Early Electrical Wiring Systems in American Buildings, 1890-1930

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Vintage electrical wiring systems are like a mystery inside your walls, maybe dangerous but often forgotten. This paper proposes that they are unique architectural objects worthy of study and even of preservation when possible.

Introduction

Electricity, one of the most important inventions of the modern age, is an indispensable ingredient in modern life. Behind that technology lies a fascinating history. This paper presents a historical survey of wiring systems used in late-nineteenth- and early-twentieth-century American buildings. It was compiled primarily from a series of electric-wiring and electricians’ manuals from the period, available to the public in a largely unknown basement archive at the John Crerar Library at the University of Chicago. The period from 1890 to 1930 was one of constant and entrepreneurial innovation in the electrical industry, including the development of many schemes of merit that were never widely adopted. Thus, many branches of the electrical revolution are not mentioned here but certainly warrant further research.

When electricity came into use, it was seen as heralding a solution to all the problems of gas lighting, as it neither flickered, smelled, nor smoked. In exchange, however, electricity did bring the very real risk of fire, and due to unreliable distribution of power and poor wire insulation in its early years, fires were common, if not occasionally expected. A constant push was made to develop better insulation and distribution practices that would allow electricity to be a consistently safe method of providing power for the needs of daily life.

Wiring Systems

Electricity was, at first, a toy for the rich. One of the first men to have it installed in his home was banker J. P. Morgan in 1882. Ironically, Morgan’s personal library also became one of the first interiors to burn due to an electrical fire. By 1900, however, an increasing number of buildings had electrical wiring retrofitted into their existing structures or, in the case of new buildings, installed from the start. By 1915 only eight percent of America’s homes had electricity. Those that did were most often in town or urban settings, where electricity companies had been extending their reach.

Types of Insulation

From the beginning, copper was used for electrical wires because it was known to be the best conductor; it was relatively inexpensive and available in sufficient quantities to be used by the burgeoning industry. Early electrical experiments were done with bare copper wires in inventor Thomas Alva Edison’s laboratory in Menlo Park, New Jersey, in 1879, but the system burned out before even lighting up the light bulb. Thus, some type of insulation around the wires seemed necessary. Aside from keeping the strength of the electrical current intact, insulation helped protect the wires from damage. There were many additional demands placed on insulation: heat and chemical resistance, abrasion resistance, durability, strength, and malleability. No material available in the late nineteenth century or first decades of the twentieth century had all of those traits, so many different products were developed for different needs, costs, and situations (Figs. 1 and 2).

Rubber insulation was perhaps the most commonly used insulation because of its wide acceptance by code officials, its relative durability, its suitability to situations where dampness might be a problem, as well as its superb flexibility. However, even in the early twentieth century, rubber was known to have a
grades of insulation with a higher rubber content were typically available, for higher cost, which were able to handle slightly higher temperatures, up to 140°F. The highest grade was 30 percent rubber and was required to be of the highest quality of rubber, "para," imported from the Amazon Basin in Brazil. Lower-quality rubber insulations typically were made of African rubbers, which were inferior but available at a fifth of the cost.

In order to be used in a rubber-insulated wire, the copper conductors had to be coated with a thin layer of tin in order to help them resist the sulfur that was added to the rubber during the vulcanization process. Aside from rubber and sulfur, other ingredients for the vulcanization compound varied but often included tcalc, red or white lead, and lampblack. A thin core of pure para rubber laid in strips was placed over the bare conductor wire, the entirety of which was then covered by a thick layer of vulcanized rubber. One or two layers of cloth braids or insulating tapes were placed on top of the vulcanized rubber, with the outermost required to be a braid. Tapes and braids for rubber wire were typically made of cotton and impregnated with a rubberized waterproofing compound. By the 1920s vulcanized vegetable oils were being mixed in with the rubber in order to produce rubber substitutes, thereby lowering the cost of rubber insulation. However, these substitutes did not address the physical vulnerabilities of rubber insulation to oil nor improve its poor mechanical strength. In the 1930s synthetic rubbers were developed; they did not deteriorate as quickly over time and were more resistant to oils.

Less expensive than rubber but more restricted in code-allowed uses was cloth insulation. There were two basic types of cloth insulation: weatherproof and slow-burning; they could be combined, in which case they were called slow-burning weatherproof. Weatherproof insulation was typically used for exterior wiring and had a rough surface, as well as a tendency to get sticky when warm, two characteristics that attracted lint and dust. Slow-burning insulation was often used in areas where rubber could not handle the high temperatures; it had a smooth, slick outer surface.

The prime operational advantage of cloth-insulated wire was its ability to handle higher temperatures than rubber insulation. The cloth sheaths consisted of multiple layers of cellulose-based fabric or yarn, such as jute, hemp, or cotton, impregnated with a waterproof or fireproof compound and then braided around the conductor. As cloth by itself absorbs too much water to be used safely, impregnating compounds were needed to reduce the cellulose base material's porosity and at the same time add resistance to heat and shrinkage. Before 1920 impregnating compounds were commonly fossil resins and linseed oil, while asphalt and paraffin wax were more commonly used later. The list of impregnating compounds included almost anything water-resistant, most of them quite toxic: asphalt, asbestos, coal tar, mica, rubber, linseed oil, wax, and others. To embed the compound in the cloth, several layers of the fabric were dipped in a trough of the compound and then baked until dry.

Fig. 2. Diagram depicting the multiple layers that made up the three primary types of wire insulation available at the time of its publication in 1923: a, rubber covered; b, weatherproof (triple-braided); c, slow-burning. The latter two are types of cloth insulation. From Arthur L. Cook, Interior Wiring and Systems for Electric Light and Power Service (New York: John Wiley & Sons, 1923), 254.

Fig. 3. Diagram showing the multiple coatings and jackets that make up the mechanically-protective outer coating of circular loom. From an advertisement for the Alphaduct Company, as published in H. C. Cushing, Standard Wiring for Electric Light and Power, 23rd ed. (New York: H. C. Cushing, Jr., 1917), 332.

Fig. 4. Drawing showing typical knob-and-tube installation, per requirements of the National Electrical Code. From William S. Lowndes, House Wiring and Bell Work (Scranton, Penn.: International Textbook Co., 1925), Sec. 5, p. 56.
Similar in concept but offering slightly more protection was varnished cambric insulation, also referred to as “varnished cloth.” This insulation was made up of layers of cotton or muslin fabric wrapped in a spiral and treated with a nonhardening insulating varnish, with a cloth or asbestos braid on the outside or a lead sheath for use in damp areas. This type of insulation was considerably less expensive than rubber, yet offered a larger carrying capacity and did not deteriorate in contact with oils. Its chief disadvantage was that the insulation tended to crack when bent into smaller radii, making it impractical for use on smaller wires.

For each of the types of insulation described above, the cloth sheath was braided around the conductors. For areas where dampness was a concern or mechanical interference was considered likely, a second, more durable outer sheath called “circular loom” (also called “flexible tubing” or simply “loom”) was required by code to be placed over the wires. Circular loom consisted of a seamless, woven inner tube with a braided cover, all of which was treated with a moisture- and flame-proof compound (Fig. 3). While it was not nail-proof nor truly moisture-proof despite the attempts to make it so, circular loom was the toughest insulation available before the invention of armored cable. Prior to 1900 loom was used widely for “fishing” wires through existing structures, which was often done when retrofitting new electrical systems in older buildings.

Knob and Tube

In its early years electricity was novel and considered risky and fire prone. For these reasons, electrical systems installed in the 1880s and 1890s tended to be left exposed both as a status symbol and for easy access in case of malfunction. In existing houses wires were run up stairwells and along walls, suspended on wooden cleats or secured onto the surface of the wall by metal clips or staples. While exposed wiring was considered obsolete by 1900 and was phased out in residential applications long before that, wiring suspended on cleats continued to be used for low-cost industrial installations well into the twentieth century. The earliest cleats were made of wood, but in systems installed after about 1900, the cleats were generally made of porcelain.

Exposed wiring evolved into a standardized and somewhat safer system known as knob and tube, which came to be used primarily in residences. Individual conductors (referred to here as wires, but differentiated from modern wires, which usually contain multiple conductors within a single wrapping) were run on the surfaces of walls or, more often, concealed from view along the surfaces of rafters and wood studs. Knobs were attached to the rafter beams or studs by a nail or screw through their centers and were protected from splitting due to the insertion of a piece of scrap leather between the nail or screw head and the top of the knob. Initially solid knobs made of porcelain or occasionally glass were used. Wires were suspended between knobs, and then separate tie wires were knotted around the wires at each knob in order to provide support (Fig. 4). However, these tied connections tended to come loose when used with small wires, so split knobs were required for use with no. 8 wire and smaller sizes. Split knobs were made of porcelain and consisted of a base onto which the wire slid and a cap that closed over it (Figs. 5 and 6). Along with being safer, split knobs saved significantly on labor. For installing a knob-and-tube system, the National Electrical Code required the wires to be suspended at least 1 inch above surfaces and to be at least 5 inches apart. In addition, the code recommended that two wires not be laid on the same side of a rafter and required that if they went through rafters or walls or crossed each other in close proximity, a porcelain tube was to be used. Porcelain tubes were made in lengths ranging from 6 to 18 inches with an internal diameter from 3/8 to 1 inch. When it was not possible to support a wire on a knob or when wires had to be placed closer than the required separation and/or within 3 inches of an outlet or switch, wires were to be enclosed in circular loom, described above.

Opinions on the safety of knob and tube varied. George J. Kirchgasser, author of an early electrical manual, wrote in 1914 that while metal conduit was “of course” considered the best option (as noted below), “there has been nothing radically weak proven against the knob and tube system as installed at present.” Yet there was a movement afoot as early as 1907 to get knob and tube disallowed by the National Electrician's Rules for Safe Electrical Practice.
effect a continuous version of the older exposed wooden-cleat systems, as the wires were laid directly against the wood, creating a fire hazard, especially when water got into the wall and the wood. Wiring guidebooks generally encouraged coating wooden molding with shellac or paint to discourage water infiltration. While molding was supposed to be made of hardwoods, the most commonly used and less expensive types were made of softwoods, which did not resist water well. Finally, disguising wiring as a decorative molding rail encouraged its use as a nailing strip by owners who did not know its primary purpose. The drawbacks of this system were well noted, and by 1910 the National Electrical Code limited the areas of a building where wooden-molding systems could be used in significant amounts and required that only rubber-insulated wire be used with it. Nonetheless, such systems remained legal and were phased out gradually and voluntarily by builders. During the 1920s wooden molding began to be referred to as “wooden raceway.”

**Metal Molding**

Metal molding was a product quite similar in concept to the wood molding described above, with a base and a cap that could be removed by sliding it off. While it appears to have been available before 1910, metal molding did not become successful commercially until after World War I, when it became widely used.

The National Electrical Code allowed the use of two brands of metal molding: National, by National Metal Molding Co. of Pittsburgh, and Lutz, by American Circular Loom Co. of Boston.
They enameled cross sections of metal Lutz through crimped sheeting lengths. It was produced rigid and deep. Figure 11. Drawing showing typical installation of enameled rigid conduit, commonly referred to as “black pipe.” From Lowndes, Sec. 6, p. 4. Sections of National molding were made of sheet metal and were rectangular in cross section, with rounded corners. They came in lengths of 8 feet, 4 inches. Typical dimensions for National were about 1 inch wide by slightly over a ½ inch deep. A smaller version was also manufactured, which was about ¾ inch wide and ½ inch deep. Sections of Lutz molding were galvanized sheet-metal channels, into which a flat strip of sheet metal was tucked, serving as the cap. It came in 10-foot lengths. A third system known as Wiremold, produced by the American Conduit Manufacturing Co. of Pittsburgh, was metal molding in which the base and the cap were crimped together in the factory, forming a rigid conduit requiring wires be pulled through it. It also came in 10-foot lengths. Figure 10 shows the sectional difference between the National and Wiremold systems.

Each of these three companies provided a set of fittings suited for every possible situation, but the fittings worked only on that system, requiring builders to use only that company’s products for a wiring job. Fittings were produced for transitioning from metal raceway to rigid conduit. Metal molding was installed using flat-head screws affixed to the wall through countersunk holes placed every 2 feet in the base of the molding. For property owners, metal molding was popular because it reduced labor costs by 20 to 30 percent over rigid conduit. During the 1920s metal molding became referred to as “metal surface raceway,” and modified versions continue to be used in new buildings today.

Rigid Conduit

From at least 1900, it was known that metal conduit was the best choice to protect wires from impact and water and was regarded as the best solution for a reliable electrical installation (Fig. 11). However, then as now, metal conduit was expensive. A conduit installation cost about two and one-half times more than the equivalent knob-and-tube installation. The earliest electrical conduits were made of vegetable fiber impregnated with a resinous compound or of brass, but neither proved durable. Ultimately, the shape, thickness, threading, and common length of conduit (10 feet) were derived directly from gas piping used previously. In fact, gas piping was often reused when retrofitting electricity into older buildings. Like gas pipe, conduit was sold in trade sizes ranging from ½ inch to 6 inches, but the interior diameter of the pipe was actually slightly larger than this dimension, a practice that continues today. Conduit specifically made for the electrical industry was required by the National Electrical Code to be reamed inside to free it of burrs and was typically made of softer steel that was easier to bend than commercial-grade pipe. Though round conduit was the most common type, oval conduit was also made. The advantage of oval conduit was that its profile was sufficiently thin so that it could be laid on the surface of a plaster wall and a customary coating of plaster would obscure it from view.

Two types of conduit existed: lined and unlined. Lined conduit had a layer of insulating fiber inside the outer edges of the conduit, most often a tube of paper treated with an asphaltic compound. Lined conduit had been popular because before about 1905 wires were available only with a single braid of outer covering; the layer of conduit lining was intended to provide a secondary level of protection. However, by 1910 unlined conduit was becoming more popular because the new double-braided wire could be used within it. There were three grades of conduit construction, and each grade came with or without screwed ends. The least expensive type, closed joint, consisted of a sheet of metal that had been bent into a tube, but the tube was left open, resulting in a C-shaped cross section and an open seam. When the pipe ends were threaded to be screwed together to adjacent lengths, the seams along the pipe length were welded, considered the least reliable joining method. A second type, brazed conduit, was also made from a bent metal sheet, but in all variations the seams were mechanically joined to create a circular tube. The third and most expensive type was solid-drawn seamless conduit, similar to the type commonly in use today. Conduit coatings also varied. Lower-grade conduits would be either galvanized or enameled, but higher-quality products would have both finishes applied to both the interior and exterior. While enamels varied in quality as well, they were generally black in color, leading to the typical contemporary name given to early conduit: “black pipe.”

Since most early electrical systems, including those running through conduit, did not have a ground wire, it was assumed that in the event that the wire insulation failed, the conductors would find their ground in the metal sheath that surrounded them. Rather than ignore this potential situation, manufacturers sold several systems of fittings intended to link lengths of unscrewed conduit together to produce a continu-
ous conducting surface to guide the current to the nearest ground, usually a water pipe (Fig. 12). In order to clamp any of the fittings to the conduit, the conduit had to be cleaned of its enamel coating at the connection location.

Flexible Conduit and Armored Cable

The first flexible conduit was developed and available around 1895. By the 1920s it was referred to as Greenfield, the name of a prominent manufacturer, just as it is today. Flexible conduit consisted of interlocking convex and concave strips of galvanized steel wind spirally upon each other, which produced a smooth surface on both the interior and the exterior. It was essentially conduit that could bend in any direction to facilitate more flexible installation, but because of gaps created in the metal sheath when it was bent, it was not completely waterproof. Versions made of both one and two layers of metal strips were available. Though the single-strip version was more commonly used, two layers of metal improved the moisture resistance. More expensive than rigid conduit, flexible conduit was used only in places where rigid conduit could not be conveniently used.

Armored cable was identical to flexible conduit in most respects, except that the wires were pre-drawn during manufacture (Fig. 13). Introduced in 1901 and commonly referred to as BX (after a popular brand) from at least the 1910s, it came in a standard version and one with a lead sheath just inside the outer coating, which was called BXL. Armored cable offered advantages over flexible conduit. Because there was not a need for the pulling of wires through it, the required diameter of armored cable could be smaller than the equivalent flexible conduit. Its heavy-duty construction also allowed it to become the de facto replacement for circular loom for inserting wires in existing structures.

Conclusion

What is the value in this information for preservation professionals? During field investigations, finding an antique wiring system can assist in dating a building, but it can also help tell even more of the building’s story. The investment made in a wiring system makes a statement as to what resources the individual or community that constructed the building had available to them at the time and as to the presumed permanence of the structure. Each installation also represents a moment in the history of the young but quickly evolving electric-lighting industry. Within each of the wiring systems described, an arm of entrepreneurs competed to provide the most useful, safe, or distinctive fittings. Since electrical systems are upgraded far more often than the buildings they are part of, it is likely that when a fitting or section of molding from the late nineteenth or early twentieth century is found, it is one of the few remaining examples of its type and thus worthy of preservation. However, the preservation of vintage electrical systems faces a challenge that buildings themselves do not: the ever-expanding load requirements of modern technological society and, most importantly, a slew of concerns about their safe operation, most of them quite valid. Thus, vintage electrical systems are obsolete and sometimes dangerous, but they still represent a fascinating historical story that is begging to be told and is in danger of being forgotten.

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Notes

2. Terrell Croft, Wiring of Finished Buildings (New York: McGraw-Hill, 1915). Little is known about Croft except that he lived in University City, Missouri, during the 1910s and early 1920s, but he appears to be the foremost leader in dissemination of practical information on electrical wiring in this era when a whole generation of new wiremen (as they were called then) needed to be educated in the trade.
6. African rubber was apparently inferior because of a parasite in the sap of the trees that destroyed the properties of the rubber. Brazilian rubber was not affected by the parasite because it was killed by smoke given off by a nut that grew in the area. From Sydney F. Walker, Electric Wiring and Fitting for Plumbers and Gasfitters (London: Scott, Greenwood & Son, 1908), 35.
7. Walker, 34.
8. Ferro and Cook, 8.
9. The inclusion of the pure para (“white”) rubber core at the center of wires seems to have been based more by tradition than requirements of technology. The first rubber insulation was pure rubber only, and that layer was kept even after the superior vulcanized layer was typically added around it. American Steel & Wire Co., p. 119, argues that layer to be unnecessary. The traditional construction of a rubber-insulated wire section is discussed in S.
10. Walker, 36.
17. F. C. Allsup, *Practical Electric-Light Fitting* (London: Whittaker & Co., 1892), 138; this book is available on Google Books. Attaching wires to walls with staples was known to be bad practice even by the time this book was published.
18. Ferro and Cook, 11.
21. Ibid.
22. Batstone, 56.
25. Ibid., 15.
27. Croft and Carr, 685.
28. Ibid. Softwood versions were made of American white wood and an even less durable version was made from yellow deal.
30. Ferro and Cook, 9.
31. Kirchgasser, 52.
32. Croft and Carr, 696.
35. Kirchgasser, 70.
37. Ferro and Cook, 15. So-called “brass-armored conduit” did not become widely used in the United States. It did, however, become commonly used in continental Europe.
38. William S. Lowndes, *House Wiring and Bell Work* (Scranton, Penn.: International Textbook Co., 1925), Sec. 6, p. 2.
39. Cook, 211.
40. Croft and Carr, 700.
42. Batstone, 33.
43. Ibid., 36.
44. The exact date is unknown, but on page 272 of his book, Englishman W. Perren Maycock states that the armored cable system was brought from America four or five years before the book’s date of publication (1899). Since America and England appear to have developed relatively parallel electrical industries, armored cable was likely developed not long before 1895. See W. Perren Maycock, *Electric Wiring, Fittings, Switches and Lamps* (London: Whittaker & Co., 1899).
45. Lowndes, Sec. 6, p. 15.
46. Cook, 226.
49. For an example of an electrical system that was preserved in place for historical value, see Elisabeth W. Doerrmann, “Restoration of Electrical Systems in the James J. Hill House,” *Bulletin of the Association for Preservation Technology* 18, no. 3 (1986): 56-64.

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