Pennsylvania Railroad Electrification Strategy

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The Pennsylvania Railroad's conversion of its multitrack mainline connecting New York, Washington, and Harrisburg from steam to electric traction represents the outcome of one of the most significant strategic decisions made by an American railroad in the 20th century. The PRR's northeast corridor electrification, begun in 1928 and completed a decade later, constituted the largest capital improvement program undertaken by an American railroad up to that time. Built at a cost of over $250 million, the sustem encompassed nearly 2,200 track miles and 700 route-miles, or about 25 percent of the electrified route-mileage of steam railroads in the United States. In view of the magnitude of this installation and its exceptionally long life (it was absorbed virtually intact by the Penn Central in 1968), an examination of the steps that led to its creation is worthwhile.

It is important first to deal briefly with the Pennsylvania Railroad's earlier applications of electric traction, if for no other reason than to show that these experiences did not comprise elements of what might be termed "corporate grand strategy," at least not the same strategy that the railroad pursued during the 1920s and later. The first instance of the conversion of a steam-powered operation to electricity on the PRR occurred in 1895 on the road's seven-mile Burlington and Mount Holly (New Jersey) branch. There the railroad substituted cars propelled by low-voltage direct current for steam-drawn trains in local passenger service. The installation was primarily an experimental one [5] and exerted minimal influence on the future course of electric traction on the Pennsylvania. The line reverted to steam operation exclusively when the power plant was destroyed by fire in 1901.

A second electrification of relatively minor consequence took place in 1906 when the Pennsylvania converted one of the mainlines of a subsidiary company, the West Jersey and Seashore Railroad, (WJ&S) to electric traction. This 65-mile line linking Camden and Atlantic City earned most or its revenue from seasonal passenger traffic to and from the shore resorts. There was little that was experimental or novel about the West

Jersey electrification. The experience of interurban railways had already proven that electric traction could be used to lower operating costs and would attract additional passenger business by offering cleaner, faster, and more frequent service. By adopting essentially the same technology as the interurbans, the Pennsylvania gave evidence that it was not looking beyond the confines of south Jersey when it electrified its subsidiary [19]. To cite just one example, the low-voltage direct current used by the WJ&S was not well suited for use in installations spanning long distances. Voltage levels dropped sharply as distance increased unless supported by an elaborate system of substations, thus making expansion of the system difficult and expensive.

The most celebrated of all the Pennsylvania's early electrification projects was the 13-mile tunnel line running beneath the Hudson and East Rivers at New York. This installation, completed in 1910, formed the core of the railroad's New York Extension, a $100-million project aimed at securing an all-rail entrance to Manhattan. Only arch rival New York Central (and tenant New Haven) heretofore possessed a rail terminal in the heart of the nation's most populous city. The entire New York improvement program including its majestic capstone, Pennsylvania Station, rested on the ability of electric locomotives to pull heavy trains through long subaqueous tunnels, a feat steam locomotives could never safely accomplish. The railroad did not choose to electrify because it hoped to exploit the efficiencies and operating economies of electric locomotives [6]. Moreover, the Pennsylvania selected for use at New York the same type of low-voltage direct current system that it had chosen for the West Jersey and Seashore (and for yet another subsidiary, the Long Island Railroad) and had therefore limited the scope of its installation to the immediate vicinity of New York.

This did not mean that the managers of the Pennsylvania Railroad had closed their eyes to the advantages of electrifying other segments of the system. The road had been experiencing serious congestion on lines leading to its Broad Street Station in central Philadelphia since the 1890s, owing to rapid growth of suburban passenger traffic. Because of their ability to accelerate more quickly, electrically powered trains could operate on more frequent schedules than steam-drawn trains, thus enlarging the capacity of the terminal area without resorting to any expansion of the physical plant. Consequently, in 1913 the PRR's board of directors voted to convert local service between Broad Street Station and Paoli, 20 miles to the west, to electric traction. The railroad used multiple-unit cars exclusively, for they could be operated from either end and eliminated the need for time-consuming switching within the station itself. Completed in 1915, the Paoli electrification proved so successful that the PRR made plans for the electrification of additional

suburban routes[7].

At Philadelphia the Pennsylvania had again turned to electric traction primarily in order to solve special operating problems. Nevertheless, the Philadelphia suburban electrification signaled a transition in the PRR's attitude toward electric traction. Previously the PRR had undertaken a conversion to electric motive power to solve unique operating difficulties that steam locomotives had shown themselves incapable of overcoming. While this reasoning was applicable to conditions at Philadelphia as well, two features of the Paoli electrification demonstrate unmistakably that by 1913 the Pennsylvania Railroad had begun to take a much broader and more farsighted view of the economic potential of the electric locomotive. First, the PRR electrified with high-voltage, single-phase alternating current, a type of current that could be transmitted over great distances very economically and with little or no line loss. Hence, as the railroad itself admitted, the entire Philadelphia electrified zone could at some future time be incorporated into an electrified system of much larger scope [7]. Second, at Philadelphia the road contracted with the Philadelphia Electric Company to supply the current. This marked the first time that a steam railraod had agreed to purchase a sizable quantity of commercially produced power. Traditionally steam railroads had generated their own electricity, believing that utilities were incapable of providing a sufficient supply of electricity on a dependable basis. Furthermore, in these days before integrated power pools and standardized current, a railroad contemplating electrifying a substantial portion of its line might have to negotiate power contracts with a dozen or more utilities, no two of which generated an identical type of current. For their part, utilities were cool to railroads as customers, fearing that the railroads' heavy unbalanced loads would be detrimental to the needs of other consumers. The Philadelphia Electric Company was an exception. It believed that by expanding its generating capability to meet the requirements of the railroad, it would achieve economies of scale that would result in lower per-unit generation costs, an outcome that would benefit all customers as well as the utility itself [3]. The Pennsylvania early on saw the wisdom of reaching an agreement with Philadelphia Electric, for the utility offered favorable rates, and virtually all the trackage to be electrified lay within its service area. The PRR also recognized that should it greatly expand its electrified system at a later date, prior experience with commercial power could prove most useful.

The Pennsylvania Railroad had by no means abandoned the idea of using electric traction in limited applications. It was seriously considering electrifying a 35-mile segment of its main line over the Allegheny Mountains between Altoona and Johnstown, Pennsylvania, as late as 1923 [11]. Yet by then it had come to regard electric traction as a technological tool of major

proportions, one that could have a considerable impact on the company's overall profitability. That realization marked a turning point in the railroad's electrification strategy. Only two other railroads share the Pennsylvania's growing awareness of the tremendous potential of electric traction: the New York, New Haven, and Hartford, and the Chicago, Milwaukee, and St. Paul, both of which had undertaken long-distance electrification just before World War I. The handful of other steam roads using electric motive power utilized it in much the same way that the PRR had initially applied it, that is, in specialized applications involving long tunnels, steep grades, and congested terminals.

Two factors caused the PRR to alter its electrification strategy. The first concerned technology. During the early years of the century the railroad rejected long distance electrification in large measure because it did not wish to become a technological innovator in that field [16]. As the first American steam railroad to opt for long distance electrification, the Pennsylvania would have been implementing electric traction on a kind of trial and error basis, an arrangement that could greatly inflate the already intimidatingly high cost of installing an electrified system. By 1915, however, the New Haven, in conjunction with its supplier, the Westinghouse Electric and Manufacturing Company, had converted a 75-mile segment of main line between Woodlawn Junction, New York, and New Haven, Connecticut, to single-phase alternating current and had proven the technological soundness of such an installation. Furthermore, the coal-hauling Norfolk and Western Railway electrified a 27-mile stretch of its mountainous main line in Virginia and West Virginia in 1915 to prove the feasibility of using electric motive power under the most rigorous topographic and operating conditions. These two railroads (and Westinghouse) did much to perfect alternating current locomotives and transmission and distribution systems. The Milwaukee Road and General Electric did likewise with their 438-route-mile, high-voltage direct current installation in the Rocky Mountains and Pacific Northwest [10].

Another aspect of the technological factor was the Pennsylvania Railroad's faith in steam locomotion. The railroad's engineering staff usually preferred to improve the performance of steam locomotives before considering the more expansive alternative of electrification. In those specialized applications previously discussed, this was not possible. On the other hand, the PRR's confidence in its capacity to design more efficient steam locomotives certainly played a major role in the railroad's decision to forgo electrifying its main line over the Alleghenies. By the mid-1920s, nonetheless, the Pennsylvania's engineers admitted that no substantial improvements could be made to the steam locomotive in the near future that would make it superior to its electric counterpart for operation between New York and

Washington, or Pittsburgh and Philadelphia. The technology of steam locomotion appeared to have reached its zenith on the Pennsylvania Railroad and had still been found wanting [17].

The second factor that had discouraged the PRR from undertaking long-distance electrification was the formidable cost of such a project. The railroad estimated in 1908 that converting its Philadelphia-Harrisburg freight line to 600-volt d.c. would cost over $10 million. In view of the technological unknowns, the railroad could not satisfy itself that the $750,000 in annual operating savings that electrification offered in theory would ever be realized in fact [9]. In addition, the PRR's managers asserted that the railroad suffered a shortage of investment capital, a condition that would have prevented the road from electrifying over a long distance even if it were willing to pioneer in new technology [15 and 16]. After the First World War, however, the railroad entered a period of unprecedented prosperity, at least over the short term, and experienced little difficulty in financing capital improvements. By about 1925, the Pennsylvania had cleared its decks, fiscally speaking, in anticipation of a major electrification project. It was then reporting annual net incomes of over $60 million, had no bonds maturing in the near future, and had no other extensive improvement projects in the works[4].

The only question that remained was, would the railroad continue to reap sufficient profits for a long enough period of time to make electrification a worthwhile venture? The man who ultimately answered that question was William Wallace Atterbury, former PRR general manager and vice-president who became president in 1925. Atterbury was cognizant of the changes that had occurred in transportation patterns during the preceding 20 years. He envisioned a future wherein nonrail forms of transport would grow increasingly competitive with the Pennsylvania and other roads for both passenger and freight traffic. The PRR, he reasoned, could ill-afford *not* to electrify. New, more efficient technology must be utilized if the Pennsylvania were to meet successfully the challenge of automobiles, trucks, buses, and aircraft. Thus on 1 November 1928, Atterbury announced his firm's intention to convert its mainline from New York south to Wilmington, Delaware, to 11,000-volt, single-phase alternating current [13]. The undertaking, while a bold one, was in essence a logical extension of electrification projects that the road had already completed or expected to complete soon. In conjunction with its terminal improvements, the PRR had already electrified its lines from Philadelphia west to Paoli and south to Wilmington, and was in the process of electrifying the line north to Trenton. It expected to convert its New York extension from direct current to alternating current and extend the catenary south to New Brunswick, New Jersey, to meet the increasing deamnd for commuter

service along that line. Therefore, what Atterbury was actually declaring was his company's intention to electrify the 35-mile gap between Trenton and New Brunswick. By electrifying in stages, the railroad blunted much of the financial impact of a single large electrification program.

The boundaries of the PRR's electrified territory were next expanded in 1935, when the road completed the electrification of its mainline from Wilmington to Washington [1], and again in 1938 with the electrification of passenger and freight routes between Paoli and the Susquehanna River. The Trenton Cut-off and the Columbia and Port Deposit branch also received catenary at that time [8]. Although not officially part of the original electrification scheme as outlined in 1928, these extensions had from the outset been considered by the Atterbury administration to be logical components of any plan to electrify the northeast corridor. By pushing catenary south to Washington and Potomac yard and west to Harrisbury and Enola yard, the railroad was taking advantage of existing points where motive power was changed and freight reclassified. Longer runs for the electric locomotive resulted in their more efficient utilization as well. Conversely, the PRR was taking on little added financial risk. All the primary electrified routes carried freight and passenger traffic of a density unmatched by any other line in North America, an important consideration in view of the high fixed costs of electrification. And by enlarging its electrified zone during the 1930s, the Pennsylvania actually saved money, since the Depression had caused the price of materials and labor to fall to unusually low levels.

In addition to the large number of route-miles and track-miles electrified, several other features distinguished the Pennsylvania Railroad electrification. The implementation of an electrified system embraced far more than a mere conversion of motive power. In order to fully exploit the electric locomotive's ability to haul longer trains at higher speeds than steam engines, the PRR upgraded much of its communication and signals systems in electrified territory. It improved track and roadbed to accommodate these faster and heavier trains. The railroad erected new through stations at Philadelphia (30th Street) and Newark (Market Street) and renovated others [12]. The cost of these and numerous other improvements when coupled to the expense of installing catenary, constructing equipment repair facilities, and training employees to operate the new system made Pennsylvania Railroad electrification a more complex and financially demanding proposition than it might at first glance appear to be.

A second distinctive feature was the Pennsylvania Railroad's extraordinary reliance on its consultants, equipment suppliers, and utilities, a reliance that contrasted sharply with the road's

traditionally independent stance in the realm of technology. The Atterbury administration realized, however, that by making electrification a cooperative venture, it was in effect shifting a significant portion of the financial and technological burden of electrification from the railroad onto these cooperating firms. Had Westinghouse, General Electric, Philadelphia Electric, the consulting firm of Gibbs and Hill, and other companies associated with the project been unable or unwilling to assume this burden, the Pennsylvania surely would not have committed itself to such a monumental undertaking. As it was, all these firms encouraged the railroad to adopt long-distance electrification and provided invaluable assistance during all phases of the installation. Even the federal government rendered aid, albeit the Pennsylvania had not anticipated this eventuality in 1928 and accepted it with reluctance. When at the nadir of the depression the road could no longer raise sufficient cash through regular earnings and bond issues to maintain construction schedules, it borrowed over $100 million from the Reconstruction Finance Corporation and the Public Works Administration [14].

A third feature distinguishing the Pennsylvania Railroad electrification was the firm's avoidance of technological innovation and its corresponding preference for equipment and techniques that had withstood the tests of time and experience. The classic instance involved the class GG1 electric locomotive, a machine hailed by one perceptive observer as "a transportation tool and motive power unit second to none in moving trains speedily over a railroad" [18], which has come to symbolize Pennsylvania Railroad electrification in general. The GG1 was actually a more powerful version of a locomotive that General Electric had built for the New Haven in 1931, which in turn was itself based on a d.c.-powered design GE had produced for the Cleveland Union Terminal Company (New York Central) two years earlier. This is not to say that a cautious approach to technology always met with success. For example, the PRR's P5 and O1 electric locomotives, predecessors of the GG1, were patterned too closely after the road's successful steam types and never fulfilled the company's high expectations [2].

Because the Pennsylvania Railroad was acutely aware of the magnitude and the irreversible nature of the commitment demanded by long-distance electrification, it delayed such an undertaking until it had satisfied itself that the technological and financial risks had been reduced to a reasonable minimum. While the road's management was quick to perceive the theoretical superiority of electric traction, it desired to weigh the experiences of other roads and to strengthen its own financial position before attempting to translate theoretical advantages into real earnings. By adopting this deliberate strategy, the PRR obtained and electrification that by nearly every standard must be rated

a technological success. The economic achievements of electrification are more difficult to evaluate, in light of the coming of the diesel locomotive after World War II and the railroad's simultaneous financial deterioration. It must be sufficient to say here that electric traction was only one of many technological tools at the railroad's disposal. It was not a panacea for the firm's ills and was never conceived as such by the PRR management.

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