DELAWARE COUNTY ELECTRIC COMPANY, CHESTER STATION
(PECO Energy Company, Chester Station)
Delaware River at end of Ward Street
Chester
Delaware County
Pennsylvania

HAER No. PA-505

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Historic American Engineering Record

Chester Waterside Station of the Delaware County Electric Company
(Chester Station of the PECO Energy Company)

HAER No. PA-505

Location: Delaware River at south end of Ward Street, City of Chester, Delaware County, Pennsylvania

Date(s) of construction: 1916-19, 1924, 1939-41

Architect: John T. Windrim

Engineer: William C. L. Eglin

Owner: PECO Energy Company, Philadelphia, Pennsylvania

Significance: Chester Waterside Station is a monument to the production and marketing of electricity in early twentieth-century America. Wartime demand for light and power led Philadelphia Electric to commission the plant for the company's Chester, Pennsylvania subsidiary in 1916. Conceived by architect John T. Windrim and engineer William C. L. Eglin, the design featured recent advances in generating technology and industrial construction. A work of City-Beautiful classicism, it also reflects it the sponsor's desire to express stability, permanence and civic responsibility at time when electric utilities faced considerable public scrutiny. This aesthetic became a hallmark of the company. In later years, Eglin and Windrim were to collaborate on similar projects, adorning the banks of the Delaware River with some of the grandest power plants ever erected in the United States.

Novel equipment, materials and planning strategies did much to determine Chester's architectural program. In conceiving the station's coal, steam and electro-mechanical systems, Eglin and his assistants sought an ideal balance between economy and efficiency. Affording low rates to customers and solid returns to investors, this balance would help validate private stewardship of public utilities. Chester went far toward satisfying these requirements. It standardized certain aspects of Philadelphia Electric's system and influenced the engineering of later company plants. As the Chester Station aged, it continued to serve as a technological testing ground. Periodic incorporation of new developments in power generation sustained the plant's productive life until 1981.

Historians: Matthew Sneddon (Section V), Aaron Wunsch (Sections I - IV)

Outline of Chester Station History

1895-96	Chester Electric Light and Power Company builds plant at 21 West Second Street, Chester, PA.
1896	Beacon Light Company founded, leasing Chester Electric Light and Power system for 999 years.
1899-1902	Philadelphia Electric Company formed through consolidation of many smaller Philadelphia-area companies, including Beacon Light.
1903	Original Schuylkill or Christian Street Station completed (known as Station A, later A-1, within P.E. system). Designed by architect John Windrim and Engineer William C. L. Eglin, plant generates 6-kilovolt, 2-phase alternating current and forms anchor of burgeoning Philadelphia Electric system.
1909	New York engineer-capitalist W. S. Barstow and other entrepreneurs consolidate power companies outside Chester, forming Delaware County Electric Company.
1910	Philadelphia Electric acquires financially weak Delaware County Electric, but initially keeps it separate from other Chester-area subsidiary Beacon Light.
1914-15	A second Schuylkill plant (A-2) is built next to the original one. Another Windrim-Eglin design, it generates the 13.2-kilovolt, three-phase current that Philadelphia Electric has now adopted.
1915	War industry and related population influx boosts demand for electricity in Chester area. After much deliberation, Philadelphia Electric decides to build new waterside station in Chester (Granger).
	December 17, Philadelphia Electric acquires land on which to build new Chester plant. This tract later proves too small (Granger).
1916	May 31, Philadelphia Electric buys Chester Station site from National Tube Company (Board Reports, Granger).

Late August, site preparation begins (*Chester Times,* Granger).

September 26, Philadelphia Electric President Joseph McCall provides company's board with rough description and construction cost estimate for Chester Station. His report suggests architect John Windrim and engineer William Eglin have produced basic plans for the plant by this time.

November 2, Philadelphia Electric officially awards Chester Station construction contract to Philadelphia-based Chester Construction and Contracting Company (*Chester Times*).

1917 April 4, 7, elevations of Chester Station published in *Current News* and *Chester Times*.

May 1, Chester Station coffer dam completed but fails soon afterward, delaying construction (Board Reports).

July 8, first concrete poured for Chester Station foundations (Granger).

August, Philadelphia Electric contracts with Stone & Webster engineering firm to erect another plant designed by Eglin and Windrim. This is Delaware Station in Philadelphia. Construction begins in fall, stops in December, and does not resume until 1919 (*Stone & Webster Journal*).

October 15, Delaware County Electric Company absorbs Beacon Light Company as part of Philadelphia Electric's broader consolidation effort (Board Reports, Beacon and DCEC Minutes); Chester Station will now bear Delaware County Electric's name instead of Beacon's.

November 8, "The 66-kilovolt transmission line between Schuylkill and Chester Stations energized" (Wainwright).

1918 Prior to July 23, first of eight original Babcock and Wilcox water-tube boilers completed and tested at Chester Station (Board Reports).

October 1, first of two original, horizontal 30,000-kilowatt

General Electric turbines starts operating at Chester Station; elaborate ceremony including state and local officials surrounds the event (*Chester Times*).

December 16, Chester Station's second turbine placed in operation (Board Reports). These two turbines, designated Units 3 and 4, are connected to boilers 9-16.

1919 Chester Station building completed, with possible exception of downriver coal tower (shown unfinished in 10/31 photo).

1920 Chester Station breaks down, halting 20,000-man ship-building operation at Hog Island (Wainwright).

First turbine at Delaware Station goes into service (*Current News*).

1924 Two more 30,000-kilowatt General Electric turbines placed in service at Chester Station (Board Reports). Identified as Units 1 and 2, and driven by boilers 1-8, these machines bring plant up to full intended capacity of 120,000 kilowatts.

1925 Permanent "maintenance and storage building" with machine shop erected next to Chester Station (Board Reports, drawings).

Philadelphia Electric's Richmond Station placed in operation (Wainwright).

1927 220-kilovolt Pennsylvania-New Jersey Interconnection formed by Philadelphia Electric, Public Service Electric and Gas Company, and Pennsylvania Power & Light Company (Wainwright); Chester Station a link in this network.

1928 United Gas Improvement Company acquires Philadelphia Electric (Wainwright).

Philadelphia Electric's Conowingo Hydroelectric Station placed in operation. This is last of company's Windrim-Eglin-designed plants.

1929 Delaware County Electric Company dissolved as part of larger Philadelphia Electric reorganization (DCEC minutes,

Wainwright).

1939-40	Philadelphia Electric spends $7,000,000 to install 50,000-kilowatt turbine and two high-pressure boilers (18 and 20) at Chester. New turbine is identified as Unit 5, the "high pressure unit." Plans are announced in October, 1939, as America prepares for war (Wainwright).
1940-42	Philadelphia Electric spends $3,400,000 to install 90,000-kilowatt Westinghouse turbine at Chester. This is Unit 6, the "low pressure unit." Brick and limestone addition at downriver end of Turbine Hall accommodates the machine. Unit 6 brings potential output of P.E.'s system up to 1,242,165 kilowatts (Wainwright).
1942-45	Philadelphia Electric again furnishes the hub of America's military-industrial complex with power.
1943	Chester Station becomes Philadelphia Electric's only unionized plant. The moves has its origins in Depression-era seasonal shutdowns (Wainwright).
1946	Coal strikes deal major blow to American industry. Philadelphia Electric hastily installs oil conversion equipment at Richmond, Deepwater, and Chester Stations.
Pre-1952	"... plans had been made to use natural gas to fire the new boilers at Chester and Barbadoes." (Wainwright)
1952	P.E. closes its central coal storage facility on Petty's Island and establishes new coal yard at Richmond Station (Wainwright).
1956	Five more power companies join 1927 regional network, forming Pennsylvania-New Jersey-Maryland Interconnection. High-voltage towers near Chester Station carry cables across Delaware River (Wainwright).
1965-70	Jet-engine turbines, fired by natural gas, installed north of Chester Station; precipitator is installed on upriver side of boiler house and connected to boilers 18 and 20 (personal interviews).

Ca. 1970	New Westinghouse turbine replaces Unit 4. Machine is identified as "Westinghouse test unit," technically Unit 7 (personal interviews).
1981	Chester Station stops generating electricity and is relegated to substation service; Westinghouse test unit continues to operate until 1984 (personal interviews).

CHESTER STATION HISTORY

I. Origins of Philadelphia Electric and its Delaware County Subsidiaries

By the year 1900, commercially produced electricity had been available in large American cities for almost two decades. Using the patents of Charles Brush and Thomas Edison, early electric companies had begun to illuminate downtown streets in New York and Philadelphia during the early 1880s. Soon they faced stiff competition. Wealthy entrepreneurs, often simultaneously involved in real estate, street car and gas lighting ventures, rushed to capitalize on new technology developed by Brush and Edison, establishing small utilities that vied for territory and municipal lighting contracts. Following a pattern of consolidation set in the streetcar business, electric utility owners repeatedly joined forces during the 1880s and 1890s. In Philadelphia, The Edison Electric Light Company merged with a group of interests controlled by Martin Maloney, ending a long-standing competition in 1896. The final step toward monopoly in that city came three years later, when Maloney's Pennsylvania Manufacturing Light and Power Company united with the National Electric Company. The result of that union was the massive, New Jersey-based Philadelphia Electric Company.[1]

Like the two corporations it absorbed, Philadelphia Electric was holding company. As such, it owned controlling interest in twenty seven older companies, many of which already overlapped in their financial and managerial structures. Some of these ventures were simply smaller holding companies while others were operating companies, charged with the daily management of power plants, transmission lines and related apparatus. There were eighteen operating companies in all, presiding over as many small generation and distribution systems. From a technical standpoint, joining these disparate parts into a single, unified system was both feasible and desirable. Although the operating companies used different kinds of equipment and generated a wide variety of currents, alternating current and the "universal system" devised by Westinghouse made integration possible. Alternating current could travel cost-effectively over much greater distances than direct current, permitting companies to serve large territories with a single plant; rotary converters and other couplers allowed such a plant to be connected to the heterogenous older systems of any given region. Thus Philadelphia Electric began planning the construction of a massive alternating-current plant almost immediately.[2]

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[1]Nicholas Wainwright, *History of the Philadelphia Electric Company*, 1881-1961 (Philadelphia: Philadelphia Electric Company, 1961), 13-62. For a general discussion of this period in Philadelphia history, see Nathaniel Burt and Wallace E. Davies, "The Iron Age, 1876-1905" in *Philadelphia: A Three Hundred Year History*, Russell F. Weigley et al., eds. (New York: W. W. Norton & Co., 1982), 471-523.

[2]W[illiam] C. L. Eglin, "Electric Lighting in the City of Benjamin Franklin," *Electrical World and Engineer* 43, no. 10 (5 March 1904): 423-4; Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880-1930* (Baltimore: Johns Hopkins University Press, 1983), 122-25.

Legal obstacles to this plan remained. According to the terms of its charter, each operating company was authorized to serve only a specific section of the city or suburbs. A unified system would violate all the charters of its constituent parts. In 1902, new legislation provided the loophole that Philadelphia Electric needed, allowing a single company to supply the entire area with electricity if the new company acquired its predecessors "by purchase or lease." Philadelphia Electric of New Jersey promptly responded by forming a giant operating company, The Philadelphia Electric Company of Pennsylvania, and arranging for this entity to lease all the companies in which the New Jersey corporation held stock. The old operating companies were effectively absorbed by the new one but "were to continue a paper existence" for several decades. Now physical integration could begin.[3]

The anchor of Philadelphia Electric's network was the Schuylkill or Christian Street Station. Completed in 1903, it was the work of company engineer William C. L. Eglin and architect John T. Windrim, at this point still associated with his father's prominent local firm. The plant stood on the east bank of the Schuylkill River less than a mile south of the downtown. Square in plan, the building was laid out within two parallel rectangles that formed the engine and boiler rooms. From the exterior it was essentially a round-arched box, resembling the palazzo-style plants erected in New York around the same time. Inside were thirty two "double-decked" boilers that drove large Wetherill-Corliss steam engines and General Electric generators. From this equipment emanated high-voltage, two-phase alternating current, converted to direct current to supply the aging but entrenched system that the Edison Company and its rivals had established downtown. Within two years, Philadelphia Electric followed Chicago precedent, installing the first of several steam turbines that would ultimately replace Schuylkill's engines.[4]

Although Schuylkill was Philadelphia Electric's largest plant, it was one of many within the company's system. Others had come to the corporation through various subsidiaries, including the Beacon Light Company. Beacon Light started out as a small holding company, set up in 1896 to supply "light, heat, and power by electricity to the City of Chester and the inhabitants thereof and vicinity."[5] Among the board's first moves was its decision to lease the property and franchises of the Chester Electric Light and Power Company for 999 years. Chester Electric had recently erected a new station at 21 West Second Street. The lease gave Beacon control of this facility and made Chester Electric Beacon's first operating company. Others soon followed. In 1898, Beacon branched out into nearby Darby, Glenolden and Ridley Park, only to be acquired by National Electric Company the following year. It was

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[3]Wainwright, 63.

[4]*Philadelphia Electrical Handbook*, 80-91; Wainwright, 70-74.

[5]Beacon Light Company minutes, 16 September 1896. Microfilm copy of minutes located at Hagley Museum and Library, Wilmington.

through National that the Beacon Light group arrived in the hands of Philadelphia Electric, making Beacon one of the conglomerate's original subsidiaries.[6]

As soon as Beacon came under Philadelphia Electric's purview, the larger company's officers filled the smaller one's board. Philadelphia Electric Vice-President William F. Harrity became Beacon's President and, in time, the position passed to other prominent figures in the Philadelphia enterprise. In 1904, Philadelphia Electric named the twenty-nine-year-old Albert R. Granger Vice-President and General Manager of Beacon. A Philadelphian by birth, Granger had started his career in that city's Edison Company twelve years earlier. Having settled into another Philadelphia Electric subsidiary after 1900, he accepted his new post somewhat reluctantly; he had recently become a father and did not wish to "disturb the even tenor of [his] life."[7] Nonetheless, Granger made the switch. Over the next four decades he would serve as Philadelphia Electric's primary representative in Chester.

During his first few years in Chester, Granger began broadening Beacon Light's customer base and updating the plant's equipment. However, while Beacon remained confined to its pre-1900 operating area, the New York engineering firm of W. S. Barstow & Company started to consolidate electric utilities in nearby parts of Delaware County (in which Chester also falls). In the summer of 1909, Barstow and fellow venture capitalists merged four enterprises that served Media, Lansdowne and other boroughs near Chester, forming the Delaware County Electric Company. Barstow was a director of the new corporation, while other board members were drawn from the management of the amalgamated companies. Following the usual pattern, Delaware County Electric set out to integrate its holdings, assigning the $16,000 contract for an "electricity transmission system" to Barstow's firm. The project reached completion late in the year, by which time Delaware County Electric had added another five companies to its holdings. Now the question of power supply was at hand. Rather than build a large central station, the company's managers opted to purchase all necessary current from Philadelphia Electric and sell off the equipment they had inherited from their predecessors. Philadelphia Electric agreed, and the new system went into operation.[8]

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[6]On the early history of Beacon Light Company, see Albert R. Granger and John Melloy, "Beacon - Ten Years Ago and Today," 1914, TD based on lecture before the Engineering Department Branch [of the Philadelphia Electric Section of the National Electric Light Association], [unpaginated], PECO Energy Company Library, Philadelphia; Albert R. Granger, "Fifty-Five Strenuous Years, 1892-1947," 1947, TD, p. 28, PECO Library. On Chester Electric Light and Power Company, see William H. Onken, Jr., "History of Philadelphia Electric Company," 1941-42, TD, pgs. 137-38, PECO Library; James Denis, "A Little of the Early History of The Chester Electric Light and Power Co." in George Ross Green, "History of The Philadelphia Electric Co," 1922, TD, pgs. 16-17, PECO Library; "Electric Power Here in 1886," *Chester Times*, 15 April 1939.

[7]Granger, "Fifty-Five Strenuous Years," 40-41.

[8]Delaware County Electric Company minutes, 3 June - 27 December 1909; microfilm copy of minutes located at Hagley Museum and Library, Wilmington; see also Onken, 140-41; Howard Deshong, "Delaware

Delaware County Electric apparently encountered fiscal trouble in the spring of 1910. Several months earlier, a Philadelphia bank owning most of the company's stock had convinced Associated Gas and Electric, a large New York holding company, to back Delaware County Electric's securities. Associated Gas extricated itself from this arrangement in April, 1910; Philadelphia Electric then took over Barstow's company. Prior to the start of Barstow's activities, Granger had been interested in acquiring companies that operated in territories near Beacon's. Philadelphia Electric President Joseph McCall had spurned the idea: he wanted to limit his company's interests to Philadelphia, and, for years, had actually contemplated selling off Beacon. Thus Philadelphia Electric's decision to purchase Delaware County Electric represented a break from company policy. Two explanations for this development exist. In Granger's recollection, the merger occurred because McCall and other managers wished to preempt Wilmington Gas & Electric from purchasing Barstow's system. On the other hand, Philadelphia Electric historian Nicholas Wainwright asserts that the decision was essentially involuntary, motivated by the prospect of Delaware County Electric defaulting on the large bills it owed McCall's company. In either case, Philadelphia Electric was now firmly rooted in Delaware County, a circumstance that would considerably benefit the company in years to come.[9]

II. Philadelphia Electric in the World War I era.

By 1910, Philadelphia Electric had grown considerably since its start. The company's burgeoning administrative staff required more space, prompting the construction of a seven-story office complex at the corner of Tenth and Chestnut Streets in 1906. Designed by John Windrim, the building featured a lavishly appointed appliance showroom on the first floor. Nor were the company's beautification efforts restricted to architecture. Responding to pressure from local businessmen, Philadelphia Mayor John Reyburn and his director of public safety moved forward with plans to increase downtown illumination. Between 1909 and 1910, Philadelphia Electric installed new lamps on Market, Broad, Chestnut, Walnut and Arch Streets. The 2,000-candle-power lamps sat atop "ornamental iron poles," casting brilliant light through the core of the city.[10]

In the meantime, the company had also suffered some public relations setbacks. Philadelphians reacted angrily when the giant gas company U. G. I. attempted to renew its lease of the city-

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County," in Green, 11-14. W. S. Barstow had old ties to Brooklyn Edison and was an important figure in the history of electric utilities in general; see Forrest McDonald, *Insull* (Chicago: University of Chicago Press, 1962), 67, 103.

[9]Delaware County Electric Company, 2, 8 April 1910; Granger, "Fifty-Five Strenuous Years," 64-64; Wainwright, 106-07.

[10]Wainwright, 101-02.

owned gasworks in 1905. Philadelphia Electric was widely believed to control U. G. I., and the outcry seriously tarnished both utilities' images. As public scrutiny intensified, interest in creating a municipally owned power plant grew. The following year, Philadelphia Electric adopted major rate reductions - denying, of course, that public pressure had played a part in the decision. Criticism subsided and U. G. I. ultimately regained its profitable contract, but issues raised by the upheaval were not dead. They surfaced again in 1910 when the City received Philadelphia Electric's bill for operating the newly installed streetlights, and yet again in 1912 when Morris Llewellyn Cooke challenged the rates of a U. G. I. subsidiary, the Welsbach Street Lighting Company.[11]

In late 1911, Rudolph Blankenburg became mayor of Philadelphia. A devout crusader in the cause of urban reform, he sought a proponent of Frederick Taylor's "scientific management" theory to serve as Director of Public Works. Failing to appoint Taylor himself, Blankenburg soon settled on a Taylor's understudy, the left-leaning engineer Morris Llewellyn Cooke. The position gave Cooke an opportunity to rationalize the areas of government over which he had control. As manager of Philadelphia's water supply, streets and highways, he could begin to "eliminate inefficiency, patronage, and graft" by reviewing city contracts for street lighting, garbage collection and the like. An early target of his attention was the Welsbach Street Lighting Company. According to Cooke, Welsbach's gas lamps supplied less light than the company's contract stipulated. As Cooke pursued this claim, his attention shifted first to Welsbach's parent company, U. G. I., and then to another city lighting contractor, Philadelphia Electric. Cooke eventually convinced Welsbach to implement better light emission tests, but the battle with Philadelphia Electric had just begun. After agreeing to an $80,000 rate reduction, the company refused to continue the policy beyond 1912. Establishment of Pennsylvania's Public Service Commission in 1913 provided a new forum for Cooke's charges; with limited resources, he initiated a lawsuit that gained national recognition.[12]

At the crux of Cooke's argument was his assertion that Philadelphia Electric overvalued its stock. The company, he believed, had not invested sufficiently in its system and had paid off investors and creditors by overcharging customers. These were weighty charges, and local politicians unsympathetic to Blankenburg's crusade refused to provide financial support for Cooke's case. Unable to bring suit as a city official, Cooke launched his attack as a private citizen. He garnered funds from his sympathizers and secured legal assistance from William Draper Lewis, former dean of University of Pennsylvania Law School. Engineer George H. Morse of West Virginia provided technical expertise. In an effort to refute Cooke's allegations,

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[11]Ibid., 87-90.

[12]Jean Christie, *Morris Llewellyn Cooke, Progressive Engineer* (New York: Garland Publishing, Inc., 1983), 8-9, 23-28; Kenneth E. Trombley, *The Life and Times of a Happy Liberal: a Biography of Morris Llewellyn Cooke* (New York: Harper & Bros., 1954), 37-38.

Philadelphia Electric hired M.I.T. professor Dugald C. Jackson to appraise the company's property. Jackson's voluminous report took over a year to prepare. Completed by October, 1915, it stated that the utility's property was worth more than $51,000,000.

Witnesses for the prosecution found fault with this estimate on several fronts. Having researched the company's financial history on Cooke's behalf, Dr. Ernest M. Patterson was well prepared to question Jackson's figures. No less qualified was Frederick W. Ballard, manager of a municipal power plant in Cleveland. The battle raged on, and by December, 1915, Philadelphia Electric was on the verge of undertaking a second appraisal. Facing the prospect of further litigation and bad publicity, President Joseph McCall moved to settle out of court. In March, 1916, the company agreed to annual rate reductions of $900,000 for average consumers and $150,000 for the City. Customers in Delaware and Montgomery counties soon "demanded" service on similar terms, and McCall obliged.[13]

During the years spanned by Cooke's rate case, other important developments occurred at Philadelphia Electric. Especially significant was the growth in transportation-related business. As far back as 1910, the Philadelphia Rapid Transit Company had begun using Philadelphia Electric power on streetcar lines. Successful service in Chester and Media led to contracts for lines closer to Philadelphia in 1912. The following year, a larger enterprise followed suit. Intent on electrifying its Paoli and Chestnut Hill lines, the Pennsylvania Railroad turned to Philadelphia Electric for power - a load that could reach 60,000 kilowatts in five years if PE's estimates were correct. When negotiations for the railroad contract began, Philadelphia Electric was in the midst of upgrading and enlarging its Schuylkill Station. Even with these changes, the company's system would soon have trouble handling normal load increases; the increase proposed by the railroad was out of the question under these circumstances. Accordingly, McCall and his colleagues pressed forward with plans for a new central station.[14]

At the time, Philadelphia Electric's system relied primarily on three plants. Schuylkill, the newest and largest, served most of Philadelphia but its output was supplemented to the north by the Tacony station. The southern part of the company's territory received much of its power from the Beacon Light plant in Chester. After considering the optimal location for the new facility, Philadelphia Electric chose a site next to Schuylkill. The old Schuylkill plant, known as Station A in the PE system, was renamed A-1. Its neighbor, A-2, would be another Eglin-Windrim endeavor, producing 65,000 kilowatts with horizontal General Electric turbo-

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[13]Christie, 29; Trombley, 41-45; Wainwright, 114-20; Philadelphia Electric Company Board Reports [from the Company President], 27 January 1914 - 1 June 1916, located in the Office of the Corporation Secretary, PECO Energy Company.

[14]"P.E. Co's New Generating Station," *Current News* 9, no. 4 (May 1914): 339-40; Onken, 147; Wainwright, 105-07.

generators. Construction began in 1914.[15]

Although the new central station was situated in Philadelphia, a significant amount of the company's load growth had been occurring further south. Between 1905 and 1910, the Beacon Light Company had wooed several large industrial customers, including the American Viscose Company. When Philadelphia Electric signed contracts with Philadelphia Rapid Transit in the early 1910s, Beacon Light and Delaware County Electric shouldered the bulk of the load. Nor were traction and industry the only promising sources of profit. Residential construction on the outskirts of Chester and Media convinced Albert Granger and other local utility managers that their business prospects were "very bright." Some of this activity coincided with the region's normal development patterns but, by the mid 1910s, the surge in war-related industry lay squarely behind the housing boom. American Viscose, Sun Ship Building and speculative developers erected hundreds of new houses for labor and management, all wired for electricity.[16]

The onset of World War I transformed the Delaware Valley into an industrial hub. Well before America abandoned neutrality, factories from Trenton to Wilmington began turning out materiel for the Allied arsenal. Although the resulting demand for power would eventually force Philadelphia Electric to reconfigure its system, the magnitude of the problem was initially unclear. The first major stumbling block appeared in June, 1915 after Beacon Light signed a contract with the Baldwin Locomotive Works. Retooled for weapons production, Baldwin wanted up to 4500KW of current over a two year period, and was willing to double the contract if satisfied with the results. On such terms, Philadelphia Electric stood to make almost $1,000,000.[17] However, as President McCall observed,

> There are questions arising which we have not yet finally decided as to whether or not to supply this current direct from Philadelphia, or to increase the size of our Chester plant, which we feel we can do in time to take the entire business.... In any event, the demand which is growing in Chester and which will increase when times are better, will be such as to entirely require the increased capacity

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[15]Onken, 146; Wainwright, 110-11; .

[16]Granger, "Fifty-Five Strenuous Years," 43, 54-56; Deshong, 12-13; Harold Goodwin, Jr., "Delaware County Electric Company: Its History and Substations," *Current News* 11, no. 13 (April 1915): 84-87; see also accounts of commercial development in *Current News* 10, no. 5 (December 1914) through 13, nos. 10-17 (May-June 1917). Though seldom mentioned, Beacon Light's acquisition of other local electric companies in the early and mid 1910s must also have played a part in the final decision to build a new plant; see Onken, 141-43.

[17]Granger, "Fifty-Five Strenuous Years," 62, 66; Wainwright, 129.

of the Chester plant.[18]

Despite the latter forecast, McCall still hoped to meet the Chester's needs through small-scale remediation. He spoke only of supplementing existing stations.

Three months later, Philadelphia Electric was pursuing both of the options McCall had weighed: the Beacon plant would have an additional turbine *and* be linked to Philadelphia by a 66-kilovolt line. Through these measures, the company tried to keep pace with development in Eddystone. Here, just north of Chester, Baldwin hurried to erect new factories, and "the constant influx of population" strained the streetcar system. As other industries expanded or took root nearby, Philadelphia Electric's efforts appeared increasingly futile. Even with Schuylkill A-2 nearing completion, the system would soon be overloaded. McCall met with Chief Engineer William Eglin who, at the same time, consulted Beacon manager Albert Granger. Granger and Eglin pushed for the construction of a massive new plant in Chester, and eventually they prevailed.[19]

Throughout the summer of 1916, Eglin worked with architect John Windrim to draw up the necessary plans. A classical colossus on the banks of the Delaware, Chester Station was to generate 60,000 kilowatts after the first phase of construction and twice that when complete. As McCall informed Philadelphia Electric's board,

> ...the general character of the building will consist of a Boiler House, Turbine House and a Switch House.
>
> The Boiler House is divided into two sections, although it is practically one building, each section being capable of supplying two units. The boilers will be arranged in batteries of four, and there will be a total of sixteen boilers in the completed plant, eight of which have now been ordered.
>
> The Turbine House is in parallel with the Boiler house, but at right angles to the batteries of boilers, and the completed station will contain four 30,000 KW units. At present there will be installed only two 30,000 KW units.

The estimated cost of land, labor, materials and equipment for this half-capacity plant came to $5,440,00.[20]

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[18]Philadelphia Electric Company Board Reports, 22 June 1915.

[19]Philadelphia Electric Company Board Reports, 28 September 1915; Wainwright, 129. McCall had initially contemplated linking the Chester and Philadelphia plants via an underground line, but by September, 1915, the company had settled on overhead construction.

[20]Philadelphia Electric Company Board Reports, 26 September 1916.

By June, Beacon Light had paid $75,000 for the former site of the National Tube Company. Located at the foot of Ward Street, the 21-acre property was bounded by steel companies to the east and west. Rail lines to the north guaranteed easy delivery of building supplies and coal if necessary, but, under ordinary circumstances, coal would arrive to the south via barge. Access to the Delaware's deep, swift current was the site's major selling point and the utility intended to take full advantage of it. Plans called for the construction of a pier that would allow the building to stand as far out in the river as possible. This arrangement would minimize dredging for barge channels while leaving plenty of land open for coal storage; perhaps there was enough room for a second plant.[21]

The *Chester Times* aroused local interest by presenting the project as a great economic boon. Capitalizing on good publicity, Albert Granger announced that "his company would construct one of the largest and finest plants in this part of the country and possibly in the world." Excavation for the railroad siding and other preliminary work was under way by September. Over the next two months, the Keystone Construction Company erected various temporary buildings throughout the site, giving it the appearance of a small town. "Clerical offices, machine shops, eating houses and a hospital of frame structure" were soon joined by a sizeable concrete mixing plant. Beacon's linemen toiled alongside Pennsylvania Railroad workers, while others operated dredges, pile drivers and derricks. In November, Beacon formally announced its long-settled decision to award the general contract to the Chester Construction and Contracting Company. This misleadingly named firm was headquartered in Philadelphia. Its Chester branch would handle the project - supposedly "the biggest ever tackled by a local corporation."[22]

Overseeing the myriad operations at Chester was Philadelphia Electric's own Joshua Morris Cope. As the project's field engineer, he worked with a small staff to assess the proper locations and conditions for construction. He moved gratefully from the office lent by a neighboring company to the "very comfortable quarters" on the site, watched as activity slowed in the winter, and was on hand with Windrim and Eglin as construction of the steel-piling cofferdam hurried forward in the spring. By April, 1917, the high-voltage line to Philadelphia

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[21]Philadelphia Electric Company Board Reports, 1 June, 26 September 1916; "General Electric Company [sic!] Buys River Front Land," *Chester Times*, 14 June 1916; Granger, "Fifty-Five Strenuous Years," 67-68. Philadelphia Electric's agent T. Woodward Trainer signed the sale agreement for National Tube property on 31 May 1916. The utility had purchased another site the previous December, but this was too small to accommodate the plant and owners of neighboring properties were unwilling to sell.

[22]"Million Dollar Improvement," *Chester Times*, 24 June 1916; "Work Moves on Big Plant," *Chester Times*, 6 September 1916; "Big Power Plant Work," *Chester Times*, 26 October 1916; "Local Firm's Big Contract," *Chester Times*, 2 November 1916. Chester Construction probably received the contract at an earlier date; see Philadelphia Electric Company Board Reports, 26 September 1916. For layout of temporary buildings, see 1917 Sanborn fire insurance map of Chester.

was taking shape. *Chester Times* readers were edified (or numbed) by a detailed list of the plant's future specifications, and granted a glimpse of Windrim's north elevation. But daunting problems soon tempered rosy predictions. Complete on May 1, the cofferdam failed dramatically and set work back several months. At the same time, labor was becoming scarce and expensive. The United States had declared war on Germany, and men not in the service could pick and choose among various high-paying construction projects. As summer passed, the question of finance grew more pressing.[23]

For several years, President McCall had been looking to end the cumbersome arrangement whereby a New-Jersey-based holding company administered multiple Pennsylvania subsidiaries. The subsidiaries' systems had functioned as one for well over a decade; bringing their "paper existence" to a close would achieve comparable business advantages. Most importantly, a unified corporation could borrow as a whole rather than in the names of its constituent parts. World War I's impact on the Delaware Valley forced the matter. Philadelphia Electric needed to obtain money for construction, but had used its subsidiaries' assets as collateral for earlier bond issues. In 1916, the company secured a $60,000,000 mortgage that allowed it to buy back the old bonds and issue others for a higher amount. Financiers further increased the utility's access to capital by raising its authorized stock by $25,000,000. Mortgage and stock were both in the name of The Philadelphia Electric Company of Pennsylvania, the operating company founded in 1902. Next, this corporation officially "bought" almost all of the long-leased subsidiaries, obliterating their names and management structures once and for all. No longer useful, The Philadelphia Electric Company of New Jersey dissolved in November, 1917.[24]

In the midst of this activity, McCall carefully isolated Philadelphia Electric's Delaware County holdings from the final stages of consolidation. As he explained to the Board of Directors, "these companies can be better financed, if it is necessary to do so, apart from the Philadelphia Company." Other motives may have driven this policy as well.[25] However, by fall of 1917,

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[23]"High Tension Cable," *Chester Times*, 19 February 1917; "Beacon's New Power Station," *Chester Times*, 7 April 1917; J. Morris Cope, "Chester Waterside Station, Land Improvements Estimate 2075," *Current News* 13, no. 5 (December 1916): 117, 120; "Our New 66,000 Volt Transmission Line," *Current News* 13, nos. 11-12 (May-June 1917): 276-79; Granger, "Fifty-Five Strenuous Years," 68-69; Philadelphia Electric Company Board Reports, 27 March, 24 April, 22 May, 26 June 1917.

[24]Wainwright, 115, 121-24; Philadelphia Electric Company Board Reports, 1 June 1916; *Seventeenth Annual Report of the Philadelphia Electric Company for the Fiscal Year Ended December 31st, 1916* (1917), 8-10.

[25]McCall's words in this Philadelphia Electric Company Board Report, 12 July 1916, seem unambiguous. However, in a letter to Pennsylvania's Public Service Commission, company counsel George S. Graham stated a technological rather than financial rationale for keeping the companies separate: Beacon Light and Delaware County Electric operated systems that were essentially distinct from Philadelphia Electric's (letter dated 26 December 1916, interleaved with Board Reports). Ultimately, McCall's intentions remain somewhat unclear. He

Beacon Light Company "owed" Philadelphia Electric almost $1,200,000, mostly in connection with work at Chester. Under the circumstances, McCall decided that localized consolidation was necessary: Delaware County Electric would absorb its financially weakened neighbor. The merger occurred on October 15, transferring all of Beacon's franchises and property to the other enterprise. Draftsmen on the Chester Station project now dropped Beacon's name from their drawings.[26]

Sweeping though it seemed, the change was largely semantic. Philadelphia Electric's upper management had long filled the boards of both companies, in many cases with the same individuals. Albert Granger, for instance, was president of Delaware County Electric at the time of the merger. During the managerial reshuffling that ensued, the only potentially significant switch was Granger's replacement with future Philadelphia Electric president Walter H. Johnson. Granger nonetheless retained the positions he had filled at Beacon and continued to serve as the utility's primary local representative.

As Philadelphia Electric maneuvered for money, demand for electricity in the company's territory continued to grow. Baldwin Locomotive's contract had presented the first great challenge to the system. In addition to running its main plant, Baldwin was turning out shells and shrapnel through the Eddystone Ammunition Company and taking on large orders for rifles at another subsidiary, Remington Arms. Steel foundries and ship builders also increased the Chester-area load. Meanwhile, electricity consumption rose sharply to the north, prompting Philadelphia Electric to initiate work on a plant at Beach and Palmer streets, Philadelphia. Ultimately identified as Delaware Station, this facility was to have the same initial generating capacity as Chester. McCall emphasized the need to begin construction "immediately" in September, 1917.[27]

That same month, the federal government took steps that intensified the company's sense of urgency. Set up to create an American merchant marine, the U.S. Shipping Board began carrying out its mission through the Emergency Fleet Corporation. The latter assumed control of Hog Island, situated in the Delaware River near Chester, and started building a giant shipyard. "[C]osting more than $35,000,000, and employing approximately 32,000 men...[i]t

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may simply have wished to protect his companies by isolating their financial structures or, conceivably, he still entertained the idea of selling off the Delaware County property at some future date.

[26]Philadelphia Electric Company Board Reports, 12 September, 26 October, 27 November 1917; Delaware County Electric Company minutes, 15 October, 14 December 1917; Beacon Light Company minutes, 15 October 1917.

[27]Granger, "Fifty-Five Strenuous Years," 62; Wainwright, 132-33; "Power Development," *Current News* 12, no. 5 (December 1915): 117; "Big Contract for Baldwin's," *Chester Times*, 2 August 1916 (one of many such articles); Philadelphia Electric Company Board Reports, 12 September 1917.

was a city by itself with streets, filtered water supply system, sewage water disposal plant, and 70 miles of railroad tracks connecting its different parts." This complex was to derive power from Philadelphia Electric. Here was further (and unsought) impetus to complete Chester Station: Chester lay at the heart of the nation's war machine.[28]

Throughout the winter of 1917-18, McCall pursued a two-pronged fund-raising strategy. On one hand, he sought support from New York bankers Harris, Forbes & Company for a $7,500,000 bond issue, earmarking $5,000,000 for Chester Station. At the same time, he traveled to Washington in hopes of securing government assistance. Underscoring the war effort's dependence on Philadelphia Electric, he noted that government projects were consuming "about 51.6 % of our capacity." Perhaps an agency such as the War Industries Board would be willing to put up $5,000,000 for Chester Station and $10,000,000 for Delaware. In January, the War Industries Board sent a team of lawyers and engineers to assess the situation. Their visit left McCall confident that federal aid would eventually arrive, and he was even willing to entertain the possibility that "the Government would contract to build these plants for us, and control them until such time as we are able to purchase them...." Aware of the significance of such a step, he added, "I somewhat hesitate to get into this position, fearing ultimate Government control, but it may just be possible that we will have to meet a situation of this kind."[29]

Harris, Forbes & Company agreed to underwrite Philadelphia Electric's bonds in February, 1918, clearing the way for Chester Station's completion. In previous months, over 45,000 cubic yards of concrete had been poured into the building's foundation and roughly half of the necessary structural steel set in place. With some imagination (or access to plans), a *Chester Times* reporter had discerned the plant's basic features in November. Since then, the high-voltage line to Schuylkill had been energized, bringing power from the company's main generating center to the place it was most needed. Now work moved ahead on the plant itself, focusing on the structure's upriver half. In late April, McCall informed the board that Turbine Four's foundation was complete, its condenser under construction, and the corresponding boilers beginning to take shape. Uncharacteristically, he refrained from predicting when electricity generation might begin.[30]

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[28]Onken, 148-49. Following Hog Island's establishment, McCall noted that Philadelphia Electric was "supplying more current to munitions factories and other war industries than any other utility in the United States;" *Annual Report of the Philadelphia Electric Company for the Fiscal Year Ended December 31st, 1917* (1918), 8.

[29]Philadelphia Electric Company Board Reports, 31 December 1917, 18, 29 January 1918.

[30]Philadelphia Electric Company Board Reports, 15 February, 30 April 1918; "Progress of New Plant," *Chester Times*, 6 November 1917. Following the Harris, Forbes agreement, Delaware County Electric took out a $15,000,000 mortgage that supplied the direct source of funding for Chester's completion; see Delaware County

Despite a favorable report from War Industries Board investigators, Philadelphia Electric's efforts to obtain government subsidies had not yet paid off. The need was more urgent than ever. Wartime production continued to strain the system, and work on Delaware Station was stalled for lack of funds. When government officials began suggesting that Philadelphia Electric serve factories in Wilmington by installing a third turbine at Chester, the board began to lose patience. True, McCall had once considered trying to bring Chester up to full 120,000-kilowatt capacity ahead of schedule, but now the additional power would go to "war industries in another state and in the territory of another company." Accordingly, Philadelphia Electric "suggested that this unit and its installation be paid for by the Government, the Electric Company acting as its agent for installing it, without profit, and that the Electric Company operate the unit for the Government on the basis of a reasonable return...." By July, the chances of receiving some form of federal aid looked good. The Emergency Fleet Corporation had hired New York engineer Cary T. Hutchinson to examine Philadelphia Electric's predicament. His report convinced the Corporation that it should loan the utility some $18,000,000 to complete Delaware Station and install Chester's third turbine. McCall, in turn, was willing to give the government title to Delaware and operate the station under lease.[31]

Hope of securing such favorable terms soon faded. While McCall negotiated with the Emergency Fleet Corporation, the federal government was reevaluating its entire wartime power strategy. First Congress considered "The Pennsylvania Plan," a proposal to erect large, mine-mouth plants in the state. A later bill called for Congress to nationalize privately owned plants carrying heavy industrial loads. Perhaps these ambitious schemes led public officials to look less charitably upon small-scale, private-sector solutions. On 2 August 1918, Philadelphia Electric received a letter from the U.S. Shipping Board effectively revoking the Fleet Corporation's offer. Instead of lending all funds needed for the utility's building program, the government would advance only forty percent. The news must have been doubly unwelcome because it came from Morris Llewellyn Cooke, then serving as the Shipping Board Chairman's Executive Assistant. Still, the offer included a significant concession: federal coffers would absorb cost increases associated with wartime construction.[32]

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electric Company minutes, 19 February 1918.

[31]Philadelphia Electric Company Board Reports, 26 June, 27 December 1917, 29 January, 30 (?) April, 16 July 1918.

[32]Philadelphia Electric Company Board Reports, 24 September, 29 October 1918 (typescript of Cooke letter interleaved); Wainwright, 139; "Emergency Power Act Passes House," *Power* 48, no. 16 (15 October 1918): 579.

Perhaps attempting to speed materials to the site, Delaware County Electric signed an agreement with The Philadelphia, Baltimore and Washington Railroad Company for the construction of a new siding west of the plant. See Delaware County Electric Company minutes, 14 August 1918.

These increases were considerable. Although Chester Station was rising steadily, war-related shortages of material and labor were a perpetual problem. McCall worried about compromises "both in quantity and quality," noting bitterly that Philadelphia Electric had to compete with the high government wages paid at Hog Island. Pay raises for the utility's Operating Force ensured that plants would continue to run. But what McCall did not tell the board was that payment on some building contracts had ceased. When Philadelphia Electric hired Chester Construction and Contracting Company, the latter had given Chester Station's concrete work to Turner Concrete Steel Company of Philadelphia. The subcontractor was a small firm, ill prepared to carry an outstanding debt. By September, 1918, Chester Construction owed Turner $200,000 and was apparently awaiting payment from Philadelphia Electric. Unable to compensate its workforce and unconvinced by any assurances the utility may have offered, Turner abandoned the Chester project. Ultimately, the standoff spelled the firm's demise.[33]

In the face of such crises, excitement over Chester Station's progress was starting to mount. Although the plant's downriver half was far from complete, upriver boilers were functional by late August, and McCall felt Turbine Four's start was imminent. In fact it would have to wait over a month. Even as workers hurried to assemble Chester's equipment, the structure itself remained partially open to the elements. This was still the case when Turbine Four was finished, requiring construction of a wood enclosure around the unit. Finally, the turbine sprang to life on October 1, 1918. The *Chester Times* reported, "With the slight pressure of a button, the charming little Jane Sproul Klaer, daughter of Mr. and Mrs. Henry J. Klaer and granddaughter of Senator William C. Sproul, started in motion the first turbine engine yesterday afternoon at the great Waterside plant of the Delaware County Electric Company." Others in attendence included Senator Sproul, Mayor W. S. McDowell, several city councilmen, McCall, Eglin, Windrim and, of course, Albert Granger.[34]

The fall of 1918 brought an end to World War I and respite for Philadelphia Electric. Promises of government aid dissolved but so did the exigencies of wartime production. Relief was not immediate, however. Just as the war drew to a close, Schuylkill A-2's larger turbine broke down, leaving 2,000 customers without power for days. The incident underscored the peacetime importance of Chester Station, where work continued apace. By mid December Chester's second turbine was running, and, before the year's end, seven boilers were complete. With most of the building enclosed, the company opted to cease interior work in the "hope and expectation that we will be able to get labor at much cheaper rates as spring approaches, and

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[33]Philadelphia Electric Company Board Reports, 25 June, 23 July 1918; personal correspondence with Donald E. Wolf, historian of Turner Construction Company of New York.

[34]Philadelphia Electric Company Board Reports, 23 July, 27 August, 24 September, 29 October 1918; Granger, "Fifty-Five Strenuous Years," 70, 73-74; "Great Day at Big Power Plant," *Chester Times*, 2 October 1918.

the better working spirit of the men who may be employed on the job."[35]

Chester Station went into regular, 60,000-kilowatt operation in 1919. Another four years would pass before more equipment arrived at Chester and major construction resumed at Delaware. In the meantime, Philadelphia Electric and the City of Chester had a machine and a monument about which they could boast.

III. Post-construction History

In the early 1920s, much of Chester Station was still a shell. Boilers, turbines and switchgear filled structure's upriver half, but, for all of Philadelphia Electric's wartime negotiations, the downriver half remained empty. Breakdowns at Chester and Schuylkill left managers wary. Even with additional power from the new Delaware Station, the company's system operated near capacity; another equipment failure could prove crippling. This situation differed significantly from the load crises of the previous decade. Instead of bolstering the war effort, Philadelphia Electric now grappled with the success of its own attempts to boost consumption. After 1918, the company had made residential service a priority. Home wiring drives paid off, supplementing other new contracts from industry and railroads. Across the Delaware, Public Service Corporation of New Jersey also made temporary arrangements to buy Philadelphia Electric power. The time for further investment in Chester Station was at hand.[36]

In August, 1923, President Joseph McCall made the case before Philadelphia Electric's board. The estimated load for 1924 was 358,000 kilowatts. A new turbine at Delaware Station would increase the system's capacity to 361,000 kilowatts, but

> This will make no provision for any additional business, and would mean that we would have to go through another year with no reserve, which is extremely dangerous. We, therefore, should order immediately a 30,000 KW machine for the Chester Station, so that if anything happens in Chester, this station would not at least have to draw on Philadelphia.

Such an investment, McCall believed, constituted a bare minimum. Wise planning dictated more:

> We should also order a second and last unit for Chester, with an additional transmission line, if we succeed in closing with the Public Service Corporation of New Jersey for an additional 15,000 KW, making a total of 25,000 KW in all,

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[35]Philadelphia Electric Company Board Reports, 3, 31 December 1918; Wainwright, 140.

[36]Wainwright, 148-151, 160.

> which they have requested from us, and which additional business we will have to decline unless we can find some means of relieving Philadelphia of an equivalent current. This additional capacity in Chester would also be useful in any enlargement of the Pennsylvania Railroad electrification plans, as well as the possibility of securing some business for the Baltimore & Ohio Railroad, which is now under consideration.[37]

Board members must have found McCall's argument convincing. Chester's new turbines appeared in the 1924 budget along with "all the necessary boilers and equipment...coal bunkers, evaporators, [and] steam valve control." The precise installation dates are uncertain, but by November the process was complete. At long last Chester Station ran at its full intended capacity of 120,000 kilowatts.[38]

Other changes were also afoot within Albert Granger's territory. In 1896, Beacon Light Company had begun leasing the equipment and franchises of the Chester Electric Light and Power Company. Delaware County Electric took over the lease when absorbing Beacon. This saddled the company with Chester Electric's old power plant - used primarily as a substation by the 1920s. Urging various improvements in 1924, McCall described the facility "as being extremely uneconomical of operation and so crowded with outgoing feeders that it is impossible to add any more." The predicament prompted action on several fronts. Delaware County Electric promptly purchased ground at Sixth and Crosby Streets on which to erect a new substation. As this building took shape, the company also acquired Chester Electric's assets in fee simple with the intention of selling them off. All was accomplished by 1925.[39]

Decrepit as it was, the retired plant provided useful storage space. Perhaps anticipating the property's sale, Philadelphia Electric's board approved construction of a "Permanent machine shop building at Chester Station, with store room and additional machine tools." The commission went, predictably enough, to John Windrim. In early 1925, he or his assistants designed a two-story brick warehouse containing machine and carpentry shops, offices, and locker rooms. Located northwest of Windrim's colossal plant, the small complex probably replaced temporary structures erected for the same purposes in 1917. The new building was

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[37]Philadelphia Electric Company Board Reports, 28 August 1923.

[38]Ibid., 8 January, 25 November 1924. If General Electric and Westinghouse met the delivery dates given in the August, 1923 report, Chester's new turbines and condensers were installed between June and October, 1924.

[39]Ibid., 8 January 1924, 25 November 1925; Delaware County Electric Company minutes, 27 February 1924, 9 February, 30 December 1925.

meant to last. Its color, form and material blended with those of its neighbor.[40]

While these developments took place in Chester, more substantial work was occurring elsewhere in the Philadelphia Electric system. Some twenty miles upriver, the company's Richmond Station came on line in November, 1925. Eglin and Windrim had conceived the plant on a grand scale, designing it as three connected yet self-contained modules that together would generate 600,000 kilowatts. Only one of these sections was ever built. This initially produced 100,000 kilowatts and was known for exceptional efficiency.[41] Structurally, the building resembled Delaware Station; reinforced concrete had become the company's material of choice. However, when it came to layout and orientation, both plants tended to follow precedent set at Chester. Boiler house, turbine hall, and switch house receded from the river's edge in separately articulated sections. And monumental neoclassicism, slightly subdued at Delaware, came back more dramatically at Richmond.

Architecture continued on as a facet of Philadelphia's Electric's publicity efforts. The stately Chester Station arose after a public relations debacle, and Richmond's appearance may again have been a sign of the times. During the mid 1920s, the company contended once more with Morris Llewellyn Cooke. Since 1923, Cooke had served as technical advisor to Pennsylvania's progressive governor, Gifford Pinchot. Together the two men became outspoken advocates of "Giant Power," a bold plan for reducing the cost of electrical service and extending it to rural areas.[42] Wrangling over Giant Power occupied the central years of the decade and set the stage for later debates over the Tennessee Valley Authority. Although much of the discourse involved technological feasibility, control of the state's (and the nation's) electric utilities was ultimately at issue. Private utilities strongly opposed greater "political" involvement in their business, and Giant Power struck many as a "prelude to government ownership."[43] In the end it was engineers like Charles Penrose, tied to Philadelphia Electric and the NELA, who brought the plan down. Meanwhile, Philadelphia Electric made its stance clear to its customers: Giant Power could not work; private ownership and public interest were still synonymous. Like Chester Station, Richmond helped make the point.

After decrying government-administered utility networks, Philadelphia Electric embarked on a networking venture of its own. In 1927, the corporation signed a power-sharing agreement with

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[40]Philadelphia Electric Company Board Reports, 8 January 1924; Windrim drawing series 491, 11 February 1925, on aperture card at PECO Energy Company's Plymouth Meeting archive; Sanborn fire insurance maps of Chester, PA, 1917, 1946.

[41]Wainwright, 190-91; "Philadelphia's New Station," *Electrical World* 85, no. 21 (23 May 1925): 1074.

[42]Wainwright, 198-99; Hughes, 297-312.

[43]Hughes, 302.

Pennsylvania Power & Light and Public Service Electric and Gas Company of New Jersey. The result was the Pennsylvania-New Jersey Interconnection, "the first great American interconnection of electric systems." Much of the power would come from Philadelphia Electric plants. By the late 1920s these included Conowingo, a huge hydroelectric station that represented Eglin and Windrim's last collaborative project. Located on the Susquehanna River, Conowingo began operating in March, 1928. Eglin had died three weeks earlier.[44]

Eglin's death came as Philadelphia Electric reached the end of an era. For months the utility's board members had been meeting with their counterparts at the United Gas Improvement Company to discuss the terms of a merger. The deal became reality in February, 1928 when U.G.I. formally assumed control of Philadelphia Electric. Thereafter, the two corporations began the formidable task of melding their systems together. U.G.I. owned Philadelphia Suburban-Counties Gas and Electric Company, whose holdings stretched across the territories Joseph McCall had so carefully avoided. Integrating the "suburban" system with Philadelphia's entailed both technical and administrative reorganization. One casualty of the process seems to have been the Delaware County Electric Company, which dissolved on April 10, 1929. Its function was, in all likelihood, replaced by Philadelphia Electric's new "Delaware" division, based in Chester.[45]

Chester Station was now linked to larger local and regional networks. While significant, these changes had relatively few consequences for the plant itself. The site's physical evolution was, in fact, slowing, and it came to a virtual standstill over the next decade. For workers this trend had unfortunate consequences. Philadelphia Electric was eager to reduce its operating expenses during the Great Depression, and because Chester had become one of the company's least efficient plants, managers initiated a series of seasonal shutdowns there. The decision avoided mass layoffs but created lingering hostility, particularly because it failed to take seniority into account.[46]

Not until 1939 did Philadelphia Electric begin comprehensive modernization of the Chester plant. At the start of the Second World War, company president Horace Liversidge announced that, in keeping with recent precedent at Schuylkill Station, Chester would receive a powerful new "topping" unit. The 50,000-kilowatt machine was to rest in the middle of turbine hall. Steam would be provided by two high-pressure boilers, designed to supplant four original ones in the upriver half of the boiler house. Work on the $7,000,000 scheme got under way quickly.

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[44]Wainwright, 184, 199-201.

[45]Ibid., 210-13; Delaware County Electric Company minutes, 10 April 1929. Philadelphia Electric's Delaware division presumably occupied the new district offices called for in Philadelphia Electric Company Board Reports, 8 January 1924.

[46]Wainwright, 233, 292.

By fall of 1940, the project's scope had widened to include a second, low-pressure turbine, costing another $3,400,000 and capable of generating 90,000 kilowatts. No room remained in turbine hall for this behemoth. Instead it occupied a downriver addition that consisted of a steel frame clad in brick and limestone. With the benefit of these installations, the Philadelphia Electric system was prepared to meet wartime loads.[47]

During World War II, Chester Station bustled. Up to three hundred workers operated the plant, following an organized routine that may well have been in place in earlier decades. Three main "gangs," tending boilers, turbines and switchgear, worked in four shifts. Their efforts were supplemented by those of "auxiliary" gangs, charged with construction and maintenance, and based at the machine shop. Most workers lived in the Chester area. Their pay was average but many, remembering the events of the Depression, lacked confidence in their job security. This unease increased the appeal of outside backing and, in October 1943, Chester became Philadelphia Electric's only unionized plant. Membership in the International Brotherhood of Electrical Workers did not lead to a standoff. Employees obtained written contracts but also agreed to a no-strike clause, and labor relations at Chester became some of the smoothest in the company's system.[48]

While Philadelphia Electric staved off internal conflict, it continued to depend on vulnerable external networks. The first of two 1946 coal strikes caught the company off guard. Fuel reserves disappeared, and customers were asked to limit their consumption of electricity. By the time the second strike occurred, Philadelphia Electric had adapted boilers at Chester and two other stations to burn oil. This conversion softened the effects of a crisis that proved more severe than the first.[49]

Efforts to modernize Chester Station slowed again after 1950, now for the last time. Late in the following decade, workmen erected an outdoor precipitator on the upriver side of the boiler house. Intended to reduce soot emissions, the unit treated smoke from the high pressure boilers (18 and 20). Around the same time, three gas-fired jet-engine turbines were installed on a site just north of the plant, their bare treatment underscoring the declining importance of architecture in electric utility design. The last major change at Chester was the construction of a

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[47]Ibid., 280-81, 285.

[48]Ibid., 292-93; personal interviews with Dick Hoffman, 9 June 1998, and Charles Bowden, 7 August 1998. Bowden, who worked at Chester from 1942 until 1959, supplied the following rough breakdown of the plant's workforce: 63 in switch house (21 per shift), 75 in turbine hall (25 per shift),117 in boiler house (39 per shift), 5 coal bureau staff, 5 clerical staff, 4 shift supervisors, 1 superintendent, unspecified number of auxiliary staff. Note that effective number of shifts is three because one was time off.

[49]Wainwright, 318-19. In the same era, Chester's boiler's were also equipped to burn natural gas: controls for boilers 18 and 20 take all three fuel types into account.

Westinghouse turbine testing facility in the location previously occupied by the plant's first turbine (ca. 1970). Thereafter, the company retired most pre-World War II equipment in the building and, in 1981, halted all electricity generation there. A small staff continued to operate substation controls in the switch house until 1986.[50]

IV. Chester Station: Building and Image.

The plant that the Chester Construction Company erected for Delaware County Electric in the late 1910s represented the latest development in the forty-year evolution of urban central station design. By the time Windrim and Eglin conceived Chester Station, the building type had passed through three major phases in the United States. Among the earliest power plants designed for commercial service in big American cities were the stations of Edison-franchise companies in New York, Philadelphia and Chicago. Because they generated direct current with a sharply limited transmission radius, these plants sat at the center the downtown districts they served. High real estate values dictated narrow building lots, and the plants took shape accordingly; sometimes identified as "vertical stations," they conformed roughly to an office-building model. Steam engines and dynamos occupied the lower floors, while boilers, coal bunkers and offices filled the spaces above. Exemplified in Philadelphia by the Sansom Street Edison Station, these compact buildings were the first to attain a broad consistency of architectural design in the U.S.[51]

Alternating current determined the form and location of the next generation of plants. Coupled with Westinghouse's universal system, AC fostered tremendous consolidation in both the technological and commercial spheres of the electricity industry. Greater transmission range was the new current's primary advantage. Among other benefits, it allowed utilities to shift the locus of electricity production from the urban core. Plants like Philadelphia Electric's 1903 Schuylkill Station now appeared at the city's edge, near open land for coal storage and deep water for transportation and cooling. Schuylkill also embodied recent advances in central station design. The spacious site was conducive to a more horizontal layout on a broad footprint. Just as importantly, Windrim and Eglin conceived the building on a "sectional plan," whereby boiler and turbine rooms formed two adjacent, parallel modules. Inside, structure and equipment were arranged to permit an indefinite number of landward extensions, creating an orderly solution to the longstanding problem of central station growth. The building's exterior was also typical of its genre: a round-arched box with coal towers incongruously attached. Unlike the vertical stations, which tended toward the Romanesque, these new plants were generally "Renaissance,"

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[50]In 1986, supervision of Chester's switch house passed from PECO's Electricity Production division to the Electricity Transmission and Distribution division. At this time, the plant's substation was listed as "unmanned." William Lockhart, telephone interview with the author, 30 April 1999.

[51]Aaron Wunsch, "Form, Function and Public Relations: The American Urban Power Station, 1880-1930" (MA thesis, University of Virginia, 1995), 14.

a label here signifying a kind of industrial palazzo.[52]

By the mid 1910s, automation and high voltages exerted a greater influence on central station design. Previously relegated to the margins of the engine room, switching apparatus now received a separate "house" commensurate with its growing size, complexity and potential volatility. Coal and ash handling became totally automated, using motorized conveyors, hoists and other equipment that had been available in less refined form since the turn of the century. Mechanical stokers were, perhaps, the biggest advance in this category. Replacing dozens of firemen, the stoker permitted the use of larger, more powerful boilers and narrower firing aisles. The boilers themselves came to occupy a single level of the plant, their efficiency enhanced by the use of economizers. These reconfigurations gave the boiler house a greater proportion of the central station's plan. The engine room's proportions changed little, but its contents evolved rapidly. Steam engines were a thing of the past, and horizontal turbines on massive condensers were fast replacing the vertical units Samuel Insull had introduced at Chicago's Fiske Street Station a decade earlier. In overall layout, most stations maintained the principle of modular extendability. Now, however, they often extended parallel to the water instead of away from it. Increasing isolation of the plant's basic functions lead architects and engineers to articulate boiler, turbine and switch rooms as discrete blocks, and the City Beautiful movement made some form of classicism the mode of choice.[53]

Chester Station was of this latter type. An automated, neo-classical giant, its design acknowledged the major engineering trends of the era. Yet, within the Philadelphia Electric system, many of Chester's advanced features had already surfaced at Schuylkill A-2. Erected between 1914 and 1915, A-2 superficially resembled its adjoining neighbor: orientation and facade were both determined by the older plant. The interior, however, told a different story.[54] Gone were the confines of the two-part plan. In 1912, Philadelphia Electric had abandoned 6-kilovolt, two-phase current and begun implementing a 13.2-kilovolt, three-phase system. The new switchgear that accompanied this change was bulkier and more lethal than its predecessors, and the "switching galleries" employed at A-1 would no longer suffice. Thus a "switch house" joined similarly defined spaces for turbines and boilers, forming the three-part plan typical of the era. Related necessities lead Eglin to centralize and protect the main electrical control panels in a separate operating room within the switch house.

Although Philadelphia Electric began employing turbines in the mid 1900s, large, horizontal

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[52]For example, see Eglin, "Electric Lighting in the City of Benjamin Franklin," 423-28; *The New York Electrical Handbook* (New York: McGraw Publishing Company, 1904), 12-13, 27-34.

[53]For example, see "The Essex Power Station," *Power* 44, no. 22 (28 November 1916): 738-44.

[54]The following comparisons are based primarily on "P.E. Co's New Generating Station," 339-52, and "Station 'A-2' - Philadelphia," *Current News* 12, no. 9 (April 1916): passim.

turbines did not play an important role in the company's system until A-2's construction. A-2 featured two great General Electric turbogenerators, similar to those installed at Chester. The units sat atop Westinghouse surface condensers of the "2-pass, radial-flow type," supported, in turn, by deep and massive foundations (again, to appear at Chester). The purified water collected in the condensers eventually returned to the boilers for another cycle of steam production. While this system had been a convention of power plant design for several years, the technology for treating, storing and supplementing boiler feed water was growing in size and sophistication. Now surge tanks, boiler feed pumps and related equipment received their own, semi-confined area in A-2's turbine hall. Identified as the "south gallery," this space would reappear in PE plants until the 1930s. A-2 anticipated Chester in other respects as well. The Schuylkill plant's forebay and screening basin foreshadowed the screening house that would filter Chetser's water supply, and the two plants' boiler houses were similar. Both employed Babcock & Wilcox water-tube boilers with automatic stokers, arranged in blocks beneath two rows of steel-and-concrete coal bunkers.

Yet the differences between the two stations were also significant. For one thing, Eglin and Windrim could start afresh with Chester in a way they could not with A-2. Accordingly, they located Chester further out in the Delaware, simplifying coal delivery, ash removal and water circulation. Free reign on a new site further permitted Chester's designers to rationalize the orientation of the plant, placing the boiler end nearest the water. Here barges could haul coal and ash, while the drier, landward half of the property provided a safe seat for electrical apparatus. At the same time, a vehicular passageway and wall recesses afforded the switch house more isolation from the main block of the building. Differences in the coal and ash handling systems were apparent too. A-2 used an elaborate sequence of hoists, cable cars, elevator buckets and roller conveyors to bring coal to the bunkers. Chester's proximity to water eliminated the need for such complex gear. Two booms with clamshell buckets did most of the work, though A-2's ground-level cable railway reappeared above the newer station's bunkers. As for ash removal, A-2 used an unusual vacuum system. Original plans had called for "side-dumping tramway cars" hauled by electric locomotives, and this arrangement surfaced at Chester.

In 1916, other large power plants exhibited layouts and equipment comparable to Chester's. Perhaps the most striking similarities were to Public Service Electric Company of New Jersey's Essex Station, conceived the previous year. N. A. Carle and other company engineers adopted a "unit system" like Chester's, treating the boiler, turbine and switching areas as "separate structures." Certain mechanical details were the same too. Eglin probably knew of Carle's project, and the chances of Essex influencing Chester are good. This connection raises the question of regional patterns in power plant design. A thorough answer would require more research, but the case seems strong here. Although contemporary plants like Detroit's Connors

Creek shared basic elements with Chester, the New Jersey-Pennsylvania link is more overt.[55]

If Chester Station exemplified the latest practice in power plant design, it also benefitted from broader advances in industrial construction technology. Schuylkill A-2 had consisted of a "steel skeleton with brick walls and reinforced concrete floor and roof slabs. All structural steel [was] fireproofed with either brick or concrete...."[56] The description applied equally well to Chester. Although reinforced concrete had proven a great boon to industrial construction since the 1900s, it remained something of a novelty. Most engineers were comfortable specifying it in their contracts but continued to debate the extent of its applicability to power plant design.[57] Thus Chester's creators shied from using a reinforced concrete frame. They did, however, employ the material more freely than at A-2, specifying it for all foundations and the lower portions of major walls.[58]

As World War I progressed, steel became an increasingly scarce commodity. The decision to make Chester's economizers an "integral part" of the boilers may have reduced the building's height in that area - a steel conservation method recommended in industry journals.[59] Yet, from a structural standpoint, this was still a cautious step. Philadelphia Electric soon realized that more strident measures were needed at Delaware Station. Following a hasty change in plans, engineers Stone & Webster managed to use reinforced concrete throughout that plant.[60] Construction dragged on for lack of funding, but the design was successful; it strongly influenced the later Richmond Station.

While Chester was not Philadelphia Electric's flagship in structural innovation, it did serve as a

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[55]"The Essex Power Station," *Power* 44, no. 22 (28 November 1916): 738-44; C. F. Hirshfield, "Connors Creek Power Plant," *Power* 42, no. 11 (14 September 1915): 388-96; "Year's Review of the Power Field," *Power* 45, no. 1 (2 January 1917): 2-7; George F. Gephardt, *Steam Power Plant Engineering* (New York: John Wiley & Sons, 1917), 914-27. A general description of power plant design processes appears in "Power-Station Buildings," *Power* 43, no. 14 (4 April 1916): 492-94. The article encourages would-be designers to examine "structures that have been built in the vicinity."

[56]"Station 'A-2' - Philadelphia," 48.

[57]"Power-Station Buildings," 494. On the role of reinforced concrete in early twentieth century industrial construction, see Lindy Biggs, *The Rational Factory: Architecture, Technology and Work in America's Age of Mass Production,* (Baltimore: Johns Hopkins University Press, 1996), 52-53, 81-85.

[58]Philadelphia Electric Company Board Reports, 28 May 1918; "Beacon's New Power Station;" Granger, "Fifty-Five Strenuous Years," 69.

[59]"Year's Review of the Power Field," 2.

[60]Philadelphia Electric Company Board Reports, 12 September 1917; "Compact Reinforced-Concrete Generating Station at Philadelphia," *Electrical World* 77, no. 21 (21 May 1921): 1145-46.

venue for testing concrete slab construction. Pioneered in the previous decade, the technique could produce great molded panels which, in Chester's case, became the outer layer of the plant's rusticated basement; after setting a course of "Pre-Cast stone" in place, workers backed it with concrete.[61] Internal use of the material was more extensive. It formed ducts, conduits, wire chases, switchgear housings and turbine foundations, making the building a direct extension of the machines it housed.

In a larger sense, both building and equipment were designed to function as a single machine. Although Chester Station did not employ the assembly line technology that revolutionized contemporary automobile manufacture, similar principles guided the plant's layout. Individual sections of the building contained multiple levels. Yet the overall arrangement of these sections was horizontal and linear. Entering from the south, coal provided energy that traveled north, first as heat, then as steam and finally as electricity. At Chester this process was almost entirely automated. The plant's most basic function, converting steam to electricity, was, of course, performed by machine. Historically labor-intensive activities such as oiling and stoking were also mechanized, bringing Chester into conformity with factory design trends of the day. Long of interest to power plant designers, the question of materials handling received special attention from industrial engineers after 1910. As a result, Chester and other large plants featured mechanical stokers, internal railways and less-novel traveling cranes - devices integral to the "rational factory" of the era.[62]

Unlike heavy industries such as mines and steel mills, large power plants relied little on hard physical labor by the 1910s. While linemen still faced dangerous and arduous work outdoors, most plant employees tended semi-automated machines. Certain tasks, usually equated with low status, required more exertion than others. At Chester, for instance, men dumped coal cars over the bunkers by hand. But in the switch house and turbine hall, workers' relationship with equipment was essentially monitorial. Moreover, even the lower echelons of workers were often in contact with the plant's engineers and supervisors, limiting the perceived distance between labor and management. All of these circumstances tended to discourage union organization.[63]

Nonetheless, utility executives took deliberate measures to accommodate plant employees. The

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[61]Philadelphia Electric Company Board Reports, 30 April 1918; Biggs, 82-85. A clear photograph of Chester Station's pre-cast stone sections appears in "Chester Station of the Philadelphia Electric Company," *Electrical Word* ??? (8 June 1918): 1223.

[62]On the role of materials handling in 1910s factory design, see Biggs, 47-52, 78-81.

[63]David E. Nye, *Electrifying America: Social Meanings of a New Technology* (Cambridge [MA]: MIT Press, 1990), 206-08; John R. Stilgoe, *Metroploitan Corridor: Railroads and the American Scene* (New Haven: Yale University Press, 127.

remote chance of a strike raised the possibility of a break in service, and even under peaceful circumstances utilities wished to retain workers whose specialized training represented an investment. Thanks to Taylorism and the "welfare work" movement, pleasant conditions were also thought crucial to maximizing worker efficiency.[64] This idea surfaced repeatedly in architecture and engineering journals, and may well have influenced Chester Station's design. Each section of the plant displayed concern for heating, lighting, and ventilation. Radiators warmed bathrooms in the switch house, skylights illuminated the turbine hall, and casement or louvered windows drew in fresh air. Some of these features catered more to mechanical than human necessity. Fire prevention underlay the extensive use of ventilator windows over the coal bunkers, where the main risk was to the structure itself. And while light aided equipment operation in the turbine hall, the boiler room remained relatively dark, perhaps facilitating coal bed inspection. In the switch house, doors closed automatically when the temperature rose, preventing the spread of fire but potentially impeding escape.[65]

Other features represented more direct concessions to workers. As the *Chester Times* reported,

> A trip to the plant reveals the fact that nothing has been left undone in the way of looking after the comfort and welfare of those who are employed on the operation. An inspection shows that the restaurant and officebuilding (i.e., the switch house)...is divided into several divisions. A locker room and wash room occupy one end of the building. Next is a portion which is known as the hospital section, being fitted up with all the necessary fixings necessary (sic) for the treatment of injuries, whether of serious or trivial nature.[66]

Among these spaces, the restaurant drew most comment. Worker dining rooms were a common feature of contemporary factories, and Philadelphia Electric had already tried the idea at Schuylkill A-2.[67] Yet Chester's example stood out. A long, vaulted room with Corinthian trim, it was lit by elaborate skylights and offered private groupings of tables and chairs. Food preparation occurred nearby in "huge electric kitchens," supposedly allowing "two hundred

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[64]Biggs, 44, 55-75. For a brief overview of welfare work in the electric utility industry during the mid 1910s, see "Educational and Welfare Work," *National Electric Light Association, Thirty-Seventh Convention, Philadelphia, PA, 1-5 June, 1914*, [v. I], 171-78.

[65]Former Chester Station electrician Dick Hoffman recalled working conditions in the switch house during a tour of the plant, 17 June 1998.

[66]"Progress of New Plant," *Chester Times*, 6 November 1917.

[67]Biggs, 68; "Ham and Eggs: 12c," *Current News* 12, no. 6 (January 1916): 133-35; "Station 'A-2' - Philadelphia," 49. After placing an "electric restaurant" in A-2's south gallery, Eglin and Windrim chose to locate the same amenity in Chester's better-lit switch house.

persons [to be] fed at one meal." If egalitarian motives influenced this design, others may also have been at work. The cafeteria and all major amenities were clustered on the [sixth] floor of the switch house, next to the management offices. Whether workers throughout the plant had equal access to these areas remains unclear.[68]

In the spring of 1917, the *Chester Times* reported that the city's new power plant would be "one of the most striking examples of engineering architecture in the country." Although this prediction had the ring of local boosterism, it was essentially accurate. Not only was Chester Station enormous in scale, it was also among the grandest plants ever built in the United States. Surviving documents do not record any explicit discussion of the intentions underlying the building's architectural treatment. Most evidence on the subject comes from the local newspaper, industry journals, and various media through which Philadelphia Electric presented itself to the public.

When architects and engineers discussed factory design in the 1910s, they spoke primarily in financial terms. Engineers frequently disparaged architecture as an unnecessary "frill," while architects defended their role as crucial from the standpoints of labor and management. The common ground between these rhetorical poles was economic. Men of both professions could agree that pleasant work environments increased productivity - a rationale relating primarily to interiors. At the same time, the need to bolster consumer and investor confidence also forced designers to address external appearance. This second consideration was especially important for electric utilities. As a columnist for *Power* wrote in 1917, "The stability and success of any enterprise and the character and ability of the men behind it are judged consciously or unconsciously by the appearance of the physical property. This is true of power stations in a marked degree..."[69] Whatever its use, such advice gave no indication of what style or form designers should adopt. These decisions depended on the specifics of time and place.

In 1916, the interlocking agendas of corporate public relations and the City Beautiful movement did much to determine Chester Station's appearance. Both strains of influence had earlier origins; those of the City Beautiful movement were more overtly architectural. Since the turn of the century, architects, planners and civic activists had joined in advocating the systematic

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[68]Dick Hoffman worked at Chester Station for approximately forty years, starting in 1946. During this period his perspective on plant operations changed as he rose from electrician to shift supervisor in the switch house. He remembers the restaurant in operation, but notes that each "gang" or department dined in its own section of the plant (personal interview, 9 June 1998). This may not have been the case before Hoffman's tenure began.

[69]"Power-Station Buildings," 492. See also Biggs, 73; Harvey Wiley Corbett, "Facts, Factories and Frills," *American Architect* 113, no. 2201 (February 1918): 235-37; Frank Koester, "Industrial Architecture," *American Architect* 106, no. 2011 (July 1914): 18-19; Robert D. Kohn, "Architecture and Factories," *Architectural Record* 25, no. 2 (February 1909): 131, 134, 136.

"improvement" of American cities. Their ideal consisted of broad, axial boulevards, landscaped parks, and monumental public buildings, all arranged so the city might function as an orderly, attractive whole. In Philadelphia, John T. Windrim was a leading practitioner of City-Beautiful design.

Windrim's architectural career began in the office of his father, James, a successful designer of institutional and industrial buildings in Philadelphia. Similar commissions became a mainstay of the younger Windrim's practice. During the 1890s he worked on banks, police stations, and at least one project for a Philadelphia Electric predecessor company. Bell Telephone and Philadelphia Electric later became his regular patrons. When City-Beautiful efforts began transforming Philadelphia in the late 1900s, Windrim assumed an important role in the process. Benjamin Franklin Parkway was the movement's main contribution to the city. Along this great boulevard, the architect conceived Bell Telephone's neo-Georgian office building (1912-16) and the sprawling headquarters of the Franklin Institute (1908-34). Though far removed from the parkway, Chester Station was related to Windrim's work there.[70]

From an early date, Windrim coined an architectural vocabulary that appealed to his institutional clients. His designs bespoke solidity and tradition, and reflected one of two schools of thought prevalent among Philadelphia classicists. Windrim's camp understood neoclassicism essentially as a style, applied to buildings like those of the 1893 World's Fair. As David Brownlee has noted, "This conception of the building as seen from the outside and from afar necessarily reduced the attention paid to planning and the rational expression of a building's structural system...."[71] Others architects, including Paul Cret, held that classicism was less an aesthetic than a method, based on the teachings of the Ecole des Beaux-Arts in Paris; discrepancies between a building's external appearance and internal configuration violated Ecole principles. Both factions believed classicism could meet the unprecedented architectural requirements posed by new technology. Their interpretations of this credo differed widely.[72]

Chester Station presented Windrim with a complex design problem. Many aspects of the building's program were fixed by mechanical necessity, and while some areas could be treated sparely, others would either have to follow classical convention or appear to do so. Only with effort could the forms of the parkway be fitted to the mechanisms of electricity production. One of the greatest challenges stemmed from the need to bring trains into Turbine Hall. Windrim

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[70]Roger W. Moss and Sandra L. Tatman, *Biographical Dictionary of Philadelphia Architects*, Boston: G. K. Hall & Co., 1985), 871-877; David B. Brownlee, *Building the City Beautiful: The Benjamin Franklin Parkway and the Philadelphia Museum of Art*, (Philadelphia: Philadelphia Museum of Art, 1989), 88-100.

[71]Brownlee, 3.

[72]Discussions of classicism's "modernity" appear in Brownlee, 4, 11, and William H. Wilson, *The City Beautiful Movement*, (Baltimore: Johns Hopkins University Press, 1989), 88.

responded by extending the room's downriver half, but this solution threw off the building's symmetry. As a result, the center line of the switch house and turbine hall falls in a different location than that of the boiler house. If this compromise offended Cret's contingent, other shifts would have been just as shocking. The steel frame supporting the boilers does not align with the boiler house's exterior columns, so beams between facade and core veer off at different angles. Elsewhere, steel piers are off center within their concrete encasements. Many of these adjustments are only visible in plan, and represent ingenuity as much as unorthodoxy. Moreover, the fit between technology and tradition was sometimes seamless. Such was the case with Turbine Hall's interior cornices, which double as beds for the traveling crane's tracks. The only features that jarred overtly with the plant's architecture were booms and smokestacks - standard sticking points of central station design.[73]

Corporate beautification was one of Windrim's strengths. His Bell Telephone offices helped anchor the Benjamin Franklin Parkway. And he was equally prepared to link Philadelphia Electric with a more modest improvement campaign in Chester. Like many American cities, Chester had assumed a gritty, industrial character by the early twentieth century; as the local paper readily confessed, "Chester has not had the reputation of being a 'City Beautiful.'" Hopes of shedding this stigma ran high in the mid 1910s. John H. Mirkil, the city's Superintendent of Parks and Improvements, performed his duties with zeal, and private sponsors supplemented his efforts. The focus of their attention was Chester's aging commercial and administrative core. By 1916 the city had begun planning a Civic Center at Fifth and Market Streets (now Avenue of the States), surrounding the 200-year-old courthouse that had long served as City Hall. A prim, neo-Georgian Municipal Building soon emerged as the scheme's centerpiece. The work of New York architect Clarence W. Brazer, it housed the city's police department and growing bureaucracy in separate quarters. A small park connected this complex to the historic courthouse (for which Brazer furnished restoration plans) while "the city's first skyscraper," the Crozer Building, loomed over the ensemble. Several blocks to the north, Frazer & Roberts' Deshong Memorial Art Gallery also contributed to the transformation.[74]

Although Chester Station was physically remote from these activities, it joined them by association. On one hand, Windrim's design was stylistically compatible with downtown construction. On the other hand, the new plant would provide power for the "great white way" that Philadelphia Electric's subsidiary, Beacon Light, had promised Chester. Brilliantly lit thoroughfares or "white ways" were contemporary symbols of urban progress. Hoping to bring

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[73]Architects on HABS/HAER's 1998 summer project at Chester Station brought the building's formal discrepancies to my attention.

[74]"Local Pride and Architecture," *Chester Times*, 2 November 1916; "Prospectus for New Year," *Chester Times*, 20 January 1917; "New Municipal Building Plans," *Chester Times*, 13 March 1917; "Beautiful City Hall is Planned," *Chester Times*, 23 April 1917; Writers' Program of the Works Progress Administration, *Pennsylvania: A Guide to the Keystone State* (New York: Oxford U. P., 1940), 205-06.

the phenomenon to Chester, John Mirkil worked with Beacon manager Albert Granger on plans to install "powerful arc lights" on "ornamental iron poles" along Third Street, Market Street, and Edgmont Avenue. Much of this "city beautiful light plan" reached completion in 1917, illuminating the business district and the Civic Center site. The handsome new lampposts held much brighter lamps than their wooden predecessors. They also carried streetcar and telephone cables, reducing the number of poles needed on streets the City wished to beautify. Windrim's architecture was an implicit part of this program.[75]

While neoclassicism related Chester Station to the City Beautiful movement, architectural style was only one of the movement's concerns. At least as important was the larger goal of urban reform. City-Beautiful advocates wished to make urban America cleaner, safer, and more orderly. They shared these priorities with a wide circle of progressive-era reformers that included city planners, politicians, civil engineers and others whose professions dealt indirectly with aesthetics. Among this group was Philadelphia's Director of Public Works, Morris Llewllyn Cooke. Cooke's appreciation of scientific management made him a champion of candor and efficiency in the operation of cities; open bidding and honest contracting were as central to his program as clean streets and "artistic" bridges. Like many City Beautiful proponents, he came to believe that utilities were taking advantage of the municipalities they served. It was this conviction that pitted him against Philadelphia Electric.[76]

Cooke's suit centered on allegations of stock watering. Yet, as the case wore on and gained national attention, it became a de facto attack on Philadelphia Electric's system. Engineer George Morse testified that the company's power plants were "curiosities" - not simply "inadequate," but "actually dangerous to operate."[77] Erected months after the case closed, Chester Station was, in a sense, a response to these charges. The sheer cost of the building attested to its sponsor's financial stability, while the structure's style, scale, and massive construction all bespoke permanence. Just as importantly, Chester Station was modern; far from resembling Morse's description, it was a clean and monumental showcase for the latest power-

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[75]"Great White Way of the City," *Chester Times*, 6 November 1916; "Council Awards Light Contract," *Chester Times*, 13 November 1916; "City's Proposed 'White Way,'" *Chester Times*, 15 March 1917; "More Light for Third Street," *Chester Times*, 28 May 1917. On Beacon Light Company's public lighting efforts, see also Granger, "Fifty-Five Strenuous Years," 51-52, and periodic updates under "Beacon Light Company," *Current News* 12, no. 5 (December 1916): 116; 12, no.6 (January 1916): 150; 13, no. 6 (January 1917): 167; 13, no. 9 (April 1917): 266. On white ways, see Nye, *Electrifying America*, 51-57, 60-61.

[76]Wilson, 44, 47, 78-87; Biggs, 44; Christie, 8-11, 26-27. Cooke's interest in smoke abatement and determination to "improve market facilities, lower utility rates, build more 'artistic' bridges and comfort stations [etc]" place him in the same urban reform context as City Beautiful advocates.

For the City-Beautiful perspective on utilities, see also Charles Mulford Robinson, *The Improvement of Towns and Cities* (New York: G. P. Putnam's Sons, fourth ed., 1901), 94-112.

[77]Trombley, 42-43.

generating technology. Programmatically, the 1916 plant drew on precedent at Schuylkill A-2. Aesthetically, it was a clear break from anything Philadelphia Electric had ever built.

Because Cooke's case put an engineering slant on City-Beautiful reform, it placed William Eglin and John Windrim in an ideal position to refute the charges through design. Eglin was an accomplished engineer. His career in electric power started in 1889 when he began working for the Edison Electric Light Company of Philadelphia. Moving quickly through that venture's ranks, he became Philadelphia Electric's Chief Engineer after the 1899 merger, and took primary responsibility for "modernizing and unifying" PE's system. He was, according to Nicholas Wainwright, "one of the foremost and most progressive engineers in the country."[78] Partly through collaborating with Eglin, Windrim earned a reputation as an eminent practitioner of "engineering architecture." The two men's work on Schuylkill A-1 and A-2 formed the hub of Philadelphia Electric's system, and Windrim's Bell Telephone projects underscored his ability to integrate architecture and technology.

Windrim and Eglin were qualified professionals, and Philadelphia Electric gladly credited them with conceiving Chester Station. The question of attribution is, of course, somewhat more complex. While Windrim and Eglin contributed materially to Chester's design, the project's vast scale demanded the time and skills of many others. Both men had large numbers of assistants at their disposal. When this consortium of engineers, architects and draftsmen completed the initial phases of design, a "corps of draftsmen," temporarily stationed in the switch house, continued to refine the plans.[79] This second group apparently suffered from attrition after the U. S. entered World War I. As members of the corps departed, their positions were filled by the Drafting Room Girls, a group of young women who worked in the mechanical drawing room of Philadelphia Electric's downtown office building. The "girls" saw the plant infrequently, but some obviously looked on their contribution with pride. After receiving a tour of the site as a "reward," Catherine Day joined other draftswomen in sending accounts of the trip to the company's in-house journal. She wrote, "The ash handling system proved very interesting to me, as I had done a great deal of the tracing for that particular part...We enjoyed the afternoon very much, and expressed the hope that we might see this fine station again and see how these different parts of machinery would look when in working order."[80]

Because the design of Chester Station involved so many different hands, Eglin and Windrim's role in the process quickly became managerial. This was another responsibility for which the

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[78]Wainwright 69, 127, 184-85; Granger, "Fifty-Five Strenuous Years," 11.

[79]"Progress of New Plant." The article states that on-site draftsmen worked in a "blue-print or layout room," but the description of this area suggests it was actually the plant's well-lit restaurant.

[80]"New Chester Station as Viewed by the Drafting Room Girls," *Current News* 15, no. 5 (October 1918): 4. The visit occurred 18 May of the same year.

two men were prepared. Both were used to working with a staff, and both could be counted on to represent the interests of Philadelphia Electric. The latter guarantee stemmed from the designers' positions within the corporation's upper ranks: Windrim had been a Director since 1912, and Eglin's tenure as Vice-President began the same year.[81] Under this arrangement, both men had an added stake in the success of their projects. They were the ideal stewards of corporate public image.

Eglin's role in shaping public perception extended beyond his connection to Philadelphia Electric. For years he had been actively involved in the National Electric Light Association (NELA), an organized mouthpiece for American electric utility interests. He had served as the NELA's President from 1908 to 1909 and been instrumental in developing the organization's state and company branches; Philadelphia Electric's own "company section" owed its genesis to Eglin. Prior to 1911, the NELA tacitly functioned as a General Electric holding company. After this fact triggered federal anti-trust litigation, the association underwent some superficial adjustments but continued to promote ingrown relationships among power companies and electrical equipment manufacturers. It also became an aggressive advocate of private utility ownership at a time when many reformers were calling that arrangement into question.[82]

The ownership controversy was one of the great debates of the early twentieth century. It flared up periodically in various parts of the country and had, in fact, embroiled Philadelphia Electric in 1905. Earlier still, Chicago utility magnate Samuel Insull began trying to stave off conflict by calling for state utility regulation. The NELA initially failed to grasp his logic, but soon "realized that state regulation would both facilitate expansion and counter the rising tide of municipal ownership."[83] In the 1910s, many states, including Pennsylvania, formed agencies that governed the operation of utilities. Men like Eglin and Insull urged their fellow NELA members to cooperate with government officials and also, in a sense, to emulate them. It was not enough, Insull argued, for utility executives to insist on the public benefit of their service. Instead, "We, central station managers, ought to look upon ourselves as semi-public officials and so conduct our affairs with the community as to give us the advantage of a reputation for

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[81]Wainwright, 374, 376.

[82]On the NELA, see Nye, *Electrifying America*, 173; idem, *Image Worlds: Corporate Identities at General Electric* (Cambridge [MA]: MIT Press, 1985), 18-24, 138-43. On Eglin's NELA involvement, see "Address of President Eglin," *National Electric Light Association, Thirty-Second Convention, Atlantic City, NJ, 1-4 June 1909*, v. I, 3-13; "Experience Meeting as to Company Section Methods," *National Electric Light Association, Thirty-Third Convention, Saint Lewis, MO, 23-27 May 1910*, v. 2, 511; F. A. Birch, "Philadelphia Electric Co. Section, NELA" *Current News* 9, no. 4 (May 1914): 332-33.

[83]Hughes, 207.

absolutely fair and impartial dealing."[84] In a similar speech before the NELA, Arthur S. Huey proclaimed, "The ideal utility manager should be an integral part of the life of the city, ...foremost among the planners for municipal advancement."[85]

Morris Cooke did not wish to place Philadelphia Electric in public hands. While many reformers in his circle favored municipal ownership, he was actually somewhat leery of it.[86] Nonetheless, his law suit challenged Philadelphia Electric's worthiness to serve as the region's electricity supplier, and it behooved the corporation to follow the NELA's public relations advice. Toward that end, the utility's Chester subsidiary could serve as a model. General Manager Albert Granger conformed seamlessly to the ideal outlined by Insull and Huey.[87] At the same time, the plant under Granger's supervision represented an attempt to reinforce his "semi-public" role through architecture. Eglin and Windrm's building towered over the city's waterfront. "If one could see over the coal piles on the landward side, one might mistake the plant for an enormous public library!"[88]

Similar objectives guided the treatment of Chester Station's interior. NELA members urged each other to "arrange and keep our plants [so] that visitors coming to the city, and also our consumers and people living in the city, can visit it, and would do so."[89] Such tours seem to have occurred frequently at Chester during the plant's early years; the first may have been led by Eglin himself, who presided over the opening-day ceremonies.[90] Turbine Hall was the one space all visitors would have seen. An immense, formal room, it possessed the public character of contemporary train stations. Here one might observe the latest generating technology and the safest, most pleasant working conditions. All validated private stewardship of utilities, especially as practiced by Philadelphia Electric. Another important showplace was the electric

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[84]Samuel Insull, "Twenty-Five Years of Central-Station Commercial Development," *National Electric Light Association, Thirty-Third Convention, Saint Lewis, MO, 23-27 May 1910*, v.1, 222.

[85]Arthur S Huey, "Latitude in Commercialism," *National Electric Light Association, Thirty-Third Convention, Saint Lewis, MO, 23-27 May 1910*, v. 2, 7.

[86]Christie, 30.

[87]Granger's "many positions of public and semi-public character" are listed in John T. Donahue, ed., *Who's Who in Delaware County* ([Chester, PA]: Press of Chester Times, 1926), 89.

[88]Wainwright, 131.

[89]Huey, 5, 14.

[90]"Great Day at Big Power Plant;" Chester F. Baker, undated papers, Delaware County Historical Society, "CFB" v. 18, p. 333. Baker's claim that Chester Station was "visited as a model by delegations from all parts of the world" is probably exaggerated. Nonetheless, he was a keen observer of life in the City of Chester, and his recollection suggests the early importance of local plant tours.

kitchen and restaurant. Filled with modern appliances, the area not only evinced concern for workers but also showed visitors how electricity might improve their own lives.[91]

Philadelphia Electric was committed to using architecture in the service of public relations. Yet this kind of publicity had distinct limitations. Power plants housed dangerous equipment, and their immediate surroundings posed additional risks. Despite the emphasis placed on tours, Chester Station was intentionally hard to reach. Utility employees had regular access to the site, but fences and a guard house guaranteed that others stayed away.

Obliged to keep the public at bay, Philadelphia Electric found other venues through which to communicate its architectural message. Over time, Chester and its sister stations appeared in company-sponsored drawings, photographs and parade floats. Accompanying text - in the form of pamphlets, articles, banners, and electric signs on the plants themselves - stressed the tightly "woven" relationship between company and community. The same media borrowed icons from Philadelphia's public past to drive home the point. City Hall, Independence Hall and Benjamin Franklin stood side by side with monumental power plants, unmistakably conflating public and private interest (Fig.). In this way, Chester Station proved useful to Philadelphia Electric many times over. The company hired Windrim and Eglin, and received a factory, a showcase, and a billboard in return.[92]

V. Chester Station: Plant Technology

In the first decades of commercial electricity generation, the question of whether large consumers of electricity should build their own dedicated sources of power or obtain it from central stations operated by utilities sparked much discussion in engineering periodicals.[93]

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[91]See discussions of the earlier kitchen at Schuylkill A-2 in Clara H. Zillessen, "A Woman's Impressions of a Great, Modern Power House," *Current News* 12, no. 9 (April 1916): 277; "We Practice What We Preach," *Bulletin of the Philadelphia Electric Company* 10, no. 5 (?): 20-22.

[92]See *The Chester Station of the Delaware County Electric Company* (ca. 1919), pamphlet in collections of the PECO Energy Company Library; *Philadelphia and the Philadelphia Electric Company System* (1924), pamphlet prepared for the Forty-Seventh Convention of the NELA, in collections of the PECO Energy Company Library; "The Philadelphia Electric Company System," *Bulletin of the Philadelphia Electric Company System* 23, no. 3 (September 1926): 4-8; various photographs of parade floats, most taken in 1926 during Philadelphia's Sesquicentennial Exposition, PECO Library.

[93]Between 1909 and 1911, roughly one third of the articles under the heading "Isolated plants" in the *Engineering Index*, and nearly all under the heading of "Economics" in the 1910 edition, concerned the isolated versus the central station debate. For specific articles of a later date see J.A. McHolland, "Future of the Private Plant," *Power* 43, no. 20 (16 May 1916): 693-694; L.W. Schmidt, "Power Consumption of National Industries," *Power* 48, no. 18 (29 October 1918): 628; "Year's Review of the Power Field," *Power* 45, no. 1 (2 January 1917): 2; see also a series of editorials discussing a well-publicized test to determine if an isolated municipal plant

Several early power stations were designed specifically to provide direct current for street lighting systems, including the Sansom Street Station of Philadelphia's Edison Electric Light Company, heralded as the largest in the world when completed in 1890.[94] For large industries and railroads considering electrification, construction of an "isolated" power plant had the advantage of independence from public utilities, still known for high rates and low dependability. Recognition of the substantial value of the contracts at stake in the isolated versus central station debate pressed utilities to enhance and promote the benefits of central station power. Aside from the challenge from isolated plants, private utilities were trying to win public trust as the rightful stewards of a public service. Toward that end, Philadelphia Electric executives sought to equate the technical prowess of their utility with the well-being of their service area: "The Philadelphia Electric Company's contribution to our city's prosperity is the supply of an adequate, reliable and economic power supply."[95] The development of power plant technology in the Philadelphia Electric system reflected this search to balance reliability and economy of operation.

Construction of the Schuylkill A-1 station in 1902 marked Philadelphia Electric's first major step toward a general-service central station system. The company's next two plants, Schuylkill A-2 and Chester, each reflected incremental steps in advancing the form of central station power. The A-2 station, essentially a self-contained addition to A-1 built between 1914 and 1915, was the first in the Philadelphia Electric system to contain the major elements of modern power plant technology: specific design for surface condensing, horizontal-shaft steam turbines; mechanical, stoker-fired boilers; high-volume circulating water system with a screening house; and a separate switch house with a three phase system divided functionally by floors. Over thirty years later, Vice-President in charge of engineering N.E. Funk commemorated the pioneering role of Schuylkill A-1 and A-2 in a speech before a gathering of Philadelphia Electric supervisors:

> Schuylkill Station is really the birthplace of virtually all of our basic operating procedure. Everyone of our station superintendents learned his first lesson in the operation of the Philadelphia Electric system in the old Schuylkill Station. Methods were developed there for which the rest of the industry more or less damned us at the time. In this category is the load-dispatching system, the

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in New York City could provide power more cheaply for the Hall of Records, City Hall, City Court, and County Court than the New York Edison Company in *Power* 43, no. 10 (7 March 1915): 329, (9 April 1915): 524, and (2 April 1918): 474.

[94]Green, 109.

[95]"Keeping Pace with Business," *Bulletin of the Philadelphia Electric Company* [vol. and no. missing on PECO copy] (December 1919): 11.

> separate maintenance bureau, and the separate coal bureau. Our method of handling load dispatching by locating the dispatcher at Tenth Street away from the main generating station was thought to be a very silly move, but now most of the systems do it our way. The idea of taking maintenance out of the hands of the plant superintendent was thought so foolish than the president of one great company came all the way to Philadelphia to tell us what he thought about it.[96]

Naturally, the design of Chester Station drew on lessons learned at A-2 and other stations, but it also departed from older practices in significant ways. The monumental architecture, tripartite layout facing the river, and certain standardized features implemented in the design for Chester served as a prototype for a future generation of plants that included the Delaware and Richmond stations. Several innovations introduced at Chester, including Babcock & Wilcox Stirling boilers and "island construction" in the turbine hall were also used at Delaware and Richmond.

The development of island foundations was likely a result of the increasing size of condensers and horizontal turbo-generators. A few years prior to Chester's construction, many plants placed turbo-generators parallel and adjacent to the boiler house wall, most likely to reduce the length of steam piping.[97] In the turbine hall at Chester, the designers rotated the turbo-generators ninety degrees and built up isolated foundations for each unit, providing generous space on the lower level for access to pumps, condensers, pipes, and other auxiliary equipment. The Philadelphia Electric island foundation was well-suited to accommodating longer turbines, but width limitations precluded consideration of cross-compound turbines -- a primary determining factor in the selection of turbines for Richmond Station.[98]

At Chester, engineers also expanded their program of standardized designs, intended to reduce construction costs and provide familiar conditions for the workforce in any station. Standardizing the location of station equipment and controls, N.E. Funk explained, facilitated the transfer of men from plant to plant, reduced training time, and aided equipment maintenance.

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[96]N.E. Funk, Philadelphia Electric Company Minutes of Supervisory Group Conference, 29 January 1937.

[97]Some examples of turbine hall layouts placing the turbo-generator parallel to the adjoining boiler house wall included the East River Station of the Consolidated Edison Company of New York (operational in 1912), the Windsor Power Station of the American Gas and Electric Company and the West Penn Power Co. (August 1917), the Joliet Plant of Public Service Company of Northern Illinois (1918), and Philadelphia Electric's Schuylkill A-2 (1915).

[98]E.L. Hopping, "Mechanical Design of Richmond," *Electrical World* 87, no. 18 (1 May 1926): 919.

> In laying out control panels for all apparatus the instruments that are common to all stations are located in the same position on the control board wherever this is possible. This causes no inconvenience in the design, does not disturb the appearance of the board and has the advantage of giving the operator the fewest number of new instrument locations to learn... if this same policy is pursued throughout the plant control equipment, it is surprising how rapidly the operating force will fall into the operation of equipment in conjunction with the main apparatus in the plant with which they have been unfamiliar in the past.[99]

Another precedent set at Chester was the exclusive generation of three-phase, alternating current electricity at 60 cycles and 13.2 kilovolts. Unlike the split-frequency system at Schuylkill A-2, all generators at Chester produced a standard electricity. This constituted a substantial step toward establishing uniform service in Philadelphia, as Chester's intended capacity of 120 MW nearly doubled the existing Philadelphia Electric system. The last major obstacle to standardized electricity lay in the Edison direct current district in downtown Philadelphia, a project tackled by Philadelphia Electric in 1924.

As previously mentioned, the plant layout differed in its orientation from the earlier Schuylkill stations, but was fairly typical of contemporary power plant designs and was continued in the Delaware and Richmond stations.[100] Division of the plant into three sections -- the boiler house, turbine hall, and switch house -- minimized damage in the event of a fire or major equipment failure, particularly boiler explosions, which had long concerned producers of steam.[101] Apart from erecting physical barriers between plant operations, the station workforce was also divided by the sectionalized plan: the boiler engineer and his assistant supervised a crew of watertenders, firemen, ashmen, and boiler cleaners in the boiler house; the running engineer, assistant running engineer, and oilers tended to the turbine hall; and the chief electrician, switchboard operators, excitermen, electric mechanics, and maintenance men staffed the switch house and fixed station electric motors and

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[99]N.E. Funk, "Past Operating Experiences Affect Design of Richmond," *Electrical World* 87, no. 18 (1 May 1926): 924-935.

[100]Several stations constructed between 1916 and 1918, such as the Essex Station of Public Service Electric Company, the Windsor Plant built by the American Gas & Electric Company and the West Penn Power Company, and the Joliet Plant of Public Service Electric of Northern Illinois, Connors Creek of the Detroit Edison Company used the tripartite layout that allowed for parallel additions and had a similar capacity generated by condensing, large steam turbo-generators.

[101]A column in *Power* 43, no. 10 (7 March 1916): 330, contained a table of 101 boiler explosions between January and June of 1915 in which 46 people lost their lives and 89 were seriously injured.

equipment.[102] At least one observer expressed surprise that remarkably few workers were needed to generate so much power.[103]

During the most useful years of production at Chester, the development of plant technology passed through several stages: original construction, 1916 - 1919; completion of intended capacity, 1923 - 1924; and World War II-era upgrade, 1939 - 1942. In keeping with Philadelphia Electric convention, Chester's equipment was numbered in relation to the river (in ascending order, from downriver to upriver sides of plant). The following discussion of plant technology is neither strictly chronological nor numerical. It aims instead to explain the plant's three basic functions, and is divided accordingly. In a sense, the history of Chester's technology is not one story but three. In each major section of the plant, the course of development reflected a different approach to balancing reliability against ease of maintenance, cost, and efficiency.

Boiler House

Activity in the Boiler house revolved around the primary task of providing the energy needed to convert water to steam. The physical center of this operation was the boiler, which at Chester marked Philadelphia Electric's first use of the Stirling-type boiler manufactured by Babcock & Wilcox. Pioneered by Allan Stirling in the late nineteenth century, the Stirling boiler offered "quicker steaming, greater ease of cleaning, improved fuel efficiency, and more efficient use of space," compared to other models; its design for rapid circulation of steam also reduced the likelihood of boiler explosions.[104] The success of the Stirling Boiler Company (later Stirling Consolidated Boiler Company) attracted the attention of established boiler manufacturer Babcock & Wilcox, which purchased the company in 1906. Philadelphia Electric ordered more conventional cross-drum boilers for Schuylkill A-2 in 1913, but the greater capacity of the Stirling boilers installed at Chester (125,000 lb/hr evaporated steam v. 60,000 lb/hr for the cross-drum boiler) permitted use of fewer boilers per turbine. A bank of four boilers supplied steam to each turbine at Chester as opposed to the bank of ten needed for each turbine at Schuylkill A-2.[105]

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[102]Philadelphia Electric Company, "Steam-Electric Generating Stations Manual," 1937, TD, 65, PECO Library.

[103]Granger, "Fifty-Five Strenuous Years," 106.

[104]*Landmarks in Mechanical Engineering,* prepared by ASME International History and Heritage, (West Lafayette, IN: Purdue University Press, 1997), 202.

[105]For A-2 boiler specifications, see *Current News* 12, no. 9 (April 1916): 18-20; and for original boiler settings at Chester, see D.F. Schick, Jr., "Unusual Mechanical Features in Chester Station Expansion," *Electric Light and Power* (May 1941): 57.

In addition, the Stirling boilers at Chester had integral economizers, which used exhaust heat from the furnace to increase the temperature of feed water before it entered the boiler. Economizers gained wider use during World War I as engineers sought new means of offsetting the rising cost of fuel by improving plant efficiency. Into the 1920s, boiler engineers debated the value of installing economizers instead of simply increasing the surface area of the main boiler tubing. However, Philadelphia Electric's experience with Chester consistently led the company to install boilers with economizers in its plants.[106] The growing popularity of economizers coincided with a period of widespread adoption of surface condensing steam systems in central stations. Many early plants utilizing condensers, such as Schuylkill A-1, opted for jet or barometric types that discharged both turbine exhaust steam and cooling water as waste water.[107] After converting steam exhausted from the turbines to water, surface condensers returned it to the boilers as part of a closed, "feed- water" system. The chief design engineer of Chester Station, W.C.L. Eglin, observed that the surface condenser was a pivotal development in maximizing steam produced by a given amount of fuel; analysis of the closed feed-water system led to the recovery of energy lost in the steam generation process through regenerative heat cycles.[108] One method used at Chester to recover heat employed an open-type heater to raise the feed-water temperature prior to entering the boiler, thereby decreasing the amount of heat input required to generate steam. In the years following the initial phase of construction at Chester, more attention was paid to decreasing fuel consumption through improving plant efficiency, commonly measured in pounds of coal consumed per kilowatt hour.[109]

As World War I had shown, utilities could be hard hit by sharp increases in the price of coal. The availability of coal -- threatened by a coal shortage in the winter of 1917-1918 and several strikes, notably in 1919, 1922, 1946 -- proved another concern. Coordinating fuel pricing, procurement, distribution, and storage, for a large urban territory presented other problems. Philadelphia Electric took several steps to ensure a regular and rationalized supply of coal. First, the company purchased Petty's Island, located in the Delaware River near northeast Philadelphia, for coal storage.[110] Second, company engineers drew up specifications for

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[106]*Steam: Its Generation and Use*, 40th ed., (Barberton, [OH]: The Babcock & Wilcox Company, 1992), 31.

[107]Two prime examples include the Fisk station in Chicago, Illinois and the Georgetown steam plant in Seattle, Washington.

[108]William C.L. Eglin, "Forty Years of Central-Station Development," *Electrical World* 84, no. 12 (20 September 1924): 610.

[109]Onken, 174.

[110]Philadelphia Electric Company Board Reports, 27 March 1917.

Chester's boilers that would allow the plant to burn coal, oil, or gas. This flexibility with regard to fuel proved farsighted. In 1946, a coal strike led to Philadelphia Electric to convert several of Chester's boilers to oil-firing operation, and the 1950s brought a another conversion for natural gas.[111] Third, Chief Engineer Horace Liversidge (later the utility's president) created a "Coal Bureau" to centralize control of all coal purchasing and distribution under one department in 1922.[112] Formerly, the separate stations arranged for coal deliveries and managed stockpiles individually. The Bureau was formed as a distinct agency to coordinate company coal policy and to ease conflict that periodically arose between stations short on fuel. Philadelphia Electric workers assigned to specific stations considered Coal Bureau personnel outsiders, and little interaction occurred between the two workforces.

Coal delivery also figured prominently in the site selection and final layout of Chester Station. Designers placed the boiler house along the river to facilitate coal loading and ash removal. The main disadvantage of this arrangement was the increased distance between turbines and river water, necessitating longer intake and discharge tunnels for the circulating water system. At Chester, engineers attempted to solve this problem and improve water access by locating the plant well into the river.

This strategy had several ramifications. On one hand, it increased coal storage space behind the plant. On the other, it precluded construction of the tilted conveyor system used to transfer coal from barges to storage bunkers at Schuylkill and elsewhere. Gone, too, was the conventional coal-loading dock. Instead, a pair of "coaling channels" flanked Chester Station. After entering the channels, coal barges were secured to a motorized pulley system controlled by hoist operators in the coal towers. From a seat high above the water, the operator maneuvered the barge and lifted coal with a grab bucket to the tower's upper floor. Because most plants used belt-conveyor systems rather than hoists to raise coal to bunkers, some unusual factor may have driven the decision to adopt an alternative arrangement at Chester. The close proximity of boiler house to river, the use of coaling channels, and the tower-hoist system could have been intended to provide a common access point to coal in the event that another power plant was added inland from Chester (a possibility anticipated in the company minutes and a Coal Bureau manual). However, the design proved expensive. Later stations maintained Chester's boiler-side-to-water orientation while reverting to more conventional coal delivery systems.[113]

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[111]Wainwright, 318.

[112]Wainwright, 146.

[113]"Coal Bureau Manual, 1937," TD prepared by Philadelphia Electric Company's Operations Department, Station Operating Division, 51; Philadelphia Electric Company Board Reports, 26 September 1916.

The coal towers served as points of entry for the gravity-feed distribution system. After passing through sorters and crushers, coal was guided by hopper into cable-driven cars that followed a set of tracks to one of two main bunkers. The distribution system was designed to maintain a constant supply of fuel in the event that one tower hoist failed. Below the bunkers, feed pipes distributed coal to mechanical stokers in the firing aisles of the boiler house. When the installation of two larger, high pressure boilers in 1939 boosted the plant's coal consumption, Philadelphia Electric replaced the tracks serving the downstream tower with a belted conveyor system that fed the bunker over the new boilers. The original system continued to operate in conjunction with the upstream coal tower.

Chester's original boilers were equipped with Taylor underfeed stokers that mechanically fed the furnace with coal. Efficient combustion, often gauged by the quantity of smoke in the exhaust, depended on careful control of air and fuel. Earlier hand-fired boilers depended on the skill of the fireman for smokeless combustion, a task replaced by mechanical stokers in larger central stations between 1900 and 1915. Uniform control of the feed-rate enabled engineers to test boiler performance by monitoring the supply of coal and air. As new methods of improving boiler performance were introduced, testing became an increasingly vital means of measuring plant efficiency. Philadelphia Electric implemented a systematic program to weigh the benefits of the latest auxiliary boiler technologies as part of the second major phase of construction at Chester between 1923 and 1924.

During its initial five years of operation, Chester ran at only half of its intended capacity. Most of Philadelphia Electric's post-World War I construction funds were allocated for completing the Delaware Station, and the post-war recession dampened demand for electricity. By 1923, company revenue had increased sufficiently for managers to advance plans for bringing Chester Station up to full capacity. Eight more Stirling boilers, two turbo-generators, and the concomitant switch gear were needed. This upgrade coincided with an interesting period of experimentation with innovative technologies in the boiler house, including air preheaters and water-cooled boiler walls.

Air preheaters transferred heat from exhaust gases to air entering the boiler furnace, reducing both the temperature of stack emissions and the heat input needed for combustion. Although air preheaters appeared to be a promising technology, their effectiveness could not yet be measured with any precision. Because boiler-house conditions often varied widely between utilities and even among stations, weighing such variables as initial cost, impact on boiler maintenance, and overall effect on boiler efficiency had proved problematic. With "great difficulty," Philadelphia Electric equipped several of the 1924 boilers with different types and sizes of air preheaters in an effort to determine the best combination.[114] Two

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[114]R. A. Walton, "Air Preheaters Discussed," *Current News* 21, no. 13 (1 April 1925): 3.

boilers, numbers 7 and 8, had particularly unusual configurations. Neither had an economizer (standard on all other boilers); an experimental Ljungstrom rotary preheater was fitted to No. 7, and No. 8 had a tubular preheater nearly twice the size of those installed on the other boilers.

Boilers 7 and 8 continued to serve as trial units in later years, as Philadelphia Electric experimented with several other innovations and modifications such as Bailey water walls on these units. The water walls at Chester were retro-fitted into the refractory brick walls of the furnace interior to reduce wall temperatures and provide further heating area for feed water. Water walls proved a successful experiment and later became a crucial part of boiler design as boiler manufacturers turned to pulverized coal to achieve higher volumetric combustion rates. A Babcock & Wilcox steam manual noted the importance of utilities' early experiments with water walls: the advantages gained by firing pulverized coal "could not have been fully exploited without the use of water-cooled furnaces" that prevented the rapid deterioration of the refractory brick caused by slag (molten ash) build-up at higher temperatures.[115] Other utilities likely found Philadelphia Electric's published comparisons of air preheater performance and Bailey water walls informative, as the reports identified problems and advantages uncovered over several years of testing.[116]

Efforts to improve boiler efficiency through modification and the addition of auxiliary equipment were characteristic of progress in plant engineering during the prosperous 1920s. But even as the U.S. economy struggled through the Great Depression, Philadelphia Electric placed new boilers in service that generated steam temperatures and pressure unattainable at Chester Station. The plant's relatively low efficiency compared to other parts of the system had significant ramifications for workers. Philadelphia Electric shut down Chester for two extended periods during the 1930s, canceled the employee wage dividend program, Christmas bonus, and laid off workers.[117] Although the plant continued to contribute to Philadelphia Electric's total system capacity during the Depression, in just over ten years the

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[115]*Steam: Its Generation and Use*, 8. For a more contemporary view on the importance of water walls, see Frederick T. Morse, *Power Plant Engineering and Design* (New York: D. Van Nostrand Company, Inc., 1932), 333.

[116]Philadelphia Electric published reports on air preheater and water wall tests in the National Electric Light Association proceedings in (1926): 1207, 1288; (1927): 1020; (1928): 1110, 1122-1123; and (1929): 1290, 1036.

[117]The Philadelphia Electric Company Board Report for 25 October 1932 recorded that "the Chester Station was placed in service September 26th, having been shut down since May 12th," and again in 25 April 1933 noted "the up-river half of the Chester Station was shut down on March 27th, and the balance shut down on April 10th with the exception of one boiler which will be kept as reserve capacity. The closing down of both stations will result in marked operating savings." On consequences for workers, see Wainwright, 233.

primary generating technologies at Chester were fast becoming out of date.

Rather than condemn Chester as obsolete, Philadelphia Electric turned to a technique, developed in 1925, known as superposing or "topping." Superposition recouped the large initial investments made in older technologies by coupling newer high-pressure systems to the existing low-pressure units. Steam entered Chester's original low pressure turbines, units 1 through 4, at approximately 230 psi and 600 degrees Fahrenheit. Essentially, the topping turbine received steam at a higher pressure and was designed to exhaust it directly into the lower pressure turbines at the required inlet conditions. By this method, older units could be made a useful part of a system that gained advantages from the higher pressures and temperatures permitted by newer designs and materials; the modification gave the plant "a new lease of life, and protect the older investment from the insidious disease of obsolescence."[118]

Philadelphia Electric initiated a superposition program to upgrade the aging Chester Station just prior to World War II. In conjunction with the topping unit, two massive, open-pass, pulverized-coal-fired, high-pressure boilers were installed, replacing the station's four oldest boilers. This new equipment brought steam up to the temperature and pressure which the topping turbine required. In Philadelphia Electric's *Current News*, company reporters noted the project's progress and photographers showed the installation of the two steam drums -- "the largest ever built by the well-known firm of Babcock & Wilcox."[119] Several less spectacular changes also accompanied the large-scale refitting. In order to supply the new boilers with large quantities of coal dust, Philadelphia Electric added the aforementioned coal conveyor system and a pulverizer. These World War II-era modifications were the last significant changes made to the steam production system at Chester.

Conversion to open-pass, pulverized-coal-type boilers followed a path taken by many utilities with large central stations, as had the adoption of the Stirling boilers in the original plant design. If the primary boiler technologies used at Chester were fairly typical of the industry, the efforts of Philadelphia Electric engineers to improve the economy and efficiency of the boiler operations were bolder. Through centralizing and streamlining coal distribution, systematically testing feed rates, coal chemistry and combustion temperatures, and experimenting with auxiliary technologies to utilize waste heat, Philadelphia Electric engineers devised their own means of reducing a utility's problematic vulnerability to the price of fuel.

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[118]Ernest L. Robinson, "The Steam Turbine in the United States: III - Developments by the General Electric Company," *Mechanical Engineering* (April 1937): 243.

[119]"Action at Chester," *Current News* (May 1940): 16.

In addition to fuel costs, which constituted a significant percentage of operating expenses, boiler technology was closely tied to the progress of steam turbine technology. Because boiler output was limited by the capacity of turbines to withstand high temperature and pressure steam, boilers and turbines developed symbiotically. As new materials and designs increased that capacity, boiler manufacturers introduced models that produced steam with commensurately higher temperatures, pressures, and flow rates. By World War II, the growth of boilers, both in sheer size and in performance, paralleled that of steam turbines. And that was no small feat. Turbines exhibited meteoric gains in output and capacity during these years; their evolution influenced the history of power industry in the United States.

Turbine Hall

On October 1, 1918, a distinguished crowd that included Pennsylvania Senator William C. Sproul attended a ceremony to place the first turbo-generator at Chester into operation. Despite the presence of a rather incongruous temporary wood shed that sheltered the unit while work continued on the roof, the design of the great turbine hall unmistakably communicated the importance of the turbo-generator as the technical centerpiece of the plant. Although the turbines appeared remarkably small in the vast space created by pilastered walls and a sky-lit, barrel-vaulted ceiling, the sense of immense power contained within the steel shells conveyed a technical sublimity that complemented the architectural design. One female observer likened the view of similar turbines under steam to "the sensations experienced when first looking into the Grand Canyon from the front of the El Tovar Hotel."[120] The attention drawn to the steam turbine by architecture was in part warranted by the machine's pivotal role in the growth and success of central station power generation. Since the first large-scale application of turbines to electricity generation in 1903, astounding increases in power output and economies of scale had been realized, ensuring the machine's continued use in American power stations.

Many of the early steam turbines ordered by utilities in the United States were based on a design conceived by Charles G. Curtis and further developed by the General Electric Company.[121] After purchasing the Curtis patents, G.E.'s research department devised a vertical-shaft turbine that offered a substantial reduction in the initial cost and space required for conventional reciprocating steam engines.[122] Despite the absence of an extended

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[120]Zillessen, 276.

[121]Robinson, 241.

[122]See Richard Rice, "Development of the Turbo-Generator," *Power* 46, no. 21 (20 November 1917): 708; T. Allan Comp, Flo Lentz, Steve Lubar, and "Georgetown Steam Plant," HAER Report WA-1, 4-6; Robinson, 243.

field service, Philadelphia Electric embraced turbine technology in its early stages of development, installing a vertical unit in 1905 at the Tacony Station. Two more units arrived in 1906: a General Electric 500 kW unit at the Beacon Light Station and a larger 5,000 kW unit at Schuylkill A-1.[123] Despite occasional trouble, the Curtis vertical turbines performed well, and Philadelphia Electric ordered several additional machines, including two 15,000 kW units for A-1 in 1913.[124] These two machines turned out to be some of the largest of their type constructed by G.E., because the increase in shaft length and weight associated with the steady rise in turbine capacities presented problems for the vertical arrangement of the G.E. design.[125] Between 1912 and 1914, a horizontal-shaft design rapidly supplanted the vertical machines, and turbine capacities continued to grow.

For Philadelphia Electric, acceptance of the turbine over the steam engine came at considerable cost. By 1913, Philadelphia Electric had replaced two large and relatively modern steam engines -- the 2000-kilowatt and 5000-kilowatt "monster" units -- with vertical turbines in the 15,000- kilowatt range. But economies of scale gained from the growth of steam turbine capacities and improved boiler designs more than offset the price of steam engine obsolescence, allowing Philadelphia Electric to keep pace with burgeoning demand for electricity without having to build numerous or overly massive generating stations. During the transition from steam engines to turbines, the company signed its first large contracts to supply the Pennsylvania Rapid Transit company (PRT) and the Pennsylvania Railroad with electricity. The 25-cycle loads for streetcar and railroad companies presented technical problems for Philadelphia Electric but led to the placement of an order for the largest turbines ever built for the new A-2 Schuylkill station in 1914.[126]

After nearly ten years of operating experience with G.E. turbines, Philadelphia Electric remained a loyal customer. In 1916, the utility ordered two of the four machines intended for Chester Station, selecting units of slightly smaller capacity than the one recently installed in A-2, but of an innovative design. Turbines of this type, first shipped to the Wheeling Electric Company in 1917,

> constituted the first large-scale embodiment of the conical-flow type eventually

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[123]On the installation of the Tacony turbine, see Green, 19; on later turbines see Onken, 140.

[124]Onken, 125, 127.

[125]The zenith of large-capacity vertical turbines was reached between 1911 and 1913 when some 20,000 kilowatt units were shipped. Thereafter, vertical turbines were supplanted by horizontal units. See Robinson, 244.

[126]Bernard Gorowitz and George Wise, eds., *The General Electric Story: 1876-1986* (Schenectady, NY: Hall of History Foundation, 1989), 51.

> approached in one way or another by every manufacturer of large efficient turbines... [The design's] importance can hardly be overestimated. The change was so radical in comparison with types which had previously been manufactured that the plans were laid before E.W. Rice, then president of the General Electric Company.[127]

Philadelphia Electric's expectations for the new units were high. Equipped with the latest generating technology, Chester was supposed to provide sorely needed base-load power for a system stretched dangerously thin by wartime demand for electricity. But confidence in General Electric was eroded by a rash of postwar turbine failures that afflicted generating stations across the United States.[128] Under the stress of meeting orders from utilities, shipbuilders, the Navy, and other wartime customers, G.E. had shipped its new turbine without proper testing. Engineers later found that vibration and bending fatigue in the rotors was causing destructive wheel and bucket failures. Power generation periodicals and utility industry groups focused on the crisis. The problem was so severe that the AEIC assembled an emergency committee in March 1919 to examine the failures. Horace P. Liversidge of the Philadelphia Electric Company chaired the committee, and sent a copy of the confidential report to President Joseph McCall in June 1919. The findings amounted to a direct indictment of G.E.:

> As a result of this study of the situation, the Committee is firmly of the opinion that the serious turbine failures which have been reported upon are directly attributable to three fundamental causes, viz.: (1) Improper design. (2) Poor workmanship. (3) Demoralization of manufacturer's plant due to war conditions.
>
> So far as the Committee is able to determine, the responsibility for failures due to the above causes rests wholly with the manufacturer. The machines in question embodied radical departures in a number of features from previous design; marked reductions having been made in weights, over all dimensions, and working clearances for the evident purpose of obtaining better economies of operation and production costs. However, with the full knowledge of the

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[127]Robinson, 246.

[128]A special report compiled by the Association of Edison Illuminating Companies on the "General Electric Company Steam Turbine Situation," in June 1919 contained the following list of serious failures (all pertaining to turbines larger than 10,000 kW): Detroit Edison Company, Boston Elevated Railway Company, Commonwealth Edison Company, New Orleans Railway & Light Company, Wheeling Electric Company, Union Gas & Electric Company, Union Electric Company, New Bedford Gas & Edison Light Company, U.S.S. New Mexico.

> important bearing these changes would have on operating performances, a large number of these machines were sold and allowed to go into operation before a few units of this newer design had been tried out and their reliability definitely established. This action, and also the evident lack of adequate consideration of the details of design and construction which seriously affect the reliability of these large units, are open to severe criticism.[129]

The report included a "List of Turbo-Generators Now in Operation, Which are Considered Doubtful, and On Which Wheel or Diaphragm Changes Will Be Made." Both units ordered by Philadelphia Electric for Chester were listed.[130]

G.E. reacted immediately to the crisis by working with the AEIC committee to address the problems, and ordered an emergency testing and analysis program. The research produced a seminal paper presented to the ASME that greatly advanced understanding of wheel vibrations and bending stresses in turbines.[131] Additional research and exhaustive tests in the early 1920s led to successful new designs. Thus, when Philadelphia Electric ordered two new 30,000-kilowatt units in 1923 to bring Chester Station up to full capacity, the turbines were similar in appearance and rating to the original units, but differed internally.

Such design improvements, however, could do little to remedy a series of problems which plagued older equipment in Philadelphia Electric's system during the early 1920s. In 1920 alone, a breakdown at Chester halted operations at Hog Island, Station A-2's 35,000-kilowatt failed, and other turbines at A-1 had to be taken out of service. A more spectacular breakdown occurred in September of the following year, when A-2's 30,000-kilowatt turbine (of the defective variety) virtually self-destructed.[132] The service disruptions were serious blows to the company's image as a reliable supplier of electricity, and were particularly costly for industrial customers. Although the growth of turbine capacities generated economies of scale, multiple equipment failures exposed the risks of relying on a few, large prime movers. To handle such failures, utilities serving large urban territories with diverse customer bases needed flexible connections between stations and substations - networks that would permit the rapid re-routing of electricity. The turbine troubles provided further stimulus for

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[129]"Special Report: General Electric Steam Turbine Situation, June 1919" prepared by the Steam Plant Committee of the Association of Edison Illuminating Companies, PECO Library, 1-2.

[130]"Special Report," 22.

[131]Wilfred Campbell, "The Protection of Steam Turbine Wheels from Axial Vibration," *American Society of Mechanical Engineers-Transactions* 46 (1924): 31-160.

[132]Wainwright, 159-160.

developing a solid system of interconnection and securing adequate reserve capacity.

The 1924 installations at Chester Station reflected these concerns. In 1923, Philadelphia Electric President Joseph McCall reported to the Board of Directors recommended purchase of the new turbines for Chester. He noted that a high peak load forecast for 1924, a request by the New Jersey utility PSC for power from the Philadelphia Electric system, and possible expansion of electrification efforts of Pennsylvania Railroad would result in an inadequate system reserve capacity.[133] Earlier in 1923, Philadelphia Electric had completed its first interstate tie line to another utility, the Public Service Company of New Jersey (PSC), to sell excess capacity. This inter-utility link occurred during a period of agitation for some form of regional interconnection between electrical producers, and presaged a more comprehensive and path-breaking arrangement worked out between Philadelphia Electric, PSC, and the Pennsylvania Power & Light Company (PP&L) in 1927.

The development of new designs and materials permitting higher steam and pressure temperatures during the last half of the 1920s brought turbine capacities to heights thought far in the future just five years earlier.[134] Output was also improved by hydrogen cooling, which allowed generators to reach higher rotational speeds (previously limited by the capacity of conventional air cooled designs to dissipate heat). Philadelphia Electric's 1932 order for Richmond Station, a 165,000-kilowatt turbo-generator of record size, was indicative of the strides made in turbine output since 1924. Moreover, high pressure turbines could be superposed with existing low pressure units, as occurred at Chester. The 1925 success of G.E.'s first commercial-service superposed unit at Boston's Edison Electric Illuminating Company led to the widespread use of superposition in the United States during the 1930s.[135] When experts predicted that loads in Chester's highly industrialized service would exceed the station's capacity by 1940, Philadelphia Electric considered superposition among the options for averting crisis.

The rapid changes in turbine technology between 1920 and 1940 complicated decisions about adding capacity to aging facilities. *Electrical World's* survey of design trends in 1940 investigated different approaches, asking, "Who is venturing into the highest pressures and

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[133]Philadelphia Electric Company Board Reports, 28 August 1923. A few months later, McCall re-emphasized the need to install the new Chester turbines as quickly as possible, adding "An unforeseen accident to any 30,000 KW. unit would necessitate a curtailment in our supply, seriously interfering with service." Philadelphia Electric Company Board Reports, 8 January 1924.

[134]Robinson, 254.

[135]Robinson called 1936 "a year of superposition," as nearly half the units ordered in that year were superposers." Ibid., 243.

superheats? Who is still finding opportunity and justification for superposition? Who prefer to continue on the pressure levels already well established in their plants? Which stations reflect a multiplicity of lesser advances in equipment and technique, while adhering to conventional trends in major matters?"[136]

Elements of each of these trends were manifest in the 1938 - 1942 construction project at Chester. Philadelphia Electric forayed into high pressures and superheat temperatures by installing a 50,000-kilowatt, 3600-r.p.m., hydrogen-cooled, superposed unit with inlet steam conditions of 1,250 psi and 950 degrees Fahrenheit (and two new boilers to supply steam at these conditions). At the same time, the company reinforced the existing low pressure system by adding a low-pressure, 80,000-kilowatt turbo-generator set. Global politics motivated this latter project. Following Germany's 1939 invasion of Poland, Philadelphia Electric had re-evaluated power needs in its service area. The resulting proposal to install a low-pressure Westinghouse unit at Chester was implemented even though it required building a major addition to the downriver side of the turbine hall.[137] *Electric Light & Power* noted that "On completion of this project, there will be installed at Chester Station the largest concentration of generation on the Philadelphia system with an effective peak capacity of 272,000 kw."[138]

In conjunction with the major equipment installations, Philadelphia Electric incorporated several new auxiliary systems -- a "multiplicity of lesser advances in equipment and technique" -- to improve the thermal efficiency of the plant. As far back as the early 1920s, Chester designer W.C.L. Eglin had recognized the importance of auxiliary equipment such as that used for heating feed water by steam bled from turbines, reheating the steam between pressure stages in turbines, and purifying feed water with evaporators and deaerators.[139] Nonetheless, the original feed water auxiliaries at Chester were minimal. Internal corrosion found in the economizers during the mid 1920s prompted the installation of deaerators, which remedied the problem, but by 1939, what few auxiliaries existed were in need of an upgrade.[140] The 1939 - 1942 construction program added the latest in deaerator, evaporator, and cascading feed water heater technologies, and multiple pumps and by-pass piping to

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[136]A.E. Knowlton, "1940 Design Trends in Steam Capacity," *Electrical World* 114, no. 22 (30 November 1940): 1615.

[137]Philadelphia Electric Company Executive Conference Minutes, September 1939.

[138]C.F. Bishop, "Unusual Electrical Features of Chester Station Expansion, Part II," *Electric Light and Power* (September 1941), 41.

[139]Eglin, "Forty Years of Central-Station Development," 611.

[140]National Electric Light Association proceedings (1927): 949.

enhance flexibility and allow full operation during periodic equipment maintenance.

Excepting a brief slump following World War I, Philadelphia Electric faced a steady increase in the demand for its service.[141] In the years separating the installation dates of the first Beacon Light Company turbine and Chester's 80,000-kilowatt unit, the remarkable growth of turbo-generator capacity helped Philadelphia Electric keep pace with consumption of electricity in Philadelphia, but also raised distinct problems. The high-output turbines forced utilities to cope with rapid cycles of technological obsolescence and concerns for turbine reliability became paramount. Philadelphia Electric protected itself from turbine failures by interconnecting its own transmission network, tying into those of other utilities, and extensively designing redundancy and by-pass piping into its steam systems.

While demand for electricity drove the development of more powerful turbines, the demand itself assumed many forms in the early years of the electric utility industry. As railroads, street cars, factories, stores, and households began to adapting electricity for their purposes, the resulting multiplicity of needs and equipment complicated the task of electricity producers. Philadelphia Electric reacted to these technical exigencies by rationalizing and standardizing its electrical system, particularly through a path-breaking conversion to alternating current.

Switch House, Part I - Railway and Streetcar Electrification

Analysis of the first two decades of electrification in Philadelphia reveals many of the technological reasons why electricity was labeled a "natural monopoly" in the twentieth century. Like other metropolises of the era, Philadelphia passed ordinances for separate distribution rights in the different wards and suburbs. Between 1881 and 1891, some seventeen companies divided the greater Philadelphia area into distinct operating territories, creating chaos by their use of different frequencies and voltages. Looking back at the situation with over two decades of hindsight, Philadelphia Electric managers pointed to the need to standardize electrical generation and distribution, justifying consolidation as necessary step in the technical evolution of electrical systems:

> Territories overlapped and controversies were frequent. Some measured the current in ampere hours, some in lamp hours and some in watt hours. Voltages ranged from 55 to 120, and cycles from 45 to 133. With these variations in all the essentials of the service, customers who removed from one section of the city to another often found their equipments of dental motors,

[141]Wainwright, 390.

fans, coffee grinders, etc., to be useless.[142]

Absorption of the Philadelphia area operating companies in 1902 left Philadelphia Electric with an assorted inventory of equipment, including direct current plants, several types of steam engines, various switch gear and transformers, and transmission lines rated for different phases, frequencies, and voltages. Although the utility began rationalizing its system by implementing two-phase alternating current, commercial consolidation was to precede technological standardization by several years. The "battle of the phases," and the "battle of the frequencies," waged since 1886, had not produced a victor in the first decade of the twentieth century, and direct current systems were still a mainstay in downtown districts. Philadelphia's direct current, three-wire system, inherited from the Edison company, was a case in point.[143] Attempts to establish uniformity of service were further complicated by customer requirements. Philadelphia Electric obtained its first large power contract in 1911 to supply single-phase, 25-cycle-, 13.2-kilovolt electricity for the Philadelphia Rapid Transit Company (PRT) - a departure from the two-phase, 60-cycle system adopted as Philadelphia Electric's standard in 1902.[144] To accommodate the 25-cycle load, the utility adapted its 60-cycle current with frequency converters rather than generate at the lower frequency. At the same time, the company embarked on a larger campaign to improve the efficiency of its distribution system by upgrading well-placed substations, abandoning obsolete ones, and builing new high-voltage transmission lines.[145] And in a third major push, Philadelphia Electric engineers set out to standardize the bulk of their company's territory on the higher voltage (13.2 kV) required by the PRT, but with three-phase electricity delivered at 60

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[142]J. T. Maxwell, "The Philadelphia Electric Co.: Its Evolution, 1881-1914," *Current News* 9, no. 4 (May 1914): 328, and *Current News* 13, no. 9 (April 1917, supplement).

[143]For a discussion of the "battle of frequencies" and the "battle of phases," see B.G. Lamme, "Brief History of Frequency Selection and Standardization" *Electrical World* 84, no. 12 (20 September 1924): 601-603; Thomas J. Higgins, "Evolution of the Three-Phase 60-Cycle Alternating-Current System" *American Journal of Physics* 13, no. 1 (February 1945): 32-36; Hughes, *Networks of Power*, 127-129. Cornell Engineering Professor J.G. Tarboux commented on two factors governing the direction of frequency and phase wars: "Probably the reason 25 cycles per sec. was adopted in some railway electrifications was owing to the fact that the early synchronous converters did not operate satisfactorily on frequencies above 40 cycles per sec.... The reason why practically all generators are three phase is that more capacity can be obtained out of a given armature when wound three phase than when wound either single or two phase. Furthermore, it is more economical to transmit power over a three-wire three-phase circuit than over a four-wire two-phase circuit." J.G. Tarboux, *Electric Power Equipment* (New York: McGraw-Hill Book Co., 1946), 59.

[144]"Schuylkill Station - The Proving Ground for the Philadelphia Electric Co. System," TD, n.d., 2.

[145]Goodwin, 84.

cycles.[146]

Another large rail contract prompted a reassessment of plans to standardize on 60 cycles. The Pennsylvania Railroad launched an experimental electrification program in 1913 by ordering electricity from Philadelphia Electric for the Paoli and Chestnut Hill rail lines. This time, instead of relying on frequency converters, Philadelphia Electric planned to supply the 25-cycle railway load with a dedicated turbo-generator in a massive new central station proposed as an addition to the 1903 Schuylkill A-1 station. The new station, designated A-2, would contain the largest turbo-generators yet constructed with separate electrical buses for each frequency (25 cycle for the rail and streetcar load, 60 cycle for general power and lighting service), and require special phase converters and voltage-balancer sets (designed by Charles Steinmetz at the General Electric Company).[147]

Electrification of the railroad and streetcars proved a significant force behind the early development of the Philadelphia Electric electrical system. Rail loads shaped the evolution of a comprehensive transmission and distribution network in Philadelphia, while rail-related frequency differences impeded attempts to standardize that system. Despite corporate claims that consolidation would eliminate the disorder created by numerous operating companies in the nineteenth century, the diversity of customer demand prior to World War I continued to prevent an easy transition to uniform service. The initial response of Philadelphia Electric to the dual-frequency demand problem was to move away from a standardized generation of electricity and instead build a state-of-the-art facility (A-2) that utilized two separate production structures: one for 25 cycle frequency, the other for 60 cycle. Two years later, Eglin and other Philadelphia Electric engineers made a different choice at Chester.

Switch House, Part II

Chester Station was designed to generate a single type of electricity: three-phase, 60-cycle, alternating current at 13.2 kilovolts. Future Philadelphia Electric power stations also generated this type of current, and relied on convertors or substations to make the necessary adjustments for different users. The original switch house at Chester was, in effect, an internal substation. It housed the equipment needed to step up electricity to higher voltages for long distance transmission, and directly connected certain large industrial customers such as Sun Ship Yards to the main station bus.

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[146]Onken, 129, on boosting the system to 13.2 kilovolts; and "P.E. Co.'s New Generating Station," 339, on the attempt to standardize on a 60 cycle, three-phase system.

[147]Wainwright, 111-12.

The bus connected all incoming and outgoing electrical transmission lines. Its structure reflected Philadelphia Electric's growing experience with central station design and increasing success in standardization. In several respects, the main bus in Chester's switch house resembled that of Schuylkill A-2. Yet the single cycle bus configuration differed from Schuylkill's two separate-cycle buses, and the structural separation from the turbine hall was more fully articulated at Chester. Physically, the bus originally consisted of a large loop or "ring" of several flat strips of copper bolted together, housed in a long compartment that occupied the third and fourth floors of the switch house. The sectionalized, double "H-connected" ring bus design at Chester combined flexibility for system maintenance with reliability. Each generator and outgoing feeder had tie lines to either bus, which could be used interchangeably in the event that a problem disabled one bus. Disconnects allowed operators to isolate sections of the bus without impeding the rest of the system for maintenance work or line failures. Directly under the control room, a "pipe room" connected the switching controls and instrumentation to the main circuits. The pipe room was designed for easy access to the control lines and for future expansion. It was first used at Chester, and later employed with success at the Delaware and Richmond stations.[148]

Feeder lines from the generators carried three-phase, 60-cycle electricity at 13.2 kV into the switch house under the main floor, through oil-filled circuit breakers and connected to the main station bus on the fourth floor. Each floor of the switch house generally contained equipment for a specific task: potential transformers, cable disconnecting switches, and the test bus were located on the ground floor; reactors and current transformers on the first floor; circuit breakers on the second floor; bus disconnects on third floor, and the main bus on the fourth floor. The design of the later switch house at Delaware Station mirrored Chester's, but Philadelphia Electric changed to a new vertical phase isolation arrangement at Richmond Station in 1925. Whereas the three phase circuits were previously mounted adjacent and parallel to each other, the Richmond bus design separated the phases by floors, virtually eliminating the potential for phase to phase faults.[149]

The Chester design also incorporated several safety procedures for accessing the lines, including the "Cory scheme" based on an interlocking system of keys.[150] All buses, switches,

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[148]John F. Calhoun, "The Problems Involved in the Design of a Generating Station, [1927?]," TD, 7.

[149]"Steam-Electric Generating Stations Manual," 54.

[150]Philadelphia Electric engineer R.A. Hentz described the operation of the Cory scheme in an article on the recently constructed Richmond Station. "This scheme prevents the possibility of any one getting into a compartment which has not been disconnected from the bus. The gang-operated disconnecting switches are mechanically interlocked with the oil circuit breakers so that they cannot be opened until after the oil circuit breaker has been opened. When the disconnecting switches have been opened, they can be locked in the open position by means of a key which can then be removed from its slot. This key will unlock a series of other key

transmission circuits, generator leads, and reactors were enclosed in compartments, protected from human contact by locked doors. The switchboard operator supervised access to the compartment keys. Chester followed a "red tag" system of blocking procedures for installation and maintenance of equipment; developed at Schuylkill, this system provided a model for permits and blocking procedures at Philadelphia Electric.[151] Remote-controlled oil-filled circuit breakers handled disconnections of the high-voltage system under load.

Aside from substation function, the switch house served as the nerve center and control point for station operations. Control of the electricity generated at Chester ultimately rested in the hands of the switch house control room operators. From a desk in the control room, an operator monitored an assortment of switches, gauges, and controls laid out in concentric, semi-circular panels and instrument boards. Behind the desk, a series of windows opened onto the turbine hall, providing a commanding view of the equipment and personnel from the third floor. The operators worked in relative serenity, insulated from the noise of the turbine hall, the heat of the boiler house, and loud hum of the electrical circuitry in the lower levels of the switch house. The comfortable environment was sometimes a place of emergency action, as millions of dollars invested in station equipment depended on the quick response of control room operators to station crises.

The confinement of the major switch gear equipment to an integrated interior space within the station eventually presented problems that led to the use of outdoor substations. Progress in power distribution transformer technology between 1920 and 1940 produced larger units with higher volt-ampere ratings and improved methods of dissipating the resulting heat. Increased station capacities also required the use of electrical equipment (circuit breakers, relays, fuses, etc.) with commensurately higher load ratings. The physical limitations of the switch house gradually began to show as station capacity grew. In 1924, Philadelphia Electric doubled the station's transformer capacity by installing two internal, water-cooled units, but after 1940 such additions occurred outside.[152]

The 1939 - 1942 plant upgrade presented engineers with the difficult task of adapting the switch house to handle twice the capacity for which it was originally designed. The new

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slots, each containing one key, these keys being used to unlock their respective compartment doors. Before the compartment can be put back in service all the keys must be returned to their respective slots in order to release the key to unlock the disconnecting switches." R.A. Hentz, "Electrical Features of Richmond," *Electrical World* 87 no. 18 (1 May 1926): 922.

[151]"Schuylkill Station - The Proving Ground," 2.

[152]F.R. Ford, "66,000 Volt System Capacity Doubled This Year," *Current News* (November 1924): 8; Bishop, 40.

turbo-generator sets necessitated extensive modifications to the switch house, including the replacement of the original multiple-bar bus with a new, hollow-channel design shown by studies to handle the higher capacity safely.[153] A few months prior to this phase of construction, Philadelphia Electric executives expressed a concern about the potential spread of damage in the event that an overloaded oil-filled circuit breaker exploded.[154] Accordingly, a partial replacement of Chester's oil-filled breakers with a recently developed air-blast design less prone to explosion began in 1939. By this date, the long-apparent drawbacks of integrating the substation function in the switch house led to the location of related electrical equipment outside.

By 1945, only a few hundred yards separated the rows of cylindrical transformers, now placed outside and isolated by a high chain link fence, from Chester Station. Aesthetically, the difference was stark. Private ownership of electric utilities was firmly established, and architecture had ceased to serve as an important public relations tool for the industry. The new outdoor substations, with their equipment exposed to the elements and devoid of any embellishment, marked the start of an entirely machine-based aesthetic in electric utility design. Gone was the neoclassicism of Philadelphia Electric's Chester, Delaware, and Richmond stations, replaced by the blunt functionalism of post-World-War-II construction.

The Larger Picture

Chester Station underwent three primary phases of development between 1917 and 1942. During this dynamic and formative period in the electric utility industry, the company's most significant innovations arguably came outside the field of power plant design. Philadelphia Electric pioneered interconnection across state lines and became the first major urban utility to convert its entire system to alternating current. In September, 1927, the company signed an agreement with Public Service Electric & Gas Company of New Jersey and Pennsylvania Power & Light Company to form the "Pennsylvania-New Jersey Interconnection" (PNJ).[155] Philadelphia Electric had supplied neighboring electric companies such as the East Pennsylvania Gas & Electric Company and the Philadelphia Suburban Gas & Electric Company with electricity for several years, but the PNJ contract marked the first formal arrangement between interstate utilities to pool power and coordinate future construction.

Significantly, the PNJ agreement concentrated control of the regional interconnection in a few private hands. A committee of three representatives, one from each company, would

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[153]Bishop, 39-40.

[154]Philadelphia Electric Company Executive Conference Minutes, June 1939.

[155]Wainwright, 200.

negotiate the grand strategies of the regional power pool.[156] Although Congress checked the growth of monopolies in energy-related industries by passing the 1935 Public Utility Holding Company Act and expanding federal regulation and involvement in power generation, private utilities successfully resisted government proposals for a national grid based on the British system.[157] Interconnection in the United States was to be directed by private utilities. Ultimately expanded several times between 1956 and 1982 to include utilities from neighboring states, the PNJ pact served as an evolving model for the regional power pools that currently comprise the bulwark of the nation's electric distribution and transmission systems.

In the mid twenties, Philadelphia Electric also embarked on an ambitious program to eliminate direct-current service in its system. As of 1920, the former Edison system had ceased to generate the direct current used in downtown Philadelphia; instead, it converted alternating current from Philadelphia Electric's main stations. Troubled by the inefficiency and expense of this process, operating engineer Horace Liversidge proposed a ten-year, nine-million-dollar project to shift the direct-current system to alternating current. Philadelphia Electric president Joseph McCall initially rejected the proposal, but approved it when the cost of maintaining the old system began to mount. Upon hearing of the plan, Chicago utility czar Samuel Insull, backed by several other executives, strongly advised against the conversion, stating emphatically that it would not work.[158] Although McCall vacillated, the program was eventually carried out, and in 1935 the last direct-current customer accepted the change. Philadelphia Electric proceeded with the project at considerable risk, encountering technical problems, substantial costs and criticism from industry leaders. These obstacles revealed the uncertainty that still surrounded AC's ability to completely supplant DC in the mid 1920s. By demonstrating the feasibility of such a project, Philadelphia Electric set an example eventually followed by many urban utilities, ending the use of Thomas Edison's hallowed system in the United States.

Interconnection and conversion to single-current service were methods Philadelphia Electric used to meet power demands it had helped to create. In addition to soliciting industrial customers, the utility aggressively promoted residential use of electricity through sales and advertising drives. Since 1908, the Philadelphia Electric Supply Department served as a showcase and clearinghouse for electric appliances. Here, consumers could learn how their lives might be improved by the latest electric refrigerator, range, washing machine and, in the

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[156]A valuable history of the pact appears in Bayla S. Singer, "Power to the People: The Pennsylvania-New Jersey-Maryland Interconnection, 1925-1970," (Ph.D. diss., University of Pennsylvania, 1983).

[157]Philadelphia Electric Company Executive Conference Minutes, June, 1940.

[158]Wainwright, 162-63.

1930s, by air conditioning. Philadelphia Electric also instituted a bulb replacement program, whereby burned-out bulbs were replaced free of charge to encourage greater use of electric light. A similar program exchanged old direct-current motors for new alternating-current ones as part of the conversion to alternating current.[159] Efforts to popularize the use of appliances were aimed particularly at women and included a series of "electrical teas," a "Home Electric Demonstration," and a "mammoth" cooking school with an "all-electric kitchen and refrigeration show." The sales department organized "information blitzes" such as "Electrical Prosperity Week" and "Better Light -- Better Sight" campaign to draw attention to the benefits of electricity, and devised methods for utilizing "virtually the entire Philadelphia Electric force to promote the sale of load-building appliances."[160] The company's contemporary advertising slogan, "if it isn't electric, it isn't modern," nicely encapsulated a multi-faceted effort to equate progressive lifestyles with electrical technologies. This sort of boosterism aided the American electric utility industry's successful drive to create a domestic culture of consumption. By the century's end, American energy consumption per capita stood at two and a half times that of the next closest nation.[161]

Chester Station was conceived during an era of intense debate over the ownership and control of electric utilities. At Philadelphia Electric, architecture and engineering became important venues for demonstrating that private ownership best served the public interest. Technologically, Chester Station was a studied balance of efficiency, reliability, and economy. Its design pointed the direction for the industry by rationalizing and standardizing electrical service, and centralizing control of plant operations, load dispatching and fuel distribution. Informed by lessons learned at Schuylkill and Chester, Philadelphia Electric expanded its network to a regional scale and exerted nation-wide influence on the industry. While changing technology and business practices made this rise possible, neither evolved in isolation from social forces. No matter what form change took, it had to appear to support Samuel Insull's claim that "the ambition, experience and initiative of this industry, working under economic law and under the American plan of encouraging private enterprise, are still the surest guaranties of 'super-power,' of 'giant-power,' of hydro-electric, or of any other

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[159]Wainwright, 235.

[160]"District 'E'," *Current News* 12, no. 4 (15 November 1915): 78; "Beacon Light Company," *Current News* 12, no. 5 (December 1915): 116; "Philadelphia's 'Home Electric' Demonstration has Encouraging Aftermath," *Electrical World* 82, no.23 (8 December 1923): 1172; Philadelphia Electric Company Executive Conference Minutes (3 March 1939); Wainwright, 254.

[161]David E. Nye, *Consuming Power: A Social History of American Energies* (Cambridge: MIT Press, 1998), 6.

phase of electrical development for the greatest good to the greatest number."[162]

Bibliography

A Note on Sources

This report draws extensively on the archives of the PECO Energy Company, located at the company's Philadelphia headquarters. The collection includes manuscript histories, minutes, board reports, promotional literature and ephemera, as well as complete runs of company and industry journals. Staff in PECO's Information Services division and Law Library are familiar with these materials, and the report could not have been written without their help. The authors would like to express particular gratitude to Librarians Christian Braig and Sabina Tannenbaum, and to Law Library Coordinator Marilyn Roth.

PECO Energy Company's Plymouth Meeting Service Center is the current repository for most visual records of Chester Station. Some early drawings are filed there, but many have been lost and may be viewed only on aperture card. In cases where neither original drawings nor aperture card images of a certain feature survive, information about the feature's design and installation date sometimes appears in the Center's card catalogue index, arranged by plant. The Center also maintains a substantial collection of plant photographs, now under the charge of PECO's Power Delivery division.

Several other institutions in the Philadelphia area hold smaller collections of relevant material. The Hagley Library in Wilmington, Delaware owns the minutes of Philadelphia Electric's predecessor companies, including those of the Delaware County Electric Company. Trade catalogues for firms such as Babcock & Wilcox, also available at Hagley, shed light on equipment ordered for Chester Station. The resources of the Delaware County Historical Society in Broomall, Pennsylvania, are the basis of most local history in this report. They include maps, microfilmed newspapers and clipping files. Some of John Windrim's drawings and papers are on file at the Athenaeum of Philadelphia, but little of this material pertains to Chester Station.

Articles

"Action at Chester." *Current News* (May 1940): 16.

"Attack on Privately Owned Electric Utilities." *Electrical World* 68, no. 17 (21 October 1916):

---

[162]Samuel Insull, "The Growth of the Power Industry: How Has It Been Done?" *Philadelphia Chamber of Commerce News Bulletin* 12, no. 6 (June 1925): 19

799.

Aylesworth, M. H. "National Electrical Development and Its Effect Upon Utility Regulation." *General Electric Review* (June 1922): 340.

"Beacon's New Power Station." *Chester Times*, 7 April 1917.

"Beautiful City Hall is Planned." *Chester Times*, 23 April 1917.

Bern, Emil G. "Some Engineering Aspects of Standardization." *General Electric Review* (Oct. 1926): 736.

"Big Contract for Baldwin's." *Chester Times*, 2 August 1916.

"Big Power Plant Work." *Chester Times*, 26 October 1916.

Birch, F. A. "Philadelphia Electric Co. Section, NELA." *Current News* 9, no. 4 (May 1914): 332-33.

Bishop, C. F. "Unusual Electrical Features of Chester Station Expansion, Part II." *Electric Light and Power* (September 1941): 38-41.

Bruere, Robert, Gifford Pinchot, Philip Wells, Alfred Smith, Interview with Herbert Hoover, Sir Adam Beck, and Morris Cooke. *Survey Graphic* (Giant Power Issue) (March 1924).

Budd, Britton I. "Electrification Surveyed." *Electrical World* 91, no. 23 (9 June 1928): 1207-1209.

Campbell, Wilfred. "The Protection of Steam Turbine Wheels from Axial Vibration," *American Society of Mechanical Engineers-Transactions* 46 (1924): 31-160.

"Chester to the Front Again." *Current News* 14, nos. 9-10 (April 1918): 9.

"Chester Station Adds 50,000 kW Top." *Power* (November 1940): 62.

"Chester Station of the Philadelphia Electric Company." (Construction Photo) *Electrical World* (8 June 1918): 1223.

"City's Proposed 'White Way.'" *Chester Times*, 15 March 1917.

Clark, F. S. "The Delaware Station of the Philadelphia Electric Company," *Stone and Webster*

Journal 26 (1920): 364-65.

"Compact Reinforced-Concrete Generating Station at Philadelphia." *Electrical World* (21 May 1921): 1145.

Conner, John L. "Chester Station Now Completed." *Current News* (1 February 1925): 8.

Cope, J. Morris. "Chester Waterside Station, Land Improvements Estimate 2075." *Current News* 13, no. 5 (December 1916): 117-18.

"Council Awards Light Contract." *Chester Times*, 13 November 1916.

Degraaf, Leonard. "Corporate Liberalism and Electric Power System Planning in the 1920s." *Business History Review* (Spring 1990): 1-31.

"Do You Know?" *Current News* (15 December 1924): 5.

Dodge, J.W. "Frequency Converter Ties Between Large Power Systems." *General Electric Review* (June 1923): 436.

Edsall, Henry J. "Screening Condensing Water Efficiently and Economically." *Steam* (November 1918): 133.

Eglin, William C. L. "The Field Occupied by the Power Company Today." *Current News*, Supplement (April 1917): 50-51.

_____. "How the Power Company Distributes Electrical Energy." (mentions typical plant layout etc.) *Current News*, Supplement (April 1917): 52-54.

_____. "The Human Side of Power Company Organization." *Current News*, Supplement (April 1917): 93, 110-11.

_____. "Our Stations." Speech delivered before the Meter Department Branch of the Philadelphia Electric Company Section of the National Electric Light Association, 14 January 1919. PECO Library Document File no. 338.7 P.90.

_____. "The Engineering Features of the Philadelphia Electric Company System." *Electrical World* (10 May 1924): 933.

_____. "Forty Years of Central-Station Development." *Electrical World* 84, no. 12 (20 September 1924): 609-611.

"Electric Power Here in 1886." *Chester Times*, 15 April 1939.

"Emergency Power Act Passes House." *Power* 48, no. 16 (15 October 1918): 579.

"The Essex Power Station." *Power* 44, no. 22 (28 November 1916): 738-44.

"Essex Station, Public Service Electric Co., Newark, N. J., as It Will Look When Completed." (illus.) *Power* 47, no. 5 (29 January 1918): 155.

"First Turbine at Chester Waterside is Turned Over." *Current News* 15, no. 4 (14 October 1918): 1.

Ford, F.R. "66,000 Volt System Capacity Doubled This Year." *Current News* (November 1924): 8-9.

Funk, N. E. "Past Operating Experiences Affect Design of Richmond." *Electrical World* (1 May 1926): 924.

_____. "The Economic Value of Major System Interconnections." *Journal of the Franklin Institute* (August 1931): 171.

_____. "Power in Philadelphia." *Electrical World* (29 August 1936): 2656.

"General Electric Company (sic) Buys River Front Land." *Chester Times*, 14 June 1916.

Goodwin, Harold, Jr. "Delaware County Electric Company: Its History and Substations." *Current News* 11, no. 3 (April 1915): 84-87.

"Great Day at Big Power Plant." *Chester Times*, 2 October 1918.

"Great White Way of the City." *Chester Times*, 6 November 1916.

Greene, Arthur M., Jr. "The Tale of Two City Stations." *Mechanical Engineering* (February 1941): 109.

"Heat Balance Diagram - Chester Station." PECO drawing archive, Drawing #F101880.

Hentz, R.A. "Electrical Features of Richmond." *Electrical World* 87, no. 18 (1 May 1926): 921-23.

_____. "Control and Pipe Room Layout of the Delaware Station." *Electrical World* 82, no. 23

(8 December 1923): 1173.

Higgins, Thomas J. "Evolution of the Three-Phase 60-Cycle Alternating-Current System." *American Journal of Physics* 13, no. 1 (February 1945): 32-36.

"High Tension Cable." *Chester Times*, 19 February 1917.

Hirshfeld, C.F. "Connors Creek Power Plant." Power 42, no.11 (14 September 1914): 388 - 396.

Honore, S. S. (?). "History of the Section." *Current News* 12, no. 9 (April 1916): 251.

Hopping, E.L. "Mechanical Design of Richmond." *Electrical World* (1 May 1926): 915.

Hughes, Thomas. "The Science-Technology Interaction: The Case of High-Voltage Power Transmission Systems." *Technology & Culture* (Oct. 1976): 646.

Insull, Samuel. "The Growth of the Power Industry: How Has It Been Done?" *Philadelphia Chamber of Commerce News Bulletin* 12, no. 6 (June 1925): 19.

"Interconnecting Power Systems." *Power* (12 June 1917): 805.

Johnson, Walter H. "Achievements of Electric Utilities." *Electrical World* (10 May 1924): 923.

"Keeping Pace with Business." *Bulletin of the Philadelphia Electric Company* [vol. and no. missing on PECO copy] (December 1919): 11-15.

Kiefer, Paul J. "Central-Station Rate Making." *Power* 42, no.8 (24 August 1915): 268 - 270.

Knowlton, A.E. "1940 Design Trends in Steam Capacity." *Electrical World* 114, no. 22 (30 November, 1940): 1614-17.

Lamme, B. G. "Brief History of Frequency Selection and Standardization." *Electrical World* 84, no. 12 (20 September 1924): 601-03.

"Last Unit Started in Delaware Station." *Current News* (3 October 1924): 10.

Lauer, Conrad, Herbert Hoover, Charles Penrose, George Gadsby, William Onken, Jr., Samuel Insull, General Guy Tripp, Major J. S. S. Richardson, Arthur Greene, Jr., and W.C.L. Eglin. *Philadelphia Chamber of Commerce News Bulletin*. (on benefits of investor owned power) (June

1925) PECO Library P.351.

Lipschutz, A. Alfred. "Station Mechanical Construction." *Current News* (1 April 1925): 8.

"Local Firm's Big Contract." *Chester Times*, November 2, 1916.

"Local Pride and Architecture." *Chester Times*, 2 November 1916.

Maxwell, J. T. "The Philadelphia Electric Company: Its Evolution, 1881-1914." *Current News* 9, no. 4 (May 1914): 324-28.

Mayers, Arnold. "Touching the High Spots in the Station Operating Section." *Current News* (15 June 1927): 7.

McCall, Joseph B. "The Philadelphia Electric Company." *Electrical World* (10 May 1924): 925.

McHolland, J. A. "Future of the Private Plant." *Power* 43, no. 20 (16 May 1916): 693-94.

"Merill, of Federal Water Power Commission, States Views on Interconnection." *Power* 61, no. 13 (31 March 1925): 513.

"Million-Dollar Improvement." *Chester Times*, 24 June 1916.

"More Light for Third Street." *Chester Times*, 28 May 1917.

"Mr. Bolton's Boomerang." *Power* 43, no. 10 (7 March 1916): 329-30.

"Mr. J. M. Cope Addresses the Engineering Dept. Branch on Chester Station." *Current News* 15, no. 14 (23 December 1918): 1.

National Electric Lighting Association - Prime Movers Committee. "Statement by the Philadelphia Electric Company." (1926): 1288, 1292.

_____. "Statement by the Philadelphia Electric Company." (1930): 1036 - 1038.

"New Chester Station as Viewed by the Drafting Room Girls." *Current News* 15, no. 5 (21 October 1918): 4.

"New High-Pressure Joliet Plant." *Power* 47 no. 4 (22 January 1918): 108-13.

"New Municipal Building Plans." *Chester Times*, 13 March 1917.

"Our New 66,000 Volt Transmission Line." *Current News* 13, nos. 10-12 (May-June 1917): 276-79.

Palme, Arthur and H. O. Stephens. "Two 60,000 kv-a. Load-Ratio Control Transformer Banks for Philadelphia Electric Company." *General Electric Review* (September 1926): 634.

"P. E. CO's New Generating Station." *Current News* 9, no. 4 (May 1914): 338-54.

Philadelphia Electric Company - Station Operating Handbook. "Schematic Diagram of Typical Unit of feed water heating sytem and connecting lines - Chester Station." PECO library Document File #1869, p.2223.

"The Philadelphia Electric Company System." *Bulletin of the Philadelphia Electric Company System* 23, no. 3 (September 1926): 4-8.

"Philadelphia Electric Expanding Its Grid." *Electrical World* (17 August 1940): 465.

"Philadelphia Electric Rushes Work at Chester." *Electrical World* (24 May 1941): 1710.

"Philadelphia's New Station." *Electrical World* (23 May 1925): 1074.

"Power House Design." *Power* 44, no. 22 (28 November 1916): 759.

"Power-Station Buildings." *Power* 43 no. 14 (4 April 1916): 492-94.

"Power System Interconnections." *Edison Electric Institute Bulletin* 1, no. 6 (September 1933): 174 - 176.

"Progress of New Plant." *Chester Times,* 6 November 1917.

"Prospectus for New Year." *Chester Times,* 20 January 1917.

Ralston, Farley C. "Features of Richmond Station." *Electrical World* (May 1, 1926): 909.

"Rendering Electric Service to Industries Supporting the War." *Electrical World* (Sept. 1, 1917): 406.

Rice, Richard. "Development of the Turbo-Generator." *Power* 46, no. 21 (20 November 1917): 708-10.

Robinson, Ernest L. "The Steam Turbine in the United States: III - Developments by the General Electric Company." *Mechanical Engineering* (April 1937): 239- 256.

Schick, D. F., Jr. "Unusual Mechanical Features in Chester Station Expansion." *Electric Light and Power* (May 1941): 56-60.

Schmidt, L. W. "Power Consumption of National Industries." *Power* 48, no. 18 (29 October 1918): 628-30.

"66,000 Volt System Capacity Doubled This Year." *Current News* (November 1924): 8.

Slaton, Amy. "Aesthetics of a Modern Industry: Buildings of the Delaware, Lacawana & Western Railroad's Scranton Yards." *IA: The Journal of the Society for Industrial Archaelogy* 22, no. 2 (1996): 25 - 39.

"Station 'A-2' - Philadelphia," *Current News* 12, no. 9 (April 1916): passim.

"Station Electrical Construction in 1921." *Current News* (January 1922): 10.

Summerhayes, H. R. "Problems and Developments in the Control and Interconnection of Power Systems." *General Electric Review* (June 1923): 328.

Walton, R.A. "Air Preheaters Discussed." *Current News* 21, no. 13 (1 April 1925): 3.

"We Practice What We Preach." *Bulletin of the Philadelphia Electric Company* 10, no. 5 (?): 20-22.

Westinghouse Electric and Manufacturing Company. Condensers, Part I Fundamental Principles (Dec., 1917): 19; and Part II - Design, Mechanical Construction (May 1918): 20.

"The Windsor Power Station." *Power* 47, no. 7 (12 January 1918): 210-16.

Woltersdore, Arthur. "An Expression on the Design of Factory and Warehouse Buildings." *American Architect* 99, no. 1851 (14 June 1911): 237-38.

"Work Moves on Big Plant." *Chester Times*, 6 September 1916.

"Year's Review of the Power Field." *Power* 45, no. 1 (2 January 1917): 2-7.

Zillessen, Clara. "A Woman's Impressions of a Great, Modern Power House." *Current News*

12, no. 9 (April 1916): 276-79.

Books

The Babcock & Wilcox Story, 1867-1957. New York: Babcock & Wilcox Co., 1957.

Biggs, Lindy. *The Rational Factory: Architecture, Technology and Work in America's Age of Mass Production.* Baltimore: Johns Hopkins University Press, 1996.

Brownlee, David B. *Building the City Beautiful: The Benjamin Franklin Parkway and the Philadelphia Museum of Art.* Philadelphia: Philadelphia Museum of Art, 1989.

Burghardt, M. David. *Engineering Thermodynamics with Applications.* 1986.

Christie, Jean. *Morris Llewellyn Cooke, Progressive Engineer.* New York: Garland Publishing, 1983.

Electric Power Stations, Telegraph Systems, Telephone Systems, Applied Electricity. Scranton: International Textbook Company, 1905.

Gebhardt, George F. *Steam Power Plant Engineering.* New York: John Wiley & Sons, 1917.

Gorowitz, Bernard, and George Wise, eds. *The General Electric Story: 1876-1986.* Schenectady: Hall of History Foundation, 1989.

Hughes, Thomas. *Networks of Power: Electrification in Western Society, 1880 - 1930.* Baltimore: The Johns Hopkins University Press, 1983.

Hunter, Louis C. *A History of Industrial Power in the United States, 1780-1930.* Volume II (*Steam*). Charlottesville: University Press of Virginia, 1985.

Landmarks in Mechanical Engineering. Prepared by ASME International History and Heritage. West Lafayette [IN]: Purdue University Press, 1997.

Morse, Frederick. *Power Plant Engineering and Design.* New York: D. Van Nostrand Company, Inc., 1932.

Nye, David E. *Image Worlds: Corporate Identities at General Electric.* Cambridge [MA]: MIT Press, 1985.

_____. *Electrifying America: Social Meanings of a New Technology.* Cambridge [MA]:

MIT Press, 1991.

The Philadelphia Electrical Handbook. Philadelphia: American Institute of Electrical Engineers, 1904.

Salisbury, J. Kenneth. *Steam Turbines and their Cycles.* New York: John Wiley & Sons, 1950.

Steam: Its Generation and Use. 40th ed. Barberton, [OH]: The Babcock & Wilcox Company, 1992.

The Stirling Water-Tube Boiler. New York: Babcock & Wilcox Co., 1912 and 1922.

Tarboux, J.G. *Electric Power Equipment.* 3rd ed. New York: McGraw-Hill Book Co., Inc., 1946.

Trombley, Kenneth E. *The Life and Times of a Happy Liberal: A Biography of Morris Llewellyn Cooke.* New York: Harper & Brothers, 1954.

Wainwright, Nicholas B. *History of the Philadelphia Electric Company, 1881-1961.* Philadelphia: Philadelphia Electric Company, 1961.

Wilson, William H. *The City Beautiful Movement.* Baltimore: Johns Hopkins University Press, 1989.

Manuscripts / Typescripts

Baker, Chester F. Papers. Undated. Delaware County Historical Society.

"Bibliography on Government Ownership." Undated[?] PECO Energy Company Library.

Calhoun, John F. "The Problems Involved in the Design of a Generating Station." [Speech delivered before the Engineering Department Branch of the Philadelphia Electric Company Section of the National Electric Light Association?]. [1927?]. PECO Energy Company Library.

"Coal Bureau Manual, 1937." Prepared by Philadelphia Electric Company's Operations Department - Station Operating Division.

Comp, T. Allan, Flo Lentz, Steve Lubar. "Georgetown Steam Plant." Historic American Engineering Record WA-1.

Granger, A[lbert] R., and John Melloy. "Beacon - Ten Years Ago and Today." Speech delivered before the Engineering Department Branch [of the Philadelphia Electric Company Section of the National Electric Light Association], 2 February 1914. PECO Energy Company Library.

_____. "Fifty-Five Strenuous Years, 1892-1947." PECO Energy Company Library.

Green, George Ross. "History of the Philadelphia Electric Company." 1922. PECO Energy Company Library.

Kershaw, Leonard F. "A Discussion on the Site for a Power Plant in Connection with the Engineering Branch of the N.E.L.A. Lectures." [Speech delivered before the Engineering Department Branch of the Philadelphia Electric Company Section of the National Electric Light Association?], 12 November 1926. PECO Energy Company Library.

Lutz, Warren H. "Some Economic Features in Connection with the Design and Selection of a Generating Station Plant and Site." [Speech delivered before the Engineering Department Branch of the Philadelphia Electric Company Section of the National Electric Light Association?], 21 May 1927. PECO Energy Company Library.

Onken, William H. Jr. "History of Philadelphia Electric Company." 1941-1942. PECO Energy Company Library.

Paquette, Joseph F., Jr. "PECO Energy: Electricity -- Back to the Future?" Address to the Newcomen Society of the United States, December, 1996. PECO Energy Company Library.

"Schuylkill Station - The Proving Ground for the Philadelphia Electric Co. System." N.d. PECO Eneregy Company.

"Special Report: General Electric Company Steam Turbine Situation, June 1919." Prepared by the Steam Plant Committee of the Association of Edison Illuminating Companies. PECO Energy Company Library.

"Steam-Electric Generating Stations Manual, 1937." Prepared by the Philadelphia Electric Company. PECO Energy Company Library.

Minutes

Beacon Light Company Board of Directors Minutes. 1896 - 1917. Hagley Museum and Library.

Delaware County Electric Company Board of Directors Minutes. 1909 - 1929. Hagley Museum and Library.

Philadelphia Electric Company Annual Reports. 1915 - 1918. PECO Energy Company Library.

Philadelphia Electric Company Board Reports [from the Company President]. 1914 - 1924. PECO Energy Company, Office of the Corporation Secretary.

Philadelphia Electric Company Executive Conference Minutes. 1924 - 1945. PECO Energy Company Library.

Philadelphia Electric Company Minutes of Supervisory Group Conferences. 1932 - 1939. PECO Energy Company Library.

Pamphlets

Chester Real Estate Board. *Chester Penna., a Modern City With Modern Methods*. 1925.

The Chester Station of the Delaware County Electric Company. [ca. 1919].

The Generating Stations and Substations of the Philadelphia Electric Company. Philadelphia. [ca. 1912].

The PA-NJ-MD Interconnection. 1973, 1980.

Philadelphia and the Philadelphia Electric Company System. Prepared for the Forty-Seventh Convention of the N.E.L.A. 1924.

Proceedings

"Address of President Eglin." *National Electric Light Association, Thirty-Second Convention, Atlantic City, NJ, 1-4 June 1909*, v. I, 3-13.

"Educational and Welfare Work." *National Electric Light Association, Thirty-Seventh Convention, Philadelphia, PA, 1-5 June, 1914*, [v. I], 171-78.

"Experience Meeting as to Company Section Methods." *National Electric Light Association, Thirty-Third Convention, Saint Lewis, MO, 23-27 May 1910*, v. 2, 509-26.

Huey, Arthur S. "Latitude in Commercialism." *National Electric Light Association, Thirty-*

Third Convention, Saint Lewis, MO, 23-27 May 1910, v. 2, 1-20.

Insull, Samuel. "Twenty-Five Years of Central-Station Commercial Development." *National Electric Light Association, Thirty-Third Convention, Saint Lewis, MO, 23-27 May 1910*, v.1, 211-24.

ADDENDUM TO
DELAWARE COUNTY ELECTRIC COMPANY, CHESTER STATION
(PECO Energy Company, Chester Station)
Delaware River at end of Ward Street
Chester
Delaware County
Pennsylvania

HAER No. PA-505

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PHOTOGRAPHS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of Interior
1849 C Street, NW
Washington, D.C. 20240

ADDENDUM TO:
DELAWARE COUNTY ELECTRIC COMPANY, CHESTER STATION
(Philadelphia Electric Company, Chester Waterside Station)
2501 Seaport Drive (Delaware River at South end of Ward Street)
Chester
Delaware County
Pennsylvania

HAER PA-505
HAER PA,23-CHES,2-

PHOTOGRAPHS

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