse – but it was enough to enable the Newfoundland station to receive messages, albeit very slowly.[172]

Why were the signals so much weaker at Newfoundland than at Valentia? As experienced electricians knew, a fault has its greatest effect on the end of the cable farthest from it. Consider a fault with a resistance equal to ten miles of cable and located ten miles from the Irish end. A current coming from Newfoundland will split at the fault; in this case, half will go directly to earth through the fault and half will continue on to Valentia, where a signal will arrive weakened but still quite readable. A current starting from Valentia will also split at the fault, but since the resistance through the fault is equal to just ten miles of cable, while that on to Newfoundland is equal to 2000 miles, almost all of the current will escape through the fault, leaving only 1/200th of it to go on to Trinity Bay – far too little to work a relay. One could, of course, try to compensate by sending more intense currents into the Valentia end, but only at the risk of damaging the insulation and worsening the fault.

Whitehouse did not frame the problem of locating the suspected fault in terms of measurable resistances, nor did he possess a set of standard resistance coils or any other reliable way to gauge how far away the fault was. While he recognized that the relative weakness of the signals at Trinity Bay pointed toward a fault lying nearer the Valentia end, he could do no more than guess at its actual location, nor did he seem to grasp that even a fault 200 or 300 miles from Valentia could greatly

170 Whitehouse to Saward, August 15, 1858, *Recent Correspondence*, 23.
171 Russell, "Notes," August 31, 1858, 54.
172 Whitehouse to Saward, August 16, 1858, *Recent Correspondence*, 26–29, on 27.

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weaken the currents received at Trinity Bay. In any case, Whitehouse soon convinced himself that the fault must lie very near the Valentia end, and he set about making plans to repair it.[173]

Company procedures in such a case called for Whitehouse to notify the directors in London and refer any repairs to Bright and his engineering department. But Bright had left Valentia for England soon after the cable was landed, and Whitehouse was concerned that an inquiry to London about repairing even a minor fault in the harbor might set off a "panic" that would damage the company. Fixing a fault so near the shore would, he thought, be a quick and easy task, and once completed, he could presumably go back to using his coils and relays as originally planned.[174] No one need ever know about these embarrassing teething problems, which Whitehouse was convinced all stemmed from the company's failure to install the heavy shore end in a timely way.

On August 13, Whitehouse wired Samuel Canning, an engineer on Bright's staff who was then in Dublin, and asked him to come to Valentia and underrun a few miles of cable in the harbor. London soon got wind of this plan – "by mere accident, and not from you," as Saward told Whitehouse – and the directors were not pleased.[175] Thomson and others in London did not think there could be a serious fault very near the Valentia end; as Thomson later explained, if such a fault existed there, no currents strong enough to work Whitehouse's relays, which had substantial internal resistance, would have been able to get past it – and the paper tapes Whitehouse had mailed to London gave every sign of having been marked by his relays.[176] Of course, the tapes notwithstanding, Whitehouse had not really received the messages on his relays, but here his coyness about using Thomson's mirror galvanometer had backfired on him.

The board's real objection, however, was not to Whitehouse's chasing a possibly imaginary fault but to his acting without its authorization and infringing on Bright's proper responsibilities. On August 14 the chairman, deputy chairman, and Saward sent Whitehouse an urgent telegram ordering him "not to underrun or otherwise interfere with the submerged

173 Russell, "Notes," August 9, 1858, 7; Whitehouse to Directors, August 13, 1858, *Recent Correspondence*, 20.

174 Whitehouse to Saward, August 16, 1858, *Recent Correspondence*, 26–29, on 28.

175 Russell, "Notes," August 14, 1858, 12; Saward to Whitehouse, August 14, 1858, *Recent Correspondence*, 22, 24.

176 Saward to Whitehouse, August 14, 1858, *Recent Correspondence*, 22; Thomson to Board, August 21, 1858, Alcatel Archive, Porthcurno; Saward, "Atlantic Telegraph," *Times* (September 24, 1858), 7. After the first few days, the currents from Trinity Bay became too weak to work Whitehouse's relays; see Whitehouse, "Professor Whitehouse and the Atlantic Telegraph," *Daily News* (September 29, 1858).

cable" until he had received permission to do so, and scolding him for not consulting them before even considering such a step.[177] By then Canning had in fact already underrun the cable in the harbor and found several kinks in it, though rough seas kept him from being able to cut and repair the suspect spots at that time. Whitehouse suspended the work after the order came in from London, but he remained convinced there was a fault in the harbor and was determined to do something about it[178] (Figure 2.11).

When France arrived at Valentia the next day, Whitehouse turned him away. Feeling that his own experience and expertise had been undervalued and ignored, and no doubt frustrated that the elaborate instruments in which he had invested so much time and effort had proven useless, Whitehouse sent Saward and the directors two long letters in which he tried to explain himself. He had been left on his own, he said, to face a myriad of urgent problems at Valentia, and "in the absence of any one at hand to whom I can instantly refer, it becomes my duty to act; in doing so I assume responsibility, and may herein be blamed by the Directors."[179] He denied he had violated their order not to underrun the cable, saying he had begun that operation before the directors' telegram arrived and had ordered Canning to stop as soon as it was received – but he did not mention that he had sent Canning out again on August 16, the very day he wrote his second letter. This time the underrunning interrupted the transmission from Valentia of the Queen's congratulatory message, leading to embarrassing reports that it had taken more than sixteen hours to send just ninety-nine words, though when allowance was made for the interruption, the time actually spent in sending the message was far less.[180] Rough seas again kept Canning from actually cutting and repairing the cable that day, but Whitehouse could hardly claim this time that he had not violated the explicit order from London that he not meddle with the cable.

Fed up with what it saw as his rank insubordination in turning away France and underrunning the cable, on August 17 the board of directors voted to dismiss Whitehouse as the electrician of the company he had helped to found and to summon him to London to

[177] Chairman (Samuel Gurney), Deputy Chairman (Curtis Lampson), and George Saward to Whitehouse, August 14, 1858, *Recent Correspondence*, 22.

[178] Russell, "Notes," August 14, 1858, 12–13; Whitehouse to Directors, August 14, 1858, and Whitehouse to Saward, August 14, 1858, *Recent Correspondence*, 21.

[179] Whitehouse to Directors, August 15, 1858, *Recent Correspondence*, 24–25, on 24.

[180] Russell, "Notes," August 16–August 17, 1858, 18–22. Because of the interruption, the banal first sentence of the Queen's message was distributed in America before the rest arrived, prompting questions about its authenticity; see "America," *Times* (August 30, 1858), 7.

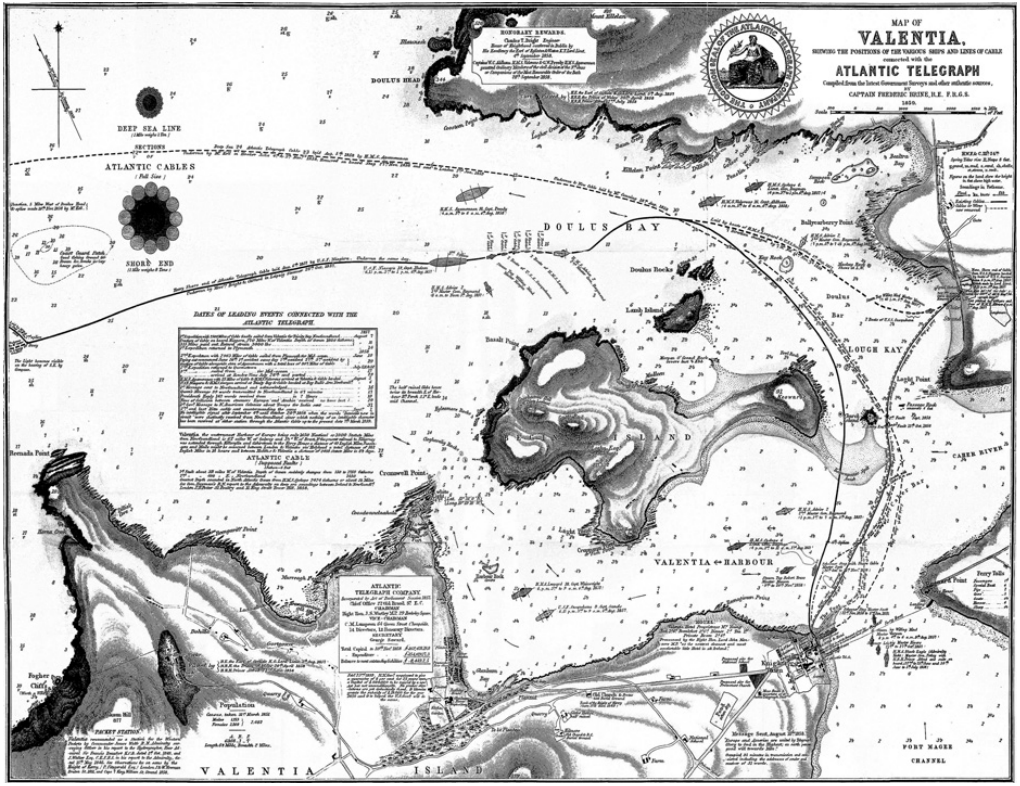

Figure 2.11 In early 1859 Captain Frederic Brine published an extraordinarily detailed map of Valentia harbor, showing the routes and landing places of the 1857 and 1858 cables, the positions of the ships involved in laying them, and even the price of rooms at the hotel in Knightstown.
(From Frederic Brine, *Map of Valentia, Shewing the positions of the various ships and lines of cable connected with the Atlantic Telegraph*, 1859; courtesy Bill Burns.)

explain himself.[181] By then Whitehouse had concluded that if the cable failed, he would bear the blame anyway, so in flagrant violation of the board's direct orders, he decided to make one last try to repair the fault he was sure was the source of all the trouble and, as he later said, "either to complete the operation and resign, or still more nobly to succeed, and rescue, the undertaking."[182] As he was leaving for London early on August 18, he therefore sent Canning and his crew out yet again. This time they underran the cable for about three miles, as far as Doulas Head, cut it, and replaced the suspect section with a surplus length that had been left by the *Agamemnon*. Whitehouse received reports on this work while he was en route to London, and he wired the directors from Dublin that he was confident Canning's efforts had fixed the problem, or at least most of it.[183] The staff at Valentia initially agreed, reporting that they were again using Whitehouse's coils to signal to Newfoundland, but on reviewing the instrument room logs a month later, Russell concluded that replacing the cable in the harbor had not really improved the quality of signaling, but in some ways had made it worse. "Mr. Whitehouse plainly I think must be astray in his testing," Russell wrote in his journal; while there may indeed have been some leakage near the Valentia end of the cable, he said, the evidence pointed toward the existence of another and far more serious fault much farther out to sea.[184]

Thomson remained perhaps Whitehouse's last supporter on the board of directors. He reluctantly went along with the August 17 vote to dismiss Whitehouse and then agreed to take over direction of the station at Valentia, but on arriving there four days later found things to be in better shape than he had been led to expect. In particular, Thomson found that the relays had been set aside in favor of his mirror galvanometer as early as August 10, rendering moot his earlier argument that there could not be a serious fault near the Valentia end – though he would soon find other evidence that no such fault existed. While admitting that Whitehouse had been wrong to turn away France and to disobey direct orders from

[181] Saward to Whitehouse, August 17, 1858, *Recent Correspondence*, 30, enclosing an extract from that day's minutes of the board of the Atlantic Telegraph Company informing him that "his engagement and authority as an officer of the Company have now ceased." In formal terms, Whitehouse's salaried appointment as electrician (and Bright's as engineer) were "to continue until the cable be laid down or until the Board shall think fit to dispense with their services," but both Whitehouse and the board had assumed he would stay on at least until routine operations at Valentia and Trinity Bay had been established; see ATC Minute Book, c. January 10, 1857, 47.

[182] Whitehouse, "Professor Whitehouse," *Daily News* (September 29, 1858).

[183] Telegrams from "Valentia" to Whitehouse at Killarney, Mallow, and Dublin, August 18, 1858, *Recent Correspondence,* 30–31; Whitehouse (at Dublin) to Directors, August 19, 1858, *Recent Correspondence,* 31; Russell, "Notes," August 18, 1858, 25–28.

[184] Russell, "Notes," September 17, 1858, 77.

London not to underrun the cable, Thomson now said that looking for a fault in the harbor had not been unreasonable, and he urged the board to reconsider its dismissal of Whitehouse.[185] He wired Whitehouse to express his support and even told the board he would like to have Whitehouse back to help him at Valentia. But Whitehouse, his pride injured and honor impugned, told Thomson he would not accept reinstatement without "ample honourable amende."[186] In any case, there was no prospect of any such reinstatement; as the board made clear in its reply to Thomson, the issue was no longer a technical one of the location of faults or the use of instruments, but one of Whitehouse's insubordination and insolence.[187]

The quality of signaling on the cable continued to fluctuate, as it had before Whitehouse's departure. Thomson pressed the operators at Trinity Bay to use his mirror galvanometer, and when they finally began doing so on August 22, they reported "signals beautiful."[188] This clarity did not last, however, as the currents gradually weakened and were often overwhelmed by earth currents. Thomson managed to nurse the cable along for a bit longer, sending and receiving several dozen messages over the next ten days, but it was increasingly clear that the insulation was badly compromised.

Perhaps the most important of the messages the cable carried in its last days were two the British government sent to Newfoundland on August 31. The army had earlier ordered two regiments to sail from Canada to aid in putting down the Indian Rebellion, but as the uprising was quelled, the authorities concluded that the troops were no longer needed. By using the cable to cancel the earlier orders before the regiments had sailed, the government saved itself about £50,000. These messages led Russell to reflect on

> what important services the cable may perform for our Govt. – both in saving money; and in knitting the limbs of empire into one gigantic frame. When we have extended these wonderful wires to India & Australia, Great Britain and her Colonies will resemble in economy the human body. London the seat of supreme intellect, whence the electric lines, the nerves, ramify and distribute themselves, the medium by which her behests are made known and executed in the remotest parts of the huge structure.[189]

[185] Thomson to Directors, August 21, 1858, *Recent Correspondence*, 35; Thomson to Board, August 21, 1858, Alcatel Archive, Porthcurno.
[186] Thomson to Whitehouse, August 21, 1858, and Whitehouse to Thomson, August 21, 1858, *Recent Correspondence*, 35.
[187] Atlantic Telegraph Company directors to William Thomson, August 25, 1858, in Thompson, *Kelvin*, *1*: 370–72.
[188] Register of messages received at Valentia, August 21, 1858, *Joint Committee Report*, 234.
[189] Russell, "Notes," August 30, 1858, 52.

It would be more than a decade before the "nerves of empire" would extend as far as Russell envisaged, and in the meantime, the link from Ireland to Newfoundland was rapidly failing. Thomson's tests indicated a dead earth between 200 and 400 miles west of Valentia, probably in waters too deep for the cable to be lifted and repaired with the means then available. After September 1, the cable spoke only in a few fitful and isolated words, and it would soon breathe its last. As Thomson remarked to Russell on September 5, "Is this not an unhappy termination to our labours?"[190]

Of course, Thomson's labors were not really over. Joined by Cromwell Fleetwood Varley of the Electric and International Telegraph Company, he would spend weeks at Valentia in what he called "the dull and heartless business of investigating the pathology of 'faults' in submerged conductors," as they tried every expedient they could think of to bring the cable back to life.[191] There were a few flickers, but nothing really worked, and when in November the company finally laid the heavy shore end that Whitehouse had so long called for, it did nothing to cure the problem; the fault, as Thomson and Varley's careful resistance measurements had established, lay in inaccessible waters hundreds of miles out to sea.[192] In the end the Atlantic Telegraph Company had to admit defeat, at least for this round. Recriminations followed, of course, with Whitehouse bearing the brunt, but the real question would be what lessons ought to be drawn from this grand failure, not just about how future cables should be made and laid, but about how electrical phenomena should best be measured and understood.

[190] Russell, "Notes," September 3 and September 5, 1858, 58–60.

[191] Thomson to James Joule, September 25, 1858, in Thompson, *Kelvin*, *1*: 378–79, on 379.

[192] On the laying of the heavy shore end in November 1858, see Frederic Brine, *Map of Valentia, Shewing the Positions of the Various Ships and Lines of Cable Connected with the Atlantic Telegraph* (London: Edward Stanford, 1859).