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THE DEVELOPMENT OF ELECTRIC TRACTION ON THE PENNSYLVANIA RAILROAD, 1895-1968

THE ROLE of electricity as a technological force in American life is fairly well known, at least in its general outlines. However, one aspect of that role—the use of electric motive power by railroads—has received scant notice from historians. This scholarly neglect is most unfortunate, especially in view of the attention railway electrification has received in recent years from both industrial and governmental sources. The present situation is not unlike that which existed in the 1920s and early 1930s. At that time, numerous owners of steam railroads, cognizant of the many technological, economic, and social advantages that electric locomotives held over their steam counterparts, displayed keen interest in converting substantial portions of their lines from steam to electric traction. The federal government, through studies conducted by the Department of the Interior and the Federal Power Commission, also surveyed the nation's steam railroad network to determine which segments could

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While almost all footnote citations are derived from primary sources of information, no reference has been made to works that would not be available to the interested reader. Hence, no official documents (other than *Annual Reports*) or correspondence belonging to the Pennsylvania Railroad, its consultants, or its suppliers have been cited, since most readers would not have access to these sources in the event they desired to obtain further information on particular areas of interest. For a complete bibliography of the topic of Pennsylvania Railroad electrification, consult the author's doctoral thesis, "The Development of Electric Traction on the Pennsylvania Railroad, 1895-1968." (The Pennsylvania State University, 1978) This paper is an overview of that thesis.

be operated more efficiently with electric power.[1] However, the onset of the Great Depression combined with certain other technological and economic factors to keep this interest from being translated into material form. Thus, even at the zenith of electrification's popularity, less than one percent of the total route-mileage of steam railroads in the United States was operated electrically.

Given today's renewed interest in electric traction, the time seems appropriate to review the experiences of the owner of the nation's most extensive electrified system, the Pennsylvania Railroad. Between 1933 and the end of its corporate life in 1968, the PRR operated more electrified track-miles (peaking at nearly 2200) than any other railroad in North America. From the standpoint of both freight and passenger traffic, the Pennsylvania's electrified lines were among the busiest in the world. By these and almost every other standard, the Pennsylvania Railroad electrification ranks as the most important yet achieved by an American railroad.

FOUNDATIONS

The Pennsylvania was one of the first railroads to recognize the superiority of the electric locomotive. Beginning in 1908 and continuing sporadically for the next twenty years, the road's motive power engineers studied the feasibility of converting a number of segments of mainline at the eastern end of the system from steam to electric traction. Routes under consideration included the heavily-traveled New York-Washington corridor, as well as the Middle and the Pittsburgh divisions, which traversed the rugged Allegheny Mountains between Harrisburg and Pittsburgh.[2]

The primary advantage of the electric locomotive lay in its ability to produce more horsepower than a steam locomotive of comparable weight. On a short-term basis, in fact, an electric locomotive could nearly double its normal or continuously rated horsepower by overloading its traction motors. These motors were so designed that for short periods of time, generally no more than one hour, they

1. W. S. Murray et al., *A Superpower System for the Region Between Boston and Washington,"* U. S. Geological Survey Paper No. 123 (Washington: Government Printing Office, 1921); Federal Power Comission, National Power Survey, *The Use of Electric Power in Transportation*, Power Series No. 4 (Washington: Government Printing Office, 1936).

2. The first such study by the PRR was Maintenance of Equipment Committee on Power Plants of the Pennsylvania Railroad, *Electric Traction—In Its Present Relation to Steam Railroads and Its Possible Use with Reference to Hauling of Heavy Trains* (Altoona, Pennsylvania: PRR, 1909).

could deliver approximately 75 percent more horsepower than their continuous rating. Only the amount of added heat the traction motors could withstand restricted the extent and duration of the overload. For example, an electric locomotive normally rated at 3000 horsepower could produce as much as 5000 horsepower or more for brief periods, especially when starting a train or ascending a grade. By contrast, the steam locomotive's horsepower was limited by the amount of steam that could be forced into its cylinders. Any quantity of steam generated in the boiler in excess of the cylinders' capacity to use it was wasted. Thus, a steam engine was physically incapable of carrying an overload of any kind. Furthermore, as the speed of a steam locomotive increased, its drawbar pull, or tractive force, decreased, because the valve cut-off had to be shortened in order to stay within the steam generating capacity of the boiler. The electric locomotive, by contrast, free from the limitations of reciprocating machinery, could exert a maximum tractive force two or even three times greater than the force produced by a steamer of comparable weight and speed (up to about 30 miles per hour).

In practical terms, this meant that a single electric locomotive could start a train with ease that a steam locomotive could not budge. Or an electrically-powered train might climb a steep grade with little or no reduction in speed, whereas the same train behind steam power might slow to a laborious crawl or even require the assistance of helper engines. Electrification, by allowing a railroad to run faster and heavier trains, yielded increased productivity. This was especially true on densely-trafficked lines, where more passenger-miles and freight ton-miles could be generated from a given amount of track, and on mountainous stretches, where trains were slow and extra motive power was required.

Mechanically, electric locomotives contained far fewer moving parts than did the steamers and were much simpler in design and construction. They had need of neither coal nor water, and had no fires to be banked nor ashes to be disposed of. Electric traction consequently offered significantly lower operating and maintenance costs and a higher degree of availability than steam.[3]

3. Informative discussions of the relative merits of steam and electricity are contained in "Advantages of Steam and Electric Locomotives," *Railway Age* 69 (29 October 1920): 739-46; Arthur Curran, "The Advantages of Steam Over Electricity on Railroads," *Cassiers Magazine* 41 (March 1912): 222-34; and N. W. Storer, "Characteristics of Electric Locomotives," *Journal of the Franklin Institute* 192 (October 1921): 453-68.

In spite of these advantages—all of which were clearly apparent soon after the turn of the century—the Pennsylvania's management consistently vetoed all proposals for a long-distance electrification project. Samuel Rea, who served as president of the road from 1913 to 1925, summarized his company's attitude toward a major electrification program in his report to the shareholders for 1916.

> Electric traction would facilitate the heavy movement on . . . . your mainline and would effect a considerable saving in operating expenses, but the Company prefers to obtain the experiences of other lines in the use of electric traction for heavy freight trains, and to see a further expansion in its revenues before procuring the new capital required for this important project.[4]

The latter reason was especially important in explaining the Pennsylvania's reluctance to approve widespread conversion from steam to electricity. Installing an electrified system demanded a vast capital outlay. The road estimated in 1913, for instance, that electrifying its 125-mile Pittsburgh division would cost at least $25 million.[5] Nevertheless, cost in itself probably would not have played a decisive role. Additional inhibiting factors were present, which combined to convince the PRR that long-distance electrification could not be undertaken on a favorable basis. As President Rea had pointed out, America steam railways lacked experience with heavy-duty electrification that spanned many miles. Only the New York, New Haven, and Hartford Railroad possessed an electrified line of any real length, yet even that stretched only 75 miles between New York City and New Haven, Connecticut. Admittedly the railroad could look to Europe for some guidance, but the bewildering variety of systems then in use on the other side of the Atlantic made the selection of any one of them for the PRR practically impossible. At home, the Pennsylvania found the so-called "battle of the systems," that is, the controversy surrounding the merits of alternating current and direct current, to be nearly as exasperating. The a.c. versus d.c. debate remained unsettled with regard to rail applications until after World War I. A railroad adopting one system could not be sure that technical advances made in an opposing system would not suddenly render its own

4. *Sixty-ninth Annual Report of the Pennsylvania Railroad Company* (Philadelphia: PRR, 1916), p. 9.

5. *Sixty-seventh Annual Report of the Pennsylvania Railroad Company* (Philadelphia: PRR, 1914), pp. 12-13.

technology obsolete. For that matter, the Pennsylvania, with its close ties to the coal industry, did not discount the possibility of developing more efficient steam locomotives that could more readily compete with electric traction. Finally, the PRR had to contend with the absence of an interconnected network of commercial power companies. During the first twenty years or so of the century, most utilities still confined themselves to serving local markets and were only beginning to settle on standard characteristics for the current they produced. And given their limited generating capacity at this time, most electric power companies were not at all eager to attract railroads, with their heavy, cycliyclical loads, as customers.[6] Had the Pennsylvania opted to begin a long-distance electrification program before, say, 1917, in all likelihood it would have been forced to generate its own power, thus adding to the already high initial cost of electric traction.

Each study of long-distance electrification that PRR engineers undertook, therefore, ultimately met with a negative response in the boardrooms of the road's Philadelphia headquarters. The railroad maintained that launching a substantial electrification program entailed too great a risk (both technologically and economically speaking), when compared to the tremendous expenditures involved. The coming of World War I, subsequent federal control of the railroads, and the need to rebuild much of the war-ravaged system after peace had returned also undermined the case for electrification.

Its refusal to convert a whole operating division or more to electric traction notwithstanding, the Pennsylvania did undertake two limited but very influential electrifications during this early period, first as part of its New York tunnel extension (completed in 1910), and then a few years later as the basis for improved suburban passenger operations at Philadelphia. The former installation encompassed some thirteen route-miles between Manhattan Transfer (Newark), New Jersey, and Sunnyside, Long Island, and included a half-dozen tunnels under the Hudson and East Rivers. The extension permitted the Pennsylvania to realize its long-sought goal

6. Interesting figures concerning the amount of coal both hauled and consumed by the PRR can be found in *Railway Age*, 4 August 1928, p. 232, and the *Seventy-ninth Annual Report of the Pennsylvania Railroad Company* (Philadelphia: PRR, 1926), p. 14. For a general outline of steam railroad/utility relations, see Fred Darlington, "Central Power Plants and Electricity Supply for Trunk Line Railroads," in *Proceedings of the Thirty-fourth Convention of the National Electric Light Association* (New York: NELA, 1911), pp. 1056-73; and Samuel Insull, "Some Comments on the Economics of Electricity Supply," *National Electric Light Association Bulletin* 13 (1926): 353-57.

of attaining a direct, all-rail access to the island of Manhattan. (Previously, PRR trains had terminated at the New Jersey shore and ferries were used to shuttle passengers to and from Manhattan.) In this instance, the railroad utilized electric traction chiefly because of its freedom from noxious smoke and gases, rather than because of its operational advantages.[7]

The Pennsylvania followed a conservative policy in connection with motive power for the extension. First, it electrified with low-voltage direct current, which was distributed by means of a ground-level third rail. Although this system was fast becoming obsolete, it had proven itself to be extraordinarily rugged and dependable—characteristics that the Pennsylvania valued highly, since the success of the extension rested almost solely upon the satisfactory performance of the motive power. The road also based the design of its new electric locomotives (Class DD1) on the tested principles of steam locomotive construction, incorporating into its new machines such features as side rod drive, a high center of gravity, and an assymetrical wheel arrangement.[8]

The problem facing the railroad a hundred miles to the south, at Philadelphia, centered around the intolerable congestion at the company's Broad Street passenger station. Burgeoning local traffic taxed the facility almost beyond endurance. Electrification of the station yard along with several of the local passenger routes into the city would enable the Pennsylvania to enlarge the capacity of the terminal without having to resort to the much more difficult alternative of physically expanding the station and accompanying trackage. Accordingly, in 1913 the PRR's board of directors approved the electrification of the four-track mainline between Broad Street Station and the town of Paoli, a distance of some twenty miles. In what was to become a milestone in the history of railroad electrification in the United States, the Philadelphia Electric Company agreed to supply virtually all the power the PRR needed for the next twenty years. The utility was already in the midst of a major expansion program and so welcomed the Pennsylvania to its growing list of heavy industrial consumers. Citing economies of scale inherent in power generation and transmission, Philadelphia Electric reasoned

7. The September and October 1910 issues of the *American Society of Civil Engineers Transactions* were devoted entirely to the construction and operation of the PRR's New York extension and contain fine surveys of the topic written by the actual participants.

8. Alfred W. Gibbs, "Some Mechanical Characteristics of High Speed, High Power Locomotives," *Journal of the Franklin Institute* 192 (October 1921): 469-95, traces the evolution of the DD1 in detail.

that the railroad would actually help the utility to lower the unit cost of electricity to all of its customers.[9]

At Philadelphia, the Pennsylvania elected to use high-voltage (11 kv), single-phase, alternating current, distributed by means of an overhead catenary wire system. The alternating current system had not been perfected at the time of the construction of the New York extension, and so was not seriously considered for that project. On the other hand, by 1913 the New Haven had demonstrated alternating current to be fully as reliable as direct current for railroad use and far more efficiently transmitted over long distances. Hence the Pennsylvania capitalized on the New Haven's pioneering efforts and adopted alternating current for its own use. Such a course of action typified the PRR's desire to have other roads bear the burden of technological experimentation and innovation in the field of electric traction, allowing the Pennsylvania to circumvent this expensive process and deal directly with proven methods and equipment.

THE GREAT ELECTRIFICATION

Except for a few additions to its electrified lines in the Philadelphia area, the PRR did not significantly enlarge its electrified territory through most of the 1920s. It did continue to study the possibility of converting either the New York-Washington corridor or the mainline through the Alleghenies to electric traction. Indeed, the railroad even constructed a few experimental locomotives (Classes FF1 and L5) for these proposed electrifications.[10] As late as 1928, however, it had still not committed itself to either of these ventures. Finally on 1 November of that year, William Wallace Atterbury, who had succeeded Samuel Rea as president, announced his company's intention to electrify the New York-Washington mainline, a total of about 225 route-miles.

9. An excellent summary of the initial electrification at Philadelphia is George Gibbs, "The Philadelphia-Paoli Electrification of the Pennsylvania Railroad," *Electric Journal* 13 (February 1916): 68-78. For Philadelphia Electric's policy toward railroad electrification, see Nicholas B. Wainwright, *History of the Philadelphia Electric Company* (Philadelphia: Philadelphia Electric Company, 1961), pp. 107-10 passim.; and W. C. L. Eglin, "The Engineering Features of the Philadelphia Electric Company System," *Electrical World* 83 (10 May 1924): 933-50.

10. Descriptions of these locomotives can be found in G. M. Eaton and A. J. Hall, "The New Split-Phase, Locomotive of the Pennsylvania Railroad," *Electric Journal* 14 (Ocotber 1917): 406-12; and T. C. Wurts, "Pennsylvania Builds Three Electric Locomotives," *Railway Age* 76 (26 January 1924): 295-96.

The Pennsylvania's management had concluded by this time that conditions had changed markedly from the earlier years, so much so that they now favored a substantial conversion from steam to electric traction. The railroad realized that even its own limited experience with electrification, plus that of the handful of other American steam railways that operated electrifications, had shown conclusively that the basic technology of electric traction was quite capable of meeting the most stringent demands of heavy-duty railroading. The alternating current installations of the New Haven, the Norfolk and Western, and the Virginian systems in particular, although all rather limited in scope, constituted sound precedents for the PRR's action. In addition, the Pennsylvania had entered a period of unparalleled prosperity by the mid-1920s and believed that it could finally afford the huge expenditures that electrification required. The wisdom of a large investment in this technology was further enhanced by the fact that the hoped-for improvements in steam locomotion had failed to materialize and gave no signs that they ever would.

Perhaps the most significant factor contributing to the changed conditions of the 1920s was the increased competition provided by nonrail forms of transportation. Trucks, buses, autos, and airplanes all threatened to lure away sizeable amounts of the PRR's freight and passenger traffic. Long-distance electrification, by boosting operating efficiency and enabling the railroad to offer better service, would help the Pennsylvania retain (and perhaps even enlarge) its share of traffic.[11]

Over the next ten years, the PRR electrified its route between New York, Philadelphia, Baltimore, and Washington, together with extensions from Paoli west to Harrisburg. By 1938 it had about 2200 track-miles and 600 route-miles under catenary. The railroad utilized the same kind of 11 kv, 25 hertz, single-phase system as it had installed at Philadelphia two decades before. Total investment exceeded $250 million. This figure included the cost of a host of related improvements, such as new signal systems, heavier rail, and new terminal and maintenance facilities, all of which were essential if the PRR were to reap all the benefits inherent in high-speed electric traction.

Given the great expense of the project, the Pennsylvania made every effort to minimize technological risk without compromising

11. The complete text of Atterbury's lengthy statement appears in *Railway Age*, (3 November 1928): 870.

Type P-5a Locomotive at Earnest, Pa., July 1964. (*Harold K. Vollrath.*)

the economic goals it had established. As in past experiences with electric traction, the railroad attempted to adhere to a conservative policy with regard to the introduction of new technology, but not one so cautious that it undermined the stated objectives of providing better service and increasing corporate profitability. Hence the great electrification program of the 1930s was a cooperative affair, in which the PRR depended far more heavily upon the advice and expertise of its consultants, equipment suppliers, and utilities than it had in the past. The Pennsylvania tried to build upon the experience of other steam railroad electrifications wherever possible and almost always insisted upon exhaustive testing of new technology before adopting it for practical service.[12]

Deviating from such a thorough approach to electrification invited ruin, as evidenced by the road's inability to develop a satisfactory class of electric motive power for passenger duties until 1934, six years after having begun the electrification program. Initially the railroad expected its 3750-horsepower Class P5 locomotives to haul most passenger trains in electrified territory. It began construction of the first pair of prototype machines at its Altoona shops in the spring of 1931. So confident was the PRR of

12. Discussions treating this phase of PRR electrification in a general way are W. D. Bearce, "The Pennsylvania Railroad Electrification: New York-Washington," *General Electric Review* 39 (February 1936): 100-107, (March 1936): 139-45; J. V. B. Duer, "The Pennsylvania Railroad Electrification," *American Institute of Electrical Engineers Transactions* 50 (March 1931): 100-104; and "Pennsylvania Electrification Links Philadelphia and New York City," *Railway Age* 94 (25 February 1933): 268-302.

the P5's capabilities that it ordered ninety additional units from Westinghouse Electric, the Baldwin Locomotive Works, and General Electric in June 1931—two months before the prototypes were completed and could begin trials. As a result, sixty-two of these units had already been delivered to the railroad before it discovered that they possessed a number of serious mechanical deficiencies. Some of these—namely, the appearance of tiny cracks in the driving axles and a tendency to exhibit a pronounced lateral motion at speeds over seventy miles per hour—so alarmed the railroad that it ultimately withdrew the P5's from service and temporarily reverted to steam operation—a most humbling action for a firm that styled itself "The Standard Railroad of the World."[13] When extensive testing revealed that not all of the flaws of the P5 (or P5a, as the production units were designated) could be satisfactorily remedied, the PRR instituted a search for a replacement locomotive, eventually settling on the 4600-horsepower Class GG1 unit in the fall of 1934. The GG1 proved to be an eminently successful machine, with over forty of the total order for 139 locomotives still in active service today.[14]

Both the P5 and the GG1 represented a conservative approach to motive power engineering. The P5 design, like so many of its predecessors on the PRR, was almost exclusively a product of the railroad's own engineering staff. It should not be surprising, therefore, to find that the locomotive embodied certain mechanical traits—such as high axle loadings, high horsepower, a rigid frame, and large-diameter driving wheels—that traditionally distinguished the road's steam locomotives. Unhappily for the Pennsylvania, many of the P5's weaknesses stemmed from this very fact. The railroad's mechanical and electrical engineers were simply unable to successfully translate what had been viewed as sound practices in steam locomotive design to the design of high speed electric locomotives. By contrast, the GG1 represented for the most part the engineering talent of the General Electric Company. The GG1 had its precedent not in steam power but in electric units GE had built for the New Haven and the Cleveland Union Terminal (New York Central) railroads. The locomotive also symbolized a watershed

13. J. V. B. Duer, "Pennsylvania Develops Three Types of Electric Locomotives," *Railway Age* 92 (21 May 1932): 869-73; "Track Tests of Electric Locomotives," *Railway Age* 101 (12 September 1936): 278-82.

14. J. W. Horine and H. S. Ogden, "The Pennsylvania Railroad Class GG-1 Electric Locomotive," *American Institute of Electrical Engineers Transactions* 79-2 (May 1960): 107-14.

Type GG-1 Locomotive at Coatesville, Pa., June 1952 (*Harold K. Vollrath.*)

in electric motive power development on the Pennsylvania. From the advent of the GG1 onward, the PRR came to place increasing reliance on the resources of its suppliers—primarily General Electric and Westinghouse—and less and less on its own corps of engineers.

At the same time it was encountering these technological difficulties, the Pennsylvania experienced equally serious problems on the financial front. The stock market had crashed only a year after President Atterbury had disclosed his road's decision to electrify. At first the PRR's chief executive was undisturbed by the subsequent downswing of the national economy. He optimistically told the Manufacturers Club of Philadelphia that "we have every intention of going ahead with our entire program of improvements as originally planned, without any slackening, retrenchment, or postponement. . . . We believe with President Herbert Hoover that the country and its fundamental business conditions are sound."[15]

As the new year of 1930 dawned, the PRR became increasingly distressed as the market for railroad securities continued to shrink. By the end of the year, the Pennsylvania was forced to curtail many of its improvement projects, although Atterbury stubbornly refused to slow the electrification activity. He contended that while traffic and thus revenues might decline during bad times, the cost of materials and labor did, too. Business conditions would surely

15. *Philadelphia Inquirer*, 8 December 1929, p. 13.

return to normal, he reasoned, so why not take advantage of the relatively depressed prices? The Pennsylvania therefore proceeded with electrification at an even faster pace than original plans had called for. In March 1931 the railroad sold $50 million worth of 4½ percent bonds, a transaction that generated sufficient cash for another year of electrical work. Early in 1932, however, the company could find no market for an additional bond issue. Its board of directors thereupon asked the Reconstruction Finance Corporation in March for a $50 million loan to be repaid over the next three years. If the RFC failed to approve the request, Atterbury warned, all electrical work would have to be halted by the end of the year.[16]

The Reconstruction Finance Corporation, after carefully appraising the situation, agreed to loan the road only half the amount, and then only on the condition that the PRR obtain a matching amount from private sources. The RFC at this time was very much imbued with the same laissez-faire spirit that characterized its reluctant founder, President Hoover. After some effort, the money was raised and the agency loaned the railroad a total of $27½ million. Despite its need for this money, the Pennsylvania hardly had an opportunity to put it to use. Its board of directors, citing the 6 percent interest rate as unduly burdensome, voted to repay the entire amount as soon as possible. The final payment was made in July 1933. This left the corporate treasury practically empty and in August 1933 all electrification work had to be suspended.[17]

The year 1933 also witnessed the transition of federal power from the Hoover administration to that of Franklin D. Roosevelt. Among the myriad of agencies established by Roosevelt to get the economy moving again was the Public Works Administration, headed by Secretary of the Interior Harold L. Ickes. The PWA was charged with helping to finance large construction projects of either a public or private nature in order to increase employment. At Ickes' urging, the Pennsylvania applied to the agency in the fall of 1933 for additional funds with which to continue the electrification program. In December the PWA approved a loan of $77 million. Two-thirds of this sum was to be spent directly on electrification—

16. *Railway Age*, 90 (4 April 1931): 689; 90 (6 June 1931): 1105; 92 (19 March 1932): 508; *Eighty-fifth Annual Report of the Pennsylvania Railroad Company* (Philadelphia: PRR, 1932), pp. 2, 9; *Eighty-sixth Annual Report of the Pennsylvania Railroad Company* (Philadelphia: PRR, 1933), p. 6.

17. Reconstruction Finance Corporation, Office of the Secretary, Minutes of the Meetings of the Board of Directors, Vol. 4, pt. 1, 1-15 May 1932, p. 98; Vol. 18, pt. 3, 22-29 July 1933, pp. 2271-76.

mainly on the trackage between Wilmington, Delaware, and the nation's capital—with the remainder to go for rolling stock. Railroad and government officials estimated that this money would create over 45 million man-hours of employment for PRR workers alone, not to mention thousands of other employees in related industries. By the end of 1934, electrification activities were once more in high gear. During that year, $56 million of the loan had been expended and 15,000 furloughed employees recalled.[18]

The last gap in the electrification between Wilmington and Washington was closed, and the first electrically-powered train left the latter city on 28 January 1935, a nine-car special carrying industry and government dignitaries and a large group of news reporters. At the dedication ceremonies held prior to the inaugural run, Secretary Ickes, who led the federal government's delegation, spoke almost as if President Roosevelt himself had been responsible for the electrification scheme. Ickes stated:

> Departure of this train establishing electrified railroad service between the nation's capital and the nation's largest metropolis for the first time . . . not only shows what can and should be done under the President's recovery program but demonstrates what actually has been accomplished under PWA when private initiative aids the Administration in carrying out its re-employment plans.[19]

If PRR Vice-President Martin W. Clement, who headed the railroad's official party, believed that in reality it was the Administration that had aided private initiative, he did not appear disturbed by Ickes' remarks. Instead, Clement acknowledged his company's "appreciation to the Administration for the pleasure we have had in working with them and in having made completion of this program possible . . . through perfect cooperation without any friction."[20]

The electrified system had been in operation only a few short years when World War II erupted and put it to its most severe

18. Harold L. Ickes, *Back to Work: The Story of PWA* (New York: Macmillan, 1935), pp. 181-83; Herman B. Byer, "Labor Requirements for a Railroad Electrification Program," *Monthly Labor Review* 43 (September 1936): 586-90.

19. Quoted in *Railway Age*, 98 2 February 1935: 106.

20. Ibid. Perhaps the best overall survey of the great electrification of the 1930s as well as its antecedents on the PRR is H. C. Griffith, "Single-Phase Electrification on the Pennsylvania Railroad," *Journal of the Institute of Electrical Engineers* (London) 81 (July 1937): 91-103.

test. While other railroads literally groaned under the burden of war-swollen traffic, the Pennsylvania, with its fleet of GG1's and P5a's (the latter were used as freight locomotives) bore these extraordinary demands with hardly any sign of strain. More than one knowledgeable observer credited electrification with preventing the horrible mass of clogged yards and stalled trains that had prevailed on the PRR during the First World War.[21]

THE CHALLENGE OF A NEW ERA

When President Atterbury had made public in 1928 his company's plans to begin long-distance electrification, he stated that the road's intention was to eventually complete an electrified line through the Allegheny Mountains as far west as Pittsburgh. The advent of World War II temporarily put an end to preparation for this extension. After the war, the technological and economic contexts within which the PRR operated underwent such a radical change that the railroad never again gave serious consideration to the prospect of enlarging its electrified region. Indeed, the great electrification of the 1930s marked the last time any American railroad converted a significant portion of its line to electric traction.

The most formidable obstacle to the further growth of electrification took the form of the diesel-electric locomotive. This machine, which began appearing in substantial numbers on American railways immediately following the war, was in essence a self-contained electric locomotive, carrying its own power plant (the diesel engine) rather than relying on overhead wires or third rail to transmit electricity from a distant source. The diesel offered nearly all the advantages of electric traction without necessitating the latter's tremendous capital outlay. Moreover, dieselization could be introduced gradually, unlike the "all or nothing" concept of electrification.[22] These considerations were extremely important to the Pennsylvania, which suffered after 1945 from the industrial decline of the northeastern United States and from the decline of the coal industry in particular. Faced with annual net incomes barely above those of the Depression years on the one hand, and crippling

21. The role of PRR electrification in World War II is analyzed by A. C. Kalmbach in "Epoch of Electrification," *Trains* 6 (April 1946): 40-47.

22. Charles Kerr, Jr., "What Diesels Mean to Railroads," *Railway Age* 134 (6 April 1953): 69-71.

Type E-44 Locomotive at Philadelphia, Pa., February 1965. (*Harold K. Vollrath.*)

inflation on the other, the PRR in the late 1940s made the obvious choice and replaced its remaining steam locomotives with diesels.[23]

For a time in the mid-1950s, the railroad even entertained the idea of doing away with electrification altogether in favor of diesels. Numerous studies pointed to the fact, however, that despite its growing obsolescence, electric traction still offered enough economies not only to warrant retention, but to justify a degree of modernization. These economies became especially alluring as the repair and maintenance costs of ten-year-old diesel units began to surpass those of twenty-five-year-old electrics. The modernization was best reflected in the acquisition of a fleet of new stainless steel multiple-unit cars beginning in 1958 for local passenger service in the Philadelphia and New York areas, and 66 new electric freight locomotives (Class E-44), the first of which was delivered by General Electric in 1960.[24] During this period the Pennsylvania, in conjunction with Westinghouse, pioneered in the use of ignitron rectifiers

23. "The Pennsy's Predicament," *Fortune* 37 (March 1948): 84-93, is an excellent portrait of the railroad and reasons for its decline.

24. Technical advances made in passenger service are discussed in S. V. Smith, "Modern, Efficient, Silicon Rectifier-Type Multiple Unit Cars for Philadelphia Area Passenger Service," *Institute of Electrical and Electronics Engineers Transactions on Applications and Industry* 83 (November 1964): 343-50. The E-44's are dealt with briefly in W. E. Kelley, "Historical Summary, Performance, and Future of Penn Central Company Electrification," in *Conference on Performance of Electrified Railways* (London: Institution of Electrical Engineers, 1968), pp. 65-109. The latter is a most interesting study of relatively recent electric traction operations on the PRR and its successors.

in motive power applications. The rectifier was a device contained on board the locomotive that converted the alternating current drawn from the overhead wire to direct current for use in the traction motors. Rectifiers, by permitting the utilization of direct current motors, increased the efficiency of operation, since this type of motor was better suited to motive power requirements.[25] All new electric units, whether locomotives or multiple-unit cars, were equipped with either the ignitron rectifier or its solid state successor, the silicon diode rectifier. The devices were also widely adopted for use aboard diesel locomotives.

After the passage of the High Speed Ground Transportation Act by Congress in 1965, the federal government aided the Pennsylvania in developing the Metroliner, a high-speed multiple-unit train for service in the New York-Washington corridor. Unfortunately, a number of technical problems so delayed the project that by the time the Metroliner finally appeared in revenue service, the Pennsylvania Railroad had ceased to exist, having joined with the New York Central system on 1 February 1968 to form the Penn Central Transportation Company.[26] From the ruins of that ill-fated merger have come the National Railroad Passenger Corporation (Amtrak) and the Consolidated Rail Corporation (Conrail). Amtrak, the quasi-governmental agency charged with operating most of the nation's passenger trains, now owns the bulk of the former PRR's electrified trackage. Conrail, another government-backed entity combining several bankrupt Northeastern rail lines, owns the remaining portion. Amtrak is presently engaged in upgrading and lengthening its share of the electrification, while Conrail continues to study the possibility of doing likewise.[27]

RETROSPECT

The Pennsylvania Railroad electrification was undeniably a success in the sense that it markedly lowered operating costs and improved service to shippers and passengers alike. Precisely how

25. For the experimental stage of rectifier development on the PRR, see Michael Bezilla, "The Pennsylvania's Pioneer Rectifiers," *Railroad History* 137 (Autumn 1977): 64-79.

26. Kelley, "Historical Summary," pp. 65-109.

27. Edward T. Myers, in "Ready or Not," *Modern Railroads* 31 (August 1976): 50-53, outlines the future of electrification on Amtrak.

much traffic the railroad gained by electrifying is impossible to calculate. The railroad itself admitted as much. What *can* be stated with assurance is that electric traction alone could not check the inroads made (especially into passenger traffic) by non-rail transport. Thus, despite its efficiencies, electrification was unable to prevent a drastic decline in the railroad's financial fortunes after World War II. On the other hand, business might have fallen off even more had it not been for the high quality of service allowed through the utilization of electric traction.

The Pennsylvania's experience also showed that the main stumbling blocks to electrification were financial, not technological. The railroad encountered its share of technical difficulties, to be sure, but it consistently overcame them. However, it was almost powerless to control economic conditions. It could do little to combat the problems of government-subsidized competition, overly stringent state and federal regulation, artificially low petroleum prices (a significant factor in dieselization), and a general decline in the economic base of the Northeast, all of which eroded the road's financial strength and prevented it from raising the capital needed for further electrification.

When the Pennsylvania launched its great conversion to electric traction a half-century ago, it was well aware that electrification represented a more efficient use of energy than did steam locomotion. A ton of coal burned in an electric generating plant produced twice as much horsepower at the rail when used to create current for an electric locomotive than it did if burned in the firebox of a steam locomotive.[28] This advantage was of little consequence in an era of cheap energy. Today, electric locomotives do not enjoy such a wide margin of superiority in this respect over diesels. Yet they are able to rely on abundant, domestic energy sources—coal, hydro, and nuclear—rather than on a single, scarce, foreign-based one—petroleum. Should the price of petroleum rise more rapidly than the cost of electric power (as supplied from non-oil-fired central stations), conditions will again become favorable for the electrification of certain heavily-traveled lines. In that case, the Pennsylvania Railroad's experience will take on renewed importance.

28. H. C. Griffith, "Electric Locomotive Operation," *Railway Age* 111 (August 1941): 230-35.