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Black diamonds no more : a technological history of the dieselization of the Lehigh Valley Railroad

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A TECHNOLOGICAL HISTORY OF THE DIESELIZATION OF THE LEHIGH VALLEY RAILROAD:

by

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ABSTRACT

This is a study of the dieselization of the Lehigh Valley railroad between 1920 and 1951. The Lehigh Valley was a medium-sized northeastern railroad with trackage running from New York City, through New Jersey, Pennsylvania, and New York to Buffalo and Niagara Falls. Dieselization was the most important technological event in the history of twentieth-century railroads. The dieselization of the Lehigh Valley Railroad also had operational, managerial, social, and cultural ramifications. In contrast to steam, diesel locomotives are more efficient and versatile, require less maintenance, and thus, in many ways are ideally suited to railroad operations. The Lehigh Valley initiated dieselization to save money and effect higher operating efficiencies, but the change in motive power did not appreciably change the way that the railroad purchased locomotives or operated until well after complete dieselization was achieved. The railroad simply substituted diesels for steam locomotives and did not utilize the new motive power to reshape dramatically their operations. The railroad integrated diesels into the existing system instead of rebuilding the system around their different

capabilities. The reasons for this failure to utilize fully the new diesel locomotive are many but include operational, labor, and business practices. The Lehigh Valley, while adopting a new technology, did not change its corporate culture or operating philosophy. In the broader historical context, this is a study of how large organizations built around a technological system, deal with the introduction of radically new technologies.

In January, 1945, in Coxton, Pennsylvania, a town near the headwaters of the Lackawanna river in the Pocono mountains of northeast Pennsylvania, a steam locomotive-powered freight train is waiting in the snow and fog for helper locomotives to help push it over the summit of the Pocono mountains to the Lehigh River valley and, ultimately, the ports and industries of Newark and New York Harbor. The war is still on and the Lehigh Valley railroad is shipping huge amounts of freight for the war effort, including supplies and munitions destined for the east coast and shipment to Europe. The locomotive is a war baby, built only two years before in 1943 to help handle the wartime traffic. It incorporates the latest advances in steam locomotive technology, and it is one of the most efficient and technologically advanced steam locomotives in service in the entire northeast. Helper locomotives have been required on this grade for almost as long as the railroad has been in operation. Steam locomotives would couple on to either the front or back of the train and help pull or push it up the long grade and over the summit.[1] However, this time something is different. Instead of the usual one or two coal burning, smoke-belching steam locomotives that have performed this job for years, a bright red, streamlined diesel-electric locomotive emerges out of the snow and fog. This diesel locomotive consists of four separate units, all operating in unison and controlled by one crew from one cab.

The crew of the freight train had seen diesels before in switching service in yards and on the docks in and around New York City. But this was different; these diesels were no small "yard goats." They were out on the mainline and judging by the speed at which they were ascending the grade, were doing a good job, better in fact than some of the old steam locomotives. At the top of the grade the diesels uncoupled and started to descend. As the freight train accelerated downgrade into the Lehigh Valley the crew speculated on what would become of these new-fangled diesels. They had heard about other railroads' experiments with diesel-powered freight and were well aware of the

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[1]Helper locomotives generally pushed a train rather than pulled it but the determination of which to use was complex. Train size, cargo, weight, terrain, and whether the caboose had a wood or steel frame were all factors. Different railroads had different operational practices for helpers as well. Fred Carlson and Robert F. Schramm, Air Brake Engineer for Association of American Railroads and Control Operator for Chicago & North Western Railroad, respectively, interviews by author, July 1994. For a good general introduction to contemporary railroading, see John H. Armstrong, The Railroad, What It Is, What It Does 3d. ed. (Omaha, NE: Simmons Boardman Books, 1993).

inroads that diesels had made into the passenger business. However, none of them could have foreseen that within three years their train would have diesel power, and in six years the steam locomotive, symbol of railroading itself, would be gone forever from the Lehigh Valley Railroad.

The technological history of American railroads in the twentieth century is dominated by the appearance and adoption of the diesel-electric locomotive. From the first experiments with diesel power in the 1920s to complete dieselization in the late 1950s, the American railroad scene was transformed. The diesel locomotive was more than a new form of motive power; it was an entirely new system of moving freight and passengers that had profound and far-reaching implications for all aspects of railroading. Diesel locomotives made huge shop complexes, coal and water towers, and hundreds of skilled workers obsolete. Railroad operations no longer were constrained by the need to coal, water, operate, and service labor intensive steam locomotives. The diesel could do whatever the steam locomotive could do and could do it faster, cheaper, and better.

Did the diesel win out over the steam locomotive simply because it was more cost effective, or did other factors come into play? The railroads claimed to have saved money and achieved higher operating efficiencies by using diesels. Some railroads dieselized as soon as possible, the mid-1940s, but others waited until the late 1950s. What effects did dieselization have on railroad operations and organization? It would take some time to realize fully the potential of the new motive power to reshape operations. At the time did railroads realize the changes, inherent in the technology, that diesels would bring? Did the coal industry, a major shipper for many railroads, have any effect on the pace of dieselization?[2] These questions must be answered to understand the process of dieselization, a process that was also affected by labor relations, politics, and economics.

The dieselization of the Lehigh Valley had social and cultural ramifications for the railroad. The decisions made by the railroad affected workers and the surrounding communities as well as the operations of the railroad itself. The Lehigh Valley dieselized to cut costs immediately but in its overall operations it did not fully realize the potential of the diesel until well after the process was complete. The railroad simply substituted the

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[2]The perceived need to remain loyal to the coal industry, a major shipper, was a factor in the relatively late dieselization of such major coal hauling railroads as the Norfolk & Western, Chesapeake & Ohio, and the Illinois Central. These railroads remained essentially steam powered until the mid-1950s. Fred Carlson, interview by author, July, 1994 and George H. Drury, <u>Guide to North American Steam Locomotives</u> (Waukesha, WI: Kalmbach, 1993).

diesels into the place of the steam locomotives and did not utilize the potential of the new motive power to revolutionize its operations. There was no test phase in which the diesels were compared with comparable power steam locomotives something other railroads had done.[3] The railroad integrated diesels into the existing system instead of building a new system around their different capabilities. The Lehigh Valley, while adopting a new technology, did not change its corporate culture or operating philosophy to take full advantage of the new technology. The change in motive power did not appreciably change the way that the railroad purchased locomotives until well after complete dieselization was achieved. In the broader historical context, this is a study of how large, traditionally conservative organizations built around a technological system, deal with the introduction of radically new technologies.

The characteristics of large integrated technological systems has been investigated by Thomas P. Hughes who asserts that over time systems attain momentum which discourages "radical" innovation.[4] Those who run and

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[3] P. W. Kiefer, A Practical Evaluation of Railroad Motive Power (New York: Steam Locomotive Research Institute, Inc., 1947). Mr. Kiefer was the Chief Engineer of Motive Power and Rolling Stock for the New York Central System. The book details the results of a test of diesel-electric, steam, and electric locomotives in various types of service.

[4] Thomas P. Hughes, American Genesis (New York: Penguin Books, 1986).

manage a system develop a vested interest in it and accept only those innovations which do not alter its configuration significantly. Inherent in Hughes' analysis is the assumption that the revolutionary aspects of a new technology are apparent to those who want to protect existing systems. However, this is not always the case. Railroads were seen as feeders for canals just as trucks were later seen as feeders for railroads. In these two examples the technologies ultimately evolved into competing systems. When considering technological change within a system, the effects of change on each aspect of the organization becomes an internal political issue. With regard to the Lehigh Valley railroad, did management merely opt for immediate short-term savings and ignore the revolutionary implications of diesel locomotives for restructuring the entire railroad? Was management nostalgically clinging to the steam age railroad that had dominated their careers? On the other hand, was the diesel locomotive a Trojan Horse, quietly introduced by management to avoid overt conflict with workers and managers. There was no reason why diesels could not pay limited immediate returns in the short run and more significant returns from future restructuring.

Another individual who has done work on railroads and their response to technological changes is Steven Usselman. Although he analyzed the railroads of the turn of the century rather than the period of dieselization, many of his observations hold true. For instance, in his work on the adoption of airbrakes he states that, "The case of the air brake demonstrates how widely different factors could influence the decision to adopt a new device."[5] Dieselization, like the adoption of the air brake fifty years before, was affected by a large number of widely different factors including labor, regulatory agencies, safety concerns, and advertising and public image.

In historical scholarship dieselization has been treated by some as a natural progression, something that had to happen sooner or later.[6] Some of the economic incentives for dieselization were dealt with in these histories but not all variables were taken into account. For example, fuel and labor savings are analyzed but operational differences in servicing, train size, and scheduling were not generally included. This history does little to explain the complex social and technical effects of dieselization. Others look at more of the issues but do

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[5]Steven W. Usselman, "Air Brakes for Freight Trains: Technological Innovation in the American Railroad Industry, 1869-1900," Business History Review 58 (Spring 1984), 31.

[6]Stover takes this view in his History of the Baltimore and Ohio Railroad as do many of the individual railroad historians. The narrow, cost accounting analysis looks at some, but not all of the respective operating costs of steam and diesel locomotives. The differences in operational capabilities that result from the introduction of new technologies are almost always ignored. These histories are generally more business oriented than operation or technology oriented.

not perform in-depth analysis.[7] Few if any look at the introduction of diesel locomotives from a systems perspective. Diesels were more than a new way to move trains; they embodied, within the technology, a fundamental shift in the way that the American rail system could operate. Their impact was far-reaching and can be felt many years after they vanquished the steam locomotive from American rails.[8]

To understand the impact of dieselization one must understand the basics of steam railroad operations including

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[7]Klein and his articles on dieselization (referenced below) are an example of this category. He treats many issues in his publications but looks at them only in passing. For instance, the labor issue is mentioned but Klein fails to make the essential distinction between the idea of separate units making up one locomotive.

[8]The dieselization of American railroads has somewhat surprisingly not been a topic of great historical interest. The "railfan" community has produced a wealth of magazine articles and books on aspects of dieselization, but most do not look at it from a critical perspective. There is much information to be gleaned from these sources however and they should not be dismissed entirely. Many of the railfan publications contain vast amounts of useful data that is impossible to find in other sources. The listings of locomotives in publications like the somewhat scholarly Railroad History and the hard-core railfan magazine Extra 2200 South, while providing little if any analysis, provide a wealth of data on the number, type, manufacturer, and service dates of all the locomotives owned by a particular railroad. Other publications such as the popular Trains magazine and the publications of the various individual railroad historical societies such as Flags Diamonds and Statues of the Anthracite Railroads Historical Society also provide much useful information as well as some analysis.

the operating efficiencies and procedures of locomotives. Railroads and steam locomotives literally came of age together. Early steam locomotives were very inefficient from an engineering and thermodynamic perspective but operated on cheap and plentiful fuels such as coal or wood. During the later nineteenth century coal won out because it was a more compact and economical fuel. Additionally, its higher combustion temperatures led to higher thermal efficiency in steam locomotives. In the twentieth century some locomotives began burning low-grade oil, especially in the southwest and far west where oil was more widely available than coal. The oil used in these steam locomotives was very heavy, industrial grade heating oil, just above asphalt in consistency. Oil-fired steam locomotives generally required less maintenance than coal fired locomotives, but they did have their drawbacks. Oil, being liquid, was somewhat more difficult to handle than coal, and burned at higher temperatures,which, although offering greater thermal efficiency also increased thermal stresses on the locomotive.

In the typical nineteenth century steam locomotive, a maximum of 4 percent of the heat was converted to usable work.[9] Over the years developments such as compounding cylinders, higher boiler pressures, superheaters, and feed water heaters were able to raise the efficiency to near 10 percent. Locomotives with compound cylinders are able to extract more energy from each ounce of steam by using the steam exhausted from one cylinder as feed for a second one. Thus, the steam exerts pressure and does work in two cylinders or sometimes more before being exhausted out the stack. Other incremental developments all served to wring more work from each ounce of steam. Superheaters took the steam and heated it an additional 200-400 degrees. At this temperature the steam would not cool enough to condense in the cylinders, a major source of inefficiency.[10] Superheaters made compounding less necessary and many later steam locomotive designs abandoned compounding because of the increased weight and maintenance costs of the second set

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[9]This ratio, work performed / available heat, is known as thermodynamic efficiency. An efficiency of 100 percent is impossible to achieve but ratings of 70-80 percent are routinely achieved by modern steam turbines located in electrical generating plants. Internal combustion engines achieve an efficiency of about 15-30 percent. Yunus A. Cengel and Michael A. Boles, Thermodynamics: An Engineering Approach (New York: McGraw-Hill, 1989), 204-5.

[10]Alfred W. Bruce, The Steam Locomotive in America (New York: W. W. Norton & Co, 1952), 152. Bruce deals mainly with post-1900 technical developments in steam locomotive design. For a definitive treatment of earlier developments, see John H. White Jr, A History of the American Locomotive: Development 1830-1880 (New York: Dover Publications, Inc., 1968). For post-1900 information and listings of individual railroad locomotives as well as a good pocket guide to steam locomotive operation, see George H. Drury, Guide to North American Steam Locomotives (Waukesha, WI: Kalmbach, 1993).

of cylinders, valves, rods, and drivers. This is a key point. Pure efficiency, in engineering terms, was not as important as the costs of maintenance and servicing. It was cheaper to use a bit more coal than to pay for the increased maintenance. The increased weight of compound locomotives was not a large concern. Locomotives have to be heavy to utilize their power fully and many large non-compound locomotives weighed just as much as compound ones.

Higher boiler pressures and, therefore, temperatures made possible greater force of expansion in the cylinders and greater efficiency. By the period of dieselization most modern steam locomotives were operating with pressures from 200 to 250 pounds per square inch. Feed water heaters preheated the boiler water by heat exchange from the exhaust steam from the cylinders, still at 250-300 degrees. The less heat exhausted up the stack, the more efficient the engine. Another major development of the 1920s was the introduction and widespread use of the automatic coal stoker. With a stoker the fireman no longer had to shovel coal into the firebox. The stoker could provide coal at a rate surpassing that of even the most brawny fireman and enabled larger fireboxes and hence, larger locomotives. The stoker did not make the fireman obsolete; however, for he still directed the placement of coal by the stoker, tended the fire, and made sure that it was burning properly.

Powerful coal-burning steam locomotives achieved speeds in excess of one hundred miles per hour before 1900.[11] The principal limiting factor in steam locomotive speed was the size of the main driving wheels. The reciprocating motion of the pistons and connecting rods as well as the rotary motion of the driving wheels themselves reaches an upper limit above which further increases in speed would stress the system beyond its limits. High speed operation places a large amount of stress on the locomotive as well as on rails and track. With each stroke of the piston, the rotating wheels exert a pounding motion that plays havoc with the rails and roadbed. At extremely high speeds, locomotives have even been known to lift their main drive wheels a couple of inches off of the rails.[12] To counter this tendency, elaborate counterbalancing was necessary on locomotive drivers. To increase speed, the driving wheels that were attached to the connecting rods had to be enlarged. The Lehigh Valley had locomotives with drivers as large as 77 inches in diameter.[13] While being necessary

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[11]In May of 1893, New York Central locomotive 999 achieved a speed of 112.5 mph between Rochester and Buffalo. James A. Kranefeld, "The Number That Became a Name," National Railway Bulletin 58, no. 1, 1993: 7. While speeds of this magnitude were not common, steam locomotives designed for high speeds would regularly achieve 80-90 miles per hour in scheduled passenger service.

[12]Kiefer, 8. Later locomotives had better counterbalancing and were not as susceptible to these problems.

[13]Dan Dover, "Lehigh Valley, Part II" Extra 2200 South, no. 77 (Oct-Dec, 1982): 15.

for higher speeds, large-drivered locomotives had difficulty starting and running at low speeds.

Large steam locomotives also had difficulties negotiating tight curves. The frame for the entire set of drivers was most often cast in one rigid piece. There was no provision made for lateral movement of the driving wheels. On tight curves locomotives would put spreading stresses on the rails. This caused excessive rail wear and could possibly cause the track to fall out of alignment. To counter this tendency, some locomotives had so called blind drivers or drivers without flanged wheels.

All of the steam locomotives of the Lehigh Valley and most other eastern roads were coal fired, but they consumed much more than just coal.[14] The steam used in the cylinders was generally used only once and then exhausted up the stack. These were so-called simple locomotives, as opposed to compound locomotives where the steam was expanded in two or more cylinders. Neither type made any effort to condense the steam for re-use. Steam locomotives therefore had to carry their own water as well as fuel. If this water ran out catastrophic boiler explosions could result. Therefore, railroads had to build and maintain coal and water stations along the right of way at correctly spaced intervals, twenty miles for water and one hundred miles for

[14]Drury, Steam Locomotives, 188-9.

coal.[15] The larger coal and water stations had to be manned. Coal needed to be delivered, most often by rail, and hoisted up to the coaling tower. In cold weather coal could freeze and jam, while in all seasons there was a large fire danger from coal dust. Water could freeze in cold weather as well, and in drought conditions, the supply itself might run low or dry up entirely. Water use was especially heavy in mountainous areas where locomotives struggled up heavy grades. Boiler water had to be treated because extraordinarily hard water was a hazard to the inner workings of the boilers and had to be softened.

Coaling and watering took a fair amount of time and caused additional maintenance and scheduling problems that had to be addressed. Coaling and watering a locomotive could take twenty to thirty minutes while watering consumed five to fifteen minutes. In addition more time would be lost slowing for the service stop and then getting the train back up to speed when finished. Provision also had to be made for passing tracks so that while one train was taking on coal and water, other trains could pass. This extra trackwork, especially the switches, required additional maintenance as well as switchmen and/or centralized control operators. Coal and water stops also required extra attention from the dispatcher, the railroad

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[15]Fred Carlson, interview by author, July 1994.

equivalent of the air traffic controller.[16] Dispatchers had to coordinate times and locations of coal and water stops to insure that every train received its needed fuel and water without unduly delaying the receiving train or any other trains.

Steam locomotives themselves were also maintenance intensive. The myriad moving parts, from the pistons and rods to the brake equipment, all had to be serviced at regular intervals. The problems of converting the reciprocating motion of the pistons to the rotary motion of the drivers made lubrication of the pistons and connecting rods critical. The expansion and contraction of the boiler tubes caused by heating and cooling, as well as the corrosive effect of coal smoke, took its toll on equipment. After each trip the ashes and clinkers had to be emptied out of the firebox. This required ash pits at every terminal. Periodically cinders also had to be cleaned out of the front of the smokebox which required workers to unbolt the front plates of the engine and climb in with a shovel. The locomotive would obviously not be operating at this time but would in all likelihood still be quite warm. Almost all

[16]The dispatcher was the man responsible for all the trains on a particular piece of railroad, usually a couple hundred miles. He issued orders via telegraph and later telephone and radio to operators at stations along the railroad. These operators would then hand these orders up to the engine and caboose crew. Robert F. Schramm, Dispatcher for Illinois Central Railroad, 1977-1987, interview by author, July 1994; Armstrong, 105, 120, 236.

locomotives built before the 1940s also had simple friction bearings on the wheels and rods. These bearings had to be oiled and greased often, usually while taking on water and coal. These bearings also required constant care from shop mechanics to ensure that they were working properly and not overheating which could cause fires, or a broken axle.[17]

Steam locomotive maintenance required large shop complexes. The Lehigh Valley had locomotive servicing facilities in almost every sizable town and shop complexes in Easton, Lehighton, and Coxton (Wilkes-Barre), Pennsylvania; Oak Island, New Jersey; and Manchester, Niagara Falls and Buffalo, New York. They also had smaller shops on branchlines at places like Delano and Hazleton, Pennsylvania and Perth Amboy, New Jersey. All the heavy repairs were done at the main shop located at Sayre, Pennsylvania. This shop even built mainline steam locomotives up until 1929.[18] Many railroads built their own locomotives in their own shop complexes. Steam locomotives were maintenance intensive but did not require

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[17]Many of these maintenance concerns were addressed during the 1930s and 1940s. Roller bearings and centralized lubrication systems eliminated many of the maintenance headaches. However, the rods still had to be lubricated by hand. For example, the Norfolk and Western J class 4-8-4 locomotives built in 1949 and 1950 incorporated all of these evolutionary advances. They even had roller bearings on the bell. One of these locomotives, the 611, is preserved at the Virginia Museum of Transportation. Drury, Steam Locomotives, 304-5.

[18]Drury, Steam Locomotives, 222-23.

highly specialized equipment or knowledge or machining to exact tolerances. To draw a parallel, the steam locomotive would be akin to a Model T that could be repaired by a shade tree mechanic or out in the barn with general tools. The diesel locomotive would be more like a current, computer-controlled automobile that has to be taken to specialized service facilities for all but the most basic maintenance.

To appreciate more fully the dieselization process specific steam locomotives should be compared and contrasted with their diesel counterparts. Steam locomotives were classified in different ways by various railroads and builders. Many times, railroads changed the classification systems with new management. Although there was no universal system, the Whyte system was the most common and, while far from complete, at least offered a relatively simple means of classifying steam locomotives. This system, established in 1900, designates locomotives by their wheel arrangement. The first number is the number of wheels in the leading truck, the second (and third if there were more than two cylinders) the number of drivers, and the third the number of trailing wheels. (see Table 1).

Steam Locomotive Classifications

Representation	Whyte System Designation	Name
OO	0-4-0	Switcher
OOO	0-6-0	"
OOOO	0-8-0	"
OOOOO	0-10-0	"
OOOOOo	0-10-2	Union
oOO	2-4-0	
oOOo	2-4-2	
oOOoo	2-4-4	
oOOO	2-6-0	Mogul
oOOOo	2-6-2	Prairie
oOOOoo	2-6-4	
oOOOO	2-8-0	Consolidation
oOOOOo	2-8-2	Mikado
oOOOOoo	2-8-4	Berkshire
oOOOOO	2-10-0	Decapod
oOOOOOo	2-10-2	Santa Fe
oOOOOOoo	2-10-4	Texas
ooOO	4-4-0	American
ooOOo	4-4-2	Atlantic
ooOOoo	4-4-4	
ooOOO	4-6-0	Ten Wheeler
ooOOOo	4-6-2	Pacific
ooOOOoo	4-6-4	Hudson
ooOOOO	4-8-0	Twelve Wheeler
ooOOOOo	4-8-2	Mountain
ooOOOOoo	4-8-4	Northern *
ooOOOOO	4-10-0	Mastodon
ooOOOOOo	4-10-2	
ooOOOOOOo	4-12-2	Union Pacific

Compound and Articulated Locomotives

ooOO=OOoo	4-4-4-4	(non-Articulated)
oooOO=OOooo	6-4-4-6	"
OO=OO	0-4-4-0	(Articulated)
OOO=OOO	0-6-6-0	"
oOOO=OOOo	2-6-6-2	"
oOOO=OOOoo	2-6-6-4	"
oOOO=OOOooo	2-6-6-6	Allegheny
ooOOO=OOOoo	4-6-6-4	Challenger
ooOOOO=OOOOoo	4-8-8-4	Big Boy

* Northern class locomotives were named Wyoming on the Lehigh Valley and Niagara on the New York Central.

Table 1.

Many factors went into determining what type of locomotive should be built for what type of service. The wheel arrangement, weight on drivers, driver diameter, number of cylinders, simple or compound, and other elements were all determined by the intended service of the locomotive. Because switching locomotives operated at low speed and needed to have a high tractive effort, they needed a small driver diameter, relatively high weight on drivers, and usually a large number of drivers. Typical switching locomotives of the 1920s and 1930s were 0-8-0 or 0-10-0 type with small, 55.5 inch diameter drivers. Road freight locomotives needed to have high tractive effort for moving tonnage but also the capability to attain high speed. Higher speeds required locomotives to have leading trucks to help them track effectively. Typical freight locomotives of this era were 2-8-2, 2-10-2, or 4-8-2 class with driver diameters from 56 to 63 inches (see Illustration 1). Built for speed, passenger locomotives had large drivers and leading trucks. The typical passenger locomotive of this era was the Pacific class or 4-6-2 with large 77 inch drivers (see Illustration 2).[19]

During the heyday of steam locomotives, the 1890s, the diesel engine was developed in Germany and brought to the

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[19]For a complete listing of modern Lehigh Valley steam locomotives, see Appendix I.

United States with the help of Adolphus Busch of Anheuser-Busch breweries.[20] The diesel is an internal combustion engine that uses the heat of compression instead of a spark plug to ignite the fuel. Diesels operate at much higher compression ratios than spark ignition engines and consequently achieve much higher thermodynamic efficiencies of 30 to 35 percent.[21] Diesels, like all internal combustion engines, come in either two or four cycle varieties.[22] The diesel locomotives produced by the Electro-Motive Division of General Motors (EMD) were two cycle, while those of the American Locomotive Works (ALCO) and Baldwin Locomotive Works were four cycle.[23] Early

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[20]Richard H. Lytle, "The Introduction of Diesel Power in the United States, 1897-1912," Business History Review 42 (Summer, 1968): 115. Also, Diesel, The Modern Power (Detroit, MI: General Motors Corporation, 1936), 6. The diesel engines were used as stationary power plants in the St. Louis brewery of Anheuser-Busch.

[21]Typical compression ratios for gasoline engines are around 8:1, while for diesels the ratio is closer to 20:1. Diesel, The Modern Power, 8-9. See also, John B. Heywood, Internal Combustion Engine Fundamentals (New York: McGraw-Hill, 1988.) 27.

[22]Two cycle engines produce power on every other stroke of the piston. Examples would be engines used on chainsaws and outboard motors. Four cycle engines produce power every fourth stroke. Almost all automobile engines are four cycle engines. Two cycles are generally more efficient but in the locomotive field, neither type had a clear advantage over the other. Ibid.

[23]All EMD diesel locomotives ever produced contained two-cycle prime movers while all Alco, Baldwin, and General Electric locomotives contained four-cycle prime movers. Locomotives produced by Fairbanks-Morse were split between the two engine types. Current locomotive production by EMD and GE is still split into two and four cycle engines, respectively.

diesels had several disadvantages compared to steam locomotives. They were relatively heavy for their power output but were capable of running at low speeds for long periods of time. Diesels had to be machined to exact tolerances and were very susceptible to dirt and grime, much more so than the more simply constructed steam engine. Therefore, they were not initially judged fit for the rigors of railroad service. Because of these limitations, diesels were first used in the more controlled environments of stationary and marine applications.

The so-called diesel locomotive is actually a diesel-electric locomotive. The diesel engine drives a generator that produces electricity which powers traction motors on the axles. The advantages of this system over a mechanical power transmission are numerous. In the diesel-electric system each axle is powered thus producing more tractive effort than other systems. In contrast to steam locomotives where significant portions of the total weight were carried by the leading and trailing trucks, as well as the tender, the Diesel-electric allows all of the weight of the locomotive to be put to use over the driving wheels. At low speeds the diesel-electric was able to exert tremendous force. The reasons are complex but are inherent in the operation of electric motors. The limiting factor at low speeds was not the output of the engine in horsepower or the output of the generator, but the adhesion between the wheel and the rail. The diesel-electric system adds weight when compared to a mechanical linkage, but railroad locomotives have to be heavy to utilize fully their power. A locomotive with an abundance of power but little weight would just sit and spin its wheels. There were a few attempts at diesel-hydraulic locomotives with transmissions similar to an automobile, but they were not generally successful in the operating environment of the United States.[24]

Another unique technical characteristic of the diesel electric locomotive is its capability for dynamic braking. Since the late nineteenth century, railroads had relied on the airbrake developed by George Westinghouse. Dynamic braking did not replace the air brake but acted in concert with it to provide better control of trains. Dynamic braking turns the electric motors on the locomotive axles into electrical generators through the flip of a switch; no mechanical transformation is necessary. The generated electricity is sent to resistor grids, usually located in the roof of the locomotive, where it is dissipated as heat.[25] Dynamic braking reduces wear and tear on wheels and brake shoes. It is especially important in mountainous territory where prolonged airbraking would generate high

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[24]Fred Carlson, interview by author, July, 1994.

[25]EMD F-3 Locomotive Operating Manual (La Grange, IL: General Motors Corporation, 1948), 639. All locomotives equipped with dynamic brakes used the same general system, regardless of the builder.

brake wear and could cause potential overheating of wheels and axles, as well as possible depletion of the air reservoirs which would lead to a runaway train.

The Lehigh Valley was in some respects typical of railroads that dieselized, especially northeastern roads. It dieselized fairly early, 1951, and did not delay dieselization to the extent that some other railroads did. For example, the Chesapeake & Ohio, Norfolk & Western, and Pennsylvania railroads all experimented with steam turbines and other types of advanced, coal burning, steam locomotives well after the diesel had proven itself more than capable.[26] While the Lehigh Valley did not actively resist dieselization it did not wholly adopt diesels until after it acquired twenty years of operating experience with them. The timing of dieselization was affected by the age of the existing locomotive fleet, wartime traffic and restrictions,

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[26]J.S. Newton and W.A. Brect, "A Geared Steam-Turbine Locomotive" Railway Age 118 (February 17, 1945): 337-40. Drury, Steam Locomotives, 87, 307, 319. The Pennsylvania railroad steam turbine locomotive was built by Baldwin. It contained a multi-stage turbine directly connected via a geared transmission to conventional steam locomotive drivers. It was not considered successful and only one example was built. The C&O and N&W locomotives were steam-turbine-electrics with the turbines driving generators that produced electricity for traction motors located on the axles. They were considered technical successes but practical failures. The functioned as designed and were thermodynamically efficient but the maintenance required was not significantly less than conventional steam locomotives and much more than diesels. Like the complex compound cylinder locomotives half a century earlier, maintenance and serviceability won out over pure efficiency.

pressure from competitors, and the corporate culture of the management.

For the first eighty years of its existence, the Lehigh Valley was primarily a coal hauler. In 1851 industrialist and financier Asa Packer bought the charter of the unbuilt Delaware, Lehigh, Schulkill, and Susquehanna railroad.[27] It was built to transport anthracite coal from the mines around Mauch Chunk to Easton, where it was loaded onto canal barges for shipment to Philadelphia via the Delaware Canal or shipment to New York via the Raritan Canal or the Central of New Jersey Railroad. The officers of the Lehigh Valley, including Asa Packer and Robert Sayre, wanted to capture more of the New York anthracite market, so they decided to extend their line from Easton, across New Jersey to the Jersey City/Newark area. The anthracite would then be loaded into barges for the trip across the harbor to the furnaces and fireplaces of New York City. The line that they built bypassed larger towns and was clearly designed not for on line traffic, but to get the anthracite to port as efficiently as possible.[28]

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[27]Robert F. Archer, Lehigh Valley Railroad: The Route of the Black Diamond (Berkeley, CA: Howell-North Books, 1978), 29.

[28]To this day, this line across New Jersey is used only for freight service. One reason is that it avoids many larger towns and the resultant potential traffic bottlenecks. It is the main Conrail line west out of the New York City area and is not a commuter route for New Jersey Transit. It did see passenger traffic under the Lehigh Valley but was never a local, commuter route.

From Mauch Chunk northward the railroad was extended over the Pocono Mountains and into the Susquehanna River valley to take advantage of the expanding economy in the Scranton/Wilkes-Barre area and to tap the anthracite mines in this area. The railroad officers also looked north and west in the search of possible markets for their anthracite. Lines were built northward to Lake Ontario and westward to Rochester, Buffalo, and Niagara Falls. Anthracite would be shipped to these cities for local use, transfer to other railroads such as the Erie for shipment further west, or loaded upon lake boats for distribution via the Great Lakes.[29] At Sayre, Easton, and Allentown, Pennsylvania, connections were made to railroads that served New England. Anthracite was shipped via these roads to the furnaces of New England.

The Lehigh Valley joined other railroads like the Delaware, Lackawanna and Western, Central of New Jersey, Lehigh and New England, and Reading in serving the anthracite coal fields. It also competed with other non-anthracite dependent railroads such as the Pennsylvania, New York Central, Erie, New York, Ontario and Western, and New York, Susquehanna and Western. The northeast was an extremely competitive area for railroads with five major roads offering New York to Buffalo service. Buffalo was not

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[29]The Lehigh Valley even owned a fleet of lake boats until forced to divest itself from them in the 1910s and early 1920s because of anti-trust proceedings.

only an important industrial city but also a transportation gateway to the Great Lakes and the Midwest. Since freight rates were fixed by the I.C.C., the northeastern railroads had to compete in terms of speed, handling, and other forms of customer service.

By the 1920s the Lehigh Valley was a mature railroad with limited growth prospects. The decline of the anthracite coal industry and the shift away from its use for home heating was beginning to be felt as early as the 1920s. (see Table 2.) While anthracite haulage still accounted for a high proportion of total operating revenue, tonnage was beginning to fall off. Merchandise freight steadily rose as a percentage of total operating revenue throughout the period. By the 1930s the Lehigh Valley made an active effort to diversify its traffic base. It concluded agreements with the New York, Chicago and St. Louis Railroad, commonly called the Nickel Plate, and the Michigan Central Railroad, a division of the New York Central System, to interchange traffic at Buffalo that was bound for the northeast. The Lehigh Valley was evolving from a coal hauler, generating most of its traffic on line, to a bridge route, with less on line traffic and more interchange traffic from other railroads, particularly at Buffalo. This traffic consisted of perishables, consumer goods, paper, auto parts, and other semi-finished goods destined for eastern factories or distribution centers.

Lehigh Valley Railroad Total Operating Revenue and percent derived from Anthracite Coal and Merchandise Freight.

Year	Total Operating Revenue ($)	Anthracite Coal %	Merchandise Freight %
1921	74,997,799.15	37	44
1922	62,418,889.12	25	53
1923	75,935,153.71	35	45
1924	76,374,805.25	30	51
1925	74,430,573.07	24	55
1926	80,453,149.97	28	52
1927	74,502,818.91	26	54
1928	71,935,071.17	26	54
1929	71,722,735.13	27	53
1930	60,664,187.72	29	52
1931	50,024,627.38	29	52
1932	38,739,138.25	30	51
1933	38,177,450.08	31	52
1934	39,866,526.18	32	52
1935	40,641,556.18	31	53
1936	49,156,397.08	32	53
1937	48,618,849.32	31	54
1938	41,230,143.18	33	53
1939	45,358,986.81	30	57
1940	47,479,836.55	28	59
1941	56,750,722.15	24	64
1942	78,171,307.16	20	66
1943	91,024,874.64	16	67
1944	97,465,274.44	16	62
1945	77,732,844.81	17	60
1946	67,007,685.93	21	66

Data from Lehigh Valley Railroad Annual Reports, 1921-1946.

Table 2.

With this new, time sensitive and highly competitive bridge traffic, the Lehigh Valley needed locomotives that would be able to perform more efficiently than its older locomotives then in service. These older locomotives were primarily designed for hauling coal out of the mountains. It did not really matter how fast the coal was moved, as long as it got there. Therefore, these coal haulers were optimized for slow, heavy service with a large number of small diameter drivers. These locomotives, the bulk of the Lehigh Valley freight fleet, were typically 2-8-2 or 2-10-2 class and were built in the 1910s and 1920s. The new locomotives had to be faster and more efficient but without sacrificing horsepower or tractive effort.

One of the Lehigh Valley's prime competitors in the Buffalo to New York corridor was the Delaware Lackawanna and Western, popularly referred to as the Lackawanna. The Lackawanna was one of the first railroads in the nation and the first in the northeast to operate the efficient 4-8-4 type of steam locomotive, ordering some in 1927.[30] The Lackawanna was having such good luck with their locomotives that the Lehigh Valley decided to look into purchasing some as well. It ordered single prototypes of modern 4-8-4 type locomotives from the American Locomotive Company (ALCO) and

[30]The first railroad to operate 4-8-4's was the Northern Pacific, purchasing some from Alco in 1927. Bruce, 89.

Baldwin Locomotive Works in 1931.[31] The tests on these prototype locomotives showed that they would be useful so the Lehigh Valley ordered ten from each builder. Further orders in 1935 and 1943 swelled the number of this type of locomotive to thirty-seven. These locomotives could power a scheduled fast-freight train from Buffalo to Oak Island (Newark) at speeds of sixty miles per hour with only one refueling stop.[32] They were the state of the art in steam locomotive power at the time, equipped with feed water heaters, superheaters, and mechanical stokers. These locomotives represented a significant evolution in technology from the 2-8-2 and 2-10-2 class built just a few years earlier.

With the growth of all-weather highways and the popularization of the automobile, passenger traffic had started to shift away from the rails by the 1920s. Passenger traffic in this period never amounted to more than 12 to 15 percent of the total operating revenue of the

[31]Lehigh Valley Railroad Company minutes, 1931. The depression hit the Lehigh Valley hard but not nearly as hard as other railroads and industries. The Lehigh Valley finished in the black in 1934 and 1935 and had done quite well in the 1920s. Therefore, it could afford to invest in new locomotives and the service and maintenance changes necessary for the operation of these locomotives. Lehigh Valley Railroad Annual Reports, 1920-1939.

[32]Archer, Lehigh Valley Railroad, 242.

Lehigh Valley.[33] In the 1920s and continuing into the lean years of the Depression, the Lehigh Valley discontinued many marginally profitable local and branch line passenger runs while attempting to revitalize the long-distance and express runs with new, streamlined equipment. Streamlining was the rage at the time and did bring passengers back to the rails for medium and long distance travel.

Rail motorcars replaced steam locomotives and passenger coaches on the surviving local and branch line runs. These motorcars were a very diverse group. About the only thing that can be said of them collectively is that they utilized internal combustion engines housed in car-bodies that also contained passenger accommodations. Some of these motorcars were gasoline-electric; some were gasoline-mechanical with geared or even chain-link power transmissions. Some motorcars could pull a trailer that housed additional passenger accommodations or even a freight car or two. Others were entirely self contained and did not have the power to pull additional cars.[34] These motorcars did save money for the Lehigh Valley. On some runs the motorcars would be as much as 50 percent less expensive to operate than comparable steam powered equipment. In 1925 the Lehigh Valley estimated that the use of motorcars on five local and

[33]Lehigh Valley Railroad Annual Reports, 1920-1960.

[34]Richard W. Jahn, "Lehigh Valley Railroad Gas-Electrics" Flags Diamonds and Statues 6, no. 1 (1985): 4-21.

branch line runs would save $122,820. The cost of five motorcars and one trailer purchased from the newly formed Electro-Motive Corporation was $183,700.[35] These new motorcars would therefore pay for themselves in approximately a year and a half. These motorcars gave the railroad experience with internal combustion motive power and electrical transmission. However, they were not looked upon with much respect by the crews. They were nicknamed "doodlebugs" and were referred to as busses on rails, a description that was not wholly inaccurate. The Lehigh Valley's motorcars were not streamlined and were generally not deemed to be aesthetically pleasing. They were not even officially listed as locomotives.

The motor railcar has had a long and varied history.[36] Early experiments in internal combustion for railroad use were carried out by the McKean company in the first decade of the twentieth century. These early railcars had mechanical transmissions similar to those found on highway trucks and busses. Some of them were literally busses with railroad wheels. The newly formed Electro-Motive Corporation had the idea to replace the mechanical transmission, the weakest link in the design, with an

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[35]Lehigh Valley Railroad Company minutes, meeting of May 26, 1925.

[36]Somewhat surprisingly, there has been little attention paid to these pioneering efforts other than railfan oriented works, mainly of a pictorial nature.

electrical generator and motor. The first production vehicle in 1924 included electric transmission. The sales statistics of EMC's gas-electric motorcars illustrates that railroads were aware of their benefits. In 1924 EMC sold 2 gas-electric motorcars; in 1925, 36, in 1926, 45 and by 1928 sales reached 105.[37] It seems a bit strange that the most advanced technology as far as motive power was concerned, was used in local, branch-line passenger service, the opposite of where one would expect innovative new technology to be used. The motor cars were the first internal combustion vehicles on the Lehigh Valley and gave years of satisfactory service on their oft overlooked, local passenger runs.

At the same time as the introduction of the motorcars into local service, the long-haul, express passenger service of the Lehigh Valley was revitalized with streamlined equipment, new trains, and faster schedules. These new streamlined trains were powered, not by diesel-electric locomotives as on some other railroads, but by streamlined steam locomotives. This was not uncommon. Many railroads decided to jump on the streamlining bandwagon by taking old, passenger locomotives and giving them a sheet metal outer

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[37]Our GM Scrapbook (Milwaukee: Kalmbach, 1971), 14.

covering to make them appear streamlined.[38] Even in the late 1930s, with the proven efficiency of diesels for high speed passenger operation, the Lehigh Valley opted for the steam locomotive. The capability of the diesel-electric for high-speed passenger service had been demonstrated by the record breaking run of the Burlington "Zephyr" in 1934.[39] On the Lehigh Valley the internal combustion engines would be relegated to the branch lines and local runs, but the big name trains would continue to be steam powered. In contrast other railroads such as the Baltimore & Ohio, Santa Fe, Seaboard Air Line, Gulf Mobile and Ohio, and Chicago, Rock Island & Pacific were dieselizing their passenger services.

Despite the conservative outlook of its management, the Lehigh Valley Railroad expressed an early interest in diesel-electric locomotives. The board of directors approved the "...purchase of two 60 ton 300 h.p. gas-electric locomotives for use in New York City..." on

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[38]The New York Central and Pennsylvania railroads, the two largest railroads in the northeast and among the largest in the world, both had fleets of streamlined steam passenger locomotives. For more information see Eric H. Archer, Streamlined Steam (New York: Quadrant Press, 1972).

[39]Much has been written on the famous "Zephyr". For general information, see: David P. Morgan, Diesels West: The Evolution of Power on the Burlington (Milwaukee: Kalmbach, 1963) and Margaret Coel, "A Silver Streak" American Heritage of Invention & Technology (Fall 1986): 10-17. Also look at Franklin M. Reck On Time (La Grange, IL): General Motors Corp., 1948.)

December 15, 1925.[40] They bought one from a consortia of Ingersol-Rand, GE, and ALCO and one from Brill in 1926. This purchase followed on the railroad's positive experience with gas-electric motorcars, but may also have partly been in response to the purchase by a Lehigh Valley competitor, the Central of New Jersey, of the first diesel-electric switching locomotive built. This locomotive was also built by Ingersol-Rand, GE, and ALCO and was placed in service in 1925.[41] The Lehigh Valley slowly bought more diesels and had sixteen on its roster by 1932. The manufacturers represented in this fleet included ALCO, GE, Ingersol-Rand, Brill, Mack, and Electro-Motive Corporation, (later to become the Electro-Motive Division of General Motors). These early diesels were used almost exclusively on the docks and yard tracks in and around New York City, which had various ordinances outlawing smoke producing steam

[40]Lehigh Valley Railroad Company minutes 1925, 122. During the early days of diesel-electric locomotives, they were often referred to as oil-electric and sometimes even confused with gasoline-electric locomotives. The terminology did not become clearly defined until the mid-1930s when oil-electric was dropped in favor of diesel-electric.

[41]Both the CNJ and LV diesel-electrics manufactured by Ingersol-Rand, GE, and Alco were successful and were in service until after World War II. The CNJ locomotive, Number 1000, is currently preserved at the Baltimore and Ohio Railroad Museum in Baltimore. The Brill built diesel was not considered satisfactory and was stored until 1931 when it was rebuilt by ALCO with a new engine. With its new engine it too lasted until after the war.

locomotives within the city limits.[42] These early diesels were crude machines, based largely on motorcar designs. They looked like motorcars shortened to exclude the passenger accommodations. Despite the crude, almost experimental nature of many of these machines, they turned out to be durable and dependable, and were not retired from service on the Lehigh Valley until after World War II.

For switching operations, the Lehigh Valley purchased twenty-two locomotives over the four year period from 1937 to 1940. These diesel switchers began to be used not just in the New York City area but in yards and terminals all over the system.[43] At this time many railroads realized the potential of the diesel-electric locomotive for switching duties. However, the Lehigh Valley was in the vanguard. Competing railroads such as the Central of New Jersey and the Lackawanna did not invest in diesel switchers to nearly the same extent as the Lehigh Valley. The CNJ, after purchasing the first diesel-electric switcher, did not purchase any more diesel locomotives until 1938 and did not fully embrace diesels until after the war.[44] After being initially forced to utilize diesels for reasons other than

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[42]These anti-smoke ordinances were also a major reason for the electrification of many rail lines into and out of the New York City area such as the New York Central, Lackawanna, and Pennsylvania.

[43]Archer, Lehigh Valley Railroad, 261.

[44]Central Railroad of New Jersey, Annual Reports, 1930-1950.

cost of operation and efficiency, the Lehigh Valley management was starting to realize some of the potential of the diesel locomotive. However, the initial introduction of diesel power was due not to its technical superiority or economic efficiency, but New York City government regulations prohibiting steam locomotives.

During the war, the dieselization drive of the Lehigh Valley, and all railroads, was put on hold. In fact, many railroads bought or built new steam locomotives to handle wartime traffic. Some of these roads wanted diesel power but had to settle for steam locomotives because of production controls. The Lehigh Valley was among this group, purchasing ten 4-8-4's from ALCO in 1943. During the war the War Production Board exercised strict control over locomotive manufacturers, designating EMD to be the sole producer of road diesel locomotives and ALCO and Baldwin to be responsible for diesel switchers and steam locomotives.[45] The manufacturers were also responsible for production of defense related material, with EMD producing engines for landing craft and ALCO producing tanks. Baldwin was to concentrate on steam locomotive manufacture as well as other, defense related activities such as ship propellers. In addition, all orders for locomotives had to be approved by the War Production Board. The war, while

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[45]The Revolutionary Diesel: EMC's FT (Halifax, PA: Diesel Era, 1994) 7.

generating huge amounts of traffic, and therefore profit for railroads, was nevertheless a taxing time. Maintenance on track and facilities was deferred to enable as many trains as possible to get over the rails. Maintenance of the complex shop facilities was also put off to allow every available man to work on keeping the locomotives in service. At the end of hostilities, the locomotives and physical plant of the Lehigh Valley and most other railroads were tired and suffering from the effects of delayed and deferred maintenance.

After the war, the Lehigh Valley decided that the time was ripe to fully convert to a dieselized railroad, the process being completed in 1951. The first true road diesels on the system were eight EMD FT's, purchased in January 1945. Again, this was partly in response to the actions of competitors. The Erie, Lackawanna, and NYS&W were all experimenting with road diesels.[46] In fact, on June 2, 1945, the Susquehanna became the first Class 1 railroad to be completely dieselized.[47] One reason that the Susquehanna dieselized so early was that the steam locomotives that it owned were all at least twenty-seven years old, and many were closer to forty years old. The expected useful life of a steam locomotive was roughly

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[46]"Erie Cuts Tops Off Hills with Diesels," Railway Age, 16 August 1947, 62-64.

[47]"Susquehanna Abandons Steam Power," Railway Age, 30 June 1945, 1132.

thirty years. After this time necessary repairs became too expensive to keep the locomotive in service.[48] The Susquehanna was in the market for new power and chose to opt for the Diesel. They could have purchased new steam locomotives that were much more efficient than the locomotives that were in service.

The experience of the Susquehanna was repeated to some extent by the Lehigh Valley. Other than the T class 4-8-4 locomotives, most steam power on the Lehigh Valley was built in the late 1910s or early 1920s. By the time the war was over these locomotives were approaching their twentieth, twenty-fifth, or even thirtieth birthdays. Maintenance costs were steadily creeping upward for these locomotives which had been driven hard for the war effort. Of the 382 locomotives in service on the railroad in the fall of 1942, only twenty-seven T class 4-8-4's, and six S class 4-8-2's could be considered truly modern. The rest were "low wheel type" locomotives not suited for high speed service. Eighty-

[48]Richard Paul Hydell, "A Study of Technological Diffusion: The Replacement of Steam by Diesel Locomotives in the United States" (Ph.D. diss., Massachusetts Institute of Technology, 1977), 228. Hydell uses data from the Erie railroad and determines that due to the age of the locomotive fleet, dieselization followed a rational modernization policy. However, he errors in assuming that the Erie is typical of all U. S. railroads.

five locomotives were twenty-nine years old or older.[49]

The FT's of the Lehigh Valley were initially put to use, not in mainline, fast freight service which was what they were designed for, but in helper service, pushing trains up mountain grades between the Lehigh and Susquehanna River valleys.[50] They did offer substantial savings in labor and fuel costs over steam helpers. Also, helper work is relatively low speed and requires great tractive force, capabilities that diesel switchers had already demonstrated. The railroad used the new road diesels for a job which it knew from direct experience that diesels could perform well, rather than letting them haul heavy road freights. Other railroads including the Lehigh Valley Competitor Erie were successfully hauling freight with their road diesels but the Lehigh Valley management was evidently still reluctant to replace the mainline steam locomotives, some of which (the wartime T-2 class 4-8-4's) were only a few years old.

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[49]Lehigh Valley Railroad Company minutes, 1942. It is somewhat curious that the large drivered, K class, 4-6-2 passenger locomotives are referred to as "low wheel type" locomotives. They were not as modern and efficient as the T class, 4-8-4 and S class, 4-8-2 locomotives but were well suited for passenger service.

[50]Archer, Lehigh Valley Railroad, 261. The FT locomotives were designed for mainline fast freight and proved to be capable of out performing even the most modern steam power on their 85,000 mile demonstration tour in 1939-1940 as well as in service on many railroads during the war including the Erie, Baltimore & Ohio, Boston and Maine, Lackawanna, and Reading. The Revolutionary Diesel: EMC's FT.

Three years later, however, the situation had changed. The Lehigh Valley had decided to pursue dieselization with all possible speed and to dieselize the mainline, scheduled fast freight trains as well as the express passenger trains with the eventual goal of complete dieselization of all operations. The steam tugboats that the railroad operated in New York Harbor were even replaced with diesel boats. It was estimated that the dieselization of all mainline fast freight trains would result in an annual saving, after depreciation, of $2,528,640.[51] This estimate was based, "...in part on study by ALCO and EMD and in part on personal knowledge and operating experience of other roads."[52] Other studies put the annual savings at a lower, but still respectable, $1,920,308.[53] This savings included not only the fuel, labor, and probable servicing costs of the diesels, but also consolidation of some trains into longer trains that could not have been moved over the road by steam power in a timely fashion. These estimates, however, did not include the cost of new, permanent servicing facilities

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[51]Lehigh Valley Railroad Company minutes, Report of Dieselization Committee, April 28, 1948.

[52]Ibid.

[53] A. H. Candee, "Report on the Use of Diesel Electric Motive Power for Symbol Freight Train Services" Westinghouse Electric Corp. collaborating with Baldwin Locomotive Works, May 1948. Symbol freight trains were the scheduled fast merchandise freight trains as opposed to non-scheduled, extra movements or coal trains. Symbol refers to the letter designation of the trains. For example, train AS-1 would run from Allentown to Sayre.

and the costs of specialized equipment for maintenance of these locomotives.

To accomplish dieselization of the scheduled fast freight trains management decided to split its order for motive power between EMD and ALCO. In October and November, 1948, the Lehigh Valley ordered five mainline freight locomotives from ALCO and five from EMD.[54] This purchasing technique was clearly a carry over from steam days. A similar purchasing arrangement as was made in 1931 with the 4-8-4 order split between ALCO and Baldwin. This split between manufactures was to characterize Lehigh Valley motive power purchasing for the rest of the railroad's existence.[55]

There were many other factors involved in the split order but perhaps the most critical was delivery time. EMD, ALCO, and Baldwin all submitted bids to the Lehigh Valley for this order. A bid was solicited from Fairbanks-Morse, another locomotive builder, but no response was received by the date of the committee report. The costs were all roughly comparable but Baldwin had a delivery date of the

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[54]Lehigh Valley Railroad Company minutes, May 25, 1948. While ordering ten locomotives, there were four units making up each locomotive. Twenty of these units were "A units" (ten Alco, ten EMD) with cabs and controls for the crew while twenty were "B units" with no provision for independent control. Each unit was, in actuality, a separate locomotive with diesel engine, fuel system, electrical system, and other systems necessary to operate.

[55]For a complete listing of all Lehigh Valley diesel locomotives, see Appendix III.

4th quarter, 1949. ALCO and EMD could each deliver half of the ordered ten locomotives in October of 1948 and the rest later in 1948 or in early 1949. President Major stated, "Because the delivery of the Baldwin locomotives is about a year later than the other two and the savings would therefore be postponed for that period, the Baldwin bid is not attractive."[56] Perhaps the largest reason other than delivery time that ALCO received part of the order was that ALCO was an on-line customer of the Lehigh Valley, with its diesel engine plant located in Auburn, New York. The Lehigh Valley also had previous experience with ALCO switchers and more importantly, road passenger locomotives.

From a maintenance standpoint it was more costly to split the order. The two types of locomotives ordered were fundamentally different, which necessitated keeping twice as many spare parts on hand, as well as learning two completely different systems. ALCO locomotives were 4-cycle while EMD locomotives were 2-cycle. All the internal systems were different and the respective units could not operate together as a single locomotive. That is to say they could not Multiple Unit (M.U.) together.[57]

Steam era thinking was illustrated in this split order. The flexibility that M.U. capable diesels could bring to

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[56]Lehigh Valley Railroad Company minutes, Dieselization Committee Report, April 28, 1948.

[57]M.U. is an abbreviation for Multiple Unit. In railroad industry usage it functions as a noun, verb, and adjective.

operations was not totally realized. Management continued to purchase locomotives solely for their intended tasks. If a situation arose where the EMD and ALCO locomotives had to operate in concert, they would have to be manned by separate crews which was how steam locomotives were operated. All the blame should not be placed on the railroad management, however. M.U. capability was not offered as standard equipment on early diesels because few people, railroad or manufacturer, foresaw its potential. As an option, M.U. capability, when offered, often cost extra. Manufacturers quickly realized their mistake, however, and by the late 1950s offered locomotives that could M.U. with locomotives from other manufacturers. The Lehigh Valley retrofitted some of their ALCO FA/B units in 1956-9 to become M.U. capable with EMD locomotives.

In 1948 the Lehigh Valley also decided to fully dieselize passenger service. Passenger service on the Lehigh Valley consisted mainly of long distance, New York to Buffalo and beyond, traffic. However, there were many shorter, branchline runs served by gas-electric motorcars. Most of these unprofitable branchline operations were curtailed in the five to seven years after the end of the war. To remain even marginally competitive on the long haul routes, the Lehigh Valley had to dieselize operations. The Lackawanna, the Lehigh Valley's arch competitor, dieselized their premier passenger train, the "Phoebe Snow" and also bought new, streamlined equipment for its flagship train. The Lehigh Valley decided not to purchase new passenger equipment but did dieselize operations to improve scheduling and maintain some degree of competitiveness.

Passenger diesels were more highly developed than freight diesels, having been in mainline, revenue service since the Burlington "Zephyr" of 1934. Even though EMD was offering passenger diesels and had a long experience with them, the Lehigh Valley decided to look closer to home and purchased its passenger diesels from ALCO. Both models generated 2000 horsepower, but the EMD version used two diesel engines driving separate generators, while the ALCO model only used one larger engine. The Lehigh Valley evidently thought that the simplicity and potential maintenance savings of a one engine design, rather than the built-in reliability of having two engines, was more important. ALCO had demonstrated its postwar passenger diesel, the PA, on the Lehigh Valley's premier, "Black Diamond" passenger train in 1946.[58] The management was impressed with the diesels, which did not require helper service on the mountain grades. This, combined with the on-line ALCO facilities and prior relationship with ALCO, was most likely the reason that the Lehigh Valley decided to

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[58] "Road Tests Completed on New 4,000-h.p. Alco-G. E. Diesel," Railway Age, 17 August 1946, 308.

dieselize passenger service with the ALCO PA.[59]

The Lehigh Valley also decided to modernize its remaining branchline passenger service, the Lehighton to Hazleton local. This service had been the province of EMC gas-electric motorcars since the early 1930s. In 1951 the Lehigh Valley purchased two Budd Rail Diesel Cars (RDC's) to replace the aging EMC cars. Clearly, the management was committed to continuing some degree of passenger service. This Lehighton to Hazleton service was to be the last passenger service on the Lehigh Valley railroad, ending in 1961.[60]

Even after complete dieselization was achieved in 1951, the Lehigh Valley continued to operate in a steam-era mindset. The capabilities of the diesel were not fully realized. Diesels could travel the length of the system without being refueled and had no need for extensive watering facilities. They could therefore move traffic faster than the steam locomotives. The speed and lack of en-route servicing of the diesels was a greater advantage the further they traveled. However, most diesels initially were not operated this way but were merely substituted for steam locomotives in shorter runs. For instance, a run

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[59]Richard W. Jahn, "PA: Lehigh Valley Style," Flags, Diamonds, and Statues 7, no. 2 (1987): 5.

[60]Archer, Lehigh Valley Railroad, 275. One of these RDC's is preserved at the Railroad Museum of Pennsylvania in Strasburg.

might be made from Oak Island, New Jersey to Allentown, Pennsylvania or from Buffalo to Manchester, New York rather than from Buffalo to Oak Island. The physical layout of the railroad also remained stuck in the steam era. Large yard complexes at Packerton and Coxton, Pennsylvania were designed to classify and store anthracite that was traveling east or west respectively. With the decline of the anthracite industry and the use of long range diesel locomotives, these yards became obsolete and unnecessary. However, they remained in operation until the end of the Lehigh Valley in 1976.

The Lehigh Valley also continued to purchase locomotives with a steam era mindset. For example, they purchased a single Baldwin DRS 4-4-15 diesel roadswitcher in September [61] It was intended to work in the Buffalo area on an evening passenger train. This practice of purchasing a small number of locomotives for a specialized assignment was a steam era holdover. Steam locomotives were highly specialized, and if a specific requirement existed, a unique type of locomotive would be designed to fill it. With diesels this was not the case. Road diesels were almost equally well suited for local or express freight, and even passenger service, provided that they were equipped with a steam generator for heating of the passenger cars. The

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[61]Richard W. Jahn, "An LV Roster Unique," Flags, Diamonds and Statues 3, no. 2 (Spring, 1980): 24.

Lehigh Valley did eventually realize this difference in capability between the two types of motive power. The same Baldwin roadswitcher purchased for passenger work was used in local freight work, in yard work, and even at Bethlehem Steel's main plant in Bethlehem hauling heavy iron ore trains.

Admittedly, to restructure completely the railroad to take advantage of all the aspects of the diesel would have taken great effort and time, but management and the operating employees did not even attempt to utilize the full potential of the new locomotives. Small operational changes such as helper service and some consolidation of trains occurred, but the conservative management and operations staff did not transform the railroad into a true diesel age road. It was a steam era railroad, utilizing diesel locomotives.

One reason that management may have been reluctant to push operations to the full potential of the technology imbedded in the diesel locomotive was the fear of conflict with labor. Typical freight trains of this era had five man crews. The crew consisted of an engineer responsible for the operation of the locomotive; a conductor responsible for the overall operation of the train; a fireman responsible for fueling and tending the fire in the locomotive, and two trainmen or brakemen responsible for other aspects of train operation. The engineer and fireman, and sometimes a brakeman, would ride in the locomotive, while the conductor and the other brakeman would follow in the caboose.

If a train required two locomotives then each locomotive would be outfitted with an engineer and fireman. Each helper locomotive also required its own crew. On steam locomotives this was necessary for operation. However, on diesel locomotives a fireman was not necessary, and one engineer could operate many units through M.U. control cables from the lead unit. This was the crux of the labor battle. The unions wanted crewmen on each unit, implying that they were separate locomotives. The rationale behind this decision was that the crewmembers would be required to monitor the equipment and make adjustments en route. This illustrated steam era thinking by the unions. Because of the inherent differences in the technologies, the diesel locomotives did not require any sort of en route maintenance or caretaking. Steam locomotives, even after the introduction of automatic coal stoking systems, did require an engineer and fireman. The engineer ran the train, and the fireman kept the locomotive in prime operating condition. Since any number of diesel units could be controlled from the lead unit, the management position was that the number of units did not matter; there was essentially only one driving locomotive and, therefore, only one crew was needed.

Engineers had been discussing these changes as early as

1934. In addition to a man on every unit, they wanted new pay classifications for these units. This labor dispute went to Emergency Board hearings in 1943 and was not totally decided until 1948.[62] Management gave in to the union demand to keep a fireman in the cab and extended the pay rate structure for the new locomotives, but management won in its desire to have only one crew for any number of units. An extra crewman for each unit was not truly needed and did not come about. Rate of pay was to be determined by the weight on drivers and any mileage over 100 miles per day was to be regarded as overtime and deserved appropriate compensation.

The social effects upon communities en route are much harder to deduce than the efficiencies of locomotive powerplants; however, some effects can be illustrated. For example, The loss of locomotive shops in Easton in favor of consolidation in Sayre could be seen as a double edged sword, cutting in one's favor or to one's detriment depending upon location.[63] The loss of the steam

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[62]Reed C. Richardson, The Locomotive Engineer: 1863-1963, (Ann Arbor, MI: Bureau of Industrial Relations, Univ. of Michigan, 1963), 415.

[63]Most shop towns on the Lehigh Valley were relatively large and there were other opportunities for employment. the notable exception was Sayre. Other railroad workers were not as fortunate and some entire communities just vanished. See Fred Cottrell, "Death by Dieselization: A Case Study in the Reaction the Technological Change," American Sociological Review 16 (June, 1951): 358-65. He chronicles the story of Caliente, a desert town whose very existance was due to the steam locomotive.

locomotives also had a detrimental effect upon an already hard-hit coal industry in northeast Pennsylvania. However, the impact was not as large as some may think for beginning in the late 1910s and early 1920s, the Lehigh Valley started to burn soft, bituminous coal in its locomotives, rather than the locally mined anthracite. Also, in 1920, the Lehigh Valley Railroad was ordered to divest itself from the Lehigh Valley Coal Company due to anti-trust proceedings.[64]

Many skills unique to servicing steam locomotives were lost, to be only partially replaced with those necessary for servicing diesels. Maintaining steam locomotives required specialized shopmen such as boilermakers, pipefitters, water treatment engineers, foundrymen, and the like. The standardized diesels required general machinists and electricians who could often get much of their knowledge from standard repair manuals thereby reducing lengthy periods of apprentiship and on the job training. The diesels were also more reliable and did not require servicing and overhauls as often. When they did require extensive service beyond what local shop forces could perform, factory representatives had to be called in with their specialized knowledge. Diesels could be refueled and serviced from just a hose and a fuel oil truck and some provision to supply sand while the steam locomotives

[64] Lehigh Valley Railroad Annual Report, 1920.

required large coaling towers, water treatment facilities, water towers and track spouts as well as ash pits and periodic cleaning.[65]

The Lehigh Valley did save money and increase operating efficiency by dieselizing. However, the corporate culture did not respond as well as the new locomotives. As evidenced by the operational usage and locomotive purchasing habits of the Lehigh Valley, the managers were still thinking in a steam era mindset. The fundamental differences that were inherent in the technology of the diesel were not fully understood and implemented.

Even the economies of the new diesels could not change the inevitable. Due to overcapitalization, shifting industrial patterns, the opening of the St. Lawrence Seaway, and the post war growth of the interstate highway system, especially the New York Thruway, the northeastern railroads, including the Lehigh Valley, were all destined for bankruptcy by the early seventies.[66] The Lehigh Valley

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[65]Sand was used by steam and diesel locomotives to increase traction when starting or ascending grades. It was deposited on the rails directly infront of the drivers by small tubes.

[66]In fact, the Lehigh Valley had been operating in the red since 1958. Lehigh Valley Railroad Annual Reports, 1920-1969. The decline and fall of the Penn Central railroad is well documented in Stephen Salsbury, <u>No Way to Run a Railroad</u> (New York: McGraw-Hill, 1982) and Joseph R. Daughen and Peter Binzen, <u>The Wreck of the Penn Central</u> (Boston: Little, Brown & Co., 1971). In addition to the Penn Central and the Lehigh Valley, the Erie - Lackawana, Reading, and Central of New Jersey were all bankrupt. The Erie and Lackawanna railroads merged in 1960 and the New York Central and Pennsylvania

ceased to exist at 12:01 am, April 1st, 1976, when it was absorbed into Conrail.

Could earlier dieselization or a more complete understanding of the capabilities of the diesel locomotive have saved the Lehigh Valley? The answer is very likely no. The Lehigh Valley was born to move anthracite and served in this capacity for well over 130 years. When the anthracite played out, the railroad, built to transport it, suddenly had to find another reason for being. Try as they might, the Lehigh Valley could not escape the legacy of the black diamonds.

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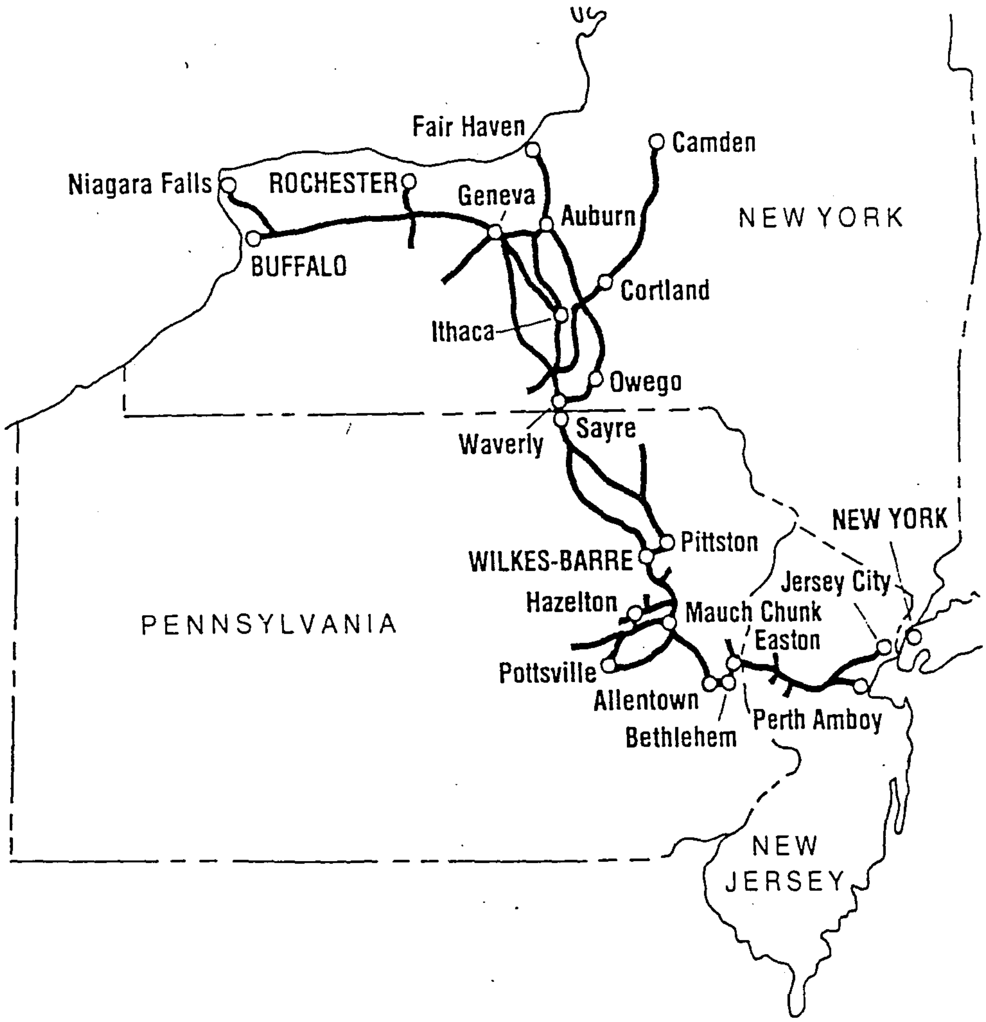
railroads merged in 1968. These mergers eliminated some duplicate management functions and redundant trackage but could not postpone the comming of Conrail.

Map of Lehigh Valley Railroad.
(Following Page)

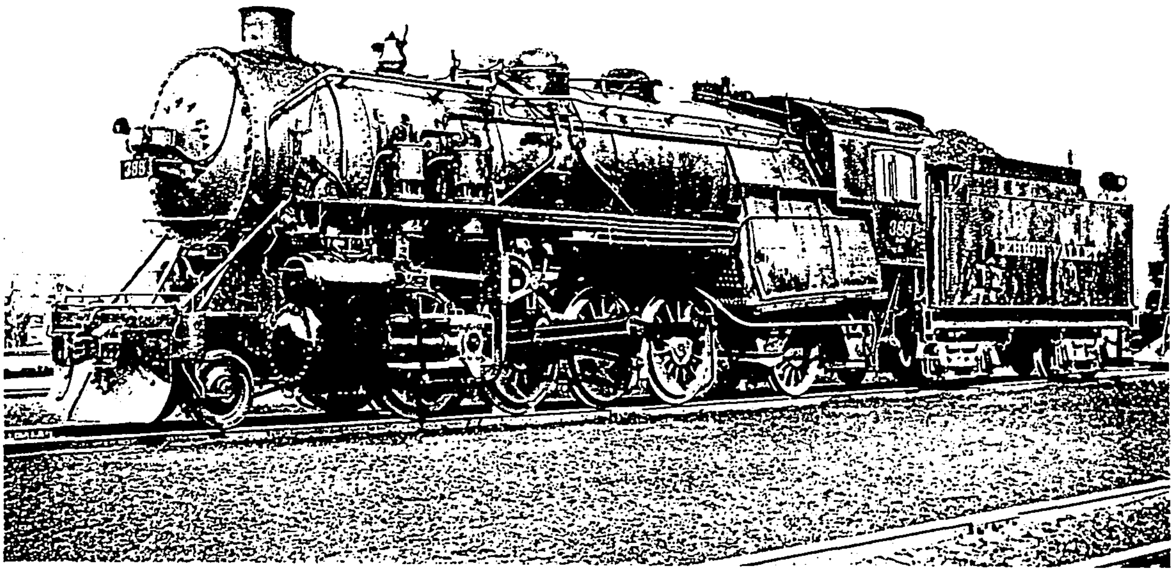
The map illustrated depicts the railroad circa 1920. It shows the many branch lines in the coal regions northwest of Allentown as well as the many branch lines in New York. During the 1930s many of these branch lines were abandoned. The main line ran from Newark, through Bethlehem and Allentown, up the Lehigh River valley and across the Pocono mountains to Wilkes-Barre. From there it followed the Susquehanna River north to Sayre on the New York, Pennsylvania border. From Sayre the main line continued north to Manchester and then turned west to Buffalo and the Niagara frontier. The Rochester branch, Hazleton branch, and Perth Amboy branch were all served by gas-electric motorcars from the mid-1920s to the late-1940s. Today the only parts left in operation are the Hazleton branch and the main line from Newark to Sayre.

Map of Lehigh Valley Railroad.



Lehigh Valley 2-8-2 type steam road freight locomotive.

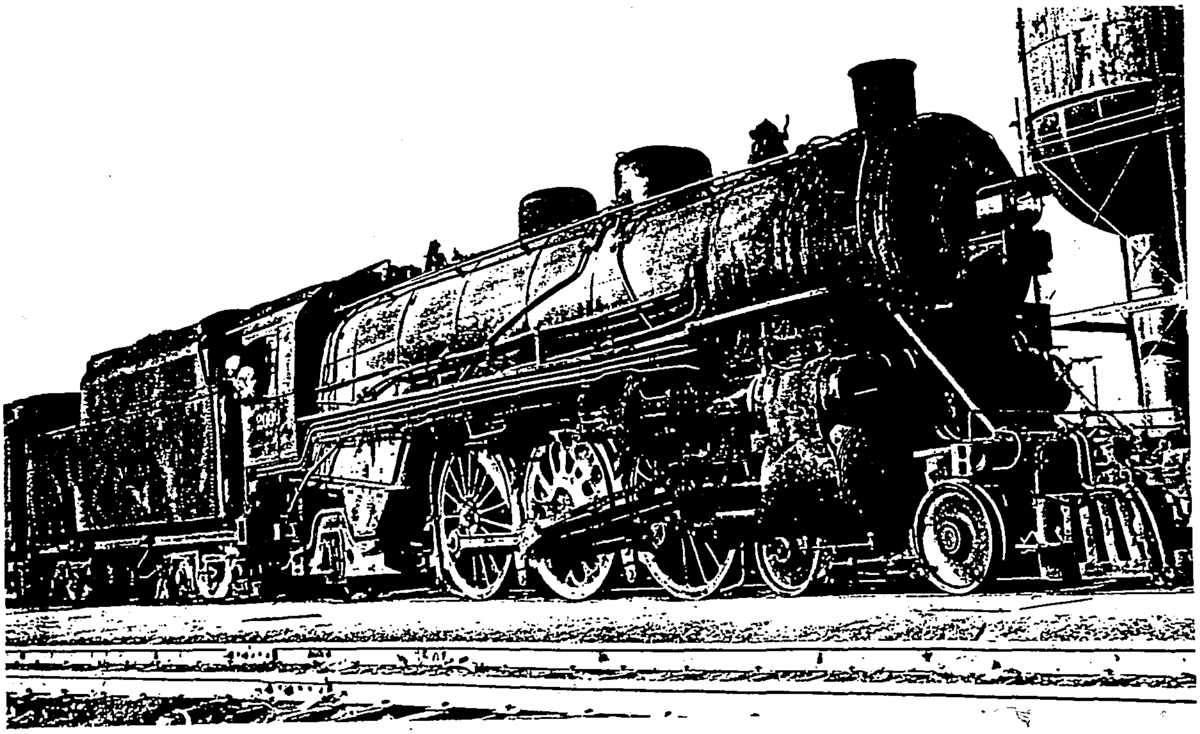
Note the small drivers and large firebox designed to burn anthracite.



All Photos by Martin S. Zak.

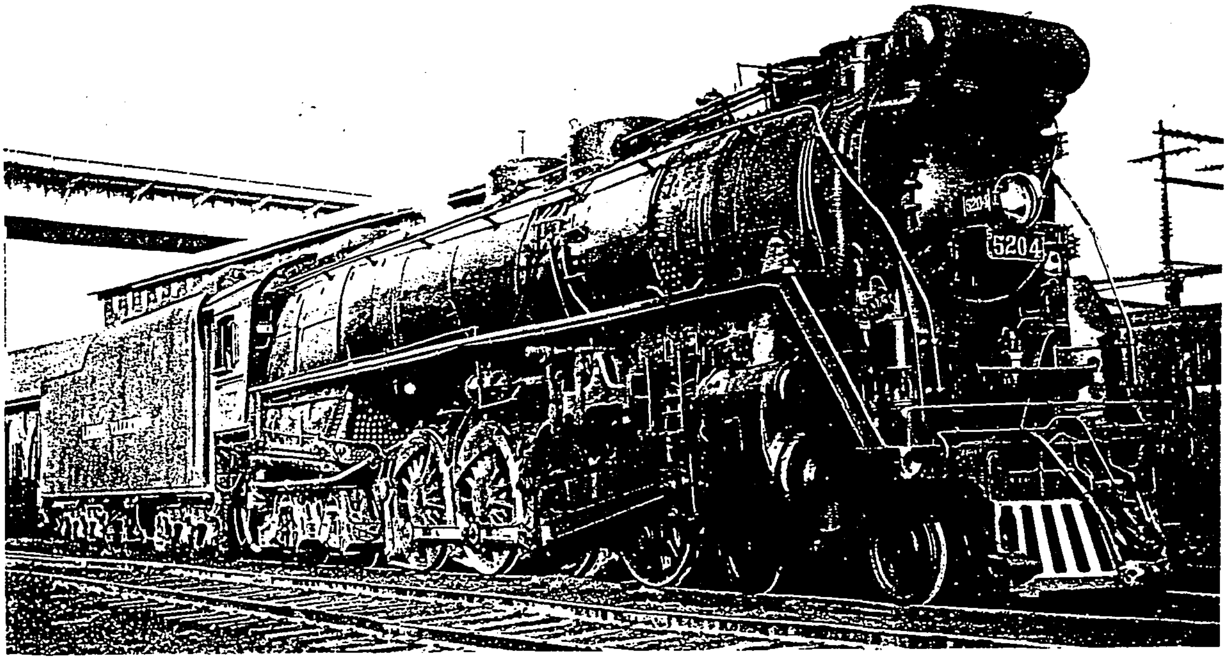
Lehigh Valley 4-6-2 type steam passenger locomotive.

Note the large drivers and four wheel leading truck, both necessary for high speeds.



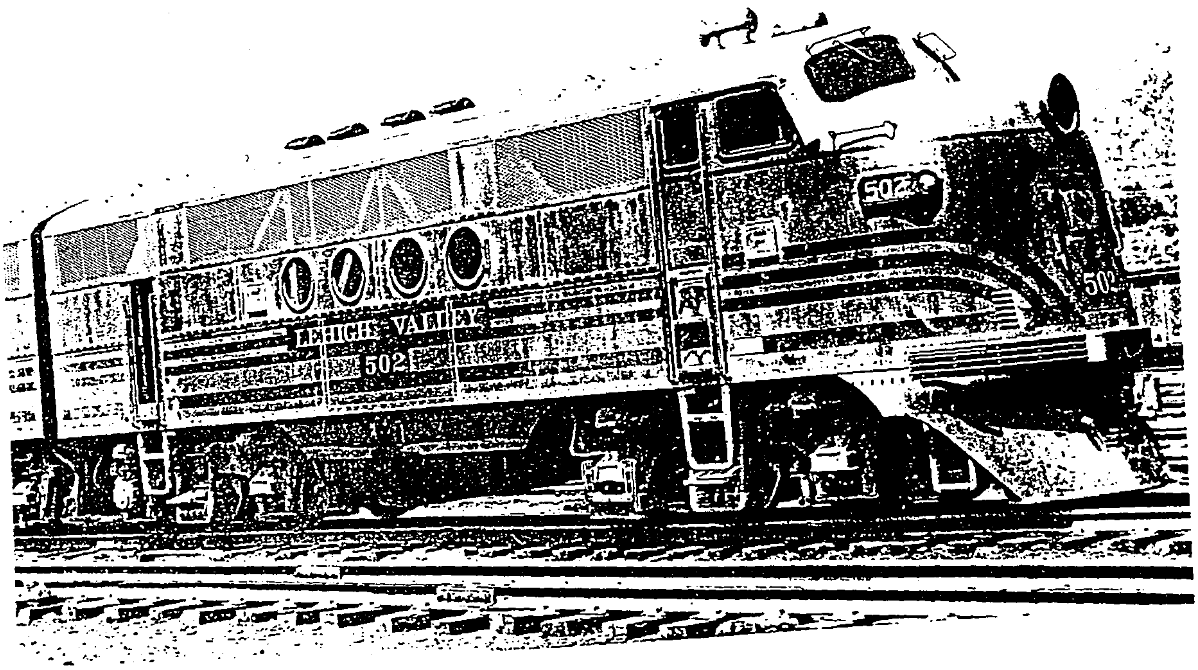
Lehigh Valley 4-8-4 type steam locomotive.

Note the large tender designed to hold as much coal and water as possible to eliminate servicing stops. The round, cylindrical object above the front headlight is a feed water heater.

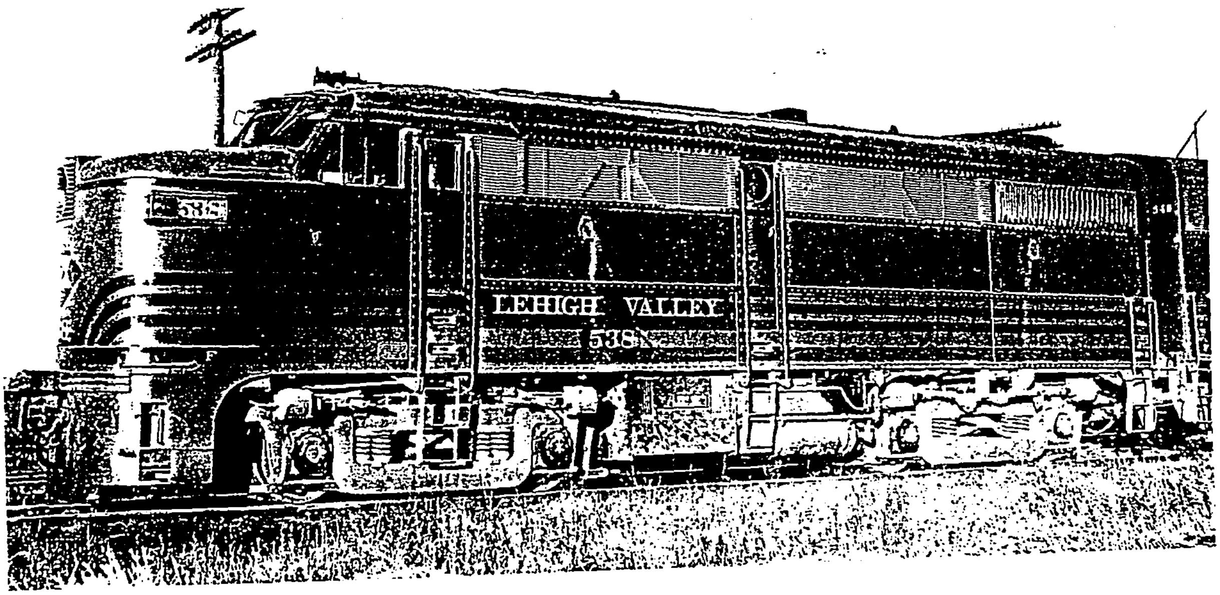


Lehigh Valley Brill gas-electric motorcar.

Lehigh Valley EMD FT type diesel-electric freight locomotive.



Lehigh Valley ALCO FA type diesel-electric freight locomotive.



Appendix I
Lehigh Valley Modern Steam Locomotives

Whyte Class	**LV Class**	**Builder**	**Builder's Date**	**Driver Dia. (in)**	**Weight (lbs)**
0-6-0	G-10 1/2	Baldwin	1891, rb., 1918	51	119,600
0-6-0	G-14	Baldwin	1910, '13	51	127,500
0-8-0	L-5	BLW & LV	1915-16	51	173,500
0-8-0	L-5 1/2	LV	1919-29	55.5	209,000
2-8-0	M-35	Baldwin	1899, rb., 1905	62.5	211,500
2-8-2	N-2	Baldwin	1912-13	56	322,000
2-8-2	N-2 1/2	Baldwin	1913, '16	63	318,500
2-8-2	N-3	Baldwin	1916, '22	63	325,000
2-8-2	N-4	Baldwin	1923	63	316,000
2-8-2	N-5	ALCO	1923-24	63	325,000
2-8-2	N-6	LV	1928	63	328,500
2-10-2	R-1	Baldwin	1917-19	63	375,000
4-6-0	J-25	LV	1917	63	137,000
4-6-2	K-3	LV	1917-21	77	272,000
4-6-2	K-4	LV	1915-17	77	262,500
4-6-2	K-5	Baldwin	1916-17	73	316,500
4-6-2	K-5 1/2	Baldwin	1918-19	73	312,000
4-6-2	K-6	ALCO & LV	1924, '26	77	282,000
4-8-2	S-1	ALCO	1924	69	369,000
4-8-4	T-1	Baldwin	1931, '32	70	415,000
4-8-4	T-2	ALCO	1931, '32	70	424,000
4-8-4	T-2	ALCO	1943	70	450,000
4-8-4	T-3	Baldwin	1934-5	77	439,000

This chart represents steam locomotives that were in service during the period of dieselization. Where LV is designated as a builder it represents locomotives that were built in the Sayre shops of the Lehigh Valley.

Appendix II

Lehigh Valley Gas-Electric Locomotives

Builder Class	Builder	Builder's Date	Horse-power	Weight (lbs)
45 Ton	Mack-Int.	1929	225	84,000
60 Ton	Mack-Int.	1930	405	136,700
Model 60	EMC	1930	400	137,300

Note: The Model 60 locomotives were constructed at Bethlehem Steel in Wilmington, DE, with electrical equipment from GE and engine from Winton. EMC was listed as the builder and indicated as the builder on the builder's plate.

Appendix III

Lehigh Valley Diesel-Electric Locomotives: Switchers

Builder Class	Builder	Builder's Date	Horse-power	Weight (lbs)
60 Ton	ALCO/GE/ Ingersol-Rand	1926	300	127,580
73 Ton	Brill/GE	1927	300	146,000
Co HH300	ALCO	1931	300	132,000
HH600	ALCO	1932, 39	600	202,000
SW	EMC	1937-38	600	204,000
SW1	EMC	1939-40	600	201,660
NW1	EMC	1937	900	254,700
VO1000	Baldwin	1944	1000	242,690
S2	ALCO	1942-4	1000	230,500
SW1	EMD	1950	600	196,870
SW900m	EMD	1958	660	230,000
S1	ALCO	1950	660	196,970
DS44-10	Baldwin	1949-50	1000	230,900
S2	ALCO	1949	1000	230,000
NW2	EMD	1949	1000	248,200
S4	ALCO	1951	1000	229,700
SW7	EMD	1950	1200	245,800
S12	Baldwin	1950	1200	238,000
SW8	EMD	1951-52 *	800	245,000
SW9	EMD	1951	1200	247,850
SW8m	EMD	1953 #	660	247,270
SW900m	EMD	1955-60 #	660	247,270

* 17 SW8 locomotives were dynamic brake equipped, uncommon for switching locomotives.

SW8m and SW900m locomotives were rebuilt from EMC SW and NW1 locomotives. Builder's date shown is that of the rebuilt (80-90% new) locomotive.

Lehigh Valley Diesel-Electric Locomotives: Road Freight

Builder Class	**Builder**	**Builder's Date**	**Horse-power**	**Weight**
FTA	EMD	1945	1350	230,000
FTB	EMD	1945	1350	222,000
F3A	EMD	1948	1500	249,000
F3B	EMD	1948	1500	249,000
FA1	ALCO	1948	1500	236,250
FB1	ALCO	1948	1500	228,500
F7A	EMD	1950-51	1500	246,000
F7B	EMD	1950-51	1500	246,000
FA2	ALCO	1950-51	1600	244,000
FB2	ALCO	1950-51	1600	244,000
GP9	EMD	1959	1750	245,940
GP18	EMD	1960	1800	247,900
RS11	ALCO	1960	1800	248,200
C420	ALCO	1964	2000	262,870
C628	ALCO	1965, 67	2750	388,280
C628	ALCO	1964 *	2750	399,950
RS11u	ALCO	1957 #	2000	252,000
GP38AC	EMD	1971	2000	261,590
GP38-2	EMD	1972	2000	265,000
U23B	GE	1974	2250	265,400

* The 1964 built C628 locomotives were purchased rebuilt from ALCO in 1967. They were previously used on the Monon Railroad in Indiana.

The RS11u locomotives were leased from the Pennsylvania Railroad in 1964.

Notes: The GP9 and GP18 locomotives were built as trade-ins for the EMD FT units. The GP38AC and GP38-2 locomotives were built as trade-ins for the EMD F3 and F7 locomotives. Likewise, the FA/B1 and FA/B2 locomotives were traded in for ALCO RS11, C420, and C628 locomotives.

Lehigh Valley Diesel-Electric Locomotives: Road Switcher

Builder Class	**Builder**	**Builder's Date**	**Horse-power**	**Weight**
DRS44-15	Baldwin	1948	1500	251,580
RS2	ALCO	1949-50	1500	244,000
RS2	ALCO	1949 *	1500	251,560
RS3	ALCO	1950	1600	248,000
RS3	ALCO	1950 #	1600	248,000
RS3	ALCO	1952, 55 @	1600	248,600

* Two RS2 locomotives were purchased used from the C & O Railroad in 1950.

One RS3 locomotive was purchased used from Precision National Corporation in 1971. This locomotive was built for the Tennessee Central in 1950.

@ Three RS2 locomotives were traded to Penn Central in 1971 for three newer RS3's. These locomotives were built for the Pennsylvania railroad in 1952 and 1955.

Lehigh Valley Diesel-Electric Locomotives: Passenger

Builder Class	**Builder**	**Builder's Date**	**Horse-power**	**Weight**
PA1	ALCO	1948	2000	304,600

Appendix IV

Lehigh Valley Gasoline Motorcars

Builder	**Engine(s) Builder**	**Transmission (Builder)**	**Builder's Date**	**Horse-power**
Brill	Midwest	Mechanical (Brill)	1923	68
Brill	Brill	Mechanical (Brill)	1925	200
Brill	Brill	Electric (Westinghouse)	1927	250
EMC	Winton (2)	Electric (GE)	1929-30	600
EMC	Winton	Electric (GE)	1925-27	220
EMC	Winton (2)	Electric (GE)	1927-28	440
Brill	Westinghouse (2)	Electric (Westinghouse)	1926	500
Brill	Hall-Scott (2)	Electric (GE)	1927-8	550

The Lehigh Valley's gasoline rail motorcars were a diverse lot. Most were scrapped or sold off during the late 1930s and 1940s but a couple lasted up until 1951 when they were replaced by Budd Rail Diesel Cars (RDC's) which, interestingly enough, had mechanical transmissions.

The preceeding information was compiled from several sources, including: Extra 2200 South, Railroad History, George H. Drury, Guide to North American Steam Locomotives, and Flags, Diamonds, and Statues.

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VITA

Jeffrey W. Schramm was born 18 July, 1969 in Granite City, Illinois to parents Robert F. and Carol A. Schramm. He graduated from Rich South High School in Richton Park, Illinois in June of 1987. He received a B.A. in History from the University of Missouri - Rolla in Rolla, Missouri in May of 1992. While at UMR he interned as a museum technician with the U.S. Army Engineer Museum at Ft. Leonard Wood, Missouri.

He was accepted into the Master's program at Lehigh University in Bethlehem, Pennsylvania and began his work in August of 1992. While pursuing his M.A. he received the assistance of a Graduate School scholarship and worked as a research assistant for the Agility Forum, a division of the Iacocca Institute, and as a teaching assistant for the History department. He plans on continuing his studies at Lehigh with the goal of a Ph.D. and a career in academia. Yes, he does like to watch trains.

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