The John A. Roebling's Sons Company Kinkora works: independent steel and wire-making in an era of consolidation, 1904-1952

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The John A. Roebling's Sons Company Kinkora Works: Independent Steel and Wire-Making...

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by

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ABSTRACT

In 1904, the John A. Roebling’s Sons Company began construction of the Kinkora Works, a state of the art steel making, rod rolling, and wire drawing facility. During their ownership (1904-1953), the Roeblings implemented many of the significant developments in wire making at Kinkora while producing the wire used in some of America’s most noted engineering achievements, including several prominent cable suspension bridges. The persistence of private, family ownership and craft production at the Roebling Company reveals another side of American industry during an era and industry dominated by corporate conglomerations. This thesis argues that Kinkora represented a response to the growth of oligopoly in the steel industry through its construction as a “two sphere production system”: a system that implemented strategies of both mass and niche market production. Special attention is paid to how manufacturing technologies and products affected the relationships between management, labor, and engineering at the Kinkora Works, relationships that have significance for understanding the variety of forms industrial development in America took in the twentieth century.
While the technology of steel has long provided a locus for historians seeking to uncover the character and organizational structure of American industry, little attention has been paid to the role of the wire industry in this history. The more familiar ferrous products such as rails, battleship armor, structural members, and automobile steel have become icons of modernization in the United States; yet wire and wire rope have arguably played as essential a role in the growth of the industrial state. Many of the notable nineteenth- and early twentieth-century engineering achievements in the United States including the Panama Canal, Empire State Building, massive federal dam projects, and long span cable suspension bridges, supported by wire suspenders, built with cable-based excavating apparatus, material conveyance systems, or made feasible by cable supported elevators, owed some debt to wire rope. A significant amount of the wire used in these prominent symbols of American engineering was produced at the facilities of the John A. Roebling's Sons Company (JARSCO).

John A. Roebling is often acknowledged as the first manufacturer of wire rope in America, which he began to produce on his western Pennsylvania farm in the early 1840s. To expand his business, John Roebling established a wire drawing and wire rope manufacturing plant in Trenton, New Jersey, and built a reputation for engineering by pioneering the application of wire rope to long-span suspension bridge building. After John's death in 1869, his sons Washington, Ferdinand, and Charles increased both the output and range of products manufactured in their Trenton plant, and incorporated the John A. Roebling's Sons Company in 1876. By the turn of the century, corporate consolidations in the steel industry convinced the Roebling brothers that onsite steel production was imperative for their company's survival. In 1904, ten miles south of
Trenton on the Delaware River, the Roeblings began construction of a new wire facility, the Kinkora Works, with an integrated steel mill. The Kinkora Works signaled the Roeblings’ intent to compete with the US Steel Company and end their dependence on outside sources of steel. Fueled by the added wire production of Kinkora, the Roeblings were able to keep pace with the vast new markets for wire and wire rope created by the growth in turn-of-the-century construction, revolutions in transportation technologies, and demands of two world wars. This thesis examines how Kinkora represented a response to the growth of oligopoly in the steel industry – an attempt to maintain private, family ownership of a steel and wire company in a rapidly changing industrial and corporate world. I focus rather narrowly on how manufacturing technologies and products impacted the relationship between management, labor, and engineering at the Kinkora Works; yet underlying the technological developments that shaped wire making at Kinkora were fundamental changes — the mechanization of manufacturing, the increasing role of scientific research and development, and the displacement of skilled labor — that affected early twentieth-century American industry more broadly.

1.0 THE ROEBLING COMPANY AS A “BRIDGE” FIRM

The Roebling Company does not fit easily into the classifications established by business historiography to analyze the corporate character of the United States in the first half of the twentieth century. In the early years of the twentieth century, the Roebling company seemed to possess all the traits of a major industrial enterprise. By 1911, the Roebling company operated wire making facilities that were vertically integrated from its Kinkora steel mill to regional sales outlets, constructed its own worker village, and boasted of...
operating one of the largest wire mills in the United States. Roebling catalogs advertised several hundred types of wire and wire rope products, many in direct competition with those of the American Steel & Wire Company owned by the industry giant US Steel. Yet several typically nineteenth-century modes of operation persisted at the JARSCO well into the next century. From the company’s incorporation in 1876 to its sale in 1953, ownership and management rested in the hands of the Roebling family. The company remained a relatively small scale, independent steel maker in an era of corporate consolidations and conglomerations. Furthermore, although not as pervasively as in the earlier century, the Roeblings allowed their workers, particularly in the wire mills, to retain a certain measure of traditional shop floor control until WWII.

Assessing the place of the Roebling Company as either big or small business has significance for understanding the variety of forms industrial evolution in America took in the twentieth century. A ready framework for this assessment lies in both well established theories of industrial change and more recent work in small business history. For modernization of large scale operations, Alfred Chandler, Jr.’s benchmark studies of the hierarchically organized corporations and managerial capitalism has provided a point of departure for further analysis of big business. According to Chandler, the most dominant companies successfully invested in three critical areas: production facilities large enough to exploit economies of scale and scope; purchasing, marketing, and

\[\text{\textsuperscript{1}}\text{The Roebling Company could produce about 150,000 tons of wire and 150,000 tons of wire rods, compared to the American Steel & Wire Company’s capacity for 1,577,000 tons of wire and 1,455,000 tons of wire rods in 1907. The American Iron and Steel Association,} \textit{Directory to the Iron and Steel Works of the United States} \textit{(Philadelphia: The American Iron and Steel Association, 1908), 50, 121.}\]
distribution networks; and recruitment of a force of salaried managers to oversee departmentalized production. Andrew Carnegie's management of Carnegie Steel perhaps best represented the efficacy of Chandler's formula for garnering substantial control in an industry. In general, the steel industry proved readily amenable to modernization and reorganization through the investment criteria described by Chandler. Of primary concern for the history of the Roebling Company was the role of technology, which was central in generating "first mover" advantages, throughput gains, and economies of scale that were crucial to fostering the structural changes that typified Chandler's modern industrial enterprise.

Despite the influence of Chandler's work, a number of historians believed its focus on the major corporations implicitly, at least, downplayed the role of small businesses in the U.S. economy. Several localized studies of regional industries and individual companies found that Chandler's analysis of large companies did not apply to the larger spectrum of strategies employed by smaller businesses to survive or gain modest growth. In a historiographic essay for the Business History Review, Mansel Blackford noted a renewed interest in smaller contributors to the U.S. economy coincided with troubled times for prominent corporations and the resurgence of small businesses in the late 1970s and 1980s. Several works relevant to the Roebling history dealt with the unique set of factors facing family-run enterprises, the efficacy of finding market niches, and manufacturing alternatives to mass production.

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In Chandler’s scheme, the development of the organizational capabilities needed to expand in the twentieth-century corporate environment precluded the continuation of an older set of business values usually connected with family ownership. The progression of the steel industry in the twentieth century toward corporate ownership seemed to guarantee extinction for family-run steel companies, yet the Roeblings resisted a corporate buyout until 1953. In the past decade, a focus on the family business has emerged in both institutional form, the *Family Business Review*, and histories that explore how the varied goals of family ownership brought certain advantages that counterbalanced other drawbacks. Matthew Roth noted in his history of the Platt Brothers and Company that family businesses often accepted slow or no growth strategies when principles of long term survival overrode expansion and short term profits. At the Platt Brothers and Company, family management instilled a commitment to tradition that enabled the zinc fabricators to weather adversity, and the more direct lines of decision making provided a flexibility to adapt to changing speciality market opportunities. In many respects, labor relations at Platt Brothers and Company reflected the “industrial personalism” that Philip Scranton found pervasive in specialty manufacturing or “batch” production firms. Because specialty firms often contended with a high degree of irregularity and uncertainty in demand, such companies required flexible employment policies that shielded key personnel in economic downswings through selective layoffs and by cutting working hours and wages. These contingencies, Scranton suggests, “regularly gave rise to industrial personalism, practices based on shared assumptions

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about right and ‘manly’ behavior that blended respect and reciprocity while leaving room for deference with dignity." In some cases, industrial personalism evinced labor relations of an earlier era. In a study of wrought iron manufacturer A.M. Byers, Michael Santos found the family owners allowed their workers to maintain a more traditional control of the shop floor, and even unionize, to perpetuate a simpler system of managerial control. In contrast to the familiar story told of mass production industries where mechanization of production processes often prompted organizational changes and displaced skilled labor, at A. M. Byers, "changes in production techniques were not accompanied by changes in managerial structure and goals, as they had been at the corporations in the economic mainstream, and workplace relations remained largely unchanged."6

The survival of A.M. Byers and the Platt Brothers and Company in the metals industry depended on finding and securing niche markets. The viability of specialty manufacturers, offering products that often complemented mass markets, has been documented by Philip Scranton and other historians of small businesses, including James Soltow, John Ingham, and Jeremy Atack.7 Scranton’s recent work, Endless Novelty: Specialty Production and American Industrialization, 1865-1925, examines in detail the


variegated contributions of the manufacturers operating outside the sphere of mass production and managerial capitalism to the U.S. economy. Building on themes developed in earlier works, Scranton divides the production of goods into four broad approaches: custom, batch, bulk, and mass production. Custom work involved items “individually crafted for a purchaser, made singly to discrete specifications,” whereas batch goods “were made in lots of varied size, often on the basis of aggregated advance orders,” such as machine tools, precision instruments, and musical instruments. Bulk manufacturing utilized a relatively lower level of skilled labor and simpler technologies to produce staple goods in large quantities, “relying on cost-saving efficiencies to realize profits from markets filled with essentially identical goods.” Barbed and plain wire, window glass, and chains could be counted as bulk goods. Mass production, commonly associated with the Ford assembly-line and the heavy steel industry, required substantial investment of capital and engineering resources in routinized manufacturing equipment and processes for high volume, standardized items. 8

Such categories are neither exclusive nor rigidly prescriptive -- companies like GE and Westinghouse, which combined different approaches to manufacturing, constituted mixed format or “bridge” firms. To Scranton, such attempts “by very large firms to bridge several formats are especially intriguing, because they originated at both batch- and bulk- oriented companies and created complex organizational contingencies.” 9

Because the concept of “bridge firm” applies particularly well to the Roebling company, I

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9Scranton, Endless Diversity, 28.
use Scranton’s analysis to illustrate how wire manufacturing at Roebling involved aspects of custom, batch, bulk, and mass production.

The Roebling Company dwelt in the worlds of both large-scale mass production, big industry and specialty manufacturing, small business. As an independent steelmaker, the company had opportunities for growth that existed outside the oligopoly, and the Roebling history allows a look at how technology influenced the structure of industry from a new perspective, one that incorporates the unlikely combination of steel, family ownership, and mass and specialty production. Through close coordination and control of engineering, finances, and labor relations, the Roebling owners constructed a technological system of wire making that successfully bridged the regimes of batch and mass production. Ultimately, the viability of this technological system was compromised by the introduction of standardized equipment and continuous manufacturing technologies that eroded advantages of specialty production. The addition of a steel mill in 1904 initiated a transition toward mass production that culminated in the installation of continuous wire drawing machines just prior to the Second World War. Over this period, the increasing investment in mass production technologies benefitted specialty goods as well, but was better suited to full-run, large-volume products. Traditional labor relations based on industrial personalism became outmoded, and executive management began to adopt mainstream corporate practices in investment and outlook. The experience of a company that bridged mass and specialty production suggests that while a confluence is possible, separate spheres of strategies function for each mode, strategies that are inextricably linked to technological choices.
2.0 THE TECHNOLOGIES OF CONSOLIDATION

Business historian Alfred Chandler Jr. labeled the building wave of mergers and consolidations that had reshaped American industry since the 1880s “the most important single episode in the evolution of the modern industrial enterprise in the United States.”\textsuperscript{10} The formation of the United States Steel Corporation in 1901, America’s first “billion dollar company,” culminated trends that in part had been sparked by developments in the U.S. wire industry during the last decade of the nineteenth century. Since 1880, the desire to ensure a predictable and profitable market for wire goods and to gain economies of scale acted as forces of consolidation in the wire industry. Both forces were closely tied to technical developments relating to the emergence of Bessemer steel, barbed wire, and wire nails.

The first widely adopted method of mass producing steel was the pneumatic process developed by Sir Henry Bessemer in the 1850s. In a seven to ten minute scene of great violence, the Bessemer converter forced air through molten pig iron, raising the bath temperature through the reaction of oxygen and the carbon in the iron to produce steel. The Bessemer process dramatically reduced the time, expense, and skilled labor involved in steel making from earlier methods. Because the hot charge of molten pig iron required by the Bessemer converter encouraged integration with a blast furnace, high capital costs discouraged new competitors from entering the steel industry. Steel companies with integrated blast furnace/Bessemer works found it most economical to keep their blast furnaces in constant operation to avoid costly and nonproductive start-up procedures, which in turn pressured the salesmen to secure large outlets for ingots, rolled

\textsuperscript{10}Chandler, \textit{Scale and Scope: The Dynamics of Industrial Capitalism}, 79.
merchant bars, billets, and rails. Between 1870 and 1900, much of the production from the largest steel concerns such as Carnegie Steel, Jones & Laughlin, and Federal Steel was channeled towards two primary consumers, railroads and finishing mills that rolled steel into plates, hoops, tubes, and wire rods. Other major steel manufacturers sought more specialized markets to avoid ruinous competition with Carnegie's rail mills, as Bethlehem Iron (later Bethlehem Steel) did by pursuing defense contracts in armor plate and gun steel.

Looking back on the nineteenth-century conditions in the steel industry that led to the formation of United States Steel, a 1911 government report affirmed this rough division of steel companies into two camps: primary or "semi-finished" steel manufacturers, and secondary manufacturers or "finishers." Primary steel concerns depended on secondary consumers, including the wire rod mills, to purchase large amounts of steel ingots and billets. In the late 1890s, this uneasy and tenuous relationship was upset by the intention of leading finishers, such as the American Wire & Steel Company and National Tube, to begin manufacturing the steel ingots and billets normally purchased from Carnegie's group. Steps taken toward backward integration by the finishers provoked Carnegie who responded in kind by drawing up plans to build a finishing mill of enormous capacity at Conneaut Harbor, Ohio. Newspapers and trade journals recognized the ensuing battle between primary and secondary companies would result in enormous enlargement of overall capacity, and undermine existing quasi-monopolies in certain fields such as tubes, plain wire, and steel hoops and send those

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firms on shaky financial ground into bankruptcy or sale.12 Facing the unsettling prospect of ruinous competition, steel industrialists and bankers turned to combination as a means of stabilizing markets and profits -- the resulting US Steel Corporation amalgamated several leading primary and secondary companies, including the American Steel & Wire Company, itself a product of earlier mergers.

Highly capitalized steel interests had previously tried several methods to avoid the reoccurring threat of competition for mass markets — the combination solution followed a pattern set earlier in the wire industry. To the commentators of the day, the leading role that individuals played in this consolidation was clear: “the rapid changes which have taken place in the wire industry during the past few years, and particularly during the last year, have been due to the efforts of a small group of men.”13 This group included John Gates, who had entered the wire industry initially as a salesman of the product that fenced the west, barbed wire. The great demand by ranchers and farmers for barbed wire, and the relatively low-capital entry costs made the barbed wire business an attractive prospect for many. In 1880, it was reported that as little as $10,000 could fund a stock of wire, a barbed wire machine, and a small workforce needed to enter the barb wire business, if only on a small scale. In his examination of the formation of the American Steel & Wire Company, Joseph McFadden observed that most of these early small barbed wire companies “were actually processors, since their manufacturing activity did not include wire production, including only barbing or arming of plain wire previously purchased

12Ibid., 104.

13Iron Age (March 23, 1899).
from a wire rod mill."  

14 Similar to barbed wire, other wire products such as wire nails and wire cloth used a readily available raw material, such as plain (and later galvanized) wire, and a relatively simple and cheap, machine-driven manufacturing process for a mass market. Machines to manufacture nails from plain wire were introduced almost concurrently with barbed wire machines, providing a quicker, less expensive alternative to the traditional process of cutting nails from sheets. As a result, competition among the barbed wire and wire nail manufacturers led to wide price fluctuations, followed by declines in prices and profits.  

15 Some manufacturers tried to use patent rights to combat the instability of nail and barbed wire markets. Owners of the original Glidden patent on barbed wire found it difficult to enforce, as many “moonshiners” sold bootleg barbed wire to consumers on remote frontier ranches. Industry leaders turned next to informal pricing agreements and price pools, although the nail pool in 1892 and wire rod pool in 1897 proved too vulnerable to competing interests among its members to remain effective. Despite the failure of the price pools, steel industry leaders recognized the importance of wire rods as the key to controlling the wire industry. Wire manufacturers usually purchased rods, or less often, rolled them from billets, bars, or blooms provided by rolling mills. Because successful wire drawing depended upon the quality of the process that preceded it (and therefore depended on high quality rods for superior wire), the wire industry was particularly susceptible to tariffs or attempts to control the price of rods or billets. In 1897, only twelve companies rolled rods for manufacturing wire, 

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15 Ibid., 470.
barbed wire, or wire nails. That year the *Iron Age* followed with great interest the developing attempt to corner the production of wire rods:

Unless our sources of information are seriously at fault, the output of wire rods in this country has been cornered... . The control of the rod market has long been in contemplation. Various schemes have been attempted, but hitherto without success. It was an inviting field for those who desired to secure better prices for wire and wire products, as the manufacturers are so few in number and the construction of an up-to-date rod mill is so costly an undertaking that competition is not to be feared very seriously. But in endeavoring to effect a combination among rod manufacturers, the diversity of interests always defeated such schemes.\(^{16}\)

Through the efforts of two engineer/mechanics in the United States, Charles Morgan and William Garrett, the mechanization of rod rolling had made great strides in the late nineteenth century, securing economies of scale for rolling wire rods and appreciably increasing the capital costs of manufacturing wire rods. Although the wire rod pool dissolved in the summer of 1897, John Gates envisioned another means of controlling wire rods, and therefore wire prices, through the horizontally integrated trust that he had successfully used in 1892 to form the Consolidated Steel and Wire Company. After Gates' initial attempt at a larger combination of wire and wire rod companies fell through when J.P. Morgan deferred on underwriting the merger, Gates organized a smaller wire trust that included six wire and wire nail companies. Gates and his industrialist colleagues began negotiations to expand this trust, ultimately founding the American Steel & Wire Company of New Jersey (AS&WC) in 1899 which controlled 96% of barbed wire production and all the patents pertaining to its manufacture, and a sizeable percentage of

all other wire products including wire nails.\textsuperscript{17} The formation of the AS&WC showed that cheaper products, with sensitivities to economies of scale and mass markets, were particularly well suited to monopolistic or oligopolistic control. Products such as wire nails, barbed wire, and woven wire fence were conducive to mechanized production and required less skill to manufacture -- a combination that encouraged competition and market instabilities. Leading wire companies sought to forge a more predictable and structured market by controlling the supply of the raw materials through combination and raising the capital costs of entry with backward integration.

During the last decades of the nineteenth century, a period of tumultuous change for the wire industry, the Roeblings felt the pull of both the forces of oligopoly and independent ownership. As a leading wire manufacturer, the Roebling Company shared the same concern for stable prices that motivated Gates and other industrialists to attempt to minimize competition. The Roeblings actively participated in the wire pool negotiations, and \textit{Iron Age} listed the company among those included in Gates’s first attempt to organize the AS&WC. Although the Roebling brothers seriously contemplated joining the oligopoly, the familial structure of ownership prevented the sale of the company when the brothers could not agree on the terms. According to Roebling historians Clifford Zink and Dorothy Hartman, when Ferdinand Roebling discovered he would have no position in the new corporation, he raised the asking price to a prohibitive level.\textsuperscript{18} Washington Roebling recalled in his memoirs that his own violent opposition

\textsuperscript{17}\textit{Iron Age} (January 12, 1899): 26; and McFadden, “Monopoly in Barbed Wire,” 466.

\textsuperscript{18}Clifford Zink and Dorothy White Hartman, \textit{Spanning the Industrial Age} (Trenton: Trenton Roebling Community Development corporation, 1992), 87.
prevented the sale.\textsuperscript{19} In either case, the buyout offer showed one example of the self
interest and personality conflicts that were characteristic of the Roeblings’ business
decisions. Interestingly, the Roeblings’ major competitor in the wire and wire rope
business, Washburn & Moen of Worcester, Massachusetts, sold out to Gates and joined
the AS&WC in 1899. Resisting absorption by the American Steel & Wire Company
excluded the Roebling Company from trends such as the reduction of family control, the
inclusion of financial institutions in the board of directors, and the nascent organization
of managerial hierarchies taking form as a result of industrial consolidations.\textsuperscript{20} By
retaining family ownership of the company, the Roebling brothers faced an unusual
business horizon in the new century, one that entailed personal control over the direction
and shape of the technological system of manufacturing wire products, yet faced with
new competition from vertically integrated industrial giants. Their vision of success in the
changing environment was manifested in the plans for a new wire making facility at
Kinkora, N.J. Kinkora represented a dual strategy of adding mass production capabilities
in addition to securing improved control over their existing niche manufacture of high
carbon rope and bridge wire. Aside from providing the means of increasing production,
the new plant added two significant dimensions to the Roebling enterprise: on-site steel
making capabilities and a company village for housing the plant workforce.

The decision to integrate backwardly into steel production and compete against
the US Steel wire divisions was made feasible by the company’s excellent financial


\textsuperscript{20}Chandler, \textit{Scale and Scope}, 80, 85.
position and existing manufacturing base. The booming wire and wire rope business that accompanied the rapid electrification and growth of telegraphy and telephony in America, combined with shrewd investments in related industries, such as Otis Elevator and mining companies, and bond purchases in municipal bridge and cable car projects enabled the Roeblings to build new facilities without ever borrowing money. Although John Roebling’s primary interest lay in bridge building, after his death in 1869 his sons Washington, Ferdinand, and Charles greatly increased both the output and range of products manufactured in their Trenton, N.J. plant. The Roeblings advertised their company as suppliers of all types of wire products, from barbed wire to insulated copper wire for electrical purposes. The success of the expanded product line evinced several of the “first mover” advantages identified by Chandler; however, his first movers, the “pioneers or other entrepreneurs who made the three interrelated sets of investments in production, distribution, and management required to achieve the competitive advantages of scale, scope, or both, inherent in the new and improved products and processes,” generally achieved such advantages in conjunction with the development of organizational capabilities more characteristic of rationalized, hierarchical management systems. In contrast, the Roeblings gained first mover advantages through a unique division of responsibilities among the brother-owners: Charles handled engineering issues related to manufacturing; Ferdinand controlled marketing and financial decisions; and Washington retained a significant voice in the decision-making process but played a lesser day to day role because of his incapacitation resulting from contracting the bends

21Ibid., 35.
during construction of the Brooklyn Bridge. Charles’s direct role in designing equipment, supervising the manufacturing processes, and purchasing supplies provided a flexibility to pursue a variegated product line. The company responded quickly to new and vast demands for galvanized wire, telegraph wire, barbed wire, and copper wire, and adroitly made the transition from drawing iron to steel. The capabilities rested largely on the links between the highly skilled immigrant labor, engineering, and management that centered on the figure of Charles Roebling. Charles’s engineering skills were complemented by Ferdinand’s business acumen. Despite a few misguided ventures, including investment in a fraudulent electric lightbulb company, on the whole, Ferdinand proved an astute judge of profitable markets and developed a nationwide network of distribution outlets by the end of the nineteenth century. He organized exhibitions at the Philadelphia Centennial and Chicago Columbian Exposition that capitalized on the association of the Roebling name with the Brooklyn Bridge (despite the fact the Roebling Company had little involvement in the project) currently under construction, and produced detailed catalogues and wire rope handbooks to advertise the Roebling products and expertise.23

As the turn of the century approached, the Roeblings’ pursuit of certain markets

22In the last three decades of the nineteenth century, the Roeblings relied largely on German rod rollers, English wire drawers, and Swedish iron and steel workers to manufacture high quality wire.

23Although John A. Roebling provided the initial design for the Brooklyn Bridge and his son Washington Roebling directed construction as chief engineer, the bridge wire contract was awarded to J. Lloyd Haigh of Brooklyn, New York. Washington actually sold his shares of stock in the Roebling Company to prevent impairing his brothers’ chance at gaining the contract by a conflict of interest. Nevertheless, under questionable circumstances, Haigh won the bid. David McCullough engagingly covers the wire contract controversy in The Great Bridge (New York: Simon & Schuster, 1972), 372-96.
reflected the changing structure of the wire industry. As mentioned earlier, the Roeblings initially touted their company as a source of all kinds of wire products. In the products most affected by the consolidation of the industry, such as wire nails, barbed wire, and copper wire, the Roeblings began to see profit margins shrink. The company eventually abandoned nails and barbed wire, and never realized significant profits from copper wire either. The Roeblings responded to the loss of these mass markets by establishing subsidiary divisions to manufacture specialty products such as woven wire cloth, insulated wire and cable, and the Roebling "Fire-Proof" Construction Company. To Scranton, such diversification into alternative finished goods exemplified the common strategy of "profusion" employed by batch manufactures. Profusion, by Scranton's definition, refers to "the capacity to create a wide range of intermediate or final goods and the strategy of amassing sufficient lumps of diverse demand to keep the works going or expanding."24 The Roeblings' primary avenue of profusion looked to the past, as they renewed a connection with long-span suspension bridges by obtaining the contract to supply and erect the bridge wire for the Williamsburg Bridge to Manhattan in 1898.

3.0 BRIDGE WIRE, WIRE ROPES AND SPECIALTY PRODUCTION

When John A. Roebling devised a crude wire rope in 1840 to replace the hemp ropes used to haul canal boats up inclined planes, he introduced a technology that proved to be a defining force governing the shape of the future Roebling enterprise. The wire that comprised John Roebling's early ropes had long been manufactured for a variety of uses, including chain mail and card wire used in the textile industry, but his primary

24Scranton, "Diversity in Diversity," 34.
concern centered on the emerging application of wire to bridge construction.

Roebling emigrated to the U.S. in 1831 from Prussia with two advantages that would serve him well in the future: a technical education difficult to obtain in a country with few engineering schools and exposure to recent trends in European civil engineering. Roebling applied his training as an engineer and knowledge of wire rope making to bridges, pioneering several methods of construction and engineering many of the early suspension bridges in America, including the Lackawaxen Aqueduct and the Niagara and Cincinnati bridges. His role in the celebrated Brooklyn Bridge project was cut short in 1869 by a fatal injury suffered while surveying the site, but the Roebling Company's manufacture and erection of the wire cables in seventeen major bridge projects, including the Williamsburg, Manhattan, George Washington, and Golden Gate bridges continued an association with bridge building that lasted well into the twentieth century.

Bridge wire called for exacting standards of manufacture. Prior to the Brooklyn Bridge, expensive wrought iron (later high carbon steel) was primarily used for the wire that had to sustain the weight of the bridge deck, variable loading from wind and traffic, and resist corrosion from the elements. John Roebling initially relied on outside sources, largely imported English wire, for many of his bridges because wire of the necessary quality and quantity was not available in the United States. Bridge wire was a specialized product in several respects. As steel gained wider use in wire drawing, bridge applications required a relatively large diameter, high quality, high carbon steel wire with ductility, hardness, and tensile strength characteristics that had very limited use in other applications. Manufacturing bridge wire involved specialized cleaning, heat treatment,
and galvanizing processes employed for only certain products in the Roebling line. The Roeblings sought to improve their position in bridge bids by coupling cable erection with supplying bridge wire. Washington Roebling's previous experience in bridge work, most notably on the Brooklyn Bridge, and the company's familiarity with specialized splices, fasteners, connectors, and handling wire proved an effective combination. The success of the Bridge Division set a precedent in the wire industry and bridge construction that was later followed by US Steel.

Prior to bridge wire, the Roeblings achieved profusion through another specialty product, wire rope. John Roebling's pioneering work in wire rope led to an early domination of the U.S. wire rope market, and his sons perpetuated this control through patents on methods and equipment pertaining to wire rope manufacturing, and the construction wire rope machines of unique sizes and capacities. Aggressive advertising and boosting of different types of wire ropes for use in power transmission systems, cable cars, and marine applications resulted in demand that taxed the capacity of the Roeblings' Trenton facilities.

A wide variety of wire ropes were developed to best match the many uses surfacing in industrializing America. Wire could be stranded in a wide assortment of patterns tailored for general or specific uses. A Roebling wire rope handbook classified wire rope as "a machine composed of a number of precise, moving parts, designed and

25Some historians estimated the Roeblings produced nearly 100% of the wire rope made in the United States before 1880. Zink and Hartman, Spanning the Industrial Age, 75.
manufactured to bear a very definite relation to one another." By changing the quality and size of the steel wire, the "lay" of the wire, and the core, rope flexibility, durability, and strength could be widely varied to suit applications from elevator cables to airplane control cords. Depending on the use, wire rope could be manufactured to custom orders, or made in batch and bulk quantities.

Despite an increasing demand for wire rope in the early decades of the twentieth century, the complexities of manufacturing quality wire rope discouraged potential competitors. Even during a production crisis brought by World War I that initiated a government-sponsored cooperative organization of the wire industry, a Roebling publication listed only seven manufactures of wire rope (with a significant percentage of production divided between two concerns, the Roebling Company and the American Steel & Wire Company).  

While bridge wire and wire rope seemed to qualify as specialized, or "batch" products, ultimately both shared a lineage with common plain wire. Well into the twentieth century, the basic stages of manufacturing all types of wire had remained relatively static over the preceding three hundred years. Except for its steam power source, the first wire drawing bench in Trenton differed little from seventeenth-century equipment used to draw wire. In essence, the basic process consisted of pulling a metal rod through a die, thus reducing the cross sectional area and correspondingly elongating the rod. The rod or wire was paid off from spools or "swifts" and pulled through a die  

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and wound by a driven cylindrical "block." Until electric motors gained wider use after
the turn of the century, a central steam engine typically powered the blocks through a set
of belts, drive trains, and gears. The wire was stripped from the block by hand, and
placed on a new swift feeding a block with a smaller die if further drawing was necessary.
Repetition of this procedure, commonly called "a draft," further reduced the cross
sectional area to the desired size. A skilled wire drawer typically handled from six to
eight "single draft" machines at any given time. Improvements in gearing, dies, and
motive force advanced the productivity of wire drawing, but until continuous (multi-
draft) drawing machines replaced the venerable single draft units, few economies of scale
could be realized in the wire mills. Increasing production capacity required the
installation of additional single draft machines and the concomitant hiring of skilled
attendants. For this reason, a large number of wire drawing companies, mostly small
concerns, continued to exist and fill niche markets with wire products in the twentieth
century.

4.0 THE CONSTRUCTION OF A TWO SPHERE PRODUCTION SYSTEM

The Roebling Company located their headquarters in Trenton, where construction
of their first wire drawing facility began in 1848. The Roeblings' Trenton facilities, the
site of several nineteenth- and twentieth-century wire drawing innovations, have a rich
history of their own that would add to several studies that document the significance of
Trenton as an early center of industry in the United States. This thesis, however,
concentrates on the Kinkora Works, built ten miles south of Trenton near Florence
Township in 1904, because Kinkora marked the commitment of the Roeblings to a "two
sphere production system”: a system that implemented strategies of both mass and niche market production. On one hand, Kinkora reflected the increasing rationalization, mechanization, and systematization typical of the wire and steel industry; on the other, the success of the system designed at Kinkora depended on the skill of a chief engineering designer, skilled attendants and engineers, many rule of thumb practices, and traditional worker control of several key processes, including wire drawing, cleaning, and heat treatment.

The site layout and selection of technologies emphasized optimum flexibility, control, and efficiency, reflecting the progressive rationalization of technological systems in early twentieth-century American industry. The farmland purchased for the new plant presented the Roebling system builders with a clean slate. Unimpinged by city growth, the experience of fifty years of manufacturing wire rope could be tangibly expressed in the Kinkora Works. Because the giant 30 ton and 80 ton rope machines built by Charles Roebling to strand wire into wire rope were too heavy and cumbersome to move from Trenton, the Roeblings dedicated the Kinkora facility to primarily making wire that would be sold in coils or finished as rope, insulated wire, or flat wire at Trenton. The Delaware River front property provided an easy access to barge traffic, and ensured a ready supply for the large quantities of water needed to make steel. Several outfalls spilled plant wastes into the river, and the Roeblings used their riparian rights to expand the property by dumping slag from the steel mill along the river front to provide foundations for future buildings.

Characteristic of many turn of the century industries, site layout emphasized process flow efficiency and future expansion. Considering the scale of Kinkora, the debt
owed the principle engineer, Charles G. Roebling, was substantial. Charles arranged the location of all buildings and equipment for the plant and the village, laid out plans for much of the machinery, and integrated a network of railroad tracks to facilitate the transfer of materials. Placement of the steel, blooming, rod, and wire mills in parallel reflected the trend toward continuous processing on a longitudinal axis -- process flow traveled roughly in a straight line from end to end, allowing anticipated growth to be met by lengthwise extensions.

In contrast, the arrangement of buildings at Trenton had impeded efficient flow between processes. Even property purchased there to supplement the original 1848 twenty-five acre plot afforded insufficient flexibility to accommodate the dynamic forces shaping the wire industry in the last half of the nineteenth century. Much of Kinkora’s design and construction drew on lessons learned from Trenton. Charles Roebling centrally situated a boiler and power house to provide steam and electricity for the entire plant, alleviating the waste and inefficiency of Trenton’s scattered boilers. The expansive site allowed for single-story design of most buildings, avoiding the fire hazards and difficulties of transmitting power to multi-story structures that plagued the Trenton plant. While a combination of steel and timber supported the structure of many Trenton mills, at Kinkora Charles used only steel construction. Steel as a structural material had several advantages over timber -- it allowed a wider building design and was thought to reduce the danger of fires.

Although Kinkora was considered a state-of-the-art facility, Trenton’s


29Zink and Hartman, Spanning the Industrial Age, 111.
shortcomings had not provided the only inspiration. In May 1902, the Grand Crossing Tack Company began ground breaking for a plant outside Chicago to manufacture wire, woven fence, nails, and staples. Although the original construction included only a steel mill, blooming mill, boiler house, and machine shop, the parallel layout of the buildings and placement of the rail lines anticipated the Kinkora design. Similarly, Kinkora’s arrangement of buildings and equipment loosely followed that of the American Steel & Wire Company’s new Donora Works in Donora, Pennsylvania, detailed in the December 1903 issue of *Scientific American.* Although reports on new plant constructions in *Iron Age, Iron Trades Review, Engineering,* and *Engineering News* often lagged a year or two behind erection dates, the trade magazines illustrate Kinkora’s antecedents in the wire industry.

Underlying the generic aspects of the Kinkora plans, however, an orientation toward specialty production shaped the final form of the plant. In plants intended to draw low carbon wire (generally used for mass market products such as nails, plain wire, and bale ties), rod bundles usually traveled to the cleaning house before entering the wire mills. At Kinkora, an arterial railroad line delivered rod bundles directly to the Tempering Shop for a patenting treatment largely unique to processing high carbon wire. The Roeblings built a large Galvanizing Shop that accommodated several galvanizing rigs for applying a corrosion resistant coating of zinc to wire that became common practice in specifying bridge wire after the Brooklyn Bridge.


The steel mill design also reflected the dichotomous nature of mass and batch production at Roebling. Rather than build a Bessemer steel works, the Roeblings turned to open hearth furnaces, which were fast becoming the preferred method of steelmaking.\(^\text{32}\) By 1904, most wire rod mills in the United States were rolling steel from open hearth furnaces.\(^\text{33}\) In the open hearth process, a regenerative system of checkers preheats a mixture of air and gasified fuel before it is burned over the charged materials. This process creates temperatures high enough to slowly convert the iron into steel under controlled conditions, yielding steel that was superior to that made in Bessemer converters. The open hearth design did not require as costly or complex a step in backwards integration as the common practice in Bessemer steel production. In the early stages of open hearth steelmaking, operators charged the furnace with cold metal, usually some combination of pig iron and scrap, and heated it gradually to the proper temperature. Since Bessemer converters required a molten charge that could be more economically supplied by an integrated blast furnace facility, the choice of an open hearth

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\(^{33}\)In 1904, *The Directory to the Iron and Steel Works of the United States* listed thirty-two producers of wire-rods. Ten of these thirty-two mills had integrated open hearth furnaces, another twelve were owned by companies that produced their own open hearth steel at nearby steel mills, two were planning to add open hearth furnace facilities, and another two were idle, leaving only six companies, relatively minor members of the wire-rod industry, without iron or steel making capabilities or using older methods of making steel in 1904. See Appendix A.
steel mill involved a substantially less drastic undertaking. The ability to use scrap as a portion of the charge in open hearth furnaces particularly benefitted the wire industry. Hot rolling ingots and rods, and wire drawing generated substantial quantities of scrap steel, providing a local source of raw materials. Although the open hearth furnace offered advantages for all wire mills, the improved control of the chemical composition of the steel ingots was especially attractive to companies drawing wire for highly specialized purposes, such as bridge or heavy duty wire. In addition to freeing the Roebling company from the vagaries of the steel market, the open hearth allowed for exacting control of the chemical composition so crucial to the hardness, toughness, strength, ductility and uniformity of the end product.

The size and type of the open hearth furnaces further reflected a flexibility of design for mass and batch production. The Kinkora plans initially specified six moderate size furnaces of 30 ton capacity. After adding three more 30 ton furnaces by 1910, the Roebling steel mill had a sizeable total output that compared well with the Worchester South Works of the American Steel & Wire Company (the former main steel facility of Washburn & Moen), but the Roebling capacity was supplied by relatively small furnaces. The smaller furnaces facilitated control of the heat, an important concern for making steel of a precisely specified composition. Steel companies manufacturing low carbon steel or lower quality, high volume products, were less concerned with close control of the heat, and built larger furnaces. Furnace size had increased since the early 10 to 15 ton open hearth furnaces of the early 1890s, but unresolved problems with lining endurance,


cooling, and crane lifting limits restrained the growth of furnace size in the first decades of the twentieth century. Despite the technical obstacles, by the time the Roebling furnaces became operational in 1907, some companies were seeking greater economies of scale by building 50 ton or larger furnaces.\textsuperscript{36} Although solution of the salient technical limitations during the 1920s initiated a period of growth in furnace size, the Roebling Company chose to increase capacity by adding new furnaces rather than greatly enlarge existing ones.\textsuperscript{37} Even as some furnace sizes exceeded 300 tons in 1930, the common experience in the wire industry held that heats intended for superior quality bridge wire should not exceed 100 tons, and the Roebling furnaces were less than half this size.

In addition to the question of size, any installation of open hearth furnaces posed a question of whether to build basic or acid types. The “basic” or “acid” designator referred to the chemical reactivity of the material used in refractory linings of the furnace or converter. When Henry Bessemer developed his famous converter in the 1850s, he fortuitously used a low phosphorous pig iron that minimized the deleterious effect of excessively high phosphorous content in iron that embrittles steel. The silica-based refractory bricks that lined early Bessemer containment vessels did not eliminate phosphorous from the molten metal.\textsuperscript{38} Low carbon steels tolerate higher percentages of


\textsuperscript{37}From 1910 to 1920, the company constructed three additional furnaces. By 1930, eight of the twelve open hearth furnaces had been modestly enlarged to a capacity of 40 tons, and a double spout 80 ton ladle was installed in 1941.

\textsuperscript{38}The acid character of the silica lining did not provide the free metal oxides needed to precipitate oxidized phosphorous, therefore allowing no removal of
phosphorous, but high carbon steels are sensitive to even 0.08 percent.  

Thomas and Gilchrist's patent for a basic lining made from a mixture of lime and magnesia that made phosphorous removal possible solved the "phosphorous problem," ushering in an era of new possibilities for the use of high phosphorous ore in steelmaking. Although America possessed sizeable reserves of low phosphorous ore well into the twentieth century, adoption of basic linings in U.S. open hearth furnaces in 1892 added a flexibility with respect to raw materials. While the basic process successfully reduced the ill effects of phosphorous, it encouraged the use of a lower quality ore or pig iron that generally did not result in a superior grade of steel. The quality of basic steel improved with later developments in metallurgy; however, during the early twentieth century, companies desiring to furnish quality high carbon products relied on acid Bessemer converters or open hearth furnaces. The need to continue manufacturing high carbon bridge wire and extend the product line to offer a variety of low to medium carbon products dictated that both basic and acid open hearth furnaces be installed at Kinkora. In short, the dual acid-basic type arrangement afforded a high degree of flexibility: the furnaces could utilize either coal gas, natural gas, or oil as a fuel, accept a charge of both iron and scrap, and produce a wide assortment of different types of steel for both bulk and batch goods.

In other sections of the plant, most notably in the Blooming and Rod Mills, innovative modifications, hydraulic lifting tables, charging devices, and overhead cranes phosphorous from the molten iron.


increasingly mechanized manufacturing and introduced new continuous processing technologies that represented the latest efforts to improve productivity. Such developments contributed to greater economies of scale that combined with a 233 percent larger production capacity, enabled the Roebling Company to compete in bulk and mass markets for wire and wire rope. WWI tested the limits of Kinkora's capacity, as myriad needs arose for wire and wire rope during the war, providing a period of high profits for the Roeblings. However, unlike the assembly line commonly connected to the emergence of mass production in the automotive industry, mass production of wire at Kinkora from 1904 to 1930 retained many skilled workers and rule of thumb practices.

41See Appendix B.

42Most importantly for the Roeblings, a major percentage of the demand consisted of high carbon products. Two technologies that revolutionized warfare during World War I, the submarine and airplane, provided a nearly unlimited demand for high carbon wire and wire rope. To defend against the crippling threat of the submarine, the allies developed steel nets to prevent penetration of harbor entrances by enemy U-boats, and devised a vast North Sea minefield to block entry into vital shipping lanes. The large diameter, high carbon steel wire used in submarine nets required minimal reduction in Kinkora's wire mill number one before being woven into rectangular sections of various sizes. Wire mill number one also drew the bulk of the wire that made the JARSCO the leading producer of wire rope for the North Sea minefields. The North Sea mines were kept in place by high quality, high carbon steel wire rope to prevent a failure that would result in the surfacing of submerged mines and the potential to migrate into the path of allied ships. Kinkora wire mills also manufactured high performance fine wire used in aircraft stays, guys, and controls. Orders for aircraft wire kept the fine wire mill number two at Kinkora in nearly constant operation, producing some five million feet by 1918. Additional demands, including both low carbon steel and copper telegraph and signal wire, generated work for nearly every department.

In the company records, a conspicuous gap exists for the profits earned during the war years, but enough capital was generated to finance extensive new construction at Kinkora. A rough indication of the profitability of the wartime market can be gained from the board of director's financial report that recorded a net profit for 1923 as $7,508,866.01, "the best in the history of the Company with the exception of 1917." John A. Roebling's Sons Company, "Index of Minutes," Roebling Collection - Rutgers University.
The slow rate of innovation in wire drawing technology exhibited what historian Thomas Hughes calls a “reverse salient,” a technological bottleneck, that perpetuated traditional practices in related processes. Because the length and speed of wire that could be drawn was limited by die materials, there was less need to improve the throughput capacities of the cleaning and baking processes that preceded wire drawing. Until continuous process technologies were adopted in all facets of wire production, the technological system at Kinkora moved toward mass production with several nineteenth-century modes still in place.

5.0 LABOR RELATIONS AT KINKORA

In the first decades of operations at Kinkora, a wire drawer might have looked upon his job at Roebling with satisfaction for several reasons, but the high degree of control he held over his work environment and the home he rented from the company undoubtedly were positive factors. Industrial personalism played a key role in defining the interrelated set of expectations between wire drawers, foremen, engineers, ancillary work crews, and management that governed work in the wire mills. Certain reciprocal agreements that determined the distribution of work among the wire drawers were not stipulated by management but evolved as a code of mutual understanding. During a normal production day, each wire drawer was expected to draw a certain allotment during his shift — if he drew too much wire, he reduced the amount of wire the next shift could draw, decreasing his successor’s wages that were based on the piece rate system, and setting an unwelcome precedent in the increased output expected of each man. The wire drawers also retained a high degree of autonomy in the production process, due in part to
the slow rate of innovation in wire drawing technology that perpetuated traditional practices. Except for the noise of several hundred wire benches, the Roebling wiremen during the 1920s worked in an environment that had undergone few significant changes in thirty years or differed much from the smaller wire mills. According to a popular 1921 manual of steel manufacturing, drawing wire was considered “an art,” reinforcing the traditional notion of wire drawers as craftsmen. The wire drawer may have operated a machine that appeared simple to understand, but this simplicity belied the complexity of manufacturing a quality finished product. Wire drawers started as apprentices or “helpers” in the wire mills and acquired the skill of threading and loading wire onto a block, controlling the speed and reduction of the draft, and monitoring die wear only with substantial experience. As in many crafts, wire drawers guarded trade secrets, such as their personal combination of lubricants used in the die boxes to reduce die friction, and took pride in the ability to lift 150 to 250 lb. coils of wire prior to the mechanization of handling and stripping by overhead cranes. Because some wire required particularly skilled drafting, a measure of prestige was associated with certain benches, such as the bridge bench. The Kinkora wiremen also gained satisfaction knowing their workmanship made vital contributions to the war effort and bridge engineering.

Those involved in cleaning, heat treating, rod rolling, or finishing operations also found traditional skills maintained by rule of thumb practices. This is not to say innovation stagnated in these areas, but it proceeded in a coordinated fashion, with the cooperation of equipment operators, work crews, engineers, and in some cases, with
upper level management directly involved in engineering process changes.\footnote{See Appendix B.}

Although the persistence of traditional practices might have minimized some labor unrest, for an ownership intent on keeping apace of the latest developments in manufacturing technologies, another means of pacifying labor was needed. The construction of a worker village to secure a loyal workforce placed the Roeblings on a path taken by several turn-of-the-century industrialists. Capital requirements precluded smaller manufacturers from building villages, but company-owned housing constituted a strategy employed more by family or individually owned enterprises than corporations. Philip Scranton notes that, like the Roeblings, several entrepreneurs of specialized manufacturing facilities including George Pullman, George Westinghouse, and Henry Disston, built worker villages to implement their particular brand of welfare capitalism. Other industrialists such as Milton Hershey, George Vanderbilt, and textile families like the Whitins, Cheneys, and Drapers could also be added to this list.\footnote{Budgett Meakin, Model Factories and Villages: Ideal Conditions of Labour and Housing (London: T. Fisher Unwin, 1905).}

When the Roeblings decided to build a new facility, proximity to Trenton, good transportation networks, and water availability heavily influenced site selection. Ten miles south of Trenton, a farm abutting the Delaware River and bounded on one side by the tracks of the Pennsylvania Railroad fit many of the required criteria, yet its rural location ensured that labor would not be readily available. Undaunted, the Roeblings planned an entire community, complete with a general store, auditorium, inn, tavern, and recreational facilities to support their industrial enterprise.
The village represented an answer to troubling labor problems that periodically interrupted the flow of production at their Trenton facilities. By the turn of the century, the technologies of steel wire making that made sense in terms of output, cost, and efficiency had ramifications for the composition and skill of the workforce. Tending open hearth furnaces operating at three thousand degrees Fahrenheit or lifting heavy coils of wire was a demanding environment that became the domain of unskilled Eastern European immigrants arriving at the turn of the century. In the past, skilled English and German wire drawers and Swedish iron masters had constituted a vital component of the JARSCO workforce, but the new scale of immigrant employment presented problematic social concerns -- how would workers from rural backgrounds adapt to the expectations of a modern industrial mill amidst a foreign culture? Attempts by employers to assimilate their foreign labor frequently followed a paradoxical course; reconciling the American concept of liberty with the desire to eliminate aspects of the worker's Old World heritage proved a difficult task. A balance was needed between liberty and social control, between personal freedoms and restriction.

Although born of necessity, the Roebling village was a form of social control that symbolized the rationalization of labor concerns and the desire to create a predictable workforce free of union influence. In several cases detailed by other studies -- the Pullman experiment, the stultifying financial stipulations that characterized some mining towns, and Ford's heavy-handed intrusion into the personal lives of his workforce -- the balance swung disproportionately to the advantage of the corporate employer.45 The

Roeblings made no attempt to mask the purpose of the town: Roebling village was “not designed in any sense as a Utopia, or built as the result of philanthropic ideals, but rather frankly contemplated as an industrial town which was designed to pay its own way.”

Yet in its execution, the Roebling plan for the village managed to reasonably equalize the benefits sought by employer with those granted the employee. The provision of a hospital, considerable recreational facilities, parks, and a home ownership association reflected a real concern for the quality of life of the Roebling workers. The construction of substantial brick houses equipped with “the usual conveniences” deviated from the small, shoddy clapboard houses of some company towns. Maintenance crews repainted and wallpapered the homes every three years, made repairs, and landscaped the village free of charge. The company built an elementary school, library, paid for town taxes and the salaries of the police and firemen, and rented the houses at rates well below those of the surrounding area. Even when the Depression revealed the deep inadequacies of corporate socialism, JARSCO used the village to aid its workforce by extending credit in


46Schuyler, _The Roeblings_, 372. This business pragmatism resonated in several of the industrialists identified by Budgett Meakin in his study of model company towns. An executive at the Reeves Engine Company wrote of their attempts to provide the very best conditions for their workers: “we can get a better grade of men, who are able to do finer work and more of it, by following this course.” Meakin, _Model Factories and Villages_, 23.


49Zink and Hartman, _Spanning the Industrial Age_, 123.

36
the general store and waiving rental fees for a number of years.\textsuperscript{50}

Nevertheless, because the town provided housing for only 40 percent of the workforce, the low rates of rental and close proximity to work assured a waiting list that was filled by careful selection of reliable workers of long employment. In essence, this assured the Roeblings of their "core" workforce when market downswings precipitated layoffs and wage reductions. Job position determined the size and proximity of the houses to the plant, which in practice, divided the neighborhoods into ethnic enclaves that survive to this day. Assessing the financial merit of the Roebling village, \textit{Iron Age} voiced the intent behind the Roebling brothers' construction of a company town:

\textit{Does it pay? Not in dollars and cents. As a matter of fact, the running expenses almost exactly balance the income -- in many years creating a deficit which the company has had to underwrite... . But it most assuredly does pay in the larger sense. It pays in attracting men of the better kind. It pays in promoting permanence of employment. And hence avoiding costly labor turnover. It pays in promoting health of employees, and thus reducing absences and errors and accidents.}\textsuperscript{51}

The Roeblings hoped that a "Progressive Town" would ameliorate labor discontent and secure a better workforce.

Kinkora offers an example of the development of labor relations in a two-sphere production system. Until WWI, the direct involvement of upper management and engineers in designing equipment and supervising and modifying production processes built strong ties between owners, engineers, and skilled workers, particularly wire drawers. The industrial personalism fostered by these links extended to the workers' broader notion of community, as long service and hard work was expected to be rewarded

\textsuperscript{50}\textsuperscript{}John Hodson, interview by author, 28 July, 1997.

\textsuperscript{51}\textsuperscript{}"Industrial Village on Sound Basis," \textit{Iron Age} (January 3, 1924):14.
by a company home. Throughout the greater part of their ownership of the worker village, the Roeblings recognized that involvement in their workers' lives carried a certain responsibility, and they worked to cultivate a mutually beneficial interdependency of company and community by providing for recreation, education, comfort, and health. If viewed as a means of preventing unionization, the village was a success: unions failed to organize Roebling workers until 1941. In addition to fostering a sense of industrial personalism, the village enabled the Roeblings to maintain traditional cycles of wage increases and decreases to match profit fluctuations, and it secured a core of critical workers, a crucial concern for batch manufacturers.

The village, however, also had its drawbacks. Maintenance of the houses, stores, utilities, and streets exacted high fixed-capital costs and managerial energies, and the success in securing loyal, long term employees conflicted with adopting technological innovations in mass production. Kinkora residents by design were the workers with the greatest experience in older methods of production. When newer high-throughput technologies displaced certain skills, the company could only damage its community relationships by terminating housing leases.

6.0 COMPANY IN TRANSITION, 1920 - 1940

Following WWI, two roughly contemporaneous developments in the steel industry — the emergence of standardized, continuous technologies and advances made in metallurgy and metallography — began to replace the nuanced technologies at Kinkora with more universally used equipment and practices. The system of wire making became structured more by generic technology than by the design of an individual system builder.
like Charles Roebling. In particular, the construction of a new blooming mill and rod mill, and the introduction of carbide die-equipped continuous wire drawing machines, flash bakers, and straight line cleaning, marked a period of transition during the decades between 1920 and 1940 to continuous production. This transition was never smooth, but punctuated by technical innovation in specific areas that in some cases affected only one mill or stage in the wire manufacturing process. Concomitantly, rule of thumb practices gave way to more systematic monitoring, automatically controlling manufacturing, and scientific analysis of products and processes.

For this study, the impact of the transition to mass production technologies on the advantages of specialty production and familial ownership is of particular interest. First, the move toward standardized, purchased equipment and scientific methods began to increasingly divide ownership, engineering, and labor into separate spheres and redefine relationships, responsibilities, and focus. Second, as mechanization sporadically displaced skilled labor and reduced the autonomy certain skilled workers had enjoyed with older methods of manufacturing, labor relations based on industrial personalism became increasingly less appropriate and effective in the mass production workplace. Third, keeping pace with latest developments in bulk wire manufacturing necessitated a commitment to high capital technologies that produced the best payoffs when running at or near full capacity. Economies of scale in wire drawing gained through the introduction of continuous wire drawing machines heightened the importance of continuous demand for sustaining profits, a development which boded ill for the production of batch and custom goods at the Roebling Company.
6.1 Standardization and the Principles of Scientific Management

As Thomas Misa details in *Nation of Steel*, Fredrick Taylor’s efforts to reform factory management provided turn-of-the-century engineers with the beacon of “scientific management” to shed light on inefficiencies holding back production. While some of Taylor’s methods proved ineffectual, Misa emphasizes the importance of Taylor as giving substance to an ideology that engineers enthusiastically adopted and interpreted as a means to wrest control of the shop floor from blue collar workers. The transformation of craft practices to standard procedures through “scientific” analysis — for example, with appropriate testing apparatus, empirical evidence, and engineering judgement, a “cherry red heat” became 1450 degrees Fahrenheit — empowered engineers to supercede traditional craft knowledge.⁵²

The shift of control over innovation in the steel and wire industry from the mechanical experimenters and inventive tinkerers to more scientifically trained engineers and scientists motivated by Taylor’s principles proceeded rather slowly at Kinkora. Evidence of a more scientific approach to wiremaking at the JARSCO was first visibly manifested in a concentrated research laboratory and the emphasis placed on rationalizing production through increased controls and testing that made its earliest inroads in the steel mill and heat treatment shops. Taylor’s work on high speed steel, informed by his “scientific methods,” suggested several lessons that could easily apply to other steel products undergoing heat treatment. As previously mentioned, patenting constituted a heat treatment of critical importance for the Roebling high carbon products, and under

Charles Roebling's guidance, had followed a rather empirical and untheoretical path toward improvement. In the late 1920s, the development of sophisticated testing and analytical equipment played a symbiotic role in improving the metallurgical and metallographical theories that began to elucidate the factors influencing metal hardness, strength, ductility, and toughness. Subsequently, plant engineers required more detailed information concerning the effect of temperature and time on the stress and strain properties of wire. From an early date the Roeblings had used tension testing machines to monitor wire performance, but since the 1920s, a proliferation of new testing apparatus and equipment controls in the plant testified to the greater desire to measure, record, and tightly control processing. Between 1927 and 1928, engineering orders called for automatic controls connected to thermocouples for billet furnaces, pyrometers on annealing pots and open hearth furnace roofs, chemical analyzers for the steel chemistry lab, and constant time-temperature recording instruments for the tempering shop. Although several product testing machines, such as bending testers for wire mill number one and torsion testing machines in wire mill number two, had been incorporated in the

53As part of the work on prestressing, in 1928 the Roeblings installed the world's largest tensioning apparatus, the Riehle Automatic Testing Machine, to apply the enormous loads needed to test bridge suspender wire ropes, and extensometers to measure yield point and ultimate elongation in wire. 1928 also inaugurated a movement toward instrument control of steel chemistry when the Roebling chemical lab purchased an Enlund Carbon Apparatus. Later additions including the Laco Sulphur Determination Apparatus and a spectroscope chemical analyzer dubbed "Iron Mike," permitted a more precise and systematic control of steel composition that replaced earlier reliance on less accurate methods and the melter's skill. For a description of the Riehle Testing Machine, see "World's Largest Machine Breaks New York Bridge Cables," *Iron Trade Review* (May 9, 1929): 1263. Types and installation dates of various testing equipment found in John A. Roebling's Sons Company, "Engineering Orders," Environmental Protection Agency - Edison, New Jersey storage facility.
mills since 1906, these technologies served more to measure the quality of the wire than to quantify the craft skills of the wire drawers. From a manufacturing standpoint, the goal was to provide a more uniform and consistent treatment of the steel; however, systematizing production as dictated by the engineers tended to induce the "dissociation of the labor process from the skill of the workers" that transformed craftsmen into processors (requiring a different sort of skill). 54

Roebling engineers paid greater attention to process in part because their earlier role as equipment designers diminished with the growing reliance on vendors for machines that accompanied the implementation of continuous technologies. Since Charles Roebling's death in 1918, instead of relying on in-house design, the JARSCO purchased much of the major equipment to update the Kinkora mills, notably the Morgan billet reheating furnace and rod mill, the Chapman-Stein soaking pits, Westinghouse bell-type and Lee-Wilson annealers, Morrison flash bakers, and Vaughn and Morgan-Connor continuous wire drawing machines. 55 Naturally this reflected the increasing difficulty in sustaining an internal capacity to develop each individual component in the increasingly sophisticated system of manufacturing wire — after WWI it became more practical and cost-effective to let specialized vendors concentrate efforts on specific equipment. Practices that had once varied as a function of unique equipment designs assumed a more standardized form as certain technologies found universal use in the wire industry.

Engineers involved in daily plant floor operations, who earlier had designed equipment,


55 JARSCO, "Engineering Orders, 1925-1941."
turned to improving process efficiency and optimization of labor inputs.

The division of responsibilities between the Roebling brothers functioned relatively well during their tenure, but as death upset the balance of executive power at Roebling, the transfer of leadership between generations precipitated a new form of family ownership. During the 1920s, the executive board did not experience the decline in active family membership that Chandler described as typical of most large scale enterprises in the United States, but to handle the expanded scale of operations, the company management structure increasingly resembled a corporate, departmentalized hierarchy. Separated from component design, the engineering aspect of executive management focused on process efficiency and assessing the financial costs of adopting new technology.

By the late 1940s, the traditional tight family control of the business had made an uneven transition into the corporate climate of postwar America. The owners continued a Roebling custom that eschewed borrowing to support expansion or plant improvements, but as the board became dominated by family members not actively involved in the daily operations, the character of company investment changed. Zink and Hartman found that unlike the earlier generations of leadership, “demand for increased dividends was often satisfied through aggressive management of the investment account for profit rather than using it to promote the wire rope business or to serve as a source of company

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56In June, 1921, executive directors appointed non-family members to the Executive Committee, and established a committee to direct plant operations. The Roeblings dissolved the Executive Committee in 1929 to implement a salaried, hierarchical structure of general plant managers, assistant plant managers, and department heads. John A. Roebling’s Sons Company, “Promotions, Wages, and Salaries.” Index of Minutes, Roebling Collection - Rutgers University.
financing."\textsuperscript{57} Despite allocating some $13.4 million (much of it to Kinkora) for plant improvements in the late 1940s, the board decided the future held a decreasing likelihood that substantial re-investment in facility upgrades would produce sufficient profits. Without recourse to the past practice of adjusting wages to balance fluctuations in revenues due to unionization, the JARSCO began to view ownership of a plant best suited to producing a high volume, high carbon steel product with a waning market future as an untenable prospect. On January 1, 1953, the Roebling family sold their manufacturing facilities to Colorado Fuel & Iron for $23 million. As the post-war owners increasingly viewed production and manufacturing from a financially oriented perspective that was characteristic of the post war corporate climate, mere survival or acceptance of slow growth, goals that inspired smaller family-owned companies like the Platt Bros. & Company, had no place at Roebling.

6.2 The erosion of industrial personalism

Ultimately, the fears of many Kinkora workers that mechanization would eliminate their skilled positions materialized in several key areas. In 1928, construction of the new Morgan continuous rod mill displaced the rod catchers who fed the wire rods into the older Garrett type rod mill. Following the introduction of continuous wire drawing, straight line cleaning, and flash bakers during WWII, many cleaning and wire mill workers found their skill and knowledge no longer applicable in the new system of production, and their old reciprocal arrangements invalidated by the rearrangement of the

\textsuperscript{57}Zink and Hartman, \textit{Spanning the Industrial Age}, 169.
shop floor. It is not clear if workers were laid off or simply found other jobs within the company, but the displacement of the skilled wire workers occurred during a period of labor unrest in the steel industry and union militancy. In the early 1940s, union organizers penetrated the Roeblings' control of labor for the first time, and a strike followed in April 1941. The connection between the disgruntled wiremen and the unionization of the Kinkora workers deserves further investigation, but additional factors related to the national labor climate of the early 1940s undoubtedly played a significant role.

Since its incorporation in 1876, the JARSCO had resisted unionization of the workforce through various means: the company town of Roebling, profit sharing plans, a pension plan, an employee association, and company publications. Prior to unionization, the JARSCO’s practice of weathering periods of poor sales by wage cuts precipitated several strikes, but the unwillingness of the executive board to negotiate with striking workers reflected the hardheaded, pro-business mentality of the first quarter of the twentieth century that placed a premium on financial stability. The end of the JARSCO’s ability to mitigate losses with wage reductions after unionization compounded the bleak market predictions of the late 1940s. Moreover, the integrated steel mill had troubling labor ramifications for the overall cost of production. As Zink and Hartman point out, strikes in 1949 and 1950 that forced the company to raise wages to the level of the rest of the steel industry put the company at a disadvantage: “while regular steel production typically required 10 man-hours per ton, the labor-intensive wire rope production required roughly 25 hours per ton. The resulting high expense of the company’s products weakened its competitiveness against other wire rope producers that operated under less
expensive contracts with unions other than the United Steelworkers." Unionization had further ramifications for the traditional bond of community between management and the workforce. Company management of Roebling village no longer provided either an incentive to employment or an efficacious means of controlling labor. Now a financial liability, the JARSCO sold the houses in the Roebling village, largely to its existing tenants, in 1947.

6.3 Mass Production, Full-run Technologies, and Market Positioning

Sale of the Roebling company to a corporate leader in the steel industry revealed the owners' pessimistic assessment of their long term market position. What had happened? Scranton argues that the demise of certain specialty producers such as Baldwin Locomotive and Cramp shipyards resulted from their inability to adopt mass production techniques. In evaluating the effect of the economic slump that followed WWI on specialty producers, Scranton holds, "do these tales of stagnation and decline imply that production by integrated anchors had run its course by the mid-1920s, unless practiced by companies diversifying toward mass-market lines? Not at all. Pullman, the electrical giants [Westinghouse and GE], Gorham, and Steinway all devised paths to profitability while retaining their specialist capabilities." Scranton could add the Roeblings to this list of integrated anchors that turned to their batch, specialty products to support the

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58 Zink and Hartman, *Spanning the Industrial Age*, 167.

59 Scranton, *Endless Novelty*, 22, 347. Scranton distinguishes between different types of specialty manufacturers in three groups: "Integrated anchors," the giant enterprises making the "big stuff" of America's infrastructure (locomotives, heavy machinery) and top-of-the-line consumer goods (Steinway pianos, Gorham silver); "networked specialists;" and "specialist auxiliaries".
company in market downswings. In the early 1920s, the Roeblings also endured a slump after the frenetic pace of wartime production, and relied on its Bridge Division for new orders. Bridge building prospects had brightened in the 1920s with the rapid expansion of automobile ownership. The Roeblings benefitted from this new source of bridge demand by successfully bidding for several long-span suspension bridges.\textsuperscript{60} Bridge projects further supported the company through the Great Depression, during which the Roeblings obtained the contracts for the San Rafael, Golden Gate, and Tacoma Narrows bridges. In addition to bridge wire, the Roeblings had historically diversified their other specialty products to complement mass markets items, and continued this practice during the 1940s by installing a lead tempering rig for specialty wires and a tire bead wire rig, investing in cutting edge work in the prestressed concrete department, and establishing the Roevar magnetic wire program in 1946 at the cost of 1.7 million dollars. The Bridge Division’s work in pioneering prestressed concrete in the United States later proved an attractive asset that influenced Colorado Fuel & Iron’s decision to buy out the owners in 1953.

Although Scranton has shown that specialty products remained an integral part of America’s industrial base, his technological model for such production was not borne out by the Roebling experience. In terms of their technology, Scranton finds “batch producers relied on ‘general purpose’ machinery and tools that could be adapted to multiple tasks, rather than seeking ‘dedicated’ mechanisms devoted to accelerating the

\textsuperscript{60}The Hudson River or George Washington (1927), Maumee River (1929), St. John’s (1929), Marysville (1930), Grand Mere (1930/1), Dome (1930/1) Bridges.
Vertically integrated wire companies, however, found the technologies that realized economies of scale in both bulk and batch production involved single purpose, high capital equipment and optimum payoffs when running at or near full capacity. This was particularly the case in the rod and blooming mills where energy losses sustained during start-up procedures could be minimized by keeping the reheat and heat treating furnaces at constant temperatures and the Morgan rod mill and blooming mill functioning continuously. The plant infrastructure, including the electrical and steam generating facilities, massive water pumping works, and coal gas converters (prior to switching to oil as the primary fuel), operated most efficiently under constant load. While well suited to meeting wartime demand, the bulk production system did not adequately accommodate the wide fluctuations that typified batch markets. Furthermore, the vertically integrated, mass production system of wire manufacturing had an inherently high cost of obsolescence. By the 1950s, the Roeblings considered the price of updating the continuous rod mill, the steam powered blooming mill, and replacing the open hearth furnaces with electric furnaces prohibitive, but compelled by a substantial increase in demand for electricity from both the plant and village, they built a new electric generating station in 1948.

Of the many innovations that aided the mass production of wire, the introduction of continuous wire drawing machines had perhaps the greatest impact on manufacturing at Kinkora. Installation of the continuous wire drawing machines began just prior to WWII, and resulted in a number of significant changes. Continuous wire drawing

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61Scranton, “Diversity in Diversity,” 38.

62See Appendix C.
marked the decline of the skilled craftsmanship associated with Roebling single draft machines that distinguished the company among their competitors. Quality wire still required skilled oversight of the entire production process, but the skill increasingly resided in machine operators using standardized equipment that ostensibly produced the same wire for any company. The superior hardness of carbide dies in the continuous machines enabled much longer lengths of wire to be drawn, thus realizing several economies of scale related to handling, shipping, and wire rod size. Thus, with the advent of continuous wire drawing, economies of scale could be gained at each stage of the wire drawing process, from pig iron to the reel of wire on the shipping decks.

The increased wire drawing capacity spurred technological changes in related processes such as cleaning and baking to supply the wire mills with more wire rods. Because the cost of a continuous wire drawing machine was not prohibitively high for a smaller company, the transformation of wire drawing from a more labor intensive to capital intensive operation did not necessarily drive smaller concerns from the industry. Between 1939 and 1963, the number of companies drawing wire from purchased wire rods modestly expanded from 135 to 198, but the bulk of wire continued to be drawn by larger, integrated firms.\textsuperscript{63} Here, in the larger scale firms, the effect of continuous wire drawing is difficult to discern from the Census of Manufacturers due to their system of classification, but the sale of two of the major independent, family-run firms, the Wickwire Company and the John A. Roebling's Sons Company, to CF&I in the 1950s was indicative of the declining prospects of integrated, independent wire manufacturing.

Since the 1920s, the system of wiremaking at Kinkora experienced a gradual uncoupling of executive management from system technology and labor control. New standardized technologies increased plant output and improved the uniformity of the products, but also separated ownership from engineering and imparted an increasingly financial focus. Threatened by deskilling and hoping to end cyclical wage policies, labor sought its own voice through unionization. A system once designed to operate in mutually supportive manner was now less viable in following the breakdown of traditional coordination between management, labor, and technology.

7.0 CONCLUSION

In advertising and company publications, the Roeblings called attention to the uniqueness of their history and experience. A centennial commemorative celebrated the lasting family ownership of a steel works on the scale of the Roebling Company and highlighted the role of the company in American wars from the Civil War to WWII. Past leaders loomed large in the Roebling memory, the builder Charles Roebling, the financier Ferdinand, bridge engineer Colonel Washington, perhaps surpassed only in significance by the mythologized figure of John Roebling, “the father” of wire rope in America. The distinctive contributions of these individuals and the Roebling Company could be found in the tangible markers of American engineering ingenuity, the great cable suspension bridges.

In certain respects, the Roebling history is indeed unique, but it provides more general insights into the nature of the steel and wire industry as well. The Roebling Company followed a path of opportunity outside the boundaries set by the corporate steel
oligopoly, and its history illustrated the degree to which family ownership was amenable to an expansionist agenda built upon a rationalized production system. From a perspective informed by Scranton’s analysis of integrated anchors, the wire industry is particularly interesting because custom, batch, bulk, and mass production used the same basic technologies. The Roebling case suggests that vertical integration was a crucial step for companies in the wire industry. Vertical integration proved problematic for a bridge firm like the Roeblings, as the demand needed to realize economies of scale in the steel, rolling, and wire mills was not always provided by specialty markets. Our overall understanding of the wire industry would benefit from further comparative studies of how other types of wire companies, family-owned or “mini” mills dedicated to solely to drawing wire, fared against the integrated, corporate firms.

The analysis of the Roebling Company has depended on the language of economics and technology -- vertical integration, economies of scale, capital versus labor intensive manufacturing, batch versus mass production -- to examine how the company fit into the industrial frameworks established by Chandler and Scranton, but ultimately the dialogue of personal relations among the owners, labor, and Roebling community figured prominently in the Roebling history. Unlike family owners of smaller companies that sought long term moderate growth or simply survival, passing up markets that intruded too closely on the domains of larger enterprises, the Roeblings largely pursued expansion and maintained a progressive attitude toward technological innovation, despite its suitability for mass markets. Industrial personalism, which extended to the workers’ families through the company village, constituted an essential element of a technological system designed to operate in both batch and mass production spheres.


________. The Roebling Story. Trenton: John A. Roebling’s Sons Company, 1941.

________. Suspension Bridges - A Century of Progress. Trenton: John A. Roebling’s Sons Company, n.d.


**Articles and Newspapers**

“A Wire Rope of Exceptional Type.” *Iron Age* (February 16, 1911): 444.


*Trenton State Gazette*

*Company Periodicals*

*Blue Center*
Roebling Magazine

Roebling Record

Roebling Wire and Wire Rope Catalogues, 1898, 1907, 1916, 1928, 1930 1931, 1945

Archival Collections

Roebling Collection, Special Collections - Rutgers University, New Brunswick, New Jersey.

Roebling drawings and boxed collection, Environmental Protection Agency - Edison storage facility, Edison, New Jersey.

Interviews

Louis Borbi, mill worker, John A. Roebling’s Sons Company, former President of the Roebling Historic Society

Carl Friday, Electrician, John A. Roebling’s Sons Company

John Hodson, Wire Foreman - Wire Mill No. One, John A. Roebling’s Sons Company

Don Sayenga, former Manager, Bethlehem Steel Corporation; Cardon Group Consulting

Paul Varga, Railman, John A. Roebling’s Sons Company
This table illustrates the high number of companies with access to open hearth furnace steel for the manufacture of wire-rods in 1904. Except where noted, Bessemer converters are not included in the table.

<table>
<thead>
<tr>
<th>COMPANIES MANUFACTURING WIRE-RODS</th>
<th>ASSOCIATED STEEL WORKS WITH OPEN HEARTH FURNACES (plant name, location, #, )</th>
<th>capacity and type</th>
</tr>
</thead>
<tbody>
<tr>
<td>US Steel</td>
<td></td>
<td></td>
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<tr>
<td>American Steel and Wire Company</td>
<td>Allentown Works, Allentown, PA</td>
<td></td>
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<td></td>
<td>American Works, Cleveland, OH</td>
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<td></td>
<td>Anderson Works, Anderson, IN</td>
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<td></td>
<td>Braddock Works, Braddock, PA</td>
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<td></td>
<td>Consolidated Works, Cleveland, OH</td>
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<td></td>
<td>Donora Works, Donora, PA</td>
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<tr>
<td></td>
<td>H.P. Works, Cleveland, OH</td>
<td></td>
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<tr>
<td></td>
<td>Newburgh Steel Works, Newburgh, OH</td>
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<td>Newburgh Steel Works, Newburgh, OH</td>
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<td></td>
<td>New Castle Works, New Castle, PA</td>
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<td></td>
<td>Rankin Works, Rankin Station, PA</td>
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<td></td>
<td>Sharon Works, Sharon, PA</td>
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<td>Waukegan Works, Waukegan, IL</td>
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<td>Worcester Works, Worcester, MA</td>
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<tr>
<td></td>
<td>Worcester works, MA</td>
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<tr>
<td></td>
<td>Everett, Middlesex, MA</td>
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<tr>
<td></td>
<td>Vandergrift Works, MA</td>
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<td>Wood's Works, McKeesport, PA</td>
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<tr>
<td></td>
<td>Donora Steel Works, Donora, PA</td>
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<tr>
<td></td>
<td>Duquesne Steel Works, Cochran, PA</td>
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<tr>
<td></td>
<td>Homestead Steel Works, Munhall, PA</td>
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<td>Sharon steel Works and South Works, Sharon, PA</td>
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<td>Federal Steel Company - Illinois Steel Company</td>
<td>Joliet Works, Joliet, IL</td>
<td></td>
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<td></td>
<td>South Works, South Chicago, IL</td>
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<td>Alabama Steel and Wire Company</td>
<td>Gadsden Works, Birmingham, AL</td>
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<td>Birmingham Works, Ensley, AL</td>
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<td>Ashland Steel Company</td>
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<td>Ashland works, Ashland, KY</td>
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<td>Carpenter Steel Company</td>
<td>Reading works, Reading, PA</td>
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<td>Reading works, Reading, PA</td>
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<tr>
<td>Colorado Fuel and Iron Company</td>
<td>Minnequa Rolling Mills and Steel Works, Pueblo, CO</td>
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<tr>
<td>Minnequa Rolling Mills and Steel Works, Pueblo, CO</td>
<td>6-50 ton (1 acid, 5 basic)</td>
<td></td>
</tr>
<tr>
<td>COMPANIES MANUFACTURING WIRE-RODS</td>
<td>ASSOCIATED STEEL WORKS WITH OPEN HEARTH FURNACES (plant name, location, #)</td>
<td>capacity and type</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>------------------</td>
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<tr>
<td>Crucible Steel Company</td>
<td>Aliquippa Steel Works, Aliquippa, PA</td>
<td>1-15 ton acid</td>
</tr>
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<td>Atha Steel Works</td>
<td>Black Diamond Steel Works, Pittsburgh, PA</td>
<td>8-various (5 acid, 3 basic)</td>
</tr>
<tr>
<td></td>
<td>Crescent Steel Works, Pittsburgh, PA</td>
<td>2-15 ton (unknown)</td>
</tr>
<tr>
<td></td>
<td>Howe, Brown &amp; Co., Pittsburgh, PA</td>
<td>1-15 ton (acid), 1-20 ton (basic)</td>
</tr>
<tr>
<td></td>
<td>La Belle Steel Works, Allegheny, PA</td>
<td>2-15 ton (acid)</td>
</tr>
<tr>
<td></td>
<td>Pittsburgh Steel Works, McKees Rocks, PA</td>
<td>1-20 ton (acid)</td>
</tr>
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<td>Cuyahoga Wire and Fence Company</td>
<td>Cuyahoga Falls Plant, Cuyahoga Falls, OH</td>
<td>no iron or steel making capabilities</td>
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<tr>
<td></td>
<td>no iron or steel making capabilities</td>
<td></td>
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<tr>
<td>Dillon-Griswold Wire Company</td>
<td>Sterling works, Sterling, IL</td>
<td>no iron or steel making capabilities, plant idle</td>
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<tr>
<td></td>
<td>Sterling works, Sterling, IL</td>
<td></td>
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<tr>
<td>Grand Crossing Tack Company</td>
<td>Grand Crossing Works, Grand Crossing, IL</td>
<td>2-40 ton (basic)</td>
</tr>
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<td></td>
<td>Grand Crossing Works, Grand Crossing, IL</td>
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<tr>
<td>John A. Roebling’s Sons Company</td>
<td>Kokora Works, Roebling, NJ</td>
<td>planning 6-30 ton open hearth furnaces (3 acid, 3 basic)</td>
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<td>Kokora Works, Roebling, NJ</td>
<td></td>
</tr>
<tr>
<td>Kokomo Steel and Wire Company</td>
<td>Kokomo works, Kokomo, IN</td>
<td>no iron or steel making capabilities</td>
</tr>
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<td>Kokomo works, Kokomo, IN</td>
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<tr>
<td>McCoy-Linn Iron Company</td>
<td>Milesburg Iron Works, Milesburg, PA</td>
<td>no open hearth facilities, 3 single puddling furnaces</td>
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<td>Milesburg Iron Works, Milesburg, PA</td>
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<td>National Steel and Wire Company</td>
<td>New Haven Works, New Haven, CT</td>
<td>2-25 ton (acid)</td>
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<td></td>
<td>National Steel Foundry Company, New Haven, CT</td>
<td></td>
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<tr>
<td>Page Woven Wire Fence Company</td>
<td>Monessen works, Monessen, PA</td>
<td>2-15 ton (basic)</td>
</tr>
<tr>
<td></td>
<td>Monessen Plant, Monessen, PA</td>
<td></td>
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<tr>
<td>Pittsburgh Steel Company</td>
<td>Monessen Works, Monessen, PA</td>
<td>planning to install basic open hearth furnaces</td>
</tr>
<tr>
<td></td>
<td>Monessen Works, Monessen, PA</td>
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<td>Trenton Iron Company</td>
<td>Trenton Works, Trenton, NJ</td>
<td>no iron or steel making capabilities</td>
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<td>Trenton Works, Trenton, NJ</td>
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<tr>
<td>United States Wire and Nail Company</td>
<td>Shousetown works, Lewis Block, PA</td>
<td>no iron or steel making capabilities, idle and for sale</td>
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<td>Shousetown works, Lewis Block, PA</td>
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<td>Washburn Wire Company</td>
<td>Phillipsdale Plant, Phillipsdale, RI</td>
<td>2-15 ton (1 acid, 1 basic)</td>
</tr>
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<td></td>
<td>Phillipsdale Plant, Phillipsdale, RI</td>
<td></td>
</tr>
<tr>
<td>Wickwire Brothers</td>
<td>Cortland Works, Cortland, NY</td>
<td>2-30 ton (basic)</td>
</tr>
<tr>
<td></td>
<td>Cortland Works, Cortland, NY</td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX B - Plant Processes and Manufacturing Technologies

Making steel wire from raw materials involved several phases, which at the turn of the century took place in separate mills, shops, or "houses." Rail cars carried pig iron, scrap iron, and various additives to the steel mill that produced cast steel ingots, measuring some twelve inches square (in later years, ingots had a larger cross-sectional area), five feet tall and weighing close to one ton. The ingots were heated and rolled to a smaller cross-section and longer length in the blooming mill, reheated, and rolled into a rod measuring approximately one quarter inch in diameter and several hundred feet long in the rod mill. Rods were heat treated, cleaned of scale and baked before entering the wire mills. At a diameter near 0.207 inches (No. 5 gage), it becomes more expedient to further reduce a rod by drawing it through a die than to continue rolling. This drawing process as described in the body of the thesis was done in the wire mills. While some wire was shipped straight from the wire mills, several products required a finishing treatment, such as galvanizing, that applied a thin, metallic protective coating to the wire. With the exception of wire drawing, covered in Appendix C, the following provides a brief discussion of the development of the various processes, and how they fit in to the Roebling scheme of production.

The Steel Mill

As previously mentioned, the installation of open hearth furnaces at Kinkora followed a general trend in the steel industry. The specifics of furnace design, however, differed widely among plants. The variety of equipment types, steel mill layouts, and operating...
practices slowed the diffusion of open hearth technology, with the result that experience
gained in one situation was not readily transferable to others.\textsuperscript{64} Attempting to wrest
maximum output and quality from the furnaces, chemists and engineers kept the methods
and equipment used in open hearth steelmaking in constant flux. In the 1890s, the work
of Ernest Saniter, J.H. Darby, Benjamin Talbot, Ernst Bertrand and Thiel in
desulphurization, recarburization and charging molten metal revealed that a standardized
practice in steel making was not to be realized in the near future. These innovators
introduced different methods for improving the quality of steel by focusing on the effects
of varying its chemical composition and temperature during the melting process.\textsuperscript{65}
Similarly, open hearth furnace design in America branched in the late 1880s, when H.H.
Campbell and S.T. Wellman introduced two types of tilting open-hearth furnaces that
rotated the furnace on its longitudinal axis to ease slag removal and tapping operations.
Perhaps deterred by the higher cost and complexity of the tilting furnace, Charles
Roebling hired Swedish furnace engineer J. Ecklund from American Steel & Wire
Company’s Worcester South Works to design stationary open hearths at Kinkora.\textsuperscript{66}
Ecklund brought several countrymen to assist in the construction and operation of the
furnaces; thus, the core of the first steel men at Kinkora were known as “the Swedes.”

Since 1880, open hearth furnaces had steadily gained acceptance in the United
States, surpassing the Bessemer converter in 1908 as the most favored method of making

\textsuperscript{64}Gold, et al., \textit{Technological Progress and Industrial Leadership}, 537.

\textsuperscript{65}For a concise description of the significant experiments in late nineteenth-century steelmaking, see Barraclough, \textit{Steelmaking}, 270-97.

\textsuperscript{66}“The New Roebling Works,” \textit{Iron Age} (April 26,1906)
The definitive manual of steelmaking in the U.S., *The Making, Shaping and Treating of Steel*, summarized the advantages of the open hearth process:

(1) By the use of ore as an oxidizing agent and by the external application of heat, the temperature of the bath is made independent of the purifying reactions, and the elimination of the impurities can be made to take place gradually, so that both the temperature and the composition of the bath are under much better control than in the bessemer process. (2) For the same reasons, a greater variety of raw materials can be used and a greater variety of products can be produced ... (3) A very important advantage is due to the increased output of finished steel from the same amount of pig iron, which means that fewer blast furnaces are required to produce a given tonnage of steel.  

Although open hearth furnaces continued as the favored method of steel making in the first half of the twentieth century, the development of electric arc furnaces and the basic oxygen process (BOP) gained wider use in the post-war steel industry.

**The Blooming Mill**

Rolling in most blooming mills utilized either a two-high reversible or three-high mills. In deciding to adopt a less expensive three-high arrangement, Charles Roebling sacrificed some flexibility with respect to the size of the billet to gain a higher output rate. Because the three-high mill required a means of lowering and raising the ingot as it passed through the upper and lower sets of rollers, Charles patented a hydraulic tilting table with a

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69 For a discussion of the advantages that encouraged use of electric furnaces and the BOP, see ibid., 29-34.
system of guides that simultaneously turned and guided the ingot into the proper position between the rollers as it was lifted.

During his last years as company president, Charles Roebling had continued to modify manufacturing at Kinkora with an eye towards future expansion. His plan to overhaul the blooming mill was carried out in 1920 by his nephew, company president Karl G. Roebling, who incorporated a new 36" mill to replace the existing 26" mill. The new system rolled harder steel more easily and quickly, and permitted future consideration of using larger ingots. Operation of the steam-powered, 36" blooming mill continued until the cessation of steel manufacturing in 1982.

The Development of Rod Mills

At the turn of the century, two competing rod mill arrangements, named after their inventors William Garrett and Charles Morgan, dominated rod rolling in the United States. Both methods represented improvements on older technologies — Garrett on the Belgian or looping mills and Morgan on George Bedson’s straight line continuous mill — and each offered certain advantages and drawbacks. The Roeblings transferred their existing Garrett-type mill and experienced operators from Trenton to Kinkora, but Charles modified this arrangement by adding a group of continuous roughing stands to the looping mill to gain the benefits offered by each type. This combination of looping and continuous mills in rod rolling, although replaced by a fully continuous arrangement in 1928, later proved a favored design in many modern rod mills.

Garrett mills faced an increasingly strong challenge from continuous mills that benefitted from improvements in electric motors and gearing that remedied timing...
problems. While the modified Garrett mill in rod mill number one offered certain advantages, the rods cooled non-uniformly on the looping floor, imparting a variation in temper that especially affected high carbon stock. Moreover, the limitations on bundle size in the Garrett mills became more acute as improved dies of either chilled cast iron or hardened steel allowed longer lengths of wire to be drawn. Furthermore, as the Morgan Company led research and development efforts to refine continuous rod mill technology, it began to capture a larger share of the growing continuous rod mill market. Although purchase of a Morgan rod mill represented a substantial investment, it held the potential to roll larger bundles and increased output rates for similar products. Despite these trends, the first construction to supplement capacity at Kinkora used a Belgian-type looping arrangement well-suited to rolling rods of various shapes and sizes. This smaller, second rod mill built in 1922 was likely added to maintain a level of flexibility for specialized rod production that was difficult to achieve in continuous mills and to sustain rod rolling during the eventual alteration or replacement of rod mill number one.

Although the demand heightened the need for increased rod production, the record bridge spans encouraged adoption of a rod rolling technology that could produce larger rod bundles, and concomitantly, longer wire. In 1928, buoyed by orders for elevator cables and the 1927 contract for the Hudson River (George Washington) Bridge, the JARSCO recorded its highest level of sales in an eighteen-year period. Subsequently, the board of directors allocated funds for a four-train 18" billet mill needed to roll a billet of a smaller cross sectional area and a Morgan rod mill in December of 1927. In contrast to

Charles Roebling’s personal design of the old mill, the new mill featured nearly all Morgan equipment, including a Morgan billet reheating furnace and rolling stands, installed by Morgan engineers. While the skilled catchers used in the old looping mill could still find work in rod mill number two, their role was substantially diminished and separated from production of the standard high carbon rod now rolled by the new number one rod mill.

Heat Treatment

The heat treatment of wire and rods varied widely between products. Turn-of-the-century wire manufacturers recognized two primary divisions in heat treating metal: tempering and annealing. The label of “Tempering House” common to wire plants in the first decades of the twentieth century reflected the generalized understanding of heat treatment that lumped together several different forms of heat treatment. For example, the primary function of the Kinkora tempering house was patenting rather than tempering. Although future developments in metallography revealed the radical transformations that distinguished the various processes of heat treatment, the ingrained misnomer of the “tempering” house remained.

Methods of annealing metal after cold working to restore ductility had been in use for centuries, and were particularly useful in alleviating internal stresses generated by wire drawing. The annealing house used an established system of heating coils of wire in sealed pots to the desired temperature range (dependent on the desired properties — “full” anneal austenitized the steel at higher than critical temperatures, “process” anneal involved sub-critical heating) followed by a period of slow cooling. Because annealing
was primarily applied to low carbon steel, less attention was focused on innovating the process at Kinkora.

In contrast, the Roeblings paid great attention to patenting, a form of heat treatment particular to high carbon wire. Patenting developed in a highly proprietary manner that reflected the influence a single technique could have on the quality and success of a product. During the first years of patenting wire in the second half of the nineteenth century, a noted consultant and historian of the wire industry, Kenneth Lewis, described the secrecy surrounding early efforts:

What I chiefly remember about patenting is that the earlier installations were surrounded by high board fences so others in the room could see nothing that went on inside. Entrance was through locked doors, wire was passed in through holes in the fence and the finished product passed out in the same manner, and the workers inside were confined to specific tasks so that practically nobody could know the whole process. 71

Even well into the twentieth century, the Roeblings guarded the details of their patenting process. Tours granted the New York branch of the Society of Electrical Engineers and visiting Japanese steel manufacturers in the 1930s excluded inspection of the patenting area. 72

Patenting imparted both high strength and a measure of ductility to high carbon steel before drawing, thus permitting several drafts of the wire without prohibitive loss of the high strength needed for its use in bridges or superior wire ropes. Patenting roughly consisted of heating to a temperature well above the critical range to reform the


72Interview with John Hodson; and “John A. Roebling’s Sons Company’s Vast Wire Plant Thrown Open to the New York Electrical Society: See Hudson River Bridge Cables Made and Tested,” *Telephone and Telegraph Age* (May 16, 1929).
microstructure of the steel, followed by a relatively rapid and controlled quench. In theory, detailed knowledge of the relation between time, temperature, quenching medium, grain size, and the microstructure awaited the electron microscope and research in metallography that began to broaden understanding of material science after 1930. Evidence of the particularly empirical approach to developing an effective system of patenting in the early wire industry had two salient manifestations. First, the successful set up and operation of heat treatment rigs generated a cadre of skilled engineers that, by force of reputation, could influence the marketability of the product. Years of experience in determining effective combinations of equipment and practice played a particularly crucial role in patenting innovation. Second, confusion marked discussion among experts in the wire industry, as late as 1932, regarding exactly what was happening to the wire as it passed through the stages of the patenting process. Without a comprehensive theoretical guide, practical experience and reasoned experiment fueled the progress of patenting technology. If the case of Kinkora can been taken as the likely state of wire plants in general, the design of patenting rigs was a protean endeavor, with many variants coexisting within the tempering house. Charles Roebling’s first method of lead patenting had actually proved better than his subsequent attempts, to which Washington Roebling noted “why, no one knows.” Early patenting at Kinkora followed a method referred to as air patenting, with wire rods heated by furnaces from thirty to eighty feet in length and quenched in air, but later models experimented with other heating and

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quenching agents such as lead. The high reputation of Roebling bridge wire drawn from patented rods attested to the skillful process design in vital aspect of wire manufacturing.

The Cleaning House

An adage in the wire industry held that “a wire well cleaned is half drawn.” Heating steel during hot rolling or annealing formed a hard, brittle oxide on the rod or wire known as mill scale. If improperly removed by cleaning, the scale scratched and resulted in off-gage wire. The rod cleaning operation at Kinkora followed an established sequence of immersion in an acid bath, a water rinse, a lime coating, and a period of baking. A quality clean depended on the foreman’s control of the temperature and duration of the immersion of each step of the cleaning process, which varied between different products. Too long of soak in the acid resulted in a condition known as acid brittleness that could be difficult to detect until the wire failed weeks or months later. Overbaking a rod reduced the effectiveness of the lime coating that aided lubrication during drawing.

Perhaps most importantly for bridge wire, skillful application of a “sull” coat during cleaning provided an essential aid to lubrication.\textsuperscript{75} While rods intended for dry drawing relied on the lime and sull coatings for lubrication, finer wire frequently employed a “wet” coating applied by a dip in copper or tin sulphates.\textsuperscript{76}

\textsuperscript{75}After the acid bath, a light spray of water allowed to dry on the rod formed a film of iron oxide that acted as a lubricant. A good rust coat, one steel manufacturing manual advised, permits rods to be given heavier drafts and to be drawn more drafts before being annealed. This “sull” coat was an essential part of lubricating bridge wire during drawing. See Backert, ed., \textit{The ABC of Steel}, 190

\textsuperscript{76}The sulphate bath forms a metallic coating on the wire that facilitates drawing fine wire. To prevent exposure to atmospheric contaminants, the coated wire is usually kept in a mixture of water and lubricating soap. McGannon, ed., \textit{Making Shaping, and
The original number one cleaning house at Kinkora employed a circle crane to raise and lower coils of rods in the various tanks of acid, water, and lime, which formed a semi-circular pattern about the crane. The cleaning house contained four cleaning stations, each one attended by a cleaning “gang.” Most jobs in the plant had two shifts, but because the cleaned rods required an overnight baking, the cleaning gangs worked one shift from 8 am to 4 pm. The gang operated much like a team, comprised daily of the same personnel led by a gang foreman, with a numerical designation that identified its station, but had skill connotations as well. For example, the number one cleaning gang handled the most critical job of cleaning all the rods intended for Roebling bridge wire. After cleaning and coating, coils of rods were loaded on to baker trucks, and wheeled into a row of ovens for a ten to twelve hour bake. Roughly one million lbs. of rod coils were processed during the cleaning shift to provide wire mill number one with its next day’s allotment of rod coils.

The superior hardness of carbide dies introduced in the early 1930s obviated the need for the heavy sull coat so essential to lubrication in previous methods of drawing high carbon wire. Baking the rods after cleaning, which had formerly required heating to relatively low temperatures for a twelve hour period to avoid burning the lime and sull coating, could now be accomplished with five to fifteen minute exposures to temperatures between 450 and 600 F in “flash bakers.” The increasing use of “inhibitors” during the cleaning process further contributed to the viability of this new technology by reducing the threat of acid brittleness that was normally alleviated by the longer baking time.

_Treating of Steel, 831._
Elimination of the twelve hour baking period radically altered the pattern of rod delivery to the wire mills. No longer did wiremen begin their day with an allotment of recently baked rods, as the flash bakers supplied rods nearly as fast as the cleaning house processing permitted. Consequently, a system of “straight line” cleaning houses emerged to clean rods more quickly. Constructed in 1943, a row of acid, water, and lime (or borax) tanks with rigid temperature and time controls and serviced by an overhead crane displaced the circular cleaning stations and cleaning house gangs. At the end of the cleaning line, several tank-like flash bakers handled the task of rod drying that was previously done in a row of fifteen alley-type drying ovens that ran the length of the north wall of wire mill number one. After lying idle for a few years, the company tore down the old drying ovens in 1947.

**Finishing in the Galvanizing Shop**

Several products required specialized finishing procedures, such as the application of protective or insulating coatings. The Trenton facility handled the insulating processes for electrical wire, while the Kinkora Works housed most of the galvanizing apparatus. Like patenting, ‘informed experimentation’ guided the development of the galvanizing process to apply a corrosion-resistant zinc coating to iron or steel wire. When the Roeblings began to explore galvanizing for the booming telegraph wire market in the 1870s, methods of heating and cleaning the wire before a dip in molten zinc proceeded on a trial and error basis. Cost had to balance quality in applying the zinc coating — too thick could be excessively expensive; too thin resulted in an inferior product. Skilled galvanizers were vital to advancing the art of galvanizing that depended on intuition and
experience. For certain wire that required extra corrosion resistance, the Roeblings developed a method of “double galvanizing” and marketed the product as “Extra Best Best Galvanized.” Several of the original galvanizing rigs erected by Charles Roebling in the Kinkora Galvanizing Shop had double galvanizing capabilities.
APPENDIX C - Wire Drawing

The system that developed in the nineteenth century to pull a wire through a lubricated die with a power driven spool or "block" involved a relatively low-level of technology that had attracted only three patents up until 1889. Foremost among the few companies that manufactured drawing machines, the Vaughn Company equipped many of the wire mills built in the first decades of the twentieth century, but Charles Roebling designed and built nearly all the original wire drawing machines at Kinkora.

In 1911, the John A. Roebling's Sons Company could boast of operating the largest wire drawing facilities in the country. In the basements of Kinkora wire mills number one and two, a central steam engine powered a drive train geared to rows of wire drawing benches. Nearly all wire received an initial draft in wire mill number one. Higher carbon wire remained in the number one mill for further reduction to diameters between 0.500 and 0.060 inches. Wire mill number two drew wire into finer sizes, typically from 0.060 to 0.015 inches in diameter. Within each mill, bench design varied to fit specific product requirements. Drawing higher carbon wire required larger diameter blocks and greater power, while finer sizes were usually "wet drawn" on single draft or early continuous machines. Charles Roebling divided the parallel rows of benches into sections, each identified by alphabetic designators. Section C contained the specially-built bridge bench that drew all the wire for Roebling bridges from 1907 until 1941. To accommodate increased demand, the Roeblings erected a third wire mill in 1914 to draw low carbon fine wire, and a fourth eventually called the Bridge Shop in 1923.  

Although some wire was drawn in the Bridge Shop, its primary purpose (and sole purpose at a later date) was to prepare reels of wire rope intended for bridge sites.
from the switch to electrically powered benches in 1928, until WWII the bulk of the Kinkora wire mills utilized practices and machinery that had undergone few technological changes since the late nineteenth century.\textsuperscript{78}

Although single draft machines drew the bulk of the wire made until the 1930s, the idea of continuous or multiple die drawing had long been pursued by enterprising inventors and engineers aware of the obvious advantage of an increased rate of output. The author of a 1907 \textit{Iron Age} article found that the desirability of multiple die system “had been recognized for many years, and various abortive attempts had been made in this country and in Europe, some of which had shown great financial courage and persistence on the part of the capitalists and inventors,”\textsuperscript{79} to produce such a machine. Another wire industry consultant marveled after a visit to the Bethlehem Steel Works at a process in which “a material of small and uniform cross-section in practically endless lengths subjected to a long series of identical operations would seem not merely to invite but to practically compel continuous treatment and yet it was treated non-continuously in a perfect bedlam of confusion.”\textsuperscript{80} The great power needed to “dry draw” rods and the difficulties encountered in aligning the speed of the revolving blocks to match the elongation of the wire proved an insurmountable hurdle for early attempts at continuous drawing. The intense generation of heat in drawing, die life, and means of lubrication

\textsuperscript{78}Information in this paragraph from John A. Roebling's Sons Company, \textit{The Roebling Story} (Trenton: John A. Roebling's Sons Company, 1941); and John Hodson, interview by the author, July 22 and July 28, 1997.


\textsuperscript{80}Lewis, \textit{Steel Wire in America}, 218.
provided further complications that prevented general use of multiple die machines in dry drawing. Because wet drawing fine wire mitigated the impact of these factors, some specialized multiple die machines successfully produced fine wire. Cognizant of the benefits this technology held for their limited production of fine wire, the JARSCO ordered ten continuous machines from Robert Wetherill & Company in March, 1916 for wire mill number two.

Successful solution of the continuous drawing problem held the potential to revolutionize wire drawing. In 1907, W.W. Gibbs, general manager of the Shenandoah Steel Wire Company of Buffalo, N.Y., heralded the development of a multiple die machine capable of drawing all sizes of wire by the Iroquois Machine Company. He foresaw that the use of these machines in his model mill under construction would nearly abolish the use of skilled labor, boasting that “only five men in the new mill will have had any previous knowledge of wire, or the wire business,” and that in the new system women would be employed to draw all wire finer than No. 21.5 gage. Gibbs stated that based on actual test data, a man who once produced 9600 lb. on single draft units in a 24 hour period could now produce 60,000 lbs using the multiple die machines. Unfortunately, the actual performance of the Iroquois machines never lived up to Gibbs’s praise, and the Shenandoah Steel Wire Company disappeared.

Although the conversion of the durable Roebling-designed wire drawing machines to electrical power in 1928 reflected the satisfactory performance of the single draft system, the JARSCO kept abreast of the slow progress toward practical multiple die

machines. The small number of continuous machines had proved useful in wet drawing fine wire, and the company experimented with four Nullmeyer dual die machines in 1926. A 1929 engineering order to remove one of the Nullmeyers from storage and ship it to Trenton indicated the value of their contribution to production. In the same year, however, the purchase of three Type A Morgan-Connor continuous machines introduced a new wire drawing technology that signaled the eventual end of the prominence of single draft drawing at Kinkora.

The Morgan Company acquired a viable platform for continuous drawing from an English firm, the Connor-Singer Wire Company, after World War I and spent several years refining and marketing their new Morgan-Connor machine. Company representatives discovered that selling the new machines to traditional wire drawers proved a difficult task. Morgan engineer Kenneth Lewis felt that the continuous machines activated a worker's instinct, deeply ingrained, which warns him of impending revolution. Lewis remembered the tribulations of the demonstrator he hired to promote the Morgan-Connor machines:

He was a genial cuss, a big man, a big tonnage producer in orthodox work, but the wiredrawers hazed him unmercifully with never a word from the foremen or superintendents. He had to clean the sand out of his soapbox every morning and after a trip to the latrine, and after running a while on rod bundles cleverly cut into about six pieces he had to adopt the practice of going into the baker and picking out his own rods, with one eye cocked toward his machines the while. If these machines hadn't been beautifully engineered, rugged, virtually foolproof, and soundly and thoroughly demonstrated and advertised, they would have flopped.82

Morgan's main competitor in the wire drawing machine business, the Vaughn Company,

82Lewis, Steel Wire in America, 229.
responded by developing a different continuous technology in their “Motoblox” benches. The two companies largely divided future sales of wire drawing machines between them. Prior to the introduction of tungsten carbide dies, however, continuous machines held little potential for drawing the bulk of high carbon, larger diameter wire at Kinkora.

The origins of the carbide die lay in the German Osram Company’s work during the last stages of WWI to find a substitute for the diamonds used in drawing light bulb filaments. Because the superior hardness of the tungsten carbide greatly extended die life, generated less die heat and decreased the lubrication needed to draw wire, the carbide dies particularly benefitted dry drawing in continuous machines. As in the case of the early Morgan-Connor machines, the threat posed by the new dies to the tradition-bred skills of the wire drawers and diemen resulted in reported cases of misplaced shipments of carbide dies that later turned up under basement floors or in rivers. Superior performance eventually overcame the initial resistance, and by the mid-1930s carbide dies had replaced virtually all older types of iron and steel dies. Contemporaneously, the JARSCO won the contract to provide and erect the cables for what would be the longest-span suspension bridge in the world, the Golden Gate Bridge. The conditions appeared favorable for the conversion to continuous drawing at Kinkora with the new dies, yet this development was still several years away. In 1939, the JARSCO first purchased Morgan-Connor machines intended for the number one wire mill, and in 1941 three type “BW” six-block machines replaced Charles Roebling’s single draft benches in aisle A.84 To

83Ibid., 241.

84John A. Roebling’s Sons Company, “Engineering order #9484-A,” January 16, 1941, Environmental Protection Agency - Edison, New Jersey storage facility.
prepare for the expected surge in wartime demand, in July 1941 the JARSCO ordered eleven new Vaughn Motoblox machines for wire mill number one. Although Vaughn and Morgan-Connor machines continued to supplant the older benches, a 1942 engineering order to construct twenty-four water-cooled blocks for conventional benches demonstrated that single draft drawing still had a place at Kinkora. Nevertheless, by the end of WWII, the pervasive use of carbide die-equipped, continuous drawing initiated an era of substantial changes that restructured the technological system of wire making at Kinkora.
## APPENDIX D - Fundamental Operating Statistics

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</table>

Matthew Sneddon graduated from the University of Notre Dame with a B.A. in History and a B.S. in Mechanical Engineering. His interest in the history of technology has been cultivated by graduate work in the History Department at Lehigh University, two summers with the Historic American Engineering Record, and a brief stint as an engineer with the consulting firm of Sargent & Lundy Engineers in Chicago. Currently, he is pursuing a Ph.D. in the History of Technology at the University of Washington in Seattle, WA.
END
OF
TITLE