

Playing with Fire

Histories of the
Lightning Rod



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EARTH GROUNDS AND HEAVENLY SPIRES

LIGHTNING ROD MEN, PATENT INVENTORS, AND TELEGRAPHERS

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Introduction

THE NEARER LIGHTNING FLASHES, the more vulnerable we feel. That feeling came to many residents of the open spaces of nineteenth century America as their churches, barns, and prairie homesteads became frequent targets of lightning that accompanied the region's destructive thunderstorms. Like Melville's "Lightning Rod Man," salesmen of the time reaped commercial advantage by exhorting fear and promising the rod as a means to control nature's fury.¹ No clear understanding of how the rod functioned was provided or sought by most rod installers, makers, or their public. Rods went up in good weather and—if everyone was lucky—were never put to a real test. This separation from the actual phenomena allowed for installations that were inadequate to deal with a real strike; even the patented contraptions often turned out to be swindles.

A different outlook took hold among another nineteenth century community whose operations were daily affected by lightning: the telegraphers. Telegraphic signals were weak and could not compete with lightning whenever it disturbed the lines. Getting the signal through to its destination involved observing lightning's behaviors and improvising ways to safely divert it. Telegraphers could not ignore lightning or shortchange the ground connection. This interactive experience developed telegraphers' understandings of paths lightning took in their wiring and showed up by contrast the groundless myths and frauds of the sales-oriented rod profession.

This contrast is especially apparent in how the two extreme ends of lightning protectors were treated in home rod installations and at telegraphic stations. The upper visible ends of many marketed devices were decorative, boasting superfluous metal points on fluted hollow poles. The lower end stopped short, seldom going far enough underground to reach a reliable reservoir for a bolt's excess

charge. In telegraphy, there was a reverse in emphasis. Lightning arresters put high up on telegraph lines were evident only to the trained—and continually checking—operator’s eye. Ground excavations were substantive and essential to maintain if the signal was to go through. Thus by looking at the rod’s ends, we gain an entry to disparate cultures and understandings that arose around lightning protection in nineteenth century America.

The Story of One “Lightning Rod Man”

In the mid-nineteenth century, philosophical proprietors anxious to protect their own buildings were not the only ones putting up lightning rods. The notion of making profit by outfitting others’ houses arose to men who, often lacking homes of their own, were free to roam about, taking on any unprotected residence along their route as a potential sale. One of these peddlers was thirty-year-old James Wylie (d. 1866?) who left the Vermont farm where he was raised to go out and see the world. One November day in 1852, he wrote home from Nashville, Tennessee: “Brother Augustus, I take the present opportunity to inform you that I am a traveling in the south and a selling Lightning rods and find it a good business and like traveling in this country very well the people are kind and hospitable to strangers I am a driving a span of horses that cost 225 dollars and a good wagon and like my business very well.”²

James was then on route to the Atlanta, Georgia, base of an outfit run by a certain Mr. Ladd (possibly a family acquaintance). Six teams of men and horses had started off traveling together, but they were about to part ways, some continuing on with Ladd to Georgia, others going to Alabama.

The following April, James was still in good health and spirits when he chided his brother for not writing: “I . . . did not know but you ware all dead or forgot this poor old bachelor . . . but I am still knocking about and climbing a houses and putting the genuine frame rods on them.”³ A month later, impatience began to show in James’ correspondence. Mr. Ladd had taken off for Ohio, stranding James in Atlanta with responsibility for shutting up shop: “Mr. Ladd wants me to stay until the rods are all sold and the business closed up and I think it will take until July to do that and maybe longer but he thinks of coming back if he does I shall come home as soon as he gets back.”⁴

There was no quick release from the job, or return to beloved Vermont for the now-homesick James. That summer stretched on and on as its heat scorched the corn and made outdoor work intolerable: “the hands have all quit but me and I shan’t stay much longer . . . the weather is very warm and it is hard work and money won’t tempt me to follow this business much longer unless the weather becomes cooler.”⁵

In August, conscientious James was off in Tennessee, still under the direction of Mr. Ladd's letters: "Mr. Ladd . . . wants me to stay awhile longer and sel the horses and a few more rods—we have three horses yet to get rid of and about one thousand feet of rods but if the horses ware sold I should start for home next week but they are not and so I don't know when I shal start."⁶

James' mind clothed Vermont in a rosy hue. Months before, he had been agog over the belles who "dress so neet" and play heavenly piano music while taking snuff.⁷ Now he urged "tel the girls not to all get maried before I get back to Vermont"; Vermont girls were ahead of those southern "whoshers and corn crackers."⁸

The next spring, James wrote a prescient epistle, which was also the last of those preserved from this stage in his life. One sunny day, to get to where he had to do a repair, he drove his horses fifteen miles to a train stop, then went twenty-five miles more by train. After finishing the repair, the next train was not due for hours, so James started walking along the tracks. Fatigued, he took respite by sitting in a store. On getting up, he felt "it began to grow dark the next that I know three men had hold of me holding me up and putting camphor on my head . . . have had a severe head ache ever since that fainting spel."⁹ A day or more passed before he got back to the horses. The incident is telling, both of daily rigors in work and transport and of James' health. A decade later, James succumbed in a similar way: "James Wylie . . . died from a sunstroke in a harvest field near this place (Fayette Iowa)."¹⁰

James' letters disclose how lightning was far more distant from a rod-outfitter's concerns than the orders of an ever-absent boss, Mr. Ladd. James understood farming and horses; he was keenly observant of local crops "caries and plumbs . . . and new Irish potatoes," and seasons—noting a "backward spring" and a dry summer.¹¹ Yet he had no acquaintance with electricity and nothing in his letters suggests that his employment involved him with it, or in working out the paths lightning might take in striking a house. James spent his days atop houses and driving horses—he never mentioned excavating to ground the rods. His eventual interest lay not at either end of the rod but only in dispensing with his obligations to the business and in dreaming about home—and about getting rich by mining the Tennessee hills for copper.

The Rods, Tips, and Grounds of Patent Inventors

James' commitment to his absentee boss—and to repair a damaged fixture—suggests that he would not intentionally cheat anyone. However, most iterant peddlers were not so scrupulous: "Next to the substitution of sawdust packages for counterfeit money . . . the business of putting up lightning rods is a favorite

field for the operations of the swindling fraternity.”¹² An early twentieth century U.S. government report linked that fraud to the treatment of the rods’ two ends: “Rods of every description were . . . erected at excessive cost. . . . The object was to make a great showing with a minimum of material and labour; to accomplish this the conductors in many instances were discontinued a few inches below the surface of the ground.”¹³

These elaborate contraptions—outclassing the straight iron bars peddled by James—were products of another new profession, the “lightning rod makers” of whom the 1850 U.S. Census registered a total of 13; a decade later their numbers had risen to 164.¹⁴ Many makers obtained patents for their inventions. The original patents now provide a resource for depicting nineteenth century lightning protection.¹⁵ Each patent included diagrams, design and construction specifications, and explanation. A three-dimensional model was also required; a few are preserved at the Smithsonian Institution. Some patents were sold or licensed to other firms, thus distributing the invention across different territories.¹⁶ One example is that of David Munson, the most prolific patenter of lightning rod apparatus, holding at least sixteen patents covering items made at his Indianapolis establishment.¹⁷ His patent for tubular rods from sheet copper was bought by Lockart & Co., of Pittsburgh, and then by Reyburn, Hunter & Co., of Philadelphia, who marketed Munson tubes along with their own.¹⁸

The rod itself might not be a stock item; it could be made of different metals and take various forms. From Franklin’s time to that of James Wylie, most rods were lengths of iron bar or chain that was braced or linked together. Experienced experimenter and Smithsonian director Joseph Henry concurred with the 1824 French Academy recommendation for a three-quarter-inch diameter solid iron bar.¹⁹ However, as copper’s high conductivity became known through telegraphy, many rod outfitters switched to copper, boasting of its superiority in their ads. Yet copper did not then provide the benefit we might suppose for it: the low-grade copper used in rods was impure, poorly conducting, brittle—yet still costly—and thus not a clear preference to iron.²⁰ The replacement of iron by copper typically brought with it a change from solid rods to hollow tubes. Although this was a cost-saving measure on the part of the maker, it was promoted as an advantage.

Another partial understanding about electricity supported this claim. Just as static electricity stays only on the surface of metals, lightning was supposed to run only down the rods’ surfaces.²¹ John Phin, a critic of the lightning protection trade, regarded this as a fallacy trumped up to sell flimsy sheet metal finery. He argued that static electricity was not a suitable model for the behavior of lightning discharges: “while static electricity . . . always disposes itself on the surface of bodies . . . electricity in motion pervades the entire substance of the bar . . .

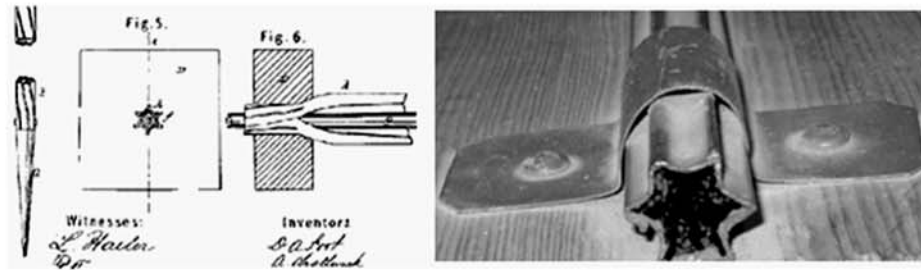


Figure 9.1. *Left:* The patent diagram (93609) of Foot and Chadwick's lightning rod with a star cross section. The rightmost diagram shows how copper sheeting was pulled through the star die shown in the middle. *Right:* The patent model of Foot and Chadwick's star rod is catalog number 326310 in the Smithsonian collection.

consequently the power of such a bar to convey electricity is measured by the quantity of metal that it contains, and not by the extent of surface."²²

However, the surface area argument won firm adherents among patenters—and some support from Joseph Henry's research.²³ Prominent maker David Munson used this argument to explain his system of "perfect protection" from lightning. He rolled copper sheet into fluted hollow tubes, which he claimed worked by "presenting a greater amount of surface upon which the electric fluid can act . . . thereby insuring its promptness of action . . . and thereby removing all danger from lightning."²⁴ He said these elegant tubes doubled as gutters to conduct both rainwater and lightning into the ground.²⁵

Other patents capitalized on the ease of manipulating sheet metal by advancing hardware that was whimsical in appearance and justification. Strips of sheet copper were fed between the hand-cranked rollers of Stearns' portable rod-maker; out they came as twisted and corrugated hollow rods.²⁶ Rather than rolling sheet into tubes, Lyon fitted rods together by interleaving long copper strips so their cross section (in the short dimension) looked like the spokes of a wheel. This rod's outer edges were serrated "to receive or break up the force of . . . electricity in its passage to or from the earth"; the barbs were there to catch and impale electricity.²⁷ Minnesotans Foot and Chadwick combined the Munson tube with the pointy edges of Lyon's rod by drawing copper tubing through a toothed die. The drawn hollow rod with its star-shaped cross section was reputed to "furnish in a small compass a great extent of surface for the electric current" (figure 9.1).²⁸

Ohioan Kleckner took the common concern for maximizing surface area to an extreme by perforating his hollow star rod and the trident of its upper tip with rows of evenly spaced holes (figure 9.2). These drill holes were seen as doubling the surface available to lightning by acting as means by which "the [electric] fluid may pass from the exterior to the interior of the rod, and vice versa."²⁹

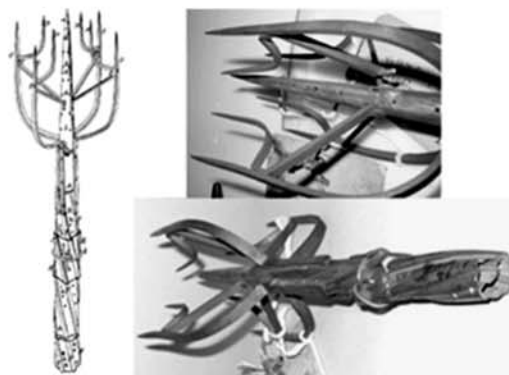


Figure 9.2. *Left:* Kleckner's patent drawing (162828) of a twisted hollow rod with trident top perforated with drill holes throughout. *Right:* Photos of Kleckner's patent model (catalog number 308577) in the Smithsonian collection.

As the rod went skyward, its upper tip was often a separate attachment. Care was lavished upon these fixtures, whose beauty and metalworking craft render them still desirable today.³⁰ Stressing simplicity, Joseph Henry steered the public away from succumbing to such embellishment in his public advice on the subject. He advocated terminating the rod with a “*single point* tipped with platinum,” an item which any ordinary instrument-maker could produce. He warned that ornate tips and thin coatings risked meltdown under the strong currents of an actual strike, and that extra prongs might provoke errant sideways electrical discharges.³¹ This was the experience of Cincinnati rod-maker James Spratt who, having “frequently observed instances of destruction of the points by lightning, . . . was led to the plan of forming my points of a number of metals incased one within the other.”³²

Although Spratt let observation of the melted tip inform him in redoing its structure, it was unusual for a maker to put experience with lightning strikes to use. Many patents and brochures featured multiple-pointed “crowns” and spears that were expressions of design rather than findings based on electrical research. They justified these bristles of points and sharp edges by adapting Franklin’s stance on points: makers contended that more metallic points would attract more lightning into the conductor, away from the house.³³ Testimonials appended to sales brochures announced “cheerful” satisfaction with points: “I have examined . . . the Patent Insulated Lightning Rod . . . [is] constructed on sound scientific principles . . . the multiplicity of points at the top . . . will not all be likely to be fused and blunted.”³⁴

Some owners described a rod’s successful handling of a strike—but without the backup of hard evidence: “I think I saw the lightning pass down the rod on my kitchen chimney; it passed off with a very vivid flash, without, however, doing any damage—the rod was probably the means of saving my house.”³⁵

Among the names listed in endorsement of rods, that of “Samuel Morse, Inventor of the Magnetic Telegraph” appeared on more than one company’s promotion.³⁶ Perhaps as tenuous a link as that influential name underlay the notion

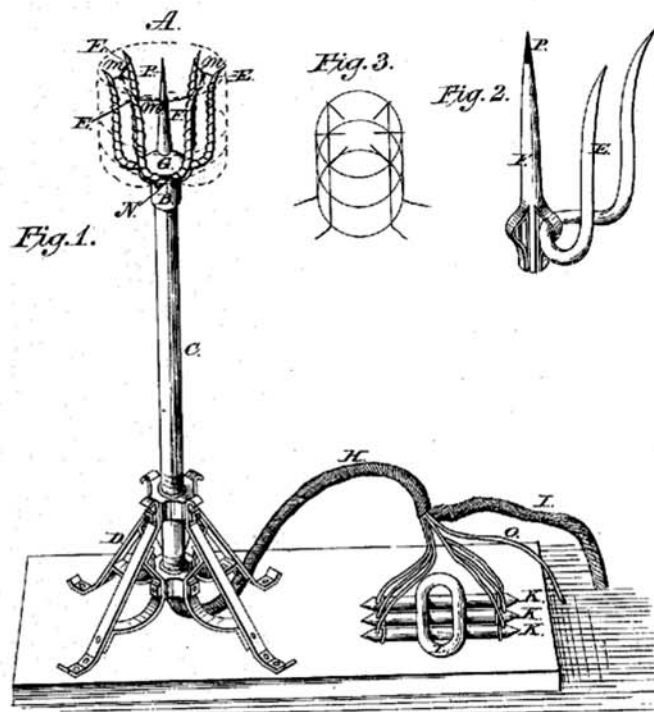


Figure 9.3. The trident roof fixture (on left) of Bryan's patent 160151 terminates underground with an "earth battery" depicted on the right. The trident is made of pointed horseshoe magnets, covered in a cage to keep out birds.

that magnetized points on rooftops could function as safe attractors of lightning. Philadelphian Bryan patented such a "Magnetic Lightning-Rod" whose trident top was assembled from three upended steel horseshoe magnets, the better to magnetically draw lightning into the rod (figure 9.3).³⁷ Even ordinary peddlers took up the cause, making for "a great FLOURISH of TRUMPETS about magnetized points" while lacking any scientific basis for their claims.³⁸

Patenters and salesmen championed excess in the rod's upper termination, but its underground lower end was often entirely neglected, as was likely the case with James Wylie's installations. Joseph Henry checked up on rodded houses that were damaged by lightning and found their rods stopped in packed, dry earth. This inadequate grounding had left lightning free to wreak havoc in coursing toward conductive masses, such as the gas mains, which were becoming more common by the midcentury.³⁹ These direct observations influenced Henry's view on what constituted a sufficient grounding. In the 1840s, Henry felt it would do to submerge the rod in an underground trench filled with charcoal.⁴⁰ Three decades later, he considered it paramount to solder the rod's end to nearby

gas or water mains; otherwise the lightning would break violently through to the mains.⁴¹ The example of a New Haven church bolstered others' arguments for including gas mains in grounding systems. This church was repeatedly damaged when lightning discharges passed from its rod's base through a two-foot brick wall to reach the city gas mains.⁴²

Gas and water mains provided such extensive underground networks that they exposed, by contrast, how ineffectual all the other installations were. In rural areas where mains were not available, it was difficult to provide an underground network sufficient to discharge the lightning without undertaking substantial excavation. In such cases, one author advised that the rod's end be embedded in several charcoal-filled trenches leading to all nearby bodies of water.⁴³ Charcoal was advantageous both by the extended surface contact it made with the surrounding ground, and by its tendency to retain water and thus constitute a moist, more conductive path for the discharge.

Calamities, such as that of the New Haven church, aroused investigative interest from some installers.⁴⁴ In Boston, inspecting disaster sites was routine for both young William Orcott in the 1840s and Fred Harris four decades later.⁴⁵ Invariably the fault lay in rods' inadequate grounding.⁴⁶ Harris believed that observing stricken buildings was the only way to build up relevant experiences of lightning's behavior:

Careful examination will show that there were either poor connections in the rod, or a very slight connection with the earth. . . . A conductor that is inserted one or two feet into the ground by pushing an iron bar down until it strikes a stone is scarcely any better than a rod that is cut off . . . above the ground. . . . People are satisfied if the end . . . is out of sight . . . [but] the rods are of no practical use. . . . My experience has taught me . . . the earth terminal should be most particularly attended to. . . . A conductor cannot be properly arranged by a person without experience. . . . Details that would be overlooked by a novice are sometimes the most important.⁴⁷

Providing adequate, functional lightning protection was not simply a matter of putting up metal rods (as James Wylie had done); it involved careful analysis of a building's structure and its surroundings, informed by experiences of how lightning shatters anything blocking its route to ground. Shortchanges in the rod's ground connection was a ploy not restricted to peddling "lightning rod men." Even the established manufacturer, David Munson, treated the ground with some abandon. His manual for rod installation went to great lengths propounding the superiority of tubular copper rods, but about the ground it merely prescribed that "the rod should extend far enough below the surface . . . to reach a permanently moist stratum . . . say four feet. The hole may be made . . . with an iron bar."⁴⁸

The adverse effects of this minimalist attitude are disclosed in a letter written by a local watchmaker to John Wise, a notable critic of lightning rods. Lightning had rampaged his house, darting to the gas pipe:

Mr. Munson hearing of the circumstance immediately came up to see me about it. After making an examination and probing around where the rod entered the ground finally concluded that it was caused by a want of dampness in the ground, although this occurred after two days of rain. In order to impress me . . . he . . . dug a hole around the rod, and then dumped in [char]coal and poured on it . . . water, then covered it up and telling me that it would never occur again, and if it did he would pay me five hundred dollars in cash. He furthermore said, if I would say nothing about it he would patronize me hugely in my business.⁴⁹

Munson's perfunctory response completely ignored the issue of the gas line, but what seemed to have angered the homeowner was Munson's greater concern for his business image than for genuinely resolving the problem.

While most rod designers expended their imagination on rooftop finery, a few were inventive about what they buried underground. The arguments given to explain these contraptions drew on ideas about electricity that were often weighted more with imagery than testable demonstration. A coil of copper ribbon was one common method of grounding rods, but the potential benefit of its large surface area was obviated by coiling it so tightly that little true earth contact was made (figure 9.4, left).⁵⁰ Similarly, the points of J. B. Burleigh's two-foot-diameter "Equilibrium Disk"—meant to be planted six feet underground—were alleged to "increase many times the inductive power" of the rod (figure 9.4, right).⁵¹ Although a committee of the Franklin Institute (where Burleigh was a prominent member) sanctioned the equilibrium disk, they condemned its design for presuming that points underground would disperse electricity just as in air and for the insufficiency of its metal surface to adequately contact the earth.⁵²

Even more bizarre was James Bryan's system for bringing about equilibrium between the electricities of air and earth by means of trident magnets posted on rooftops to collect atmospheric electricity and direct it by cable to an underground "earth magnetic battery." This battery supposedly restored electrical balance by uniting atmospheric electricity with galvanic currents extracted from the earth (see figure 9.3). Bryan's underground battery modeled an induction coil in form, not function. Its core of steel magnets was overwound first with a primary coil terminating in galvanic plates, and then with a secondary coil whose ends went up the lightning cable to the roof.⁵³ The whole was embedded in sulphur, said to intensify the current being educed from the earth. Deriding Byran's assembly as "one of the most ridiculous and unscientific combination of conductors . . . ever

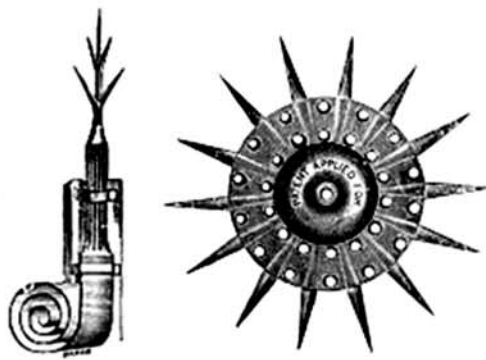


Figure 9.4. *Left:* Kissell & Blickensderfer's 1867 brochure showed the rod's trident top and the coil of copper ribbon that was buried underground as a ground. *Right:* Burleigh's "Equilibrium Disk" was buried underground as a ground for lightning rods; its points were supposed to discharge the electricity. *Journal of the Franklin Institute* 92 (1871): 4.

suggested for lightning protection," fellow Pennsylvanian Spang countered with his own "reliable system" consisting of a perforated iron pipe buried vertically to catch rainwater—and lightning—from gutters and direct both water and charge into the earth.⁵⁴

The lightning rod's ends were distinguished in many ways: up and down; visibly prominent and out of sight; a spire crowned with fine points or a bar pounded in the dirt—perhaps into a maze of charcoal trenches. In the instance when lightning did strike the top, it might not take the rod's prescribed path to the bottom but might instead divert to some unseen reserve of water or metal piping. Since lightning strokes were not an everyday occurrence, itinerant lightning rod men, such as James Wylie, had no direct feedback on their installations. Patent inventors were more stable and identifiable than peddlers, yet they too reaped profits by inflating costs while neglecting function.⁵⁵ The public did not realize that nothing in the process of getting a patent certified that the invention fulfilled its reputed claims. There was no accountability, no actual test. Phin, a critic, railed: "Nine tenths of all the inventions protected by patents are perfectly worthless. . . . All the various devices of hollow rods, twisted rods, hacked rods . . . are perfectly childish."⁵⁶

Developing understandings of how to direct lightning safely to ground took critical experience and time. Despite the claims so often made, there was no invincible patent protection from lightning—yet there were ways of learning to become more critical. Homeowners, like Munson's client, learned they had been "had" when their rods failed. From the damage a stroke left behind, conscientious inspectors such as Joseph Henry and Fred Harris learned to infer the breaks in rod continuity and ground features that had stopped or redirected the stroke. Eventually, through a crossover of expertise with telegraphy, it became possible to interactively test an implanted rod's continuity and grounding by including it in a circuit with a battery and galvanometer.⁵⁷ Such galvanometric testing, while not foolproof, enabled knowledgeable installers to interactively evaluate rods

and their surroundings—an interaction whose absence had given rise to such extensive fraud.

Telegraphers' Lightning Arresters

From the mid-nineteenth century on, telegraphy extended across increasingly long distances in America, steadily involving more people in its operation and maintenance. The United States census of 1850 records 544 telegraph operators, indicating that telegraphy was a small skilled profession, on the order of that of bankers (552), gas fitters (564), or undertakers (495), and far more numerous than those identified as lightning rod manufacturers (13). Telegraphers increased in number by nearly a factor of four in successive decades: 1,956 in 1860; 8,500 in 1870; and 22,809 (including 1,131 women) in 1880.⁵⁸

These telegraphers worked a wiring that differed materially from most power lines and circuitry of today. One wire only—not two—carried the electric signal between any pair of stations; the circuit was completed by taps made at each station to the common earth. Such inclusion of earth in electrical paths was integral to eighteenth century friction machines, where high tension electricity sparked as it discharged to anything grounded. One early (1828) American telegraph used this form of electricity, keying it from a friction machine, through one wire to a recorder and then to ground.⁵⁹ However, the first telegraphs operating on galvanic sources were strung with multiple signal wires and one common “return” wire.⁶⁰

The possibility of dispensing with the return (or “home”) wire emerged in 1837 during Karl August Steinheil's experimenting to construct a twelve-mile telegraph near Munich where he was an instrument-maker and conservator.⁶¹ His trials soon made evident what the lightning rod installers long disregarded: a reliable earth connection depended on a large area of surface contact between earth and the electrical system: “Quite recently, I made the discovery that the ground may be employed as one-half of the connecting chain. . . . It is necessary that at the two places where the metal conductor is in connection with the [earth], the former should present very large surfaces of contact. . . . Not only do we by this means save half the conducting wire, but we can even reduce the resistance of the ground below what that of the wire would be, as has been fully established by experiments.”⁶²

In the United States, Samuel Morse's early efforts independently yielded the same observation. Morse's business colleague Amos Kendall even experimented with running the telegraphic circuit off the ground—with no other battery—by embedding a copper ground plate at one end and a zinc plate at the other. He described this in a private letter, saying “I have all along said the ground was to become our battery.”⁶³

The ground return was built into subsequent telegraphic circuits, giving a common natural reference for all stations, no matter how distant. The interactive relations arising among earth, air, and telegraphic wiring, figured in how telegraphic circuits were designed and used. For example, local soil conditions affected the grounding provided by the three-foot-square metal plate typically implanted horizontally in it;⁶⁴ in very dry soils, where “earth cannot be found,” a relative ground could be made by putting in several plates at different tensions. Nearby stations had to coordinate the materials used in the ground plates; if these were made of dissimilar metals, a permanent galvanic current would flow between them, undermining the telegraphic signal. And it took special care to insulate the wiring carrying the telegraphed signal from the ground—any direct contact introduced an inadvertent ground: “Dead earth in American phraseology . . . occurs when the line at any point touches the earth. . . . It practically divides the line in two . . . each terminal station working on its own battery to the fault.”⁶⁵

For example, the bare iron wire used for most overhead telegraph wires leaked electricity at the support posts, especially in wet weather. Although underground or submarine cables were coated in an insulator such as gutta-percha, moisture eventually degraded that insulation, making for further faults. How the ground return worked was puzzling. It was popularly pictured as equivalent to a wire: “the earth is practically one vast conductor.”⁶⁶ But that image did not stand up to close inspection. Unlike ordinary wires, the earth ground showed no resistance to electricity—and yet if a tray of soil was inserted into a circuit, it was far more resistive than any wire. Increasing a wire’s diameter reduced its resistance, but applying this analogy to earth would imply that the earth plates needed to be enormous. Further, the earth return was unlike ordinary conduction in that it did not exhibit the chemical decomposition products that accompanied galvanic currents. Observing that the analogy between earth and a resistive wire did not hold up to scrutiny, a leading British telegrapher offered an alternative understanding: “For myself, I have long seen the confusion in which this question involves us, and have been unable to admit the existence of [earth conduction]. . . . [We] are thus reduced to . . . rejecting altogether the idea of conduction . . . and of regarding the globe merely as a vast reservoir of electricity.”⁶⁷

Confusing as it was to understand, the ground figured in everyday telegraphic operations. Routine maintenance involved setting up tests to distinguish and track down leaks, wiring breaks, and inadequate grounds,⁶⁸ as advised in one manual: “the first business in the morning is to examine the batteries, test the lines, and ascertain if the connecting lines are all in working order . . . note [this] in the [office] journal.”⁶⁹

Telegraphers were in such continual interaction with ground, and each other, that their exchanges became encoded in shorthand—such as “G” for ground. The parodies by which telegraphic insiders poked fun at public inexperience

with electricity resembled the critical responses to lightning rod men.⁷⁰ For example, a traveling telegrapher stops by an outpost telegraph office. In one tale, playing on the local's naiveté, this passing telegrapher claims things will work better if the ground line is disconnected and replaced with a line ending in a pail of water kept under the table. In another, the traveling expert spies a broken wire that turns out to be the ground, whose break had gone unnoticed for months since it was accidentally cut.⁷¹ Telegraphic experience engendered a practical knowledge that was essential in ferreting out such faults, yet inscrutable to the uninitiated.

The environmentally scaled circuits of telegraphy encompassed both earth and sky. Just as earth could hamper the signal from below, atmospheric electricity—and lightning—disrupted telegraphic circuits from above. Wires spanning the big spaces of the American landscape were particularly afflicted: “Lines traversing several hundred miles, north and south, were subjected to repeated and almost constant interruptions. The adjustment of the apparatus had to be changed from moment to moment . . . very destructive . . . sometimes totally destroying [apparatus] . . . and at other times it has temporarily rendered ineffective the electromagnet.”⁷² This problem showed up immediately with the first trial telegraph installations. Morse attempted to redirect the high voltage atmospheric electricity to ground by sending line current through a conducting ball with ground lines nearly grazing its surface, but this proved inadequate.⁷³

A telegrapher's pleas moved Joseph Henry to observe for himself what happened in a telegraph office while an electrical storm raged outside. The electrical ferocity borne by the wires astonished even the dean of American science. In that Philadelphia office, the incoming telegraphic signal wire was merely an inch away from the ground wire. Henry described how every few minutes there passed between these two wires “a series of sparks in rapid succession . . . simultaneous with a flash in the heavens. . . . The effect became so powerful that the superintendent, alarmed for the safety of the building, connected the [signal] wire with the city gas pipes, and thus transmitted the current silently to the ground. I was surprised at the quantity and intensity of the current.”⁷⁴

Henry advised running ground lines up the individual telegraph poles, mounted to not quite touch the signal wire, just like the wire arrangement in the Philadelphia office. However, there was no simple solution to the problem, and lightning continued to plague American telegraphy, giving rise to a diverse range of inventions. To protect their circuits, telegraphers devised “lightning arresters.” All these arresters operated similarly. A single wire, suspended outdoors on poles, provided the electrical link between one telegraph station and the next. The signal's transmission was along this wire. The arrester was placed on it, just before the wire went inside the office with its delicate instruments. In the arrester, the signal current passed through a wire or surface, which was almost in contact

with a ground line. At the low voltages of ordinary transmissions, the signal current would pass through the arrester, into the office equipment where the operator decoded it. But when an electrical storm raged outside, disturbances of high voltage and high current were induced on the long suspended lines, even in cases where no lightning was in sight. These disturbances overwhelmed the signal and endangered office equipment. The arrester circumvented this calamity by providing a quick route to ground that could be taken only by high voltage electricity, leaving the signal unaffected. The disturbance would tend to spark through the arrester's short air gap to get to ground, rather than traverse the high resistance electromagnet coils intervening between the arrester and the office's own ground wire. Sometimes a short length of very thin wire was inserted between the arrester and the office to behave like a fuse: under high currents (such as a direct lightning strike to the lines), it burned and broke the circuit. No device was infallible; in a severe storm, it was best to do as the Philadelphia superintendent had and disconnect the office from the outside line.

A multitude of arrester designs emerged along the American telegraph lines. Few were patented; individual improvisation was more prevalent. In a crunch, almost anything handy might do, even a cup of water. Wires coming from office equipment could be immersed in the water so their ends nearly touched a ground line, allowing high voltages to jump through the water gap to ground.⁷⁵ Or, instead of the cup, a water-filled flowerpot was fitted with a thin gauge wire that went through the water and out the hole in the pot's bottom, and carried the signal current. Any excess electricity was expected to dissipate in the water, or burn and break the fine wire, thus protecting the office equipment. A related device sent the signal onto a central line of fine wire hanging in the center of a grounded brass tube weighted at its lower end (figure 9.5).

Electricity of high voltage and current would jump from the fine wire to the ground, breaking the wire and letting the weight fall to open the circuit.⁷⁶ In this case, the line had to be repaired after every break, whereas the electromagnet-activated spring switch of another arrester opened when line current in the coils was high and sprang back on its own to reestablish the telegraphic circuit.⁷⁷ Royal House, a well-known telegraphic inventor, patented a similar arrester as part of his extensive system for postal telegraphy.⁷⁸

An alternative design used side-by-side metal plates; one was at ground, the other at line potential. These plates were separated by a tiny air gap across which high voltage electricity could dart. The plates' adjacent edges were serrated with sharp points, to assist electricity's jump to ground, an analogy to the lightning rod tips (figure 9.6, left).⁷⁹ However, lightning's terrific currents could literally fuse the two plates' edges together. Fusion protected the equipment but also sent the signal to ground, which lost its information. In a later design, the ground plate also had a vertical post with a fine insulated wire carrying the signal coiled



Figure 9.5. In this lightning arrester by Royal House, the signal wire on the left attaches to the ornamental brass support and enters a fine wire that passes through a hole in the cylindrical weight and connects to the office equipment. The fine wire supports the weight by a silk thread so that when high voltages pass on the fine wire, the wire breaks and the weight falls and transmits the discharge to ground. Turnbull, *Electro-Magnetic Telegraph*, 188.

around it. Very high voltages would simply dart across the gap between the line and ground plates while lesser disturbances migrated from the coil to the inner ground post (figure 9.6, right).⁸⁰

A design that was widely adopted in mid-century telegraphy expanded the surface area held in common between line and ground by positioning the plates in parallel, one above the other. To emulate the sharp points of lightning rods, a wire bristle resembling a wire hairbrush made up the facing surface; its thousands of wire tips nearly grazed the ground plate—and sometimes dropped out (figure 9.7, left). The wire surface was hard to maintain; its teeth dropped out and

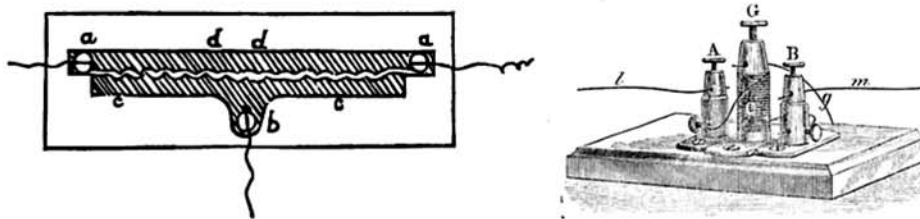


Figure 9.6. *Left*: In telegrapher Charles S. Bulkley's arrester, the signal enters the top brass plate from the left; the office wire leaves it at the right. The lower serrated plate is grounded; it leads high voltages away from the office. *Right*: Line wire enters this arrester at post A, then coils around the grounded middle post G with a thin insulative sheet separating it from ground, and goes on the office connection at post B. Lightning pierces the insulation and discharges to ground via post G. *Left*, Turnbull, *Electro-Magnetic Telegraph*, 187; *right*, *The Telegrapher*, May 25, 1865, 100.

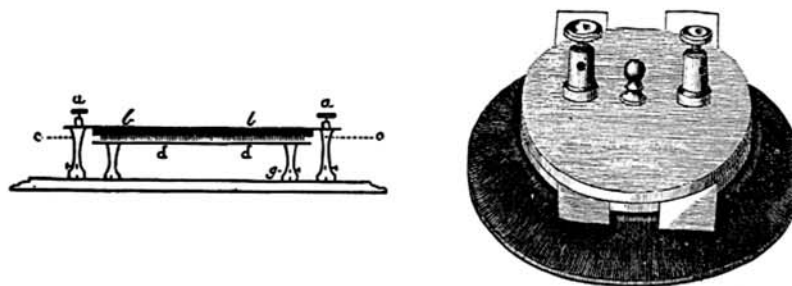


Figure 9.7. *Left:* A lightning arrester where the top plate is in the form of a wire brush with multiple teeth just grazing the top of the grounded lower plate dd. *Right:* A lightning arrester produced by Boston instrument-maker Thomas Hall. The signal and office lines enter the posts on the top plate. The lower plate is grounded and separated from the top plate by a thin insulating tissue which breaks down under the high discharges of lightning. *Left:* Turnbull, *Electro-Magnetic Telegraph*, 187. *Right:* Shaffner, *Telegraph Manual*, 571.

the separation distance warped. This instrument evolved into a sandwich where a nonconducting tissue, such as paper, silk, or gutta-percha, intervened between the ground and line plates, keeping them a fixed distance apart (figure 9.7, right). The tissue prevented ordinary current from escaping the line while high voltages pierced through to ground.⁸¹ But the erratic electricity of summer afternoons would not drain off the line, rendering “the wires almost entirely useless for hours . . . sometimes for days.”⁸²

No device could effectively insulate telegraphy from the vagaries of weather’s electricity. Yet it was just this continual close contact between signals, and what telegraphers called the “fantastic tricks . . . [of the] Spirit of the Storms,”⁸³ that deepened telegraphers’ understanding of lightning. As compared to the lightning rod men who rigged houses and then left without realistically testing their rods, telegraphers were always dealing with what environmental electricity did to their instruments and signals. In response, telegraphers adjusted circuits, repaired wiring and ground connections, and invented new instruments to protect their circuits—and then observed what happened next. This interactive exchange between instrument modification and observing the phenomena developed their experience. Telegraphers, as a group, were learning to handle electricity through interacting with it—a way of learning inaccessible to most lightning rod men and patent inventors.

Learning by Working with Lightning’s Fire

Two themes informed the work of all the inventors and installers, one psychological, which addressed people’s fear of lightning, and the other physical, which

sought to safely dissipate lightning's discharges. Where people's hold on fear was greater — involving personal property and lives — their attention to electrical matters weakened, leaving them vulnerable to both deception and harm. Where people observed lightning's effects and were provoked to investigate it, those fears receded, enabling them to work and learn.

Telegraphers and rod inventors pulled differently on these two strands, the psychological and the physical strand. Telegraphers experienced atmospheric electricity as integral with the daily running of their apparatus. They could not ignore high voltage electricity; it came with each passing storm. If a line had no protective arrester, or if it failed, they had to improvise, and through improvising they learned about materials, lightning's terrific discharges, and the paths it took to ground. Because telegraphers were always signaling each other, they shared ideas and revised devices as a community, learning together. By contrast, the lightning rod men were not present when lightning hit. Patent inventors could get feedback on the adequacy of their work only by taking the time to investigate and dissect a stricken house. Because few did this with the intent to remedy the rod's failings, their patented fixtures often became fanciful reflections of how lightning was believed to behave, rather than successive efforts at diverting lightning to a safe ground. Rather than coalescing as a community, their efforts splintered competitively.

Evidence of this story is recorded in the various forms taken by the lightning conductor's ends. For lightning rod men, from peddlers such as James Wylie to patent-holding businessmen such as David Munson, it was only the upper, visible end that mattered. Spiky rooftop spires often terminated as a rod forced into dry dirt. But telegraphers did not need to erect tall rods to receive lightning; it alighted of its own on their wires. Instead of the rod's top, telegraphers were concerned with its bottom. They worked at maintaining a good ground and devising instruments to bleed high voltage electricity off the signal lines and direct it to ground.

History is a doubled mirror, looking into both where we were and where we might be. These stories of professions and instruments gone by can still speak to us today and can suggest how the ways we experience natural phenomena provoke different inventive responses. Where the experience rests on accounts lacking direct tests with nature, all anyone can make of it will be a sham easily struck down by an actual bolt. But when experiences offer many ways of interacting with natural effects, any inventions exerted to handle those effects will undergo continual testing and growth.⁸⁴ These stories also reveal how community enables people to deepen their learning. Where community is diverse and interactive, everyone benefits; their work creates something real. But where people's work is without substance and isolated, there is also no basis for community; rivalries fashion fraud.⁸⁵

The psychological and physical aspects also underlie a tension between work that is shaped by its market and work that evolves as an ongoing process of research. Lightning rod men and makers operated on the stage of the market; they benefited more from gauging what people would buy and from cultivating persuasive tactics than by studying electricity's strange behaviors. Conversely, telegraphers' primary commitment was to sustain and work with the electrical signal; this entailed experimenting directly with it and inventing apparatus that would immediately be put to a practical test. Yet there was some crossing over between the differing pulls of market and research on these professions. The effectual grounding of telegraphers found advocacy and, in some cases, a role in the lightning protection of buildings: "The rod should . . . have a large plate or bar of metal at the base, according to the arrangement of the electric circuits at all the telegraph stations."⁸⁶ And although telegraphers were daily involved in the intricacies of weak signals, faulty connections and noxious battery fluids, they were also affected by such market agencies as monopolies and patent rivalries among the many incipient American telegraph companies.⁸⁷

Lightning is one of the most tremendous actions of nature that ordinary people witness directly. Its destructive power and paths are well beyond our control, and yet it does not forever freeze us in terror; we can respond to its behavior and our fears. In these responses, the worlds of human doings and markets come together with nature's ways and wonders. We can hope that strategies and understandings, such as worked out by lightning rod men and telegraphers, will arise as people today deal with the perennial occurrences of lightning—and with the newer dangers of our present world.

Notes

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offered comments, reflections, and focus in responding to this manuscript. Alva Couch insightfully extended my interpretations. The teaching of Philip Morrison, which deepened my sensitivity to inventive and observant responses to nature, is here continued in his memory.

1. Herman Melville, "The Lightning-Rod Man" (1853) in *The Piazza Tales and Other Prose Pieces 1839–1860* (Evanston, Ill.: Northwestern University Press, 1987). Melville's short story is available online in full, for example, at <http://www.online-literature.com/melville/2056/>.

2. James Wylie, November 14, 1852, Nashville, Tennessee; Augustus Wylie papers, New England Genealogical Society Library, Boston, Mass.

3. *Ibid.*, April (1853?), Cave Springs, Georgia.

4. *Ibid.*, May 29, 1853, Atlanta, Georgia.

5. *Ibid.*, July 10, 1853, Calhoun, Georgia.

6. *Ibid.*, August 9, 1853, Charleston, Tennessee.

7. James Wylie, letter of April 1853.

8. James Wylie, letter of August 9, 1853. James never married.

9. James Wylie, May 29, 1854(?), Loudon, Tennessee; see also the August 9, 1853 letter. However, the following year, James wrote home from Iowa, where he had bought land for framing and timber.

10. A. W. Callender, letter of March 16, 1901, Fayette, Iowa; Augustus Wylie papers, New England Genealogical Society Library, Boston, Mass.

11. James Wylie, letters of May 29, 1853, Atlanta, Georgia, and July 10, 1853, Calhoun, Georgia, Augustus Wylie papers, New England Genealogical Society Library, Boston, Mass.

12. John Phin, *Plain Directions for the Construction and Erection of Lightning-Rods* (New York: Handicraft Pub. Co, 1871), 27.

13. O. S. Peters, *Protection of Life and Property against Lightning*, Technologic Papers of the Bureau of Standards (Washington, D.C.: U.S. Government Printing Office, 1916), 8.

14. J. D. B. DeBow, *Statistical View of the United States . . . Being a Compendium of the Seventh Census (1850)*, vol. 5 (1854; repr., New York: Gordon and Breach Science Pub., 1970), 127; *Eighth Census of the United States (1860)* (New York: Norman Ross Pub., 1990), 666–67. Lightning rod men such as James were lumped among the ranks of over ten thousand peddlers tabulated.

15. All U.S. patents are now searchable online from the website <http://www.uspto.gov/patft/index.html>. Patents issued before 1976 are available in image format only, and can be accessed only by patent number. For determining patent numbers of inventions, see M. D. Leggett, *Subject Matter Index of Patents Issued from the United States Patent Office from 1790 to 1873* (Washington, D.C.: 1874).

16. For background on nineteenth century patenting, see Carolyn C. Cooper, *Shaping Invention: Thomas Blanchard's Machinery and Patent Management in Nineteenth-Century America* (New York: Columbia University Press, 1991).

17. The "Improvement in Lightning-Rods" U.S. patents of David Munson, Indianapolis, Indiana, include August 5, 1856, 15491; November 1, 1864, 22880; February

11, 1868, 74406; November 17, 1868, 84210; February 1, 1870, 99461; March 8, 1870, 100549; January 3, 1871, 110778; September 19, 1871, 119043; and July 23, 1872, 129675–7.

18. Circular of 1877, North American Lightning Rod Company of Reyburn, Hunter & Co., Philadelphia, Pennsylvania, held in Warshaw Collection, Archives Center, National Museum of American History, Smithsonian Institution, Washington, D.C.

19. Joseph Henry to John Torrey, August 2, 1838, *The Papers of Joseph Henry*, vol. 4 (Washington, D.C.: Smithsonian Institution, 1981), 81–83; Joseph Henry to M. W. Jacobus, July 19, 1843, in *ibid.*, 372; “Directions for Constructing Lightning Rods,” *Smithsonian Miscellaneous Collections*, 10, 1871, 1.

20. Phin, *Plain Directions* (cit. n. 12), 11; I. N. Miller, “Lightning and Lightning Rods,” *American Electrical Society Journal* 1 (1875–77): 36–48. The best copper available was that mined at Lake Superior. Miller reports that copper from other sources could be more resistive than iron. Chicago rod company Kissell & Blickensderfer advertised their use of “pure COLD ROLLED Lake Superior Copper” in their pamphlet “The Best System of Protection from Thunder Storms” (Chicago: Church, Goodman & Donnelley, 1867).

21. For critiques of this assumption in practice see Phin, *Plain Directions* (cit. n. 12), 11; Miller, “Lightning” (cit. n. 20), 40; John Phin, “The Form of Lightning-Rods,” *Popular Science Monthly* 7 (1875): 399–402; and H. W. Spang, *A Practical Treatise on Lightning Protection* (Philadelphia: Claxton, Remson & Haffelfinger, 1877), 121.

22. Phin, *Plain Directions* (cit. n. 12), 11; see also Phin, “Form of Lightning-Rods” (cit. n. 21).

23. Joseph Henry, “On the Protection of Houses from Lightning,” *Proceedings of the American Philosophical Society* 4 (1845): 179–80; reprinted in *The Scientific Writings of Joseph Henry*, vol. 1 (Washington, D.C.: Smithsonian Institution, 1886), 231f.

24. Munson patent, August 5, 1856, 15491.

25. David Munson, *A Chapter on Thunder and Lightning: Their Causes and Effects Together with a Description of David Munson’s Copper Tubular Lightning Rod with Spiral Flanges as Perfect Protection against the Disasters of Electricity* (Indianapolis: Indianapolis Journal Co., 1858), 16. Also see Patent of February 11, 1868, 74406.

26. Charles Stearns, Lowell, Massachusetts, U.S. Patent of September 20, 1859, 25534.

27. Amos Lyon, Worcester, Massachusetts, U.S. Patent of July 11, 1854, 11261.

28. David A. Foot and Avery Chadwick, Winona, Minnesota, U.S. Patent of August 10, 1869, 93609. A sample of the Star Copper Lightning Rod, manufactured by Hooker and Rich of Gainesville, Georgia in 1872, is catalog number 326310 in the Smithsonian’s National Museum of American History collection.

29. John Kleckner, Canton, Ohio, U.S. Patent, January 26, 1874, 162828. Kleckner’s patent model is catalog number 308577 in the National Museum of American History, Smithsonian Institution, Washington, D.C.

30. While the brochures of lightning rod firms typically included illustrations of the many-pointed tips, their texts argued for the functionality and efficacy of the devices without giving primacy to their decorative qualities. Today, that very quality of decoration and

craft imbues lightning rod artifacts with value for collectors. Illustrations of lightning rod points and paraphernalia, along with estimated market prices, are provided by Russell Barnes, *The Lightning Rod Collectibles Price Guide* (Austin, Tex.: R. Barnes, 1997).

31. Joseph Henry to James Rodney, March 25, 1846, *The Papers of Joseph Henry*, vol. 6, 1992, 404, where he mentions McAllister of Philadelphia, and Pike of New York, as suppliers of rod tips; "Directions for Constructing Lightning-Rods," *Smithsonian Miscellaneous Collections* 10 (1871): 1f.

32. James Spratt, Cincinnati, Ohio, U.S. Patent, May 4, 1852, 8930.

33. See George W. Otis, Lynn, Massachusetts, U.S. Patent of July 21, 1868, 8025; S. J. Mitchell, St. Louis, Missouri, U.S. Patent, May 23, 1865, 47846. For critiques of the view that lightning rod points attract lightning, see "Lightning Conductors and Attractors," *Scientific American* 1 (1859): 367; H. W. Sprang's critique in *A Practical Treatise on Lightning Protection* (Philadelphia: Claxton, Remsen & Haffelfinger 1877), 92, and Phin's critique, *Plain Directions* (cit. n. 12), 21. Illustrations of nineteenth century lightning rod points, as now identified by collectors, are provided in Russell Barnes, *The Lightning Rod Collectibles Price Guide* (Austin Tex.: R. Barnes, 1997).

34. "Otis's Patent. The only method of Absolute Protection Against Lightning" (New York: Lyon Manufacturing Co., 1858), 28.

35. Reyburn, Hunter & Co., *Lightning Rod Works*, Philadelphia, 1858, 8, Warsaw Collection, Archive Center, National Museum of American History, Smithsonian Institution, Washington, D.C.

36. Samuel Morse is listed as endorsing both the Pennsylvania Lightning Rod Co., Warsaw Collection, Archive Center, National Museum of American History, Smithsonian Institution, Washington, D.C., and the Cleveland Lightning Rod Co., formerly at Burndy Library, Cambridge, Mass.; now in the collection of The Huntington Library, Art Collections, and Botanical Gardens, San Marino, Calif.

37. James C. Bryan, Philadelphia, U.S. Patent of February 23, 1875, 160151.

38. "Otis's Patent" (cit. n. 34), 21.

39. Joseph Henry, "Record of Experiments," entries of July 16, 1841 (printed in *Papers of Joseph Henry*, vol. 5, 73–74), and May 18, 1858 (unpublished manuscript in Smithsonian Archives). Joseph Henry's drawing in this entry shows that lightning hit a house's rod at the tip, left the rod to pass along the roof's coping, then followed a gutter and then leapt to a gas pipe, leaving a destructive path. Henry published his 1858 observations in "Meteorology in its Connection with Agriculture," Agricultural Report of Commissioner of Patents, 1859, 461–524, reprinted in *The Scientific Writings of Joseph Henry*, vol. 2 (Washington D.C.: Smithsonian, 1886), 376–78. Municipal gas lighting is referenced in Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (Philadelphia: Temple University Press, 1985), 58.

40. Joseph Henry to James Rodney, March 25, 1846 (printed in *Papers of Joseph Henry*, vol. 6, 404).

41. Joseph Henry, "Directions for Constructing Lightning-Rods," *Smithsonian Miscellaneous Collections* 10 (1871): 1f.

42. Benjamin Sillimen Jr. documented the strikes on the church in *Principles of Physics* (Philadelphia: Bliss, 1870), 662. Other references to the story appear in David

Brooks, "Lightning and Lightning Rods," *Journal of the Franklin Institute* 94 (1872): 132–43; "Ground Connection of Lightning," *Popular Science Monthly* 1872: 120–21; John Mott, "Lightning and Lightning Rods," *Journal of the Franklin Institute* 96 (1873): 118–27; H. W. Spang, *Practical Treatise* (cit. n. 21), 103f.

43. Miller, "Lightning and Lightning Rods" (cit. n. 20), 46.

44. For a list of 505 buildings (with and without rods) damaged by lightning from 1665 to 1883, see Arthur Parnell, *The Action of Lightning Strokes in Regard to the Metals and Chimneys of Buildings* (London: 9 Conduit St, 1884). Examples of houses protected by a patent lightning rod are used as testimonials in the *Circular of William A. Orcutt, Manufacturer of Orcutt's Patent Lightning Rods* (Boston: John M. Hewes, 1857).

45. *Circular of William A. Orcutt*, 31; *Lightning* broadside of Orcutt, c. 1841, The Huntington Library, San Marino, Calif.

46. Fred E. Harris, *On Lightning Conductors* (Boston: J. E. Farwell, 1885). Harris' diagram on page 15 shows lightning hitting a rodded house, following the conductors down the sides, and then jumping to the cows standing in moist earth in the basement. The rod was not properly grounded; the cows were killed.

47. Harris, *Lightning Conductors* (cit. n.46), 3, 19–20.

48. Munson, *Chapter on Thunder and Lightning* (cit. n. 25), 17.

49. Mr. C. A. Ferguson to John Wise, quoted in John Wise manuscript "Thunderbolts and Lightning Rods," text of lecture given at the Franklin Institute, John and Charles Wise Ballooning Collection (Acc. 2001–0002), Archives Division, National Air and Space Museum, Smithsonian Institution, Washington, D.C.

50. Kissell & Blickensderfer, *The Best System of Protection from Thunderstorms* (Chicago: Goodman & Donnelly, 1867). See Miller's critique, "Lightning and Lightning Rods" (cit. n. 20), 46.

51. "The Equilibrium Disk," *Journal of the Franklin Institute* 92 (1871): 4.

52. Phin, *Plain Directions* (cit. n. 12), 24 and Spang, *Practical Treatise* (cit. n. 21), 131f.

53. James C. Bryan, Philadelphia, U.S. Patents of February 23, 1875, 160151–2. See Spang's critique, *Practical Treatise* (cit. n. 21), 132–34.

54. Spang, *Practical Treatise* (cit. n. 21), 134–37; also Henry W. Spang, Reading, Pennsylvania, U.S. Patents of September 7, 1875, 167415, and October 23, 1877, 196493.

55. Similar fraudulent behavior among traveling medicine salesmen of the time is described in Ann Anderson, *Snake Oil, Hustlers, Hambones: The American Medicine Show* (Jefferson, N.C.: McFarland & Company, 2000). One source quoted there reports that for the person who used medical galvanic belts, "all the wearer ever got out of his belt was a dream—and a blister" (35).

56. Phin, *Plain Directions* (cit. n. 12), iv.

57. Spang, *Practical Treatise* (cit. n. 21), 112–15.

58. DeBow, *Statistical View of the United States* (cit. n. 14), 128. *Eighth Census of the United States* (1860), 676f.; *Ninth Census of the United States* (1870), Francis A. Walker, 1872, 706; *Tenth Census of the United States* (1880), 746.

59. Ken Beauchamp, *History of Telegraphy* (London: Institution of Electrical Engineers, 2001), 22.

60. *Ibid.*, 32.

61. Alto Brachner, "C. A. Steinheil, a Munich Instrument Maker," *Bulletin of the Scientific Instrument Society* 12 (1987): 3–7.

62. Karl August Steinheil, "Upon Telegraphic Communication, Especially by Means of Galvanism," *Annals of Electricity, Magnetism, and Chemistry* 3 (April 1839): 509–20.

63. For Morse's use of the ground return, see Lewis Coe, *The Telegraph: A History of Morse's Invention and Its Predecessors in the United States* (Jefferson, N.C.: McFarland & Co, 1993), 71. Amos Kendall's letter of April 2, 1846, Washington, D.C., to Thomas Clark, Treasurer, New York, is held in the Papers of Amos Kendall, Library of Congress Manuscript Collection, Washington, D.C.

64. The grounding plate is described in a footnote in J. E. Smith, *Manual of Telegraphy Designed for Beginners* (Chicago: Western Electric, 1865), 41.

65. Thomas Lockwood, *Electricity, Magnetism and Electric Telegraphy: A Practical Guide and Hand-book* (New York: D. Van Nostrand, 1883), 231.

66. *Manual of Telegraphy and Description of Instruments* (New York: J. H. Bunnell and Co., 1889), 9.

67. Charles V. Walker, *Electric Telegraph Manipulation* (London: George Knight and Son, 1850), 37.

68. For the problems in making and testing a ground, see R. S. Culley, *A Handbook of Practical Telegraphy* (London: Longman, 1863), 54–58, 103–17; William Henry Preece and James Sivewright, *Telegraphy* (New York: D. Appleton, 1876), 251–81; Smith, *Manual of Telegraphy* (cit. n. 64), 41–47; Lockwood, *Electricity, Magnetism and Electric Telegraphy* (cit. n. 65), 195–96, 228–30.

69. Tal Shaffner, *Telegraph Manual: History and Description of the Semaphoric, Electric and Magnetic Telegraphs of Europe, Asia, Africa and America* (New York: Pudney & Russell, 1859), 752.

70. See the tales in *Anecdotes of the Electric Telegraph* (London: William Tegg and Co., 1848), and William John Johnston, comp., *Lightning Flashes and Electric Dashes: A Volume of Choice Telegraphic Literature, Humor, Fun, Wit & Wisdom, Contributed to by all the Principal Writers in the Ranks of Telegraphic Literature as Well as Several Well-known Outsiders* (New York: W. J. Johnston, 1877).

71. "Telegraphic Humor," *The Telegrapher*, October 15, 1866, 41. A genderized variant of this story is expressed in the poem "Out of Adjustment" in *Lightning Flashes and Electric Dashes* (cit. n. 70), 62, where a passing telegrapher applies his expertise not to mock the local female telegraph operator but to fix a fault and thereby steal a kiss from her.

For I was a knight of the telegraph key,
 And knowing that currents when terribly weak
 Beget a fell anguish, a dire misery
 That pen can't portray nor human voice speak,
 My heart urged me forward; go in there I must,
 And do what I can to offer relief . . .

72. Shaffner, *Telegraph Manual* (cit. n. 69).

73. Laurence Turnbull, *The Electro-Magnetic Telegraph: With an Historical Account of its Rise, Progress and Present Condition* (Philadelphia: A Hart, Carey, Hart, 1853), 182. Turnbull's book is online at Google books <http://books.google.com/books?vid=HARVARD32044056200454&printsec=titlepage>.

74. Joseph Henry, "On the Relation of Telegraph Lines to Lightning," June 19, 1846, *Proceedings of the American Philosophical Society*, iv, 260–68; reprinted in *The Scientific Writings of Joseph Henry*, vol. 1 (Washington, D.C.: Smithsonian Institution, 1886), 251. See also "Meteorology in its Connection with Agriculture," Agricultural Report of Commissioner of Patents, 1859, 461–524, reprinted in *The Scientific Writings of Joseph Henry*, vol. 2 (Washington, D.C.: Smithsonian Institution, 1886), 380–84.

75. Smith, *Manual of Telegraphy* (cit. n. 64), 47; Turnbull, *Electro-Magnetic Telegraph* (cit. n. 73), 188.

76. Turnbull, *Electro-Magnetic Telegraph* (cit. n. 73), 188. The arrester with the weighted line was used by all stations operating with designed equipment by Royal House.

77. Shaffner, *Telegraph Manual* (cit. n. 69), 567–69.

78. Royal E. House, Binghamton, New York, U.S. Patent of February 20, 1874, 180090.

79. The "Bulkley protector," which had two brass plates, is described in Turnbull, *Electro-Magnetic Telegraph* (cit. n. 73), 187; a later two-line version is illustrated in Spang, *Practical Treatise* (cit. n. 21), 171. Because any office intermediate on a telegraph line would have two incoming wires, its arrester was fitted with two-line plates; see Spang, *Practical Treatise* (cit. n. 21), 170–71. A serrated grounded plate placed near the telegraph line where it is held on a pole was patented by J. L. Finn, Elyria, Ohio, on March 24, 1858, U.S. Patent 75889. The telegraphic line itself provided the serrations in a patent device that ran the telegraph line in a long zigzag with each pointed zag almost grazing the ground; J. N. Gamewell, U.S. Patent of August 7, 1855, 13389.

80. "A New Lightning Arrester," *The Telegrapher*, May 29, 1865, 100.

81. The wire card or "Carey's protector" is described in Turnbull, *Electro-Magnetic Telegraph* (cit. n. 73), 187; both it and the parallel plates are discussed in Shaffner, *Telegraph Manual* (cit. n. 69), 570f.

82. "A New Lightning Arrester," *The Telegrapher*, May 29, 1865, 100.

83. *American Telegraphic Magazine* 1, 280.

84. In an essay citing recent analyses of urban structures at stress with natural elements and written with the hindsight of Hurricane Katrina (2005), Ari Kelman reflects on what history shows about the limitations, failings, and lessons of even our best efforts to control nature; "Nature Bats Last: Some Recent Works on Technology and Urban Disaster," *Technology and Culture* 47 (2006): 391–402. While modern technological constructions benefit from extensive engineering tests and experience, the colossal failures of some are traced to organizations driven by production and management concerns where data analyses on physical, engineering, and safety issues are minimized and not admitted to the decision-making process and culture; for examples, see Eda Kranakis, "Fixing the Blame: Organizational Culture and the Quebec Bridge Collapse," *Technology and Culture* 45 (2004): 487–518; Philip Tompkins, *Apollo, Challenger, Columbia: The Decline*

of the Space Program: A Study in Organizational Communication (Los Angeles: Roxbury, 2005). The role of feedback and interaction in technological development is discussed in Henry Petroski, *Success through Failure: The Paradox of Design* (Princeton, N.J.: Princeton University Press, 2006); and Davis Baird, *Thing Knowledge: A Philosophy of Scientific Instruments* (Berkeley: University of California Press, 2004). In applying this kind of argument to education, the learners' interactive experiences with nature (or other subject matter) are crucial to developing workable understandings whereas formulaic instruction is analogous to the ungrounded rod; see John Dewey, *Democracy and Education* (1916; repr. New York: Free Press, 1944); Frances Hawkins, *The Logic of Action* (Boulder: Mountain View Center, 1969); Eleanor Duckworth, "The Having of Wonderful Ideas" and *Other Essays on Teaching and Learning* (1987; repr. New York: Teachers College Press, 2006).

85. Experiences and developments of diversity in communities are analyzed by Shelly Harrell and Meg Bond, "Listening to Diversity Stories: Principles for Practice in Community Research and Action," *American Journal of Community Psychology* 37 (2006): 365–76; specific narrative examples of diversity and community are provided in the same journal's volume 37 special issue.

86. "Lightning Conductors," *Scientific American* 1 (1859): 305–6. Spang, *Practical Treatise* (cit. n. 21), 129, used a galvanometer to evaluate the groundings of his installations. He measured the earth ground resistance of a telegrapher's earth terminal (50 ohms), and found that it was much lower (and thus more effective in conducting discharges) than that of a typical lightning rod termination (70–1600 ohms). These measurements offer a check on the rod's grounding without requiring the hazard of a lightning strike.

87. David Paul Hochfelder, "Taming the Lightning: American Telegraphy as a Revolutionary Technology, 1832–1860" (PhD diss., Case Western Reserve University, 1999); Robert Luther Thompson, *Wiring a Continent: The History of the Telegraph Industry in the United States: 1832–1866* (Princeton, N.J.: Princeton University Press, 1947).