Electrics in the diesel age

Railroad electrification was the bright new dawn that never came

By William D. Middleton

FOR MOST OF THE FIRST HALF of the 20th century, the United States led the world in railroad electrification. American inventors and experimentation in the 19th century had developed much of the new technology of electric operation. Electric traction became feasible for street railways in the late 1880's, and within a decade had been applied to the much more demanding requirements of mainline railroading.

Electric locomotives capable of railroad duties began to appear as early as 1893. Even before then, in 1892, the Baltimore & Ohio had made the daring decision to bet the success of its new Howard Street Tunnel in Baltimore on electric operation. B&O contracted with the fledgling General Electric Company to supply the 500-volt D.C. electric power system and three locomotives to pull trains through the tunnel. Electric operation began in 1895, and the new motive power quickly proved itself.

The first decade of the new century was a time of remarkable progress for the new technology. In New York, the New York Central completed an extensive third-rail D.C. suburban electrification; the New Haven Railroad launched a pioneering A.C. project that would ultimately reach New Haven, Conn.; and the Pennsylvania began work on its great New York tunnel and terminal project that would depend upon electrification to bring trains into Manhattan through Hudson and East River tunnels.

Electrification proved to be the answer to the problems of steam operation in tunnels, and electrics went to work in Grand Trunk Western and Michigan Central bores under the St. Clair and Detroit rivers in Michigan; Great Northern's Cascade Tunnel in Washington; and Boston & Maine's Hoosac Tunnel in Massachusetts. Electric multiple-unit suburban trains began operating on the PRR's Long Island and West Jersey & Seashore subsidiaries, and on suburban lines in the San Francisco Bay Area.

More triumphs followed. In the West, the Butte, Anaconda & Pacific and much of the Milwaukee Road's Pacific Extension were wired up for high-voltage D.C. Pocahontas coal roads Norfolk & Western and Virginian both installed single-phase A.C. systems. At Chicago, the Illinois Central put its suburban service under catenary, and the Lackawanna and the Reading soon followed suit in northern New Jersey and at Philadelphia.

The greatest of all U.S. electrifications was completed by the Pennsylvania during the 1930's. When the last extension reached Harrisburg in 1938, Pennsy had almost 2200 track-miles of some of the busiest railroad in North America under catenary. By this time the U.S. stood as the world leader in railroad electrification. With 2400 route-miles and more than 6300 track-miles under electric power—far more than any other country—U.S. electrification represented more than 20 percent of the world total.

In almost every instance, electrification had delivered on its promise. Electric power substantially reduced running times and boosted line capacity. Electric locomotives operated at much lower fuel and maintenance costs than the steam power they replaced. Their availability was two to three times greater, and their effective service lives promised to be twice as long as those of steam locomotives. Electric traction's proponents pointed to these benefits and predicted a bright future for U.S. electrification. A 1936 report by the Federal Power Commission, for example, suggested that electrification of an additional 12,000 miles of track on 20 railroads was economically feasible. The outbreak of World War II only temporarily—it was thought—brought the expansion of U.S. electrification to a halt.

Postwar optimism

While the war delayed any additional electrification, it helped accelerate some technological developments that promised to make it more attractive than ever before.

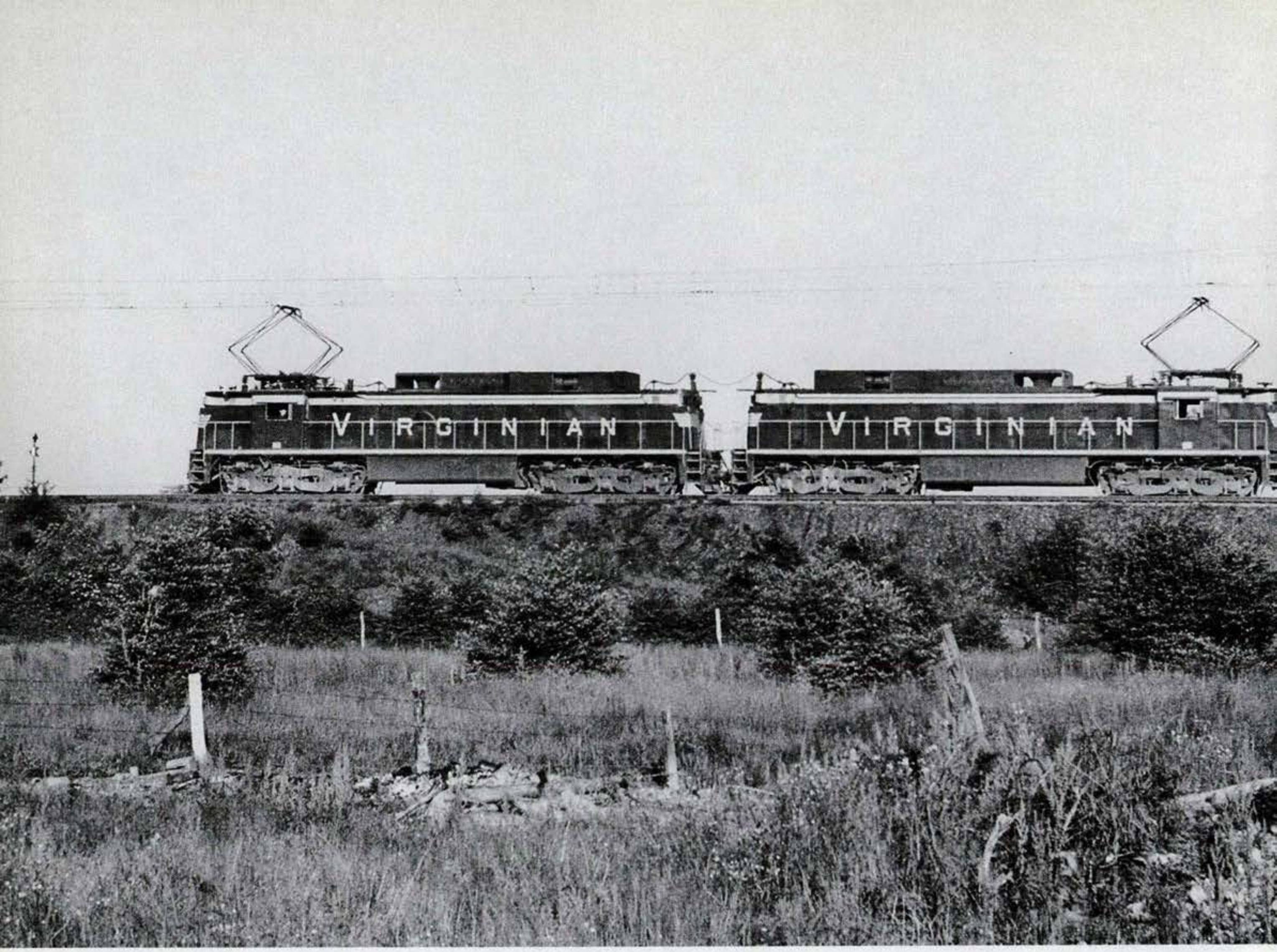
Most important by far was the development of practical rectifiers for locomotives, an advance that resolved several long-standing problems. The industry had long debated the relative merits of single-phase A.C. vs. D.C. High-voltage, single-phase A.C. provided substantial efficiencies in power distribution, while low-voltage D.C. traction motors offered the best control and performance characteristics. The rectifier, which permitted the efficient conversion of A.C. to D.C. power, made it possible to combine the best of both systems. Previously, too, the large single-phase motors used for A.C. electrification had required the use of low-frequency power. With rectifiers, the catenary could be energized with 60-cycle current directly from the commercial power grid, eliminating the costly substations, conversion equipment, and separate transmission lines that had been required for A.C. electrification.

Another handicap to electrification had been the anticipated unbalanced power loads that would have resulted from powering large, single-phase railroad electrifications from the three-phase commercial power system. The growth of the electric power market after World War II, however, minimized this potential problem, and the threat of unbalanced railroad power demands ceased to be a major deterrent.

Even dieselization, which rose in the

After helping diesel-powered freight 261 over St. Paul Pass, a Milwaukee Road "Little Joe" electric moves into the clear at Avery, Idaho, in July 1972.

TED BENSON



Virginian E33's 132 and 133 lead a coal train east out of Princeton, W.Va., in June 1958. These early rectifier units later worked for NH, PC, and Conrail.

late 1930's as the principal rival to electrification, brought developments that were seen as helpful to electric power as well. Since they were, after all, simply electric locomotives that carried their own power plant with them, diesel-electrics incorporated a number of components common to straight electrics. Thus, the mass-production techniques that the diesel builders applied to locomotives for the first time developed rugged, efficient, low-cost traction motors, trucks, drive systems, controls, and other components that were equally applicable to straight electrics.

Diesels could help in another way, too. In the pre-diesel era the full economic advantages of electrification could be realized only through the complete replacement of steam power and its costly servicing and maintenance facilities. To do this, electrification had to include yard tracks, branches, and other lightly used trackage at great additional cost. But by operating such secondary trackage with diesel power, which required less expensive servicing facilities, it became possible to confine electrification to the main running tracks.

With all these new advantages, together with emerging technologies, there was much talk of renewed electrification in the postwar years. Surveying the potential market for electrification shortly after the war, Earl Bill, manager of General Electric's railroad rolling-stock division, identified electrification projects totaling 1200 route-miles that were then under consideration. Most were additions to existing installations, including an extension of PRR catenary from Harrisburg to Pittsburgh, the New Haven's long-deferred New Haven-Boston electrification, extension of Great Northern's Cascade electrification into Seattle, and —the longest of all—a New York Central electrification from Harmon, N.Y., to Buffalo. An entirely new electrification under discussion would have put the Denver & Rio Grande Western under catenary through the Rockies.

In the Pacific Northwest, there was talk of low power rates from federal hydroelectric power plants and government investment to supply power at the trolley wire on as many as 8000 miles of line. Similarly, the Tennessee Valley Authority was looking at railroad electrification as a new market for its power-generation plants.

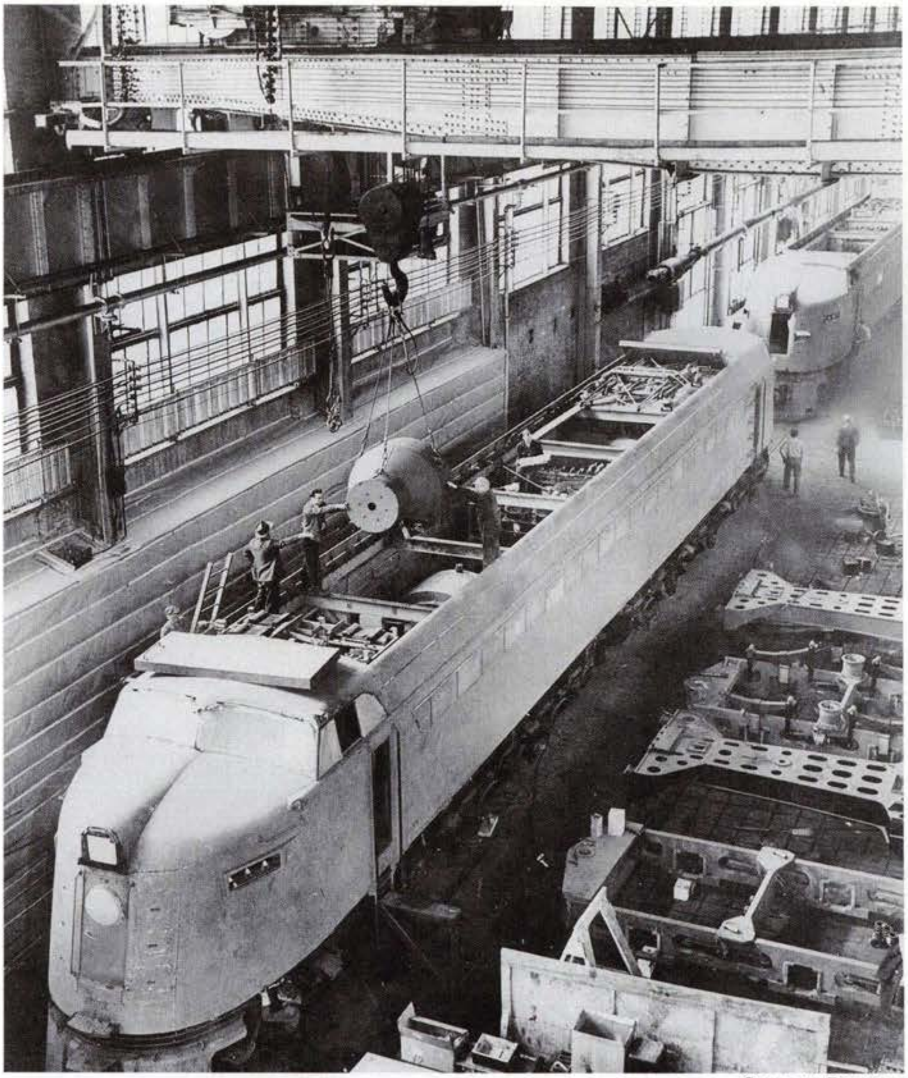
"Currently there is enough interest in electrification so that should the projects materialize into actualities the electric locomotive manufacturers would be unable to handle the business," commented Bill.

New technology brings new motive power

While there was no immediate action toward new electrifications, there were some interesting applications of new technologies on existing systems.

The first electric locomotives ordered after the war represented what was essentially an "old" technology. Needing additional power for their single-phase A.C. electrifications, both the Virginian

J. PARKER LAMB



GENERAL ELECTRIC

At GE's Erie (Pa.) plant, a traction generator is set into one of Great Northern's W-1 electrics. Colossal in size, the W-1's were conservative in design.

and Great Northern placed orders with GE for what would be some of the largest electric locomotives ever built. Instead of trying the new and as yet unproven rectifier technology to convert high-voltage A.C. power from the trolley wire to low-voltage D.C. for the traction motors, both orders employed the older concept of motor-generators to accomplish the same thing. GN's two streamlined W-1's, delivered in 1947, were enormous 101-foot-long, 360-ton B-D+D-B units with a continuous rating of 5000 h.p. that ranked as the largest single-unit electrics ever built. Virginian's four EL-2B's, also streamlined, were made up of paired B-B+B-B units that were 150 feet, 8 inches long and weighed 517 tons. Each EL-2B set was rated at 6800 h.p.

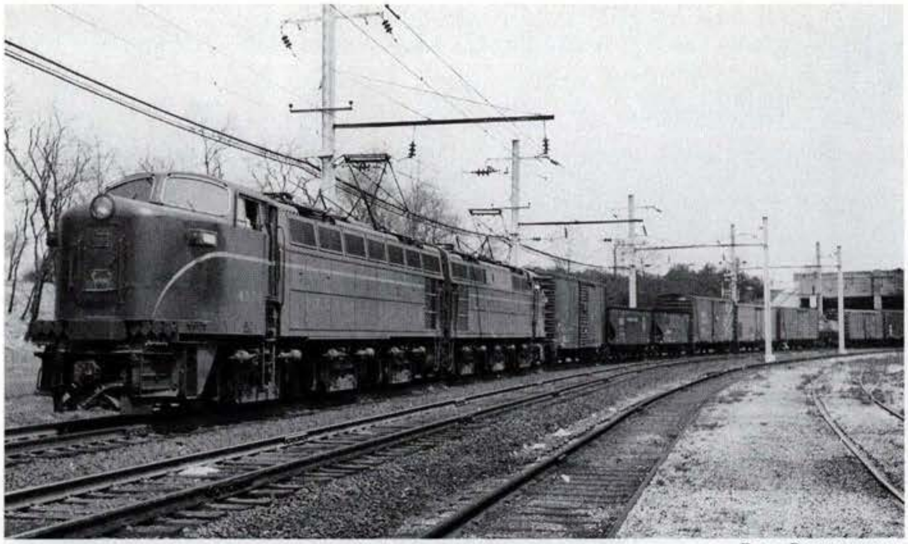
Impressive as these new locomotives were, they were technological dinosaurs. Both of the principal suppliers of electric motive power, GE and Westinghouse, soon came forth with new experimental units for the PRR that were seen as prototypes for the anticipated new electrification market.

During 1951, GE delivered six Pennsy E2b-class units that, with their carbody design and B-B wheel arrangement, were based upon contemporary diesel-electric practice and ideas GE engineers had developed for a "standard" locomotive for new U.S. electrification. But instead of employing the new rectifier technology, with D.C. traction motors, GE used A.C. commutator motors similar to those employed on earlier PRR electrics. Operated as two-unit locomotives, the E2b's could produce a continuous output of 5000 h.p.

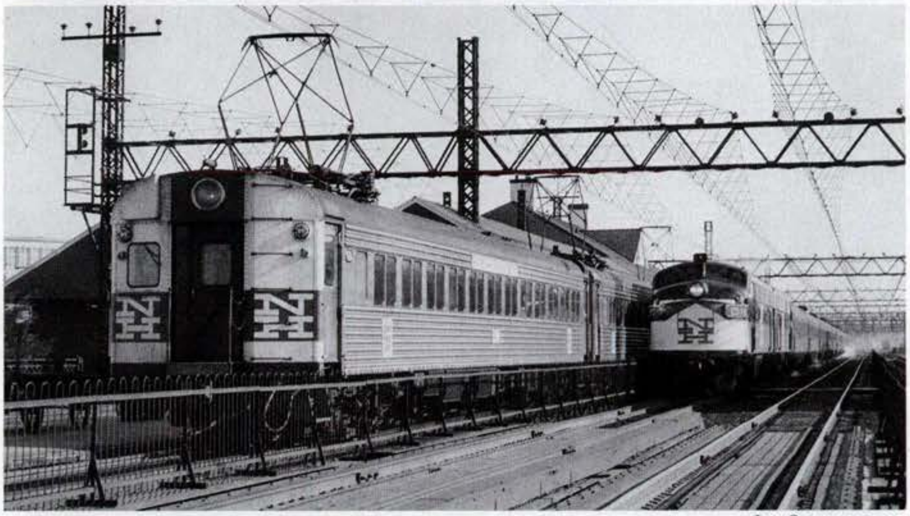
In 1949 the PRR had equipped one of its MP54 M.U. cars with an experimental ignitron-rectifier, with encouraging results, and the same technology was selected for a pair of experimental two-unit, 6000 h.p. locomotives delivered by Baldwin-Lima-Hamilton and Westinghouse during 1951 and '52. Otherwise identical, two class E3b units had a B-B-B wheel arrangement, while two E3c units had a C-C arrangement.

Both experimental designs worked well, but the Westinghouse ignitron-rectifier design was particularly successful. While the Pennsy delayed the replacement of its aging P5a locomotive fleet for almost another decade, other electrified roads soon adopted the new technology. The New Haven was the first, with an order for 100 Pullman-Standard M.U. cars in 1954 that were equipped with Westinghouse ignitron rectifiers.

Despite the Westinghouse success with its experimental ignitron-rectifier units, GE came up with all the locomotive orders. In 1955 GE completed 10 4000 h.p. E40 electrics for the New Haven. These EP-5's, as the NH called them, were the first production-model rectifier locomotives to operate in the U.S. The Virginian followed suit with an order for a dozen 3300 h.p. C-C ignitron-rectifier units from GE. Arranged in the same road-switcher configuration typical of diesel-electric practice, each of the E33's (VGN class EL-C) weighed 174



BERT PENNYPACKER



JIM SHAUGHNESSY

PRR Baldwin-Westinghouse E3b's 4995 and 4996 (top) leave South Philadelphia in April 1952. New Haven was first to order rectifier electrics, but later cut back its juice operations, as seen at Stamford, Conn., where dual-power FL9 diesels pass a train of rectifier M.U.'s ("Washboards") in May 1959.

tons. Beginning in 1960, GE delivered what would be its last big order for electric motive power, a fleet of 66 4400 h.p. E44 units that were essentially an advanced version of the earlier Virginian E33's. The last five units delivered had newer air-cooled silicone-diode rectifiers, which were both simpler than the ignitron rectifiers and permitted an increase in output to 5000 h.p. Subsequently, the entire E44 fleet was converted.

The E44's were prodigious performers that ably demonstrated the capabilities of modern electrification practice. The 66 units had been intended to replace all 92 of the Pennsy's older P5a's. In practice they proved capable of more than half again as much work per unit-month as a P5. Even before getting the upgraded rectifiers, the E44's were able to handle 20 percent more drag freight tonnage than either a P5 or a GG1. Availability, even during the break-in period, was nearly 92 percent. Maintenance costs were only one-third of those for the P5's, and only 25 percent of those for diesel-electric power in the same service.

The Pennsylvania acquired its first rectifier-equipped M.U. cars in 1958, and over the next decade large fleets of similar equipment were ordered for both PRR and Reading commuter services at Philadelphia, and for the Pennsy's New Jersey services.

What went wrong?

Despite the strong performance of this advanced electric motive power, U.S. electrification languished. Not a single one of the electrifications that had seemed so likely at war's end ever went ahead. Indeed, much of the earlier electrification began to disappear.

What went wrong? A simple answer: the diesel-electric.

But there was more to it than that, for the failure of electrification was tied as well to the availability of capital, the prospective availability and cost of electric power, and the willingness of railroad managers to commit to such a costly, long-term and, ultimately, uncertain investment.

The diesel-electric, of course, was the primary force that frustrated electrification. When the Pennsylvania undertook what proved to be the last major electrification in the 1930's, diesel power was still unproven. But by the time the war was over, there was little doubt about what the diesel could do. The war left the railroads with some hard choices to make. With plant and equipment worn out, they were faced with large and costly renewal and replacement requirements. At the same time, the capital available for these needs was limited.

Under these conditions, dieselization was an attractive investment. From a strictly operational point of view, electrification had a big edge over either steam or diesel power in both performance characteristics and operating costs. But the diesel afforded many of these same efficiencies at much lower capital cost. Some data developed by GE's Earl Bill from a 1946 study of New York Central motive-power modernization between Harmon and Buffalo is revealing.

The Central's study, which compared capital and operating costs for electric, diesel-electric, and modern steam power, projected annual operating and fixed-charge savings of more than $2.9 million for electric power over those for steam. Comparable savings for diesel operation were just under $1.8 million. While this would seem to give a clear advantage to electrification, the picture changed when a return on investment was considered. A Harmon-Buffalo conversion to modern steam power would have cost $80.5 million, while dieselization would have cost $104.5 million and electrification $135 million. At these estimated costs, NYC's return on the excess cost of electrification over modern steam power would have been 5.39 percent, while the return would have risen to 7.5 percent for the excess cost of dieselization over steam power. When the relative investments required for electrification and dieselization were compared, the return on the excess first cost of electrification was only 3.75 percent.

With numbers like this and investment capital in short supply, the Central began a conversion to diesel power. For other roads considering electrification, the results were more or less the same, and none of the expansive projects being talked about at war's end ever moved beyond the drawing board.

RICHARD STEINHEIMER

Five of GE's hugely successful E44's—three on one train, two on another—depart side-by-side from Pennsy's big Enola (Pa.) freight yard in 1965.

Not only had electrification ceased to grow, it began to decline as well. Here, too, the diesel was often the culprit.

One decided advantage of the diesel over steam power was its ability to run over long distances without changes of power. Electrifications that had been installed primarily for smoke abatement in long tunnels impeded the efficiencies of run-through operation, while diesel exhaust proved to be manageable with improved tunnel ventilation systems. The Boston & Maine ended electric operation through the long Hoosac Tunnel as early as 1946, and before the end of the 1950's, B&O's Howard Street Tunnel at Baltimore, NYC's Detroit River Tunnel, GN's Cascade Tunnel, and CN-GTW's St. Clair River Tunnel all had been dieselized. Urban smoke abatement being the only reason for NYC's Cleveland Union Terminal electrification, it was gone by 1953.

The merger movement that began to rearrange the railroad industry in the 1950's took more electrifications off the map. Following the merger of the Virginian into Norfolk & Western in 1959, the N&W revised the flow of coal traffic to take advantage of the best grades on the merged system. This left the former Virginian electrification with largely one-way eastbound traffic over its eastern end. This handicapped the utilization of both electric and diesel power, and N&W shut down the VGN electrification in 1962. (By contrast, N&W's own electrified district had reverted to steam operation in 1950 after a line relocation eased grades and curves.)

The Pennsylvania's extensive electrification survived into the 1968 Penn Central merger, but the subsequent PC bankruptcy and the formation of Conrail in 1976 brought major changes to the flow of freight that had once moved under Pennsy catenary. The New York-Washington segment of the Northeast Corridor had been conveyed to Amtrak, and Conrail shifted much of the freight to non-electrified former Reading and Lehigh Valley lines, while much of the traffic west of Philadelphia that had used the PRR's electrified low-grade routes was shifted to former Reading track. With these changes, electric operation was no longer economic, and Conrail lowered its pantographs in 1981.

A few electrifications disappeared for still other reasons. When the installation of a new ore concentrator at Butte, Mont., dramatically reduced ore traffic over the Butte, Anaconda & Pacific, the railroad shifted what traffic remained to diesels and shut off the power in 1967. After 50 years of operation, the electric locomotives and power system on the Milwaukee Road's Pacific Extension were largely worn out. Run-through diesels took over an increasing share of the traffic, and the catenary was de-energized on the last segment in 1974.

Another false dawn

But even as these older electrifications were fading away, there was once again renewed consideration of the

Suburban success stories

BETHLEHEM STEEL

Budd-built Silverliner 9007 pulls into Fox Chase station, outer end of a 5.2-mile extension of Reading catenary opened in 1966.

WHILE MOST mainline electrifications declined after World War II, suburban or commuter installations fared much better. The new Golden Gate and Bay bridges had helped end the San Francisco Bay Area's Northwestern Pacific and Southern Pacific suburban electrifications on the eve of the war, while automobile commuting into Philadelphia via the Ben Franklin Bridge helped shut down similar West Jersey & Seashore services in 1949. But elsewhere, the electrified 5:15 continued to flourish; electric operation provided performance characteristics for these demanding, high-density services that could not be equaled with diesel power.

Most suburban electrifications suffered from deteriorating maintenance and deferred equipment renewal during the long postwar decline of rail passenger services, but by the end of the 1950's a flow of public funding had begun that would ultimately re-equip, rehabilitate, and modernize rail commuter services. Two of them were even completely re-electrified. In 1984, New Jersey Transit completed a conversion of the former Lackawanna electrification from D.C. to a modern A.C. system, while the Montreal-area commuter authority completed a similar conversion of the former Canadian National installation in 1995.

As the suburbs grew, a few of the electric systems were even extended. Modest additions pushed Reading's Philadelphia-area catenary to Fox Chase and Warminster, while Illinois Central's Chicago suburban wires were extended south to University Park. In the 1980's, Philadelphia's SEPTA realized a decades-old dream by unifying the former Pennsy and Reading commuter services with a connecting Center City Commuter Tunnel; SEPTA also added a new line to Philadelphia International Airport.

NJ Transit wire reached Long Branch, N.J., in 1988. Under New York's MTA, the former NYC third-rail electrification saw a modest extension from North White Plains to Brewster in 1984, while Long Island third rail grew by almost 40 miles, with extensions to Hicksville and Huntington in 1970, and to Ronkonkoma in 1988. By 2000 an entirely new 25 kV electrification of the fast-growing 80-mile Caltrain (formerly Southern Pacific) route from San Francisco to San Jose and Gilroy was under serious study. The installation would represent North America's first new commuter rail electrification since the Reading completed its Philadelphia system during 1931-33.—*W.D.M.*

promise of electric operation for American railroads.

In 1965 a special task force of the Edison Electric Institute, a utility industry association, studied electrification of the New York Central main line between Harmon and Cleveland as a basis for investigating the feasibility of electrification of high-density rail operations. The report, published in 1970, concluded there were no serious technical obstacles to commercial-frequency electric operation, and recommended electrification of high-density corridors as both advantageous to the railroads and a desirable new market for utility companies. About 22,000 track-miles, the report estimated, supported a traffic density sufficient to warrant electrification.

This interest in electrification took on a new urgency with the advent of the energy crisis of the early 1970's and the rise in diesel fuel prices that came with it. Southern Pacific began studying electrification of its Sunset Route between Colton, Calif., and El Paso, Texas, in the late 1960's. By the early '70's, Canadian Pacific was considering an 850-mile installation across the Rocky Mountains. Burlington Northern studied electrification for several principal lines in 1973, with the route between Laurel, Mont., and Lincoln, Nebr., a leading candidate because of growing traffic in low-sulfur coal. Union Pacific looked at wires for its main line from North Platte, Nebr., to Salt Lake City and Pocatello, Idaho, in the early 1970's. The Santa Fe, which weighed electrification at the end of World War II and again in 1960, began another study in 1972, this time for its entire Chicago-Los Angeles main line.

Illinois Central Gulf contemplated wiring its Chicago-New Orleans main line and several of its branches. Together with the Tennessee Valley Authority, the Southern Railway began a study of electrification of its Cincinnati-Chattanooga main line, later extended to Atlanta. In 1971, even in bankruptcy, Penn Central was mulling an extension of its former PRR electrification on the former New York Central line up the west shore of the Hudson River to Selkirk Yard at Albany, N.Y. By the end of the decade, only a few years before it shut down its existing electrification, successor Conrail was studying a Harrisburg-Pittsburgh project over the Alleghenies that the Pennsy had considered many times before. Still other roads that at least considered electrification included Missouri Pacific; Duluth, Missabe & Iron Range; Bessemer & Lake Erie; Canadian National; Denver & Rio Grande Western; Quebec North Shore & Labrador; and C&O/B&O.

All of these studies were based upon a new concept of high-voltage, commercial frequency A.C. electrification. The principal motive-power suppliers saw it as a major new market. "We're committed to electrification," said a GE spokesman, "the apparent economic benefits make it inevitable." Even diesel builder Electro-Motive hedged its bet and acquired licenses for electrification technology from Swedish manufacturer ASEA. In 1975 and '76 EMD put experimental 6000 and 10,000 h.p. prototype locomotives for a new line of electric power into service on Penn Central.

Several new mine-to-generating plant coal lines completed in the late 1960's and '70's were seen as prototypes for this new vision of railroad electrification. The Muskingum Electric Railroad in Ohio and two Texas Utilities Co. lignite lines in east Texas were equipped with 25,000-volt, 60-cycle, single-phase A.C. systems, while the Black Mesa & Lake Powell in Arizona was wired up with a 50,000-volt system that was seen as the prototype for Western electrification. GE supplied thyristor-controlled, silicon-diode rectifier locomotives for all three installations.

But once again, electrification proponents were in for disappointment. For despite all the interest and all the studies, very little happened. Two more new, isolated coal lines were electrified in the West, and the British Columbia Railway electrified a new branch built for export coal traffic. There was only one new mainline electrification, for a new National Railways of Mexico route between Mexico City and Querétaro, and it never did go into full operation.

What happened this time?

After a decade of sharply rising diesel fuel prices, the petroleum-based energy crisis of the 1970's had largely abated by the early '80's, and diesel prices began to fall. At the same time, the diesel builders continued to develop new generations of locomotives of steadily improving performance and increasing fuel efficiency. Over the 40-year period from 1955 to 1995, for example, diesel fuel efficiency more than doubled. The diesel-electric remained a formidable alternative to railroad electrification.

The enormous capital cost and the risks associated with electrification, too, were still strong deterrents. Even if the projected return on investment looked good, there was still plenty to worry about. Could the electrification be completed on time and at the projected cost? Would electric power be available at stable rates? Would the utilities have the generating capacity to take on the railroad load? If new power plants were needed could the utilities bring them on line in time? Change any of these parameters and electrification might not produce the anticipated benefits.

With diesel-electrics that continued to gain in performance and efficiency, and faced with all the risks and uncertainties that accompanied expensive electrification projects, the railroads yet again turned away from electrification.

Will the bright new dawn of widespread electrification *ever* come?

Consider the steadily rising curve of annual freight ton-miles, and think about the way more and more traffic is being concentrated on key routes as the industry consolidates through merger, and it's easy to think that electrification will one day be needed just to deal with capacity needs. But if and when that day comes, will the railroads have the resources to carry it out? Or will it take government support, as it did to finally get Amtrak's old New Haven catenary into Boston recently, or as it has where electrification has flourished almost everywhere else in the world?

Only one thing is certain, and that is that we'll surely be talking about the uncertain prospects for railroad electrification for many years to come. ■

WILLIAM D. MIDDLETON has written extensively about railroad electrification. This article was adapted from the second edition of his book When the Steam Railroads Electrified, *to be published later this year by Indiana University Press.*

For more on electrification in the diesel age, visit our website: ***classictrainsmag.com***

Muskingum Electric GE E50 locomotive 200 rolls a train southward shortly after the opening of the 15-mile, mine-to-power plant railroad in 1969.

Ohio Power Co.; collection of John B. Corns