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Unfulfilled Promise: Electrification and the Chicago, Milwaukee & St. Paul Railroad

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Unfulfilled Promise: Electrification and the Chicago,

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LIST OF ABBREVIATIONS

AC	Alternating Current
AT&T	American Telephone and Telegraph Company
ABS	Automatic Block System
B&O	Baltimore and Ohio Railroad
B&M	Boston and Maine Railroad
Burlington	Chicago, Burlington, and Quincy Railroad
BNSF	Burlington Northern Santa Fe Railroad
BA&P	Butte, Anaconda, and Pacific Railroad
CN	Canadian National Railway
CP	Canadian Pacific Railway
CB&Q	Chicago, Burlington, and Quincy Railroad
CM&PS	Chicago, Milwaukee, and Puget Sound Railroad
CM&StP	Chicago, Milwaukee, and St. Paul Railroad
DC	Direct Current
EMD	Electro-Motive Division of General Motors
GE	General Electric Company
GT	Grand Trunk Railway
GN	Great Northern Railway
IRT	Interborough Rapid Transit
Long Island	Long Island Railroad
LIRR	Long Island Railroad
MC	Michigan Central Railroad
Milwaukee	Chicago, Milwaukee, and St. Paul Railroad
MPC	Montana Power Company
MU	Multiple-Unit Cars
New Haven	New York, New Haven, and Hartford Railroad
NYC	New York Central Railroad
NY&E	New York and Erie Railroad
NYC&HRRR	New York Central and Hudson River Railroad
N&W	Norfolk and Western Railroad
NP	Northern Pacific Railroad
Pennsylvania	Pennsylvania Railroad
PRR	Pennsylvania Railroad
PRTC	Philadelphia Rapid Transit Company
PW&B	Philadelphia, Wilmington, and Baltimore Railroad
PSTL&P	Puget Sound Traction, Light, and Power Company
RBC	John W. Barriger III National Library, University of Missouri-St. Louis, Reinier Beeuwkes Collection
SP	Southern Pacific Railroad
WJ&S	West Jersey and Seashore Railroad

GLOSSARY

Arc lighting. An electric light in which a current traverses a gas between two incandescent electrodes and generates an arc that produces light.

Cable-powered. A railroad car that moves on a steel cable driven by a stationary engine.

Couplings. Mechanisms at the ends of railroad cars that connect one railroad car to another.

Distribution system. The final step of delivering power, carrying electricity from the transmission system to the customer.

Drawbar pull. The towing force of a locomotive, exerted at a coupler in the direction of motion of the coupling point (typically expressed in pounds or Newtons).

Frog. A device at the intersection of two tracks to permit the wheels and flanges on one track to cross or branch from the other.

Motive power. A locomotive that supplies tractive power to move a train.

Overhead. The wires from the distribution system suspended over the railroad tracks that supply power to the electric locomotive.

Pantograph. a device usually consisting of two parallel, hinged, double-diamond frames, for transferring current from an overhead wire to an electric locomotive.

Regenerative braking. A braking system where a train reduces speed by converting the train’s kinetic energy into electricity that can be fed back into the distribution system for other trains to use or sent back to the power grid for other customers to use.

Rolling stock. Any wheeled vehicle on a railroad, such as locomotives, freight cars, and passenger cars.

Route miles. The actual distance traveled over railroad tracks between two points.

Siding. A short railroad track, opening onto a main track at one or both ends, on which one of two meeting trains is switched until the other has passed.

Third-rail. A rail laid parallel and adjacent to the running rails of an electrified railroad to provide electric current to the motors of a car or locomotive through contact shoes.

Tractive effort. The force exerted by a locomotive on its driving wheels.

Transformer. A device used to transfer electrical energy from one circuit to another, while raising or lowering the voltage in the transfer process.

Transmission system. The second step of delivering power, carrying electricity from the generating plant over high-voltage wires to a transformer, which sends the electricity to the distribution system.

Trolley. A grooved metallic wheel carried on the end of a pole by an electric car or locomotive, and held in contact with an overhead wire, from which it collects the current for the propulsion of the car or locomotive.

Trolley wires. (See: Overhead)

Truck. A group of two or more pairs of wheels in one frame, for supporting one end of a railroad car or locomotive.

Chapter 1

INTRODUCTION

"In this forward movement electricity challenges the supremacy of steam, and on the Scroll of Time the year 1916 marks the dawn of the electrical era of railroading," exclaimed a Chicago, Milwaukee, and St. Paul Railroad advertisement.[1] The Milwaukee's revolutionary technological breakthrough warranted the attention it received. The railroad world was on the verge of something spectacular and never before seen: the electric operation of 440 miles of mainline railroading on the CM&StP Railroad. It was the most ambitious railroad electrification project ever undertaken in the world. The railroad eventually added another 216 miles of electrification, bringing its total to 656 miles. The Milwaukee, as the railroad was nicknamed, was at the forefront of railroad electrification technology.

While the promise of electricity for propelling trains was still a novel idea during the early 1900s, the American public experienced electricity's potential in everyday life for over twenty years. Fairs and expositions, for example, displayed some of the biggest demonstrations of electricity's potential. These spectacular events captured the imagination of visitors, fascinating young and old alike with the potential of electricity's power. Manufacturers displayed new electrically operated machines, which offered a look in the future and promised the benefits of improved productivity. One of the biggest draws, however, was electric lighting. The exposition grounds were typically lit with incandescent light bulbs and, in many cases, these encounters with electric lighting were

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[1] Chicago, Milwaukee, & St. Paul Railway, *The Dawn of the Electrical Era in Railroading: The Electrification of the Mountain District of the Chicago, Milwaukee, & St. Paul Railway* (Chicago: Poole Brothers, 1916), 1.

usually the visitor's first. In fact, many of the fairs' guests preferred to visit the grounds at night to enjoy the electrically lighted landscape.

Although the first expositions to use electric lighting occurred in Europe in 1881, the United States quickly adopted electric lighting at its fairs. The nation's first exposition to use electric lighting, as well as the last to use gas lamps, was Louisville's Southern Exposition in 1883. The exposition featured an Edison system with 4,000 sixteen-candlepower incandescent filament lamps, as well as lights outlining the exhibition halls and electric arc lamps lighting the grounds.[2] A decade later, Chicago's Columbian Exposition used a variety of 92,600 electric lamps to light the buildings and the grounds.[3] Between 1898 and 1915, other expositions at Omaha, Buffalo, St. Louis, and San Francisco demonstrated to the admiring public the promise of electric lighting in similar fashions.

Americans realized rapidly they could utilize electricity's power in many different capacities. Electricity made communications faster. Street lighting improved safety and revolutionized advertising. Electricity promised better manufacturing techniques and allowed industries to locate away from water sources, as well. In addition, Americans invited electricity into their homes with the promise that it would improve comfort and simplify domestic chores. The American public looked forward to electricity's potential. Steam railroad executives, however, were reluctant to adopt electricity for hauling trains.

The promise of electricity was nothing new to the railroad industry. Beginning in the early 1880s, steam railroads used electricity to light freight yards, major passenger terminals, and passenger cars. By the 1890s, urban railroads, as exemplified by streetcars,

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[2] John A. Jakle, *City Lights: Illuminating the American Night*, (Baltimore: The Johns Hopkins University Press, 2001), 147.
[3] Ibid., 152.

interurbans, and subways, began using electric propulsion. These local systems proved well-suited for electric operation. In contrast, steam railroads were slow to adopt electric traction. During the 1890s, only the Baltimore and Ohio Railroad operated a stretch of track, a 3.6-mile route through the city of Baltimore, under electric power. Steam railroads, however, started implementing electrified operations en masse during the first decade of the twentieth century, especially in urban areas and short sections through tunnels and mountain ranges.

The Milwaukee, however, attempted to revolutionize steam railroad electrification. Instead of focusing on electrifying an occasional five-mile stretch of tunnels or an urban terminal, the Milwaukee executives wanted to electrify whole steam divisions, which were generally one hundred miles in length. In addition, while other railroads electrified out of necessity, the Milwaukee electrified for economic reasons. Furthermore, the CM&StP executives thought electrification would improve service and enhance the passenger experience. The railroad's officials considered themselves pioneers in the field of electricity, as exemplified by the preceding quote from a 1916 railroad advertisement. Despite proving electricity's benefits over steam, widespread steam railroad electrification never caught on in the United States. This thesis will examine the unfulfilled promise of electricity in railroading.

Before delving into the topic, a background on electricity in America is necessary. Chapter Two explores electricity in America from roughly 1879, when the incandescent light bulb first appeared, to 1910, just prior to the Milwaukee's decision to electrify sections of its railroad line. This chapter describes early uses of electricity in America, including communications, industry, the home, and transportation.

Chapter Three looks at steam railroad electrification before 1916. This chapter discusses the various reasons why some steam railroads chose electrification between 1895 and 1916. Chapter Three also examines the details of each major U. S. steam railroad electrification project during this period.

Chapter Four briefly explains why the Chicago, Milwaukee, and St. Paul Railroad built a transcontinental route to Puget Sound (widely known as the “Pacific Coast Extension”) before exploring the Milwaukee’s electrification. Chapter Four explores some of the factors involved in the railroad’s decision to electrify the Pacific Coast Extension’s Rocky Mountain and Missoula Divisions . Next, Chapter Four looks at the electrification technology on these two divisions, from substation equipment to locomotives, before briefly discussing the technology used on the Pacific Coast Extension’s Coast Division electrification.

Chapter Five examines the benefits and results of the Milwaukee’s electrification. This chapter looks at the operational benefits to the railroad, the electrification’s public relations effect, and the costs of the Milwaukee’s electrification. The chapter also explores the drawbacks of electrification on steam railroads.

Chapter 2

The Promise of Electricity in Everyday Life

Electric pumps milked cows and artificial light hatched chickens. Girls in pink gowns sewed and ironed clothes, while others worked in the kitchen boiling coffee and baking. Meanwhile, a woman tidied her carpets and walls with a cleaning machine as a young man bored a hole through a rock nearby. What remotely sounds like activities related to a farm were in actuality the events that took place at the second annual Electric Show in New York City's Madison Square Garden in October 1908. Electricity's wonders were on display, including speeches by Thomas Edison and Charles Evans Hughes, New York's governor, played over a phonograph. Electric lights flooded Madison Square Garden, turning nighttime into day. Electricity's versatility, from the farm to the home, was on display for the world to see.[4]

In the late nineteenth century and early twentieth century, inventors discovered new ways to harness the power of electricity. The field of communications was the first major use for electricity. Later, engineers developed electric lighting to illuminate city streets, homes, and factories. Railroads, such as the Pennsylvania and the Chicago, Milwaukee, and St. Paul, incorporated electricity into their repair shops, passenger trains, and main terminals. Electric motors powered everything from sewing machines to streetcars. As America electrified, people encountered electricity in myriad ways in both public and private life. The promise of electricity transformed everyday life.

Communication

Early on, electricity gained widespread usage in the field of communications. Telegraphy, first used commercially in 1844 by its inventor, Samuel Morse, became the

[4] "Electric Wonders Shown at the Garden," *The New York Times*, October 4, 1908, 9.

first major use of electricity. Telegraph wires connected cities, which provided instant communication over long distances and eliminated the need for the Pony Express. For several years, telegraph operators were the primary user of electricity and electrical services. In 1877, the total outlay in commercial electrical enterprises in the United States was about $50 million, with most of the investment expended on telegraphs and ocean cables.[5]

The telegraph provided a favorable way to conduct railroad business. In 1850 the New York and Erie Railroad strung a telegraph wire along its mainline between Piermont, New York (twenty miles north of New York City), and its Lake Erie terminus at Dunkirk, New York. Initially, the NY&E used the telegraph for internal communications between executives and employees. Officials, however, realized quickly that the telegraph could be used to dispatch trains. In 1851, a freight train was waiting at Corning, New York, for a delayed express train. Luther G. Tillotson, the NY&E's Superintendent of the Telegraph Line, used the telegraph to order the freight train to proceed to the next station. The experiment proved successful. Despite the initial reluctance of train crews to proceed to the next station without following a timetable or physically seeing the approaching train, the NY&E used the telegraph to dispatch trains on the Susquehanna Division.[6] Other major railroads in the coming years adopted the NY&E's train dispatching method. Dispatching trains with telegraphs was safe and saved railroads valuable time and money.

Later, the telephone, patented by Alexander Graham Bell in 1876, expanded the use of electricity. Within a year of a receiving a patent, Bell developed the first

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[5] Abram John Foster, *The Coming of the Electrical Age to the United States* (New York: Arno Press, 1979), 43.

[6] Henry W. Spang, *A Treatise on Perfect Railway Signaling* (New York: Henry W. Spang, 1902), 14.

commercially viable telephone and began leasing the new communications device for private use on May 1, 1877. Telephone communication reached another milestone in May 1877 when E. T. Holmes operated the country's first telephone exchanges in Boston.[7] The telephone business grew rapidly; about 10,000 telephones were in use by mid-1878, and, by early 1880, the industry claimed 60,000 subscribers.[8]

Despite the promise of the new technology, Bell needed to respond to the technical problems from the growth of telephone use. For example, switchboards with large numbers of wires became difficult for operators to use. Bell developed new switchboards and procedures to alleviate switchboard congestion.[9] Additionally, interference from electric and streetcar power lines made talking on the telephone problematic. To reduce this problem, Bell replaced single iron or steel wires with pairs of copper wires that returned the current.[10] Bell created a telephone service that was more reliable and easier for businesses to use.

The improvements significantly altered telephone service, which eventually created greater demand for Bell's product. By 1893, 260,000 telephones were in service with businesses accounting for approximately two-thirds of its use.[11] A reduction in rates, attributed to the increased competition after Bell's telephone patents expired, also contributed to an increase in telephone use. AT&T reported that its average annual rates for residential service dropped from $56 in 1894 to $24 in 1909, resulting in a 30 percent a year increase in telephone usage between 1894 and 1907.[12] Technological

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[7] Foster, 45.
[8] Claude S. Fischer, *America Calling: A Social History of the Telephone to 1940* (Berkeley: University of California Press, 1992), 36-37.
[9] Ibid., 38.
[10] Ibid.
[11] Ibid., 41.
[12] Ibid., 48-49.

improvements and the corresponding rate decreases led to widespread telephone usage throughout the United States.

Outdoor Lighting

During the late nineteenth and early twentieth centuries, United States urban areas underwent dramatic changes in population. Between 1870 and 1920, the urban population of the nation increased from under ten to over fifty-four million people.[13] As more people crowded into the nation's cities, the work and social habits of the urban population shifted. The number of laborers working at night increased, while those who toiled during the day found more leisure opportunities during the nighttime hours. With increasing numbers of the urban population out at night, the necessity of better lighting became increasingly apparent.

Urban street lighting improved when cities utilized electricity over gas. Gaslights were a problem because they created smoke and caused fires. In addition, each lamp needed to be cleaned regularly and lit individually, all while providing less light for the same expense as electricity.[14] Muncie, Indiana, a city surrounded by natural gas deposits, tried lighting its streets with gas lamps in the late 1880s. In many cases, however, high winds and poor gas pressure knocked out the light. To counter the gas light problems and attract more industry, Muncie businessmen installed 132 arc lights between 1892 and 1894.[15] The arc lights were a major improvement over the unreliable gas lamps.

Additionally, electric lighting in urban areas improved advertising. New York quickly adopted electric lighting in the 1890s to increase business on Broadway. More

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[13] David Nasaw, *Going Out: The Rise and Fall of Public Amusements*, (Cambridge, MA: Harvard University Press, 1999), 3.
[14] David E. Nye, *Electrifying America: Social Meanings of a New Technology, 1880-1940* (Cambridge: The MIT Press, 1990), 6.
[15] Ibid.

storefronts along the busy thoroughfare included electrically lighted signs, ultimately creating "The Great White Way." H. J. Heinz, the famous condiment magnate, placed a 45-foot-long pickle made of green light bulbs that included the phrase “57 Varieties” spelled out below it in Madison Square. Critics described the area with its incredibly bright advertisements as “Advertising Gone Mad.”[16] Despite a few protests, the new glowing advertisements increased along Broadway. “The Great White Way” included more than twenty blocks covered with electric advertisements by 1910.[17]

Railroads also attempted to use lighting for outdoor uses, such as rights-of-way and marshaling yards. In fact, the promise of electric lighting prompted one Pennsylvania Railroad official to discourage inventors from wasting time developing a 100-candlepower electric headlight for locomotives, since future railroads would be illuminated electrically from one end of the line to the other, eliminating the need for such a device.[18] While widespread adoption of lighted rights-of-way never materialized, lighted marshaling yards did come to fruition. Lighting a marshaling yard, however, proved more difficult than lighting city streets. In the case of street lighting, city engineers placed lamps lower to the ground and at street corners, which brilliantly illuminated the street directly beneath the lamp, but did not distribute the light widely. For lighting marshaling yards, where locomotive engineers and trainmen work, evenly distributed light was more important than brilliant light.[19]

The Pennsylvania Railroad’s electrical engineers developed a plan to illuminate its Altoona, Pennsylvania, marshaling yards in 1891. The engineers positioned lamps

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[16] Ibid., 51.
[17] Ibid., 52.
[18] W. H. Markland, “Electric Light as Applied and Used by Steam Railroads,” *Electrical Engineer*, 11, no. 147 (February 25, 1891): 234.
[19] Ibid., 233.

atop of 65-foot poles that were moored eight feet into the ground, preventing the wind and vibrations from the trains from knocking them over. In addition, engineers placed the lights at strategic locations, such as switches and crossovers between sets of tracks, where trainmen needed good visibility. In wide, long portions of the yard, lamps were spaced approximated 600 feet apart and zig-zagged throughout the yard, which prevented shadows and diffused light better. This pattern of lighting resulted in a glow similar to moonlight. The PRR noticed positive results from illuminating the Altoona marshaling yards. Trainmen had an easier time judging distances when switching freight cars at night, resulting in fewer accidents. In addition, the PRR officials concluded that installing and maintaining the lamps was cheaper than paying claims on damaged or stolen goods, since watchmen noted a decline in thieves pilfering freight cars at night.[20] Flooding marshaling yards with electric lighting at night created a safer working environment for trainmen and saved the railroad money.

Industry

Industry became one of the first fields to harness the power of electricity during the late nineteenth century, because it provided enormous benefits. To paraphrase author David E. Nye, electricity could drive multiple small motors; produce high temperatures without consuming oxygen; link a series of machines through automatic feeding devices, scanners, and moving belts; and regulate a system with temperature gauges, meters, warning bells, automatic shut-off devices, heat sensors, and electrical control devices.[21] Electricity markedly improved productivity and the quality of manufactured products.

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[20] Ibid.
[21] Nye, 13.

The promise of electricity for industrial applications had a major breakthrough with the development of the steam-powered central power station. To make the central power station successful, the former railroad telegrapher-turned-inventor, Thomas Edison, and his assistants spent considerable time developing a generator and tackling power distribution issues. In July 1882, the first steam-powered generator was installed and tested at Edison's plant on Pearl Street in New York City.[22] Testing proved successful and on September 4, the station went into operation, lighting the offices of J. Pierpont Morgan, where the Edison Electric Light Company directors gathered.[23] The directors were pleased with the results. Edison soon enrolled customers from several major New York institutions including the New York Stock Exchange and the *New York Times*.[24] Edison's Pearl Street central power station, powered by steam, demonstrated that electricity could be generated anywhere, freeing factories from the limits of waterpower.

More factories located away from water sources and used alternating current power to drive machines. Horatio Livermore, a wealthy California businessman, constructed a dam on the American River twenty miles upstream from Sacramento, California, with the intention of building a manufacturing plant powered by water. In 1895, however, he purchased electrical generating equipment from General Electric instead and delivered electricity to Sacramento's local industries.[25] That same year Westinghouse installed alternating current equipment in another California power plant and at Niagara Falls.[26] Now factories could be placed virtually anywhere without having to worry about a power supply. The process of electrifying manufacturing started slowly,

[22] Paul Israel, *Edison: A Life of Invention*, (New York: John Wiley & Sons, Inc., 1998), 206.
[23] Ibid.
[24] Charles Bazerman, *The Languages of Edison's Light* (Cambridge: The MIT Press, 1999), 230.
[25] Nye, 196.
[26] Ibid.

but eventually gained momentum. In 1889, electricity was responsible for 1 percent of the nation's manufacturing output; by 1919, it accounted for 50.2 percent.[27]

Electricity also transformed railroad maintenance facilities during the last two decades of the nineteenth century. The Pennsylvania Railroad became one of the first railroads to install a dynamo and lamps at its sprawling Juniata shop complex in Altoona, Pennsylvania, in 1881.[28] Eventually, electrically-operated machines appeared in the railroad shops. The traveling overhead crane, for instance, provided an easier means of transferring locomotives within the repair shop and revolutionized engine maintenance. Electrically-operated machine tools, such as drilling machines and lathes, also appeared, which improved the quality of work and did it in a timely fashion. The new machine tools permitted railroads to use heavier locomotives and cars, but also made recently built shop complexes obsolete. The Northern Pacific Railroad's fifty-two-stall roundhouse and repair facilities in Brainerd, Minnesota, were considered state of the art when they opened during the 1890s. The Brainerd shops (as well as the NP's Como shops in St. Paul, Minnesota), however, required expansion during the first decade of the twentieth century to accommodate the larger equipment and the electrically-driven machine tools.[29] Electricity profoundly impacted railroad repair facilities, improving work quality, saving time and required updating outmoded facilities.

Home

Electrification improved domestic conditions in several ways. Electricity made everyday chores, like sewing, cooking, laundry, and vacuuming, easier and faster. Other tasks, such as drawing and hauling water, were virtually eliminated. New household

[27] Ibid., 187.
[28] Markland, 233.
[29] "Electricity in Railroad Shops," *Railway and Locomotive Engineering*, 15, no. 3 (March 1902): 118.

appliances like the ceiling fan and phonograph, made domestic life more comfortable. Household lighting, however, was one of the first applications of electricity, which vastly improved indoor lighting quality and safety.

Practical indoor electric lighting appeared in 1879 when Edison invented the first commercially viable incandescent light bulb. Assistants Charles Batchelor and Francis Upton, using a process of carbonizing thread they had developed, carbonized a thin ribbon of cardboard, shaped into a horseshoe, and watched it glow brightly for thirteen hours.[30] Edison placed the new filaments inside a vacuum-sealed glass bulb and placed them in lamps throughout his house. When Edison lit the lamps, they provided a mild, even, and steady glow, unlike gas or arc lamps. Marshall Fox, a reporter for the *New York Herald*, upon seeing the lamps for himself on December 20, 1879, reported the next day: “Edison’s Light. The great inventor’s triumph in electric illumination. A scrap of paper. It makes light without gas or flame, cheaper than oil.”[31] Soon, homes harnessed the promise of electric lighting.

By the early 1880s, central stations transmitted power reasonably and safely to homes for the purposes of electric lighting. The first homes to be lighted by power from a central station were those in Appleton, Wisconsin, in September 1882.[32] Electric lighting in the home provided several advantages. It could be installed anywhere, there was no flame or odor, and the risk of setting a fire was minimal.[33] Additionally, electric lighting was more child-friendly than gas lamps. Children could flick a light switch more

[30] Linda Simon, *Dark Light: Electricity and Anxiety from the Telegraph to the X-ray*, (Orlando: Harcourt, Inc., 2004), 83.
[31] Ibid., 84.
[32] Foster, 311.
[33] Nye, 31.

easily than regulating a gas lamp, making electric lighting uncomplicated and safe to use for people of all ages.

Electricity revolutionized all rooms of the house, but especially the kitchen. There were several benefits to using electric appliances in the kitchen. The required heat was available immediately by easily turning on the switch or switches. Electric appliances provided constant heat, which allowed the cook to prepare food consistently and thoroughly. In addition, while gas ovens needed a large vent to the outside to remove poisonous gases and flames**,** which also evaporated juices from cooked meats, electric ovens had no poisonous gases and kept the cooked meats moist and juicy. Electric ovens also were more efficient than gas ovens, because they concentrated the heat on cooking food and kept the kitchen cooler. Furthermore, coal and its byproduct, cinders, disappeared from the kitchen, keeping the house cleaner. Finally, cooking with electric appliances saved money. Because gas ovens dried out meat, using electric ovens retained at least 15 percent of the meat's weight.[34]

In the electric kitchen, there was no need to fire up a stove, stand around, and wait for it to get to the proper temperature before cooking. Cooking food became a sit down affair with meals prepared in minutes. Manufacturers designed several cooking devices, such as the "Heetorboil" Food Warmer, "Just for Two" Table Cooker, "Pygmy" Heater, and the toaster, for convenient tabletop cooking.[35] The devices simply plugged into any lamp socket, allowing the user to make a pot of coffee, fry up bacon, cook pancakes, and make toast right at the kitchen table. Making a meal in the kitchen, typically a labor-intensive process, suddenly became effortless with electric appliances.

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[34] Maud Lancaster, *Electric Cooking, Heating and Cleaning: A Manual of Electricity in the Service of the Home*, (New York: D. Van Nostrand Company, 1914), 31.
[35] Ibid., 85-87.

Electricity also modernized the bathroom. Electric water heaters in the home provided hot bath water instantaneously. The new water heaters obtained great cost efficiencies, as well. Electricity converted 87 percent of the thermal units paid for to useful energy while coal only converted 10 percent and gas converted 30 percent.[36] Other bathroom appliances, such as massage vibrators, hair dryers, and curling irons, became popular health and beauty aids at the turn of the century.

Electric heat made its way into the bedroom, as well, in the form of bed warmers. Bed warmers served several purposes: it could be used to warm bed sheets, applied to the body to reduce muscle pain and inflammation, or as a foot warmer. Bed warmers also provided the consumer hours of relief at a constant temperature, offering better health results. The soft and flexible pad, covered with eiderdown, could be used in any position and was so light that it was never uncomfortable.[37] Bed warmers applied heat to the body more evenly and easily than any other device before its development.

Electricity also simplified cleaning the house. Vacuum cleaners, initially referred to as "suction" cleaners, were developed during the early 1900s to clean household floors. Vacuum cleaners were so simple to use that even children could use them to remove dust from the wall.[38] Doing the laundry, once an unpleasant weekly undertaking, became a pleasure, thanks to the Maytag clothes washer and the electric iron. The introduction of the electric dish and plate washer made washing dishes easier, as well. The apparatus consisted of two or three vessels, the first for washing dishes in water at 100 degrees Fahrenheit, and others for rinsing and sterilizing in hot water at 160-212 degrees

[36] Ibid., 203.
[37] Ibid., 243.
[38] Ibid., 260.

Fahrenheit.[39] The electric dish and plate washer could clean just about anything from plates to silverware. Cleaning around the house with these appliances saved great amounts of labor and made homemakers more productive.

Electrically heating portions of the house also made living quarters more comfortable. H. J. Dowsing invented the "radiant lamp" system of electric heating in 1899, which made heating a single room of a house more effective.[40] Electric heat proved to be more efficient, as well. Electric heaters gave off 100 percent of the heat produced as useful heat, compared to only 10 percent for coal and 20 percent for gas.[41] Additionally, since the heat could be turned on or off at the flick of the switch, no heat was wasted, unlike having to wait for a coal fire to burn out or waiting for a gas fire to heat up until it could provide useful heat. Electric heaters were also portable, permitting the user to place heaters in different rooms. While they did not replace gas or coal as the primary source of heating, electric radiators and convectors became common household appliances by 1914.

As American mobility increased during the late nineteenth century, railroad officials touted their efforts to provide the amenities of home to passengers. In addition to sleeping cars equipped with convertible berths, dressing rooms, and lavatories, railroads added cars with reclining chairs, parlor cars, dining cars, library cars and barbershops.[42] Passenger comfort received a great deal of attention from railroad executives. The Chicago, Milwaukee, and St. Paul Railroad, for example, aimed to

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[39] Ibid., 280.
[40] Ibid., 225.
[41] Ibid., 221-222.
[42] Amy G. Richter, *Home on the Rails: Women, the Railroad, and the Rise of Public Domesticity* (Chapel Hill: The University of North Carolina Press, 2005), 67-68.

"provide every luxury to which one is accustomed in his home."[43] To this end, the railroads strived to provide modern amenities, such as electric lighting, on passenger trains and in terminals.

The Pennsylvania Railroad pioneered the use of electric lighting in passenger cars in 1882. The road's engineers developed a battery-powered lighting system and tested it in some of the Pennsylvania's passenger cars. While the battery-powered lighting system occasionally discharged the battery en route to its destination, the illumination method proved successful. In 1887, two of the railroad's best trains, the *Florida Special* and the *Chicago Limited*, were outfitted with electric lights.[44] Following the Pennsylvania's success with battery-powered lights, other railroads, such as the Boston and Albany Railroad and the Connecticut River Railroad, tested electric lighting in their passenger cars, as well. George Gibbs, however, developed a more elaborate and reliable passenger car lighting system.

Gibbs, the CM&StP's electrical engineer, created an electrical lighting system using onboard steam generators in 1888. Utilizing a special car equipped with boilers, high-speed engines, and generators, the Milwaukee provided electricity to illuminate its passenger trains. In 1892, the road operated eighty-two wired cars and ran five electrically lit trains daily between Chicago and Minneapolis.[45] Despite costing several times more than gas illumination, the Milwaukee equipped more passenger cars with electric lighting. By 1904, the Milwaukee wired three hundred passenger cars – more

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[43] Ibid, 68.
[44] John H. White, *The American Railroad Passenger Car* (Baltimore: Johns Hopkins University Press, 1978), 422.
[45] Ibid, 423.

than any United States railroad.[46] Most railroads, however, considered electric lighting an expensive luxury. By 1911, only 30 percent of the nation's passenger car fleet used electric lighting.[47]

Railroads also improved passenger comfort by electrically illuminating terminals in major cities. The Indianapolis Brush Electric Light and Power Company successfully displayed electric arc lighting at Indianapolis's Union Railroad Station on January 11, 1882, becoming one of the first major terminals in the United States to use electric light.[48] The Chicago, Milwaukee, and St. Paul Railroad's handsome new terminal in Milwaukee, completed in 1886, included electric lighting throughout the station. To prevent passengers staying in Downtown Milwaukee from being late for a departure, the CM&StP built a 160-foot clock tower next to the station and illuminated the clock's faces with electric light.[49] Beside electricity's practicality in lighting waiting areas and imposing clock towers, architects knew it could serve as an ornate decorative tool in railroad terminals. In 1894, German-trained architect Theodore C. Link hung a chandelier twenty feet in diameter from the ceiling of the lavish Grand Hall at St. Louis Union Station, sparkling with 350 lamps and weighing 4,500 pounds.[50] Electric lighting, while still a novelty in many respects, improved passenger comfort and awed travelers as they made their way through the nation's railroad terminals.

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[46] Ibid.
[47] Ibid., 426.
[48] Zane G. Todd, *Electrifying Indianapolis: The Story of the Indianapolis Power & Light Company* (New York: Newcomen Society in North America), 10.
[49] Walter G. Berg, *Buildings and Structures of American Railroads*, (New York: John Wiley & Sons, 1893), 372.
[50] James Neal Primm, *Lion of the Valley: St. Louis, Missouri 1764-1980*, 3rd Ed. (St. Louis: Missouri Historical Society Press, 1998), 296.

Transportation

One of the first major advancements in railroad electrification came with the development of the electric streetcar. Several inventors tried to create a viable electric streetcar. In 1883, Leo Daft of Greenville, New Jersey, installed a 120-volt, third rail system about three miles long in Baltimore. A year later, Charles J. Van Depoele, an electrical engineer from Chicago, developed a car using an under-running trolley wheel attached to a weighted pole connecting to an overhead wire.[51] Both systems showed promise, but each had their flaws. Daft's third rail system made pedestrians susceptible to electrocution and, thus, was not safe. The wooden cars Van Depoele built could not withstand the electric motor's weight, resulting in chain slippage failures as the vehicles aged. Frank Julian Sprague, however, designed a successful electric streetcar and distribution system.

Sprague was born in 1857 in Milford, Connecticut. He experimented in his free time and, after resigning from the Navy, became an electrical engineer.[52] Thomas Edison hired Sprague in 1885 to work on his New York Elevated Railroad. He helped develop an experimental electric locomotive and designed the three-point "wheelbarrow" geared suspension that later became standard on many trolley car systems.[53] These developments inspired Sprague to prove streetcar systems could work.

In 1888, Sprague constructed the nation's first large-scale streetcar system in the city of Richmond, Virginia. The system was equipped with forty cars consisting of eighty motors, several miles of track, and a central terminal and expected to cost

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[51] George W. Hilton and John F. Due, *The Electric Interurban Railways in America* (Stanford, CA: Stanford University Press, 1960), 5-6.
[52] Keith Uher, *A History of Land Transportation in the IEEE: From the Age of Electricity to the Computer Age* (Pittsburgh: Carnegie Mellon University Press, 1988), 11.
[53] Ibid., 11.

$110,000.[54] Although Sprague lost approximately $100,000 on the project, the system was greatly successful. Other cities practically replaced their horse cars, the mainstay of street railroads for fifty years, overnight based on Sprague's successes at Richmond. By the end of 1890, 412 transit companies operated 6,732 cars on 3,000 miles of electric railway.[55]

Streetcar operators not only transformed urban transportation, but they also provided an outlet for recreation. Amusement parks developed out of the streetcar operators' desire to use surplus electricity. Streetcar operators did not garner much business over the weekends, since most people did not have to work. The power companies, however, tended to charge the streetcar operators a flat monthly rate for the electricity they used. Building an amusement park at the end of the line created business for the streetcar operators. The excess electricity controlled elaborate lighting displays, impressive merry-go-rounds, Ferris wheels, and rickety roller coasters. The first modern, enclosed amusement park using this model was Paul Boynton's Sea Lion Park at Coney Island in 1895.[56] Several others followed, especially on streetcar lines in the Northeast and Midwest. By 1919 over 1,500 amusement parks existed in the United States, entertaining millions of visitors.[57]

Sprague's streetcar invention eventually led to the development of interurban lines. While similar to streetcars, interurban railroads had different characteristics that set them apart. Interurbans operated on electric power; primarily served passengers; had

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[54] Ibid., 12.
[55] Ibid., 12.
[56] Michael Immerso, *Coney Island: the People's Playground*, (Piscataway, NJ: Rutgers University Press, 2002): 6.
[57] Charles R. Goeldner and J. R. Brent Ritchie, *Tourism: Principles, Practices, Philosophies*, 10th ed. (New York: John Wiley and Sons, 2005): 235.

heavier, faster equipment than city streetcars; and operated on streets in the city, but alongside highways or on private rights-of-way in rural areas.[58] Interurban lines were designed to compete with local passenger service on steam railroads. In many parts of the country steam railroads provided inadequate local passenger service to connect smaller cities with regional hubs. Interurban companies wanted to capitalize on the steam railroads' weakness in providing service between major cities and their immediate surrounding areas. Interurbans had greatest success in attracting traffic from towns ten to forty miles from a major city; they offered service at two-thirds the speed of steam railroads, but with at least four to six times the frequency and at half or two-thirds the fare.[59]

While most regions of the country constructed interurbans, the Midwest relied on them heavily to connect major cities with smaller outlying towns. America's first interurban was the Newark and Granville Street Railway, which operated in Ohio, and began service in December 1889. At its peak around 1908, Ohio had the highest interurban mileage of any state in the country at 2,798. Much of the network connected major cities like Cleveland and Toledo to cities such as Akron, Ashtabula, Canton, Sandusky, and Dayton. Indiana also had a substantial web of interurban lines radiating from Indianapolis, with a network extending 1,825 miles.[60] Other significant networks developed in Michigan, Illinois, Wisconsin, and Iowa, as well. By 1916, the nation had 15,580 miles of interurban lines, with approximately 40 percent located in the Midwest.[61]

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[58] Hilton and Due, 9.
[59] Ibid., 15.
[60] Ibid., 275.
[61] Ibid., 42, 186.

The next form of electrified urban railroads to develop was the elevated electric railroad. The first elevated railroads were cable-powered and constructed in New York City in 1867.[62] Later, other New York lines developed steam powered elevated railroads. Chicago, however, decided to construct an electrically operated elevated line. The Metropolitan West Side Elevated Railway opened its electric elevated line in 1895.[63] The electrified "L's" provided faster service and there were no steam locomotives belching smoke into the city's air. Other cities adopted Chicago's method of electrifying its elevated lines. Boston operated its first electric elevated trains in 1901 and New York electrified all of its "El" trains by 1903.

To operate "L" trains more efficiently, multiple-unit (MU) cars were used. Sprague developed multiple-unit control for elevators in 1893 and applied the same principals to electric trains. The railroad cars were outfitted with the same power and traction equipment of an electric locomotive, but the components were spread throughout each car. Therefore, no locomotive was necessary and a motorman could operate the car or a number of cars from one cab at the beginning of the train. In 1897, the Chicago South Side Elevated Railroad Company owned and successfully operated 120 MU cars.[64] Multiple-unit control cars were adopted quickly on other elevated, subway, and commuter lines, and are still widely used today.

Subways were another major development in the United States. The first subway was completed in London in 1863 and adopted in the U. S. in Boston in 1897. The Boston subway cost $5 million and the initial leg of the 2 ⅔-mile long route connected

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[62] David M. Young, *Chicago Transit: An Illustrated History* (DeKalb: Northern Illinois University Press, 1998), 55.
[63] Ibid.
[64] Michael C. Duffy, *Electric Railways 1880-1990* (Stevenage, UK: IET, 2003), 31.

Park Street terminal with the Boylston-Public Gardens incline.[65] The line operated with four-wheel, open-bench trolley cars, which were common on Boston area streetcar lines of the era. The new service received rave reviews from the press. “The air is good, the temperature is comfortable, and the light-hued walls reflect the glow of many hundreds of incandescent lamps that brightly illuminate it,” one magazine noted.[66]

Within a decade of Boston’s subway construction, other major east coast cities implemented subways for their own use. New York’s first subway line, the Interborough Rapid Transit, which opened October 27, 1904, started at City Hall, ran up the east side under Fourth Avenue, Park Avenue South, and Broadway, and terminated at 145th Street.[67] New Yorkers quickly took to the subway and the city’s two rapid transit systems, the IRT and Brooklyn Rapid Transit, swiftly expanded to meet New York’s demands. By 1920, New York City had the largest rapid transit system in the world with a combined 201.8 route miles of subway and elevated trains.[68] Meanwhile, a transit operator built its own subway line in Philadelphia. On March 4, 1907, the Philadelphia Rapid Transit Company started service on its east-west Market Street Subway-Elevated Line, with service operating through West Philadelphia on elevated tracks before continuing through Center City in a tunnel.[69] With the city’s population predicted to expand further, Philadelphia would need more subways. In 1913, Philadelphia’s Rapid Transit Commissioner recommended expanding its subway system including a line running north and south along Broad Street from approximately Erie Avenue (continuing

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[65] Brian J. Cudahy, *Change at Park Street* Tunnel (Brattleboro, VT: The Stephen Greene Press, 1972), 15.
[66] Ibid.
[67] Gene Sansone, *New York Subways: An Illustrated History of New York City’s Transit Cars* (Baltimore: The Johns Hopkins University Press, 1997), 5.
[68] Clifton Hood, *722 Miles: The Building of the Subways and How They Transformed New York* (Baltimore: The Johns Hopkins University Press, 2004), 159.
[69] SEPTA, *Market-Frankford Subway-Elevated Line*, <http://www.septa.com/inside/history/mfse.html>, accessed June 9, 2009.

north of Erie Avenue as an elevated line) to the Delaware River across from League Island.[70] Philadelphia's Broad Street Subway, however, would not be built for another fifteen years.

Sprague's development proved that electric traction had a future in railroading. Several electric traction companies sprang up around the nation after 1888. Within a quarter century, those figures grew exponentially. By 1913, there were 1,115 electric railway companies controlling 43,043.97 miles of track in the nation.[71] Electricity's promise in railroading looked secure.

Conclusion

The modern miracle of electricity gained widespread use in a variety of applications. It could be used to send messages via telegraph and sound across telephone wires. Once dark streets were now lit with reliable electric lamps and lined with illuminated advertisements. Homes and factories were lighted with Edison's incandescent lamps. Kitchens employed handy new electric toasters and hot plates. People visited the brightly lit amusement parks. Railroads illuminated their terminals with electric lights. Electricity's versatility certainly proved impressive.

Electricity's promise, however, was not limited to lighting streets, brewing coffee, or improving productivity in factories. Transportation, particularly in urban settings, also benefited from electricity's promise. Electrified streetcar lines sprang up all over the nation practically overnight. The technology designed for streetcars led to the development of interurbans, electrified elevated trains and subways. All of these

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[70] "Rapid Transit Lines Recommended for Immediate Construction with Surface Transfer Feeder Lines Operated by Philadelphia Rapid Transit Co.", *Report of Transit Commissioner, City of Philadelphia*, Vol. 2 (1913), Map No. 43.
[71] "Statistics of Electric Railway Companies," *Electric Railway Journal* 42, no. 15 (October 11, 1913): 691.

applications were highly successful. Steam railroads, however, were reluctant to adopt the new technology for use on their own lines. Nonetheless, in some instances electrifying steam railroads was necessary.

Chapter 3

Early Electrification of Steam Railroads

"We believe that is it (sic) becoming very thoroughly recognized that the adoption of electric traction, even for the severest kind of railroad service, involves today nothing in the nature of an experiment," exclaimed an unknown author in the *General Electric Review*, a corporate publication, in 1914.[72] It is not surprising that this belief permeated the halls of General Electric's offices and shops. GE supplied the railroad industry with freight and passenger electric motors for almost twenty years.

During the early twentieth century, steam railroad executives realized the advantages electrification provided over steam. First, electric motors provided greater cleanliness than steam locomotives. Coal was unnecessary and the smoke byproduct was nonexistent. It was virtually essential to paint steam locomotives black to mask the dirt and grime they collected during operation. Although electric motors were initially painted black like their steam counterparts, they could easily be painted in any variety of colors without risk of becoming immediately filthy.

Second, compared to steam locomotives, electric trains provided greater reliability during inclement weather. Steam locomotives had difficulty creating enough heat to sustain sufficient steam pressure for operation when temperatures dropped substantially. Cold temperatures, however, did not affect electric locomotives adversely. Electrics also performed well in the snow. Because of the difficulties encountered with building steam pressure in the cold, steam locomotives hauled shorter trains during snowy weather, resulting in less force to break through snowdrifts and more snowbound trains. Meanwhile, electric locomotives, which were always ready to start at the flick of a

[72] "The Paths of Progress," *General Electric Review*, 17, (November, 1914): 1007.

hand-switch, effortlessly transported longer, heavier trains through the snow without worry.

Third, electrification had the ability to improve operations. Steam locomotives generally needed to stop every one hundred miles for routine repairs, water, fuel, and a crew change. Electric locomotives, however, could travel over a thousand miles without needing any maintenance. Stopping for fuel was unnecessary, since energy flowed to the train's motors from overhead wires or on a third rail next to the track. Crew changes could also be stretched out longer than one hundred miles, since electrics operated faster and with fewer maintenance needs. Such reliability meant electrics could operate over several steam divisions. Railroad electrification promised better scheduling and a more flexible locomotive fleet.

Fourth, with improved operations also came the promise of lower maintenance costs. Electric locomotives did not have any ashes to dump, flues to clean, or boilers to inspect. Engine facilities that were necessary every one hundred miles under steam operations became obsolete. The army of maintenance personnel, from blacksmiths to roundhouse foremen, could be reduced significantly. Additionally, electric locomotives operated more smoothly than steam locomotives, which decreased wear and tear on the track and roadbed.

Finally, passengers reaped the benefits of electrification. The electrics were practically silent. The quieter whirring of the electric motor replaced the louder, more familiar chugging noise of the steam locomotive, making conversation aboard the train easier and more pleasant. Electric motors also diminished the jarring that steam engines normally produced upon acceleration, reducing whiplash for passengers. In addition, steam locomotives obstructed views with the smoke and cinders they expelled. Electrics eliminated the visual impediments, allowing passengers a commanding view of the unfolding landscape. Passengers encountered remarkably greater comfort while traveling on electrified railroad lines.

Early in the twentieth century, railroad company executives realized electrification's advantages. It held the promise of being cleaner, more reliable, and available anytime. Railroads could reduce operating and maintenance costs by switching to electricity. Additionally, passengers would find increased comfort when riding trains hauled by electric motors. Despite all of the wonderful advantages electrification provided, the top brass of most steam railroads opted not to electrify their routes.

Steam railroad officials balked at electrification primarily because of the cost. Some estimates predicted a total cost of $100 million to electrify the entire Pennsylvania Railroad system (which extended roughly from New York and Philadelphia in the east to Chicago and St. Louis in the west) in 1899.[73] Even the "Standard Railroad of the World," as the Pennsylvania branded itself, could not afford to electrify its entire rail network. Because of the huge outlay of capital necessary to operate electric trains, only 3.6 miles of the 190,000-mile steam railroad network in the United States operated under electricity in 1900.[74] Outfitting a steam railroad with a new electrical system required an enormous capital investment.

Nevertheless, a few steam railroad companies implemented electric operations out of necessity during the early 1900s. Some railroads used electric motors to improve

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[73] Albert Shaw, ed., "Electric Railroads Instead of Steam," *The American Monthly Review of Reviews*, 19, no. 1 (January, 1899), 99.
[74] William D. Middleton, "Electrification," in *Encyclopedia of North American Railroads* (Bloomington, IN: Indiana Univeristy Press, 2007), 420.

capacity and abate smoke in tunnels. Railroads entering New York City were obligated to operate electric trains because of severe accidents with steam trains. Other railroads entering urban areas, such as Philadelphia and Oakland, California, needed to improve capacity to avoid costly terminal expansions. Still another adopted electrification to improve service over its mountainous terrain in the Appalachians.

Most of the projects were completed on a small scale, only providing a benefit to a tiny fraction of the railroads' operating systems. Still, the railroads captured some of the major advantages of electrification. The railroads operated trains faster, enhanced safety, increased capacity, reduced maintenance costs, and improved the quality of service, especially for passengers. These small projects, executives hoped, would showcase electricity's advantages to steam railroads and become the incubators for large-scale railroad electrification projects throughout the United States.

Tunnels

The first practical use of electrification on a steam railroad occurred on the Baltimore and Ohio Railroad. The B&O did not have direct rail access to the city of Baltimore, Maryland. B&O trains running between Baltimore and Philadelphia were routed to Locust Point, southeast of downtown Baltimore, where the railroad used a carferry to cross Balitmore's Inner Harbor to Canton. From Canton the trains proceeded north to Philadelphia on the Philadelphia, Wilmington & Baltimore Railroad, a Pennsylvania Railroad subsidiary. During the 1880s, however, the PRR refused to let B&O trains operate on the PW&B tracks, forcing the Baltimore and Ohio to construct its own line to Philadelphia. As the traffic increased between Baltimore and Philadelphia it was clear that B&O's carferry service was inadequate. The B&O resolved to excavate a tunnel underneath the Inner Harbor to connect Baltimore and its line to Philadelphia.[75]

During the early 1890s, engineers constructed a seven-mile belt line from downtown Baltimore's Camden Station north and east to a junction with the B&O's Philadelphia route at Waverly, giving the railroad a route into the city. A portion of the line from north of Camden Station needed a 7,000-foot tunnel, bored on a difficult 0.9 percent grade, beneath Howard Street.[76] Adequate ventilation could not be provided, however, for steam locomotives to operate on the heavy grade. After considering alternatives, the B&O contracted with the General Electric Company to electrify the Howard Street Tunnel in 1892.

The wires in the Howard Street Tunnel went live on July 1, 1895. Engineers installed a 600-volt direct current system using an unusual system of a single pantograph collecting current from inverted iron troughs. General Electric supplied a 96-ton locomotive comprised of two semi-permanently coupled units with 360-horsepower motors mounted on each of the locomotive's four axles.[77] The new motive power proved successful, as the motors hauled trains as heavy as 1,200 tons through the tunnel. The first practical steam railroad electrification became a success. It would take a little more than a decade, however, for another steam railroad to electrify its tunnel operations.

The Grand Trunk Railway experienced capacity issues at the St. Clair Tunnel during the early 1900s. The GT completed the 6,032-foot tunnel, located about sixty

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[75] John F. Stover, *The History of the Baltimore and Ohio* (West Lafayette, IN: Purdue University Press, 1995): 172.
[76] Michael Bezilla, *Electric Traction on the Pennsylvania Railroad, 1895-1968* (University Park: The Pennsylvania State University Press, 1980): 5-6.
[77] Ibid., 6.

miles north of Detroit, between Port Huron, Michigan, and Sarnia, Ontario, in 1890.[78] The tunnel was designed to handle 750-ton steam-hauled freight trains. Nonetheless, the locomotives' noxious gases, proved troublesome. On the morning of October 9, 1904, a GT freight train broke apart in the tunnel, leaving a portion of the train, including train crew members, inside. The train's locomotive crew entered the tunnel twice to retrieve cars without properly ventilating the tunnel. Eventually, the locomotive became stuck inside the tunnel, because the engineer was overcome with smoke and could not operate his locomotive. As the engine was stuck inside the tunnel longer, the noxious fumes increased . The conductors and brakemen in the caboose on the portion of the train that broke apart inside the tunnel, presumably unaware of the locomotive crew's plight, were unable to get out of the tunnel in time and suffocated. Once the smoke finally cleared officials found the remains of six train crew members in the tunnel.[79] The accident ultimately led the GT to explore tunnel electrification.

In May 1908, the GT completed the electrification of the St. Clair Tunnel. Railroad engineers outfitted the tunnel with 3,300-volt single-phase electric power and utilized six, 66-ton, 1,500 horsepower Baldwin-Westinghouse locomotives.[80] One thousand-ton trains easily operated with electric motors became commonplace in the tunnel. The new locomotives increased the tunnel's capacity without adding any track and eliminated the risk of asphyxiation to railroad crews.

The Great Northern Railway also experienced major headaches on a section of its main line through the Cascade Tunnel. Located about one hundred miles east of Seattle,

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[78] R. L. Herman, "St. Clair Tunnel Operation Most Successful." *Railway Electrical Engineer*, 12, no. 1 (January 1921): 21.

[79] Canada Department of Labour, "Disaster in the St. Clair Tunnel, Ont.," *The Labour Gazette*, 5, no. 5 (November, 1904): 514.

[80] Walter D. Hall, "Results of Six Years Heavy Haulage." *The Electric Journal* (December, 1915), 542.

Washington, the Cascade Tunnel became a bottleneck for the GN. The railroad operated heavy freight trains on the steep Cascade Mountain grades, ranging from 1.7 percent inside the tunnel to 2.2 percent in the yards located at each end of the tunnel. In many cases, two to four steam locomotives operating at a top speed of eight miles per hour were necessary to haul the trains through the mountains and the tunnel.[81] The tunnel quickly filled with noxious fumes, and soot made the rails slick, creating harrowing conditions for train crews. The GN had no option but to utilize electric locomotives to increase capacity and improve safety at the Cascade Tunnel.

The GN's plans called for an alternating current distribution system. Engineers at the GN preferred AC to Direct Current for several reasons.[82] AC motor and control was electrically and mechanically simple; the motors withstood greater abuse and rough use. AC motors also provided greater continuous output than DC motors. Additionally, AC motors provided uniform torque, which DC motors could not. Finally, AC systems were conducive to regenerative braking on down grades because AC motors did not require additional components on the locomotive.[83]

Work on the four-mile electrification project began in 1908. The GN used a 6,600-volt, three-phase AC distribution system, utilizing two trolley wires and the

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[81] General Electric Company, "The Electrification of the Cascade Tunnel of the Great Northern Railway Company," Bulletin No. 4755 (Schnectady, NY: General Electric Company, June, 1910), 1.

[82] AC had several advantages over DC. AC used transformers to step the voltage up or down, which made it ideal for transmitting over long distances and for train operations. DC was more difficult to transmit over long distances, which required closer substation spacing. AC substations were also simpler because they used transformers to step down the voltage. AC also was more efficient for power transmission, motors, and easily used regenerative braking. AC, however, was more complex and expensive to install than DC. In addition, the AC motors on electric locomotives were heavier, increasingly complex, and more expensive than DC motors. Despite its expense, as AC technology improved during the twentieth century DC fell out of favor for railroad use. For more information on AC and DC electrification of North American railroads see Middleton, "Electrification," 404-421.

[83] General Electric Company, "The Electrification of the Cascade Tunnel of the Great Northern Railway Company," 13.

running rails for the three phases of current.[84] The GN favored the overhead type of construction rather than the third rail because of the lower overall costs.[85] Additionally, since the third rail was located beside the track instead of overhead as the trolley wires were placed, GN leadership found unattractive the difficulty in removing the third rail from the tunnel in the event of an emergency (e.g., rescuing passengers from the tunnel during a train derailment). With the completion of the electrification, the GN pioneered AC use in tunnel and heavy mountain grade applications.

By the summer of 1909, the Cascade Tunnel was ready for electric train service. Current flowed on track two at the Cascade Tunnel starting June 22 and the GN tested the four new AC electric locomotives from General Electric. On July 1, the first electrically operated trains through the tunnel included a 480-ton freight train and a passenger train hauling ten coaches, two steam engines, and two electrics.[86] All trains through the Cascade Tunnel operated with electric locomotives by February 1910. AC traction successfully replaced steam locomotives at the Cascade Tunnel.

Prior to 1910, the Michigan Central Railroad faced difficulties with car ferries between Detroit, Michigan, and Windsor, Ontario. The car ferries took valuable time in transferring rolling stock across the Detroit River, each trip usually taking a half-hour to load freight cars onto the car ferry, cross the river, and unload the cars for waiting trains. The average capacity of each boat was eighteen freight cars, requiring three or four car ferries for many trains.[87] By 1905, the MC's four car ferries handled 1,097 freight and

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[84] Great Northern Railway Company Engineering Department, "Description of Overhead Construction, Cascade Electrification, Great Northern Ry.", September 23, 1909, Box 2, B-13-6-1-1-1, RBC.
[85] "Overhead Trolley," letter, circa 1908, Box 2, B-13-6-1-1-1, RBC.
[86] Reinier Beeuwkes, "Log of Operation from June 22nd to Aug. 18th," Report on Cascade Tunnel Electrification to Dr. Cary T. Hutchinson, August 19, 1909, Box 2, B-13-6-1-9-2, RBC.
[87] "The Electrical Equipment of the Detroit River Tunnel – I," *Electric Railway Journal* 37, no. 2 (January 14, 1911), 62.

passenger cars each day.[88] In addition, ice hampered the car ferries' operations during winter months. In some of the worst conditions car ferries became stuck in the ice; the MC had to send freight across the Detroit River on sleighs; or the MC lost the business and turned over the traffic to the GT for delivery via the St. Clair Tunnel. All of these scenarios created the potential for serious delays or lost business.

To expedite trains across the Detroit River and avoid weather-related service interruptions, the Michigan Central constructed a double track tunnel underneath the waterway in 1910. Since using steam locomotives in the tunnel would take too long to ventilate, the railroad utilized three-phase, sixty-hertz, 4,400-volt DC distributed through a third rail. To power the trains, GE and the American Locomotive Company teamed up to create a locomotive equipped with four 300 horsepower GE-209 motors. The locomotives were the most powerful DC machines ever constructed.[89]

By June 1910, the Detroit River Tunnel was ready for limited operations. The MC took the final car ferries out of service and converted all operations to the tunnels on October 16, 1910.[90] The MC designed the tunnel to handle 247,200 tons of cargo per day.[91] The railroad, however, only operated the tunnel at about half capacity. After witnessing the major time and cost savings the tunnel provided, the MC's leadership was confident that the competing railroads would want to use the Detroit River Tunnel and exit the car ferry business. The MC encouraged other railroads in the Detroit area to use the tunnel; the additional traffic would approximately double the scheduled number of trains and tonnage, thus operating the Detroit River Tunnel at full capacity and bringing

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[88] George W. Hilton, *The Great Lakes Car Ferries* (Berkeley, CA: Howell-North Books), 33.
[89] "*The Electrical Equipment*," 67.
[90] Hilton, 34.
[91] "*The Electrical Equipment*," 63.

in more business to the Michigan Central.[92] Other railroads in the area, including the Canadian Pacific, Grand Trunk, Wabash, and Pere Marquette, operated Detroit River car ferries. Only one railroad, the Canadian Pacific, took up the MC's offer, mainly because the CP's railroad tracks paralleled the MC's in Windsor. The remaining railroads operating ferries across the Detroit River clung to their car ferries well into the twentieth century.

Capacity issues also plagued the Boston and Maine Railroad's Hoosac Tunnel in northwestern Massachusetts. Construction of the 25,031-foot Hoosac Tunnel began in 1851 and finally ended in 1875. Engineers constructed a 1,100-foot shaft in the middle of the tunnel extending to the top of the mountain for ventilation purposes.[93] After traffic volumes increased during the first decade of the twentieth century, however, the Hoosac Tunnel could not handle the vast number of steam locomotives necessary to haul the tonnage. Ventilation was the main problem, but condensed steam on the rails proved worrisome, as well. In one instance, an engineer of a passenger train did not realize his train had stopped in the tunnel. He allowed the driving wheels to slip until an official signaled to him from the baggage car that the train had come to a stop.[94] The B&M determined electrification would be the solution to the tunnel's safety issues and capacity constraints.

The 7.92-mile Hoosac Tunnel electrification project was completed in 1911. The B&M adopted the New Haven Railroad's arrangement of a single-phase alternating

[92] Ibid.
[93] Westinghouse Electric & Manufacturing Company, *The Hoosac Tunnel Electrification* (East Pittsburgh, PA: Westinghouse Electric & Manufacturing Company, February 1930), 1.
[94] L.C. Winship, "The Electrified Hoosac Tunnel," *The Electric Journal* (October 1914), 509.

current system using overhead catenary construction and 25-cycle, 11,000-volt current.[95] Additionally, the B&M installed block signals during the electrification process, which doubled the tunnel's capacity. Using seven 1,350-horsepower Baldwin-Westinghouse motors, service improved in the tunnel almost immediately. Under electrification, the railroad could haul trains at fifteen-minute intervals through the Hoosac Tunnel, which would have been impossible under steam operation. No longer did B&M train crews waste time waiting for smoke and gas to clear from the tunnel. Without electrification, the B&M simply could not have handled such a high volume of traffic moving through the Hoosac Tunnel.

Urban Terminals and Commuter Service

Railroading in New York City changed forever on January 8, 1902. A New Haven Railroad commuter train from Danbury, Connecticut, was headed for Grand Central Station when it stopped for a red signal at the Park Avenue Tunnel, just short of its final destination. Meanwhile, a New York Central & Hudson River Railroad inbound morning commuter train from White Plains, New York, approached from behind and plowed halfway through the rear car of the New Haven train. Sixty people were trapped in the wreckage, prompting the fire department to saw through the wooden cars to rescue passengers. Fifteen people died in the accident, including several who were scalded to death by the locomotive's boiler. John Wisker, the engineer on the NYC&HRRR train, reported he was unable to see the smoke-obscured stop signal, thus causing his train to smash into rear of the New Haven train. The Park Avenue Tunnel accident was one of the city's worst railroad disasters.[96]

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[95] Westinghouse Electric & Manufacturing Company, *The Hoosac Tunnel Electrification*, 1.
[96] "Fifteen Killed in Rear End Collision," *New York Times*, January 9, 1902.

A month later, on February 7, the New York State Railroad Commission issued its findings on the Park Avenue Tunnel disaster. The commission determined that Wisker was inexperienced and, since he missed or could not see the signals, should have stopped his train in any event. Meanwhile, the commission found the NYC&HRRR grossly negligent in having an inexperienced engineer at the throttle and for failing to keep pace with improving terminal facilities in Manhattan based on yearly traffic increases. The commission also suggested that electric motors should replace steam locomotives in the Park Avenue Tunnel.[97] The commission's recommendation did not fall on deaf ears. The New York State Legislature shortly afterwards enacted legislation prohibiting the use of steam locomotives in the Park Avenue Tunnel south of the Harlem River after July 1, 1908. The two railroads most affected by the new law, the New York Central and Hudson River and the New Haven, quickly drew up plans for electrifying their routes into Manhattan.

Although intent on meeting legal requirements, the NYC&HRRR ambitiously electrified its New York suburban services. Plans called for electrifying its twenty-four-mile line from Grand Central Station to North White Plains and another twenty-eight-mile line from Mott Haven (located in the Bronx and the junction with the line between Grand Central Station and North White Plains) along the Hudson River to South Croton, New York.[98] A commission of experts, which included the inventor of the streetcar, Frank J. Sprague, recommended the system should operate with 660-volts, direct current, and use a protective third rail. The commission took a conservative approach and used this distribution system because it had been thoroughly tried and tested in several

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[97] "State Railroad Board Censures N. Y. Central," *The New York Times*, February 8, 1902.
[98] New York Electrical Society, "268th Meeting of the New York Electrical Society Visit to the Port Morris Power Station, Saturday Afternoon, May 25th, 1907: Descriptive Data," Box 20, 4-6-1-4, RBC.

applications. Furthermore, overhead wires could not be used because of legal obstacles and restricted clearances.[99]

The NYCHR&RR purchased new equipment for the electrified service. General Electric delivered the first forty-seven electric locomotives, known as the class "S" locomotives, between 1906 and 1909. Each locomotive was equipped with four gearless motors, and at each end a four-wheel guiding truck.[100] The railroad also purchased an additional 161 multiple-unit cars for commuter service.[101]

The electrification was completed well ahead of the legislature's deadline. The first scheduled NYC&HRRR multiple-unit trains began service in December 1906 and electric locomotive trains started operating in February 1907.[102] Despite the increased capacity and improved safety afforded to the electric trains, Edwin B. Katte, Chief Engineer of Electric Traction for the NYCHR&RR, lamented the circumstances under which electrification was completed:

> Electric operation in the case of the New York Central and Hudson River Railroad was not a choice; it was a necessity and was not installed with the hope of effecting any economy in operation, but to permit trains to enter New York City under Park Avenue without smoke and to make possible the new Grand Central Terminal. The property owners along Park Avenue have benefited financially more by the change in motive power than has the railroad company.[103]

While the public benefited from safer trains, smoke abatement, and increased property values, the NYCHR&RR was obligated to bear the capital and operating costs of complying with New York State's legislative burden.

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[99] General Electric Company, *The New York Central Electrification* (Schenectady, NY: General Electric Company, January 1929), 5.
[100] Ibid.
[101] New York Electrical Society, "268th Meeting of the New York Electrical Society Visit to the Port Morris Power Station, Saturday Afternoon, May 25th, 1907: Descriptive Data," RBC.
[102] General Electric Company, *The New York Central Electrification*, 4.
[103] Edwin B. Katte, "Multiple Unit Train Service on the New York Central and Hudson River Railroad," *General Electric Review* (November 1914):1025.

In the meantime, the New Haven made plans to electrify its line between Stamford, Connecticut, and Woodlawn Junction, the meeting point with the NYC&HRRR's line into Grand Central. The New Haven became a pioneer in the field of alternating current when, in 1905, the railroad contracted with Westinghouse to install an 11,000-volt, single-phase AC system over the twenty-one mile route.[104] The New Haven also took delivery of the first AC locomotives Westinghouse built, the EP-1. The locomotives, weighing in at 102 tons and generating 1,420 horsepower, were also designed to work on the NYC&HRRR's DC electrification between Woodlawn Junction and Grand Central, utilizing a third rail shoe on the side of the engine to collect the current.[105] Because the New Haven was the first steam railroad to employ an AC distribution system and motors, it became a major novelty of its day.

Construction of the historic system began in 1905 and the overhead wire from Cos Cob, Connecticut, to New York was energized in April 1907.[106] A few months later on July 24, the first trains rolled under electric power. As with virtually any new technology, problems ensued. The EP-1s tended to oscillate from side to side at high speeds and the overhead contact wire was too rigid, which interfered with current collection. Furthermore, the New Haven's powerhouse at Cos Cob overheated when operating at two-thirds capacity.[107] These issues and other less significant glitches were corrected immediately. Despite the growing pains, the new electrification program permitted the New Haven to accommodate increasing interstate freight, passenger, and

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[104] Bezilla, 37.
[105] Ibid., 38.
[106] "IEEE History Center: Alternating Current Electrification of the New York, New Haven, and Hartford Railroad, 1907," IEEE, <http://www.ieee.org/web/aboutus/history_center/alternating_current.html>; Accessed April 18, 2009.
[107] Bezilla, 37.

commuter traffic demands without having to expand its four-track mainline, providing considerable value to the region.[108]

During the late 1890s, the PRR wanted a direct route into New York City. For a number of years the PRR disembarked New York-bound passengers at Exchange Place, located across the Hudson River in New Jersey, and ferried the travelers to lower Manhattan. Ferrying travelers, which could take fifteen minutes to an hour depending upon the weather, was a major inconvenience.[109] The PRR's main competitor for New York passenger traffic, the New York Central, had a direct route into midtown Manhattan, giving the rival the upper hand in terms of access and efficiency. PRR executives could not let the NYC continue indefinitely with such an advantage.

In 1902, PRR engineers finalized plans to bore tunnels beneath the Hudson River into Manhattan. The new subaqueous tunnels needed electric trains because steam locomotives would have been too dangerous to operate and the City of New York officials barred steam locomotives from ruining the atmosphere in Manhattan.[110] Therefore, the PRR chose a 650-volt, third rail, DC distribution system for the tunnels. The railroad purchased its electric motors from Westinghouse. The Class DD1, a two-unit set, contained a total of 3,160 continuous horsepower, making it the world's most powerful locomotive.[111] The new motors were ready when PRR opened the Hudson River Tunnels in 1910.

Another railroad serving New York City, the Long Island Railroad, considered electrification for a number of years. Government officials wanted the Long Island to

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[108] IEEE.
[109] Bezilla, 10.
[110] Ibid., 18.
[111] Ibid., 48.

improve air quality along its route. Moreover, with the line's traffic density reaching 100 million passengers annually, installing electrification merited serious consideration.[112] Action finally came when the prestigious and affluent Pennsylvania Railroad purchased a controlling interest in the LIRR in 1900, giving the smaller road an infusion of capital to embark on the long-awaited electrification project.[113]

The Long Island electrified its line into New York with a 650-volt, DC, third-rail distribution system in 1905. The Long Island electrified forty-four miles of line from Brooklyn east to Far Rockaway, making it the longest steam railroad conversion in the United States. The new trains attracted greater ridership, so that by 1912 the LIRR doubled the amount of electrified route-miles to eighty-nine and operated four hundred multiple-unit cars.[114] The successful electrification of the Long Island's lines increased patronage and cleaned up the smog hanging over much of the New York metropolitan area.

Around the same time electric operations commenced on the railroads of New York City, another steam railroad electrification project was completed in New Jersey. The West Jersey and Seashore Railroad, a Pennsylvania Railroad subsidiary, electrified its sixty-five-mile mainline between Camden and Atlantic City, as well as a ten-mile branch line between Newfield and Millville.[115] Railroad officials elected to electrify the double track route because of its high traffic volumes and because electrification could increase the line's capacity without installing additional track.

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[112] Ibid., 29.
[113] Ibid., 15.
[114] Ibid., 29.
[115] General Electric Company, "The Electrification of the West Jersey & Seashore Railroad" (Schenectady, NY: General Electric Company, May, 1907), 3.

Skillfully and safely, the General Electric engineers and laborers completed the West Jersey and Seashore electrification in record time. Engineers selected the site for the power house on January 17, 1906, and the workers drove the first pile two days later.[116] Despite the railroad's heavy traffic volumes, laborers spent the winter and spring precisely installing the 650-volt, third rail distribution system along the double track line. Meanwhile, GE constructed sixty-two multiple-unit passenger cars and six combination baggage and mail cars each containing two GE-69 motors rated at two hundred horsepower.[117] On July 1, the WJ&S operated its first train with current from the power house.[118]

The electrified route provided many scheduling advantages for the WJ&S. Initially, the electrified operations included a three-car express train between Camden and Atlantic City at one-hour intervals, with local service to intermediate stations running at a minimum of fifteen-minute intervals. After a few months, however, the WJ&S determined it could better utilize its newfound capacity. The railroad began operating three-car express trains between Camden and Atlantic City on fifteen-minute headways at sixty miles per hour, as well as operating the local service with two-car trains between Camden and Millville running at half-hourly intervals, and single-cars between Camden and Woodbury at ten-minute intervals.[119] The increased capacity electricity allowed helped the WJ&S to run more express and local trains on tighter schedules.

After the successful electrification of its Hudson River Tunnels in 1910, the Pennsylvania Railroad pondered stringing wires along its commuter service route from

[116] Ibid.
[117] Ibid., 21.
[118] Ibid., 3.
[119] Ibid., 4.

Philadelphia to Paoli, Pennsylvania. The PRR had a major congestion problem at its Broad Street Station in downtown Philadelphia. Commuter traffic grew substantially on the PRR during the first decade of the twentieth century. In 1911, nearly six hundred trains a day used a station designed to handle 160.[120] Enlarging the station would not be an option, since real estate prices in downtown Philadelphia were at a premium and adding more tracks to an already cluttered landscape would have been difficult. Electrification was the cheapest method to increase capacity at Broad Street.

The PRR installed an 11,000-volt, single-phase AC system. Instead of generating their own electricity as the majority of electrified steam railroads did at the time, the PRR asked the Philadelphia Electric Company to provide the power for the Paoli electrification. The PRR based its decision on the Philadelphia Electric's contract to furnish the Philadelphia Rapid Transit Company with 25-cycle alternating current for its streetcar and subway operations.[121] The PRR needed the same type of current for its operations that the Philadelphia Electric generated for the PRTC. After careful analysis by both parties, Philadelphia Electric agreed to supply the PRR with the power the railroad needed for its distribution system in 1914.

In 1915, the new electrification was almost ready for operation. The railroad only needed to finish getting the commuter cars ready for electrified service. PRR's engineers designed the P54 series coaches for use on suburban steam trains, but could easily modify them for multiple-unit train service. Before the electrification project was nearly completed, the railroad sent ninety-three P54s back to its Altoona, Pennsylvania, shops to be modified with a powered truck containing two 255-horsepower Westinghouse traction

[120] Bezilla., 57.
[121] Ibid., 64.

motors, which were the largest and most powerful that the railroad could fit between the wheels of these cars, and reclassified them as MP54s.[122] The trains were ready for service.

The Pennsylvania energized all twenty route miles between Broad Street and Paoli for the first time on September 4, 1915.[123] Regular service, however, started on September 11 with a run between Paoli and Broad Street. The trains quickly proved to be a remarkable success. Because the electric trains needed less time to accelerate than the steam trains, the PRR modified the running time of the schedule within a few months. The PRR reduced the eastbound running times between Paoli and Broad Street from fifty-nine to forty-nine minutes.[124] The electrics maintained an on-time performance record of 90 percent compared to 80 percent for the steam trains they replaced. Electrification allowed the PRR to offer faster train schedules and better on-time performance, which helped alleviate the capacity issue at Broad Street Station.

The East Coast railroads were not alone in their quest to electrify suburban routes. Out on the Pacific Coast in 1908, Edward H. Harriman, president of the Southern Pacific Railroad, planned the electrification of the railroad's commuter lines from Oakland to Alameda and Berkeley, California. The SP installed a 1,200-volt DC overhead system over its 49.6-mile East Bay railroad network.[125] When completed in 1912, the SP was the first railroad in the nation to install a high-voltage, DC overhead system.[126] The railroad purchased sixty multiple-unit cars to handle the commuter service, but eventually

[122] Ibid., 69.
[123] Ibid.
[124] Ibid., 71.
[125] Middleton, 421.
[126] Don J. Hofsommer, *The Southern Pacific, 1901-1985*, (College Station: Texas A&M University Press, 1986), 60.

bought eighty more as ridership increased. Passengers used the SP's electrified service extensively. The railroad handled over six hundred electric trains daily at its Oakland Mole terminal during its peak in the early 1920s, making SP's electrified commuter rail service one of the most heavily used in the country.[127]

Mountain Railroading

Electrifying steam railroads operating over mountain ranges seemed like an obvious choice, because many operated heavy trains carrying ore or coal on steep grades reaching 2 percent. Electric locomotives improved operations, allowing one locomotive to pull heavier trains than two steam locomotives could, and at a faster pace. Two railroads, the Butte, Anaconda, and Pacific and the Norfolk and Western, electrified sections of their mainline to take advantage of electricity's benefits.

The Butte, Anaconda, and Pacific considered electrifying its mainline to reduce operating costs in 1910. The railroad's primary business came from handling the heavy copper ore trains from the Butte, Montana, mines to the smelters thirty-seven miles northwest at Anaconda. It was with the economy argument that General Electric, desiring to showcase its direct current technology in hopes of advancing sales, convinced BA&P management that the railroad would move more tonnage at a lower cost with electricity.[128] Persuaded that electrification would be successful on the BA&P, the management awarded GE the contract in 1911.

Construction on the BA&P electrification began in 1912. Because the BA&P hauled heavy copper ore trains over the Rocky Mountains, the railroad utilized 2,400

[127] Ibid., 121.
[128] Charles V. Mutschler, *Wired for Success: The Butte, Anaconda & Pacific Railway, 1892-1985* (Pullman: Washington State University Press, 2002), 63.

volts, direct current, on the route. The BA&P's distribution system was the largest of its kind in the United States and far more powerful than those of its eastern counterparts. In addition, GE equipped the railroad with seventeen eighty-ton locomotives, each equipped with four three hundred-horsepower motors.[129] By October 1913, the first electric trains over the BA&P were ready to roll.

For the first test, railroad officials assigned the electrics to the copper ore runs operating from East Anaconda over the 1.1 percent grade at Smelter Hill to the Washoe concentrator, a distance of seven miles. To break in the electrics the BA&P started the motors off hauling sixteen-car trains up Smelter Hill, the same number of cars the steam locomotives pulled. The electrics pulled the heavy sixteen-car trains up to the concentrator in about half the amount of time as their steam counterpart, resulting with 128 cars delivered to the concentrator per shift, versus ninety-six loads under steam power.[130] After passing the test, the BA&P added an extra ten cars to each Smelter Hill ore train, which the electrics handled effortlessly, and later did the same with mainline trains. Electrification improved operations on the BA&P and determined their usefulness in mountain railroading.

The West Virginia coal fields, located in the Appalachian Mountains, provided another opportunity for electrification. The Norfolk and Western struggled with capacity issues on its mainline north of Bluefield, located near the southern tip of West Virginia on the border with Virginia. The railroad did what it could to improve capacity through conventional means by adding a second track and, in some cases, a third track. There were other issues, however, that affected capacity. Several branch lines spurred off to

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[129] Ibid., 65.
[130] Ibid., 68.

coal mines, which provided the bulk of the N&W's traffic. Using switching locomotives, train crews gathered loaded coal hoppers from the branches and stored them at yards along the mainline. Unfortunately, these operations, while necessary, snarled traffic on the mainline. Additionally, the N&W battled heavy grades that sometimes reached 2 percent, and 60 percent of the line was on curves, the maximum being 12 degrees.[131] Because of these conditions, coal drags crawled through the mountains at the average speed of 7.5 miles per hour. Electrification appeared to be the solution to the N&W's capacity problems.

In 1915, the N&W electrified its mainline from Bluefield northwest to Vivian, West Virginia, a distance of thirty miles, using an 11,000-volt, single-phase, 25-hertz, AC system. The railroad purchased twelve Baldwin-Westinghouse locomotives, weighing 135-tons each, to propel the trains over the line. The electric motors easily outperformed steam over the mountain grades. Three steam locomotives used to pull coal trains, weighing 3,250 tons, up the grade.[132] Under wires, three electric engines hauled a 4,800-ton train over the division.[133] Furthermore, the N&W electrics were designed to tow the heavy coal trains almost twice as fast as their steam counterparts, reaching breakneck speeds of fourteen miles per hour. N&W's electrification improved the line's ability to handle additional, heavier trains quickly and easily.

Conclusion

Electrification improved tunnel operations significantly. Subaqueous tunnels allowed railroads to avoid the time consuming process of transferring cars and passengers to ferries and the delays resulting from hazardous weather conditions. Capacity and

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[131] "The Norfolk & Western Electrification," *Electric Railway Journal* 45, no. 23 (June 5, 1915): 1058.
[132] Ibid., 1059.
[133] Ibid.

safety improved in mountain tunnels, since trains no longer needed to wait for smoke to clear before proceeding. No longer would there be any worries about train crews and passengers asphyxiating on noxious gases if the train became stuck inside the tunnel.

Urban areas were one of the major benefactors of steam railroad electrification, especially New York and Philadelphia. Billowing smoke no longer polluted business districts. Furthermore, with no exhaust to impair the view of signals, electric trains improved the engineer's visibility of the indicators, creating safer trains. Quiet electric motors silently handled trains through neighborhoods, creating a more pleasant atmosphere for occupants near the railroad tracks and improving property values. Additionally, more trains could be operated and at faster running speeds.

Electrification also showed promise on mountain railroads. Electric motors could move trains through the mountain districts faster than they could with steam locomotives. Heavy trains no longer needed to be broken into two sections to be hauled over the mountains, and, in some cases, more cars were added. In addition, coupling two electrics to help a train over a mountain pass was more efficient than operating with two steam locomotives, since one crew could run both electric locomotives, while an engine crew was required for each steam locomotive.

Whether it was tunnels, urban terminals, or mountain passes, electric operations promised improved safety and reduced congestion. Most of the electrification projects until 1915, however, were done out of necessity. Smoke abatement laws prohibited the steam engine's use in New York City. Steam railroads could not realistically operate subaqueous tunnels without electric motors. Capacity issues forced railroads with high traffic volumes in urban areas to use electric motors. Furthermore, electrification projects in mountain tunnels and on mountain passes were affected by capacity concerns. Only one railroad, however, attempted an electrification project based mainly on economics and did it on a magnitude never challenged before: The Chicago, Milwaukee, and St. Paul Railroad.

Chapter 4

The Milwaukee Electrification

During the early 1900s, as other railroads on the East Coast electrified out of necessity, the Milwaukee looked at the possibility of electrifying their newly constructed "Pacific Coast Extension" out of economy. The Milwaukee built a line to the West Coast through Montana, Idaho, and Washington, a region full of resources and economic promise. One of the primary resources in the area was "white coal": rushing mountain streams that could generate electricity. By the early 1910s Washington and Montana developed several hydroelectric power plants. The Milwaukee executives, trying to preserve capital after constructing the "Pacific Coast Extension," looked for ways to cut costs. One option management considered was electrifying its operations on the new route. Prior to delving into the Milwaukee's electrification project, however, some background on the Chicago, Milwaukee, and St. Paul Railroad's Pacific Coast Extension is necessary.

The Pacific Coast Extension

In 1900, the Chicago, Milwaukee, and St. Paul Railroad was thriving. The railroad was financially sound and well-managed. By 1901, the CM&StP had a 6,500-mile rail network connecting Chicago with Wisconsin, the Upper Peninsula of Michigan, Minnesota, Iowa, Nebraska, and the Dakotas. Like most Midwest railroads it, too, was a Granger road, which meant that it primarily hauled agricultural goods from its numerous rural branch lines to the markets in Minneapolis and Chicago. The Milwaukee, as it was nicknamed, was doing well for itself.

Nonetheless, the Milwaukee's top brass did not want to be another Granger road. Unsatisfied, the executives set their sights on the Pacific Coast. The northern Great Plains and the Pacific Northwest were growing at an extraordinary rate. It was mining and agricultural country, a land where hydroelectric power use grew rapidly and many irrigation projects were underway.[134] Furthermore, Seattle, Washington, was a growing port city serving Alaska and the developing Asian markets. The Great Northern and Northern Pacific handled the lucrative traffic that came into the Port of Seattle, including highly prized raw silk shipments from China and Japan. The raw silk (with each shipment valued at approximately $1 million) had to be shipped expeditiously to the East Coast on trains operating faster than passenger trains to be spun into hosiery and clothing before it rotted.[135] The Milwaukee wanted a cut of the profitable business in the Pacific Northwest.

James J. Hill's railroads, the Great Northern and the Northern Pacific (collectively known as "The Hill Lines"), which served the northern tier region between St. Paul, Minnesota, and Seattle, aggressively pursued merging with a connecting railroad between St. Paul and the booming rail terminus of Chicago during the 1890s. Several options were available, including the Chicago and Northwestern; the Chicago, Rock Island, and Pacific; the Wisconsin Central; the Chicago Great Western; the Chicago, Milwaukee, and St. Paul; and the Chicago, Burlington, and Quincy. Hill, however, narrowed his choices

[134] August Derleth, *The Milwaukee Road: Its First Hundred Years* (Iowa City: University of Iowa Press, 2002), 167.
[135] Monroe Woolley, "The Race of the Silk Specials," *The Technical World Magazine*, 22, no. 3 (November 1914): 369.

to the Milwaukee and the CB&Q. Hill favored the CB&Q and J. P. Morgan, co-owner of the Northern Pacific, preferred the Milwaukee.[136]

While the CB&Q had a longer route between St. Paul and Chicago, the railroad paired better with the Hill Lines than the Milwaukee. The Hill Lines could interchange Seattle to Chicago trains with the CB&Q at St. Paul or Billings, Montana, 850 miles to the west.[137] Interchanging traffic at Billings would, in essence, short haul the GN and NP, meaning the Hill Lines would make less money on Seattle to Chicago traffic if they handed it over to the CB&Q in Montana rather than at St. Paul. On the other hand, if the Hill Lines purchased the CB&Q and turned over the traffic at Billings instead of St. Paul, the profits would return to the Hill Lines in the form of stock dividends from the CB&Q. The Burlington, therefore, won out as the favored route to Chicago. By the end of 1901, the Hill Lines purchased $108 million, or 96.79 percent, of the CB&Q stock.[138]

Milwaukee executives were frustrated when the Hill Lines purchased the CB&Q. After the Hill Lines' rejection, Milwaukee executives planned an extension to the Pacific Coast. As early as 1901, the railroad made preliminary investigations into constructing a line to the Pacific. One of the lines considered was farther south through Nebraska, Wyoming, and out to California, the states in which the Union Pacific and Southern Pacific railroads operated. Meanwhile, the Milwaukee executives contemplated another line farther north in the territory served by the Hill Lines.[139] After the GN and NP slighted the CM&StP, the Milwaukee officials determined to compete with the Hill Lines in the Pacific Northwest.

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[136] Louis Renz, *The History of the Northern Pacific Railroad*, (Fairfield, WA: Ye Galleon Press, 1980), 209.
[137] Ibid.
[138] Ibid., 210.
[139] H. H. Field, *History of Milwaukee Railroad: 1892-1940*, n.p., 114.

Milwaukee executives quietly geared up for construction. In 1902, the Milwaukee consulted an engineer about duplicating the NP line and estimated the cost at $45 million. Still, Albert J. Earling, the CM&StP's president, increased the estimate to $60 million, in an effort to allow for unforeseen expenses.[140] Unfortunately, the CM&StP had a major disadvantage. Unlike all the previous transcontinental railroads, the Milwaukee did not depend on any land grants from the United States government. Instead, the Milwaukee executives purchased all the real estate it needed to construct the line to Puget Sound. In 1904, the company inconspicuously acquired land in Seattle and Tacoma for terminal purposes and purchased land for rights-of-way between South Dakota and Puget Sound.[141] Despite the disadvantage, the Milwaukee's executives forged ahead with their plans. The railroad was finally ready to go public with its intentions.

On December 1, 1905, the Milwaukee announced its decision to build a route to the Pacific and construction began in April 1906. Most of the work was relatively easy and progressed rapidly. The line began at the Missouri River in Mobridge, South Dakota, 400 miles west of St. Paul. The line pushed west through the plains of southeastern Montana to Miles City. From there the line headed west to the central Montana town of Harlowton and then southwest through Three Forks. From Three Forks the route tracked northwest to the mining center at Butte and the western Montana college town of Missoula. The railroad then continued west through the Bitterroot Mountains and the northern panhandle of Idaho before bypassing the eastern Washington city of Spokane to the south. The line crossed central Washington via the towns of Othello and Ellensburg,

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[140] Charles R. Wood and Dorothy M. Wood, *Milwaukee Road West* (Seattle: Superior Publishing Co., 1972), 29.
[141] Field, 114.

passed over the Cascade Range, and terminated in the Puget Sound cities of Seattle and Tacoma. The CM&StP also constructed a branch line from Three Forks to Gallatin Gateway, Montana (located seventy-five miles north of West Yellowstone, Montana), for Yellowstone National Park vacationers. In addition, the Milwaukee constructed branch lines to serve customers in major cities, such as Spokane and the north central Montana industrial center of Great Falls. Because the line bypassed the few cities between St. Paul and Seattle, the CM&StP had the shortest and fastest route between Chicago and Puget Sound at 2,195 miles.[142]

Freight and passenger operation between Mobridge and Butte commenced on August 20, 1908.[143] However, some projects took more time to complete. Flooding, for example, washed out one hundred miles of roadbed in Hell Gate Canyon, located just east of Missoula, in October 1908. Meanwhile, the St. Paul Pass Tunnel, located on the Idaho-Montana border, took longer to complete than anticipated and was finished in February 1909.[144] Track laying concluded May 14, 1909, and, while most of the terminal facilities along the route were incomplete, the Milwaukee opened the Pacific Coast Extension for freight service on July 1, 1909.

The Milwaukee executives risked financial failure during the Pacific Coast Extension's construction. President Earling's 1902 cost estimates were not even close.

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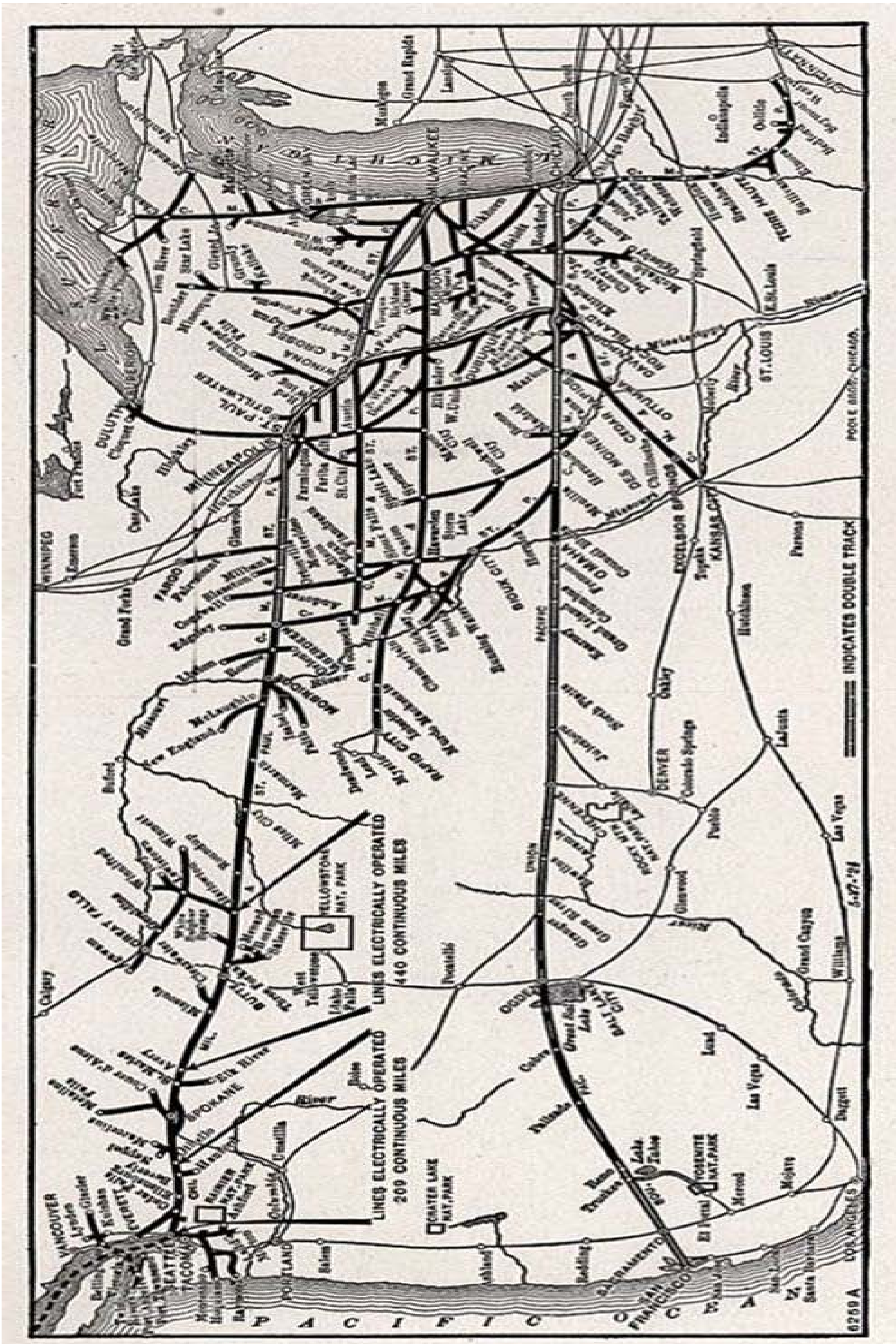
[142] Frederick W. Hyde, *The Milwaukee Road* (Denver: Hyrail Productions, 1990), 157.
[143] Insely J. Brain, Jr., *The Milwaukee Road Electrification* (San Mateo, CA: The Bay Area Electric Railroad Association and the Western Railroader, 1961), 5.
[144] Ibid.


LINES ELECTRICALLY OPERATED
440 CONTINUOUS MILES
LINES ELECTRICALLY OPERATED
209 CONTINUOUS MILES
INDICATES DOUBLE TRACK
YELLOWSTONE NAT. PARK
CRATER LAKE NAT. PARK
YOSEMITE NAT. PARK
SPOKANE
MINNEAPOLIS
ST. PAUL
MILWAUKEE
CHICAGO
KANSAS CITY
ST. LOUIS
DENVER
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Preceding Page: Chicago, Milwaukee & St. Paul Railway Map, circa 1920, (Advertising Ephemera Collection - Database #A0573 [pages 23-24], Emergence of Advertising On-Line Project, John W. Hartman Center for Sales, Advertising & Marketing History, Duke University Rare Book, Manuscript, and Special Collections Library, <http://library.duke.edu/digitalcollections/eaa/>).

By 1912, the total cost of the Pacific Coast Extension was almost $268 million, a figure over four times the original estimates.[145] Furthermore, in 1913, the Chicago, Milwaukee, and Puget Sound Railroad, the railroad incorporated to build the Pacific Coast Extension for the Chicago, Milwaukee, and St. Paul, was folded into the parent company, which assumed the CM&PS's $156 million bond debt used to finance the construction.[146] Despite increasing tonnage from 1.5 million in 1910 to 2.7 million in 1912, the CM&PS's net operating revenues were $6.6 million and the total bond interest outstanding was around $7 million.[147] The Milwaukee's executives could not even afford to pay the bondholders. Building the Pacific Coast Extension proved costly for the Milwaukee and the line's executives looked for ways to cut expenses. One option was electrification.

Initial Interest in Electrification

The Milwaukee showed interest in electrifying portions of the Pacific Coast Extension early on. In 1904, right-of-way agents purchased parcels of land for substations and power generating plants along the proposed route.[148] In 1907, the Milwaukee executives publicized its intentions to electrify a fifty-four mile portion of its uncompleted mainline through the Bitterroot Mountains in Montana.[149] The CM&StP's officials, however, held off electrifying its route and tried steam locomotives instead.

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[145] Chicago, Milwaukee, & Puget Sound Railway Company, *Annual Report For the Fiscal Year Ending June 30th, 1912* (Chicago: Chicago, Milwaukee and Puget Sound Railway Company, 1912), 27.
[146] Ibid., 13.
[147] Ibid., 7, 27; *Annual Report For the Fiscal Year Ending June 30th, 1911* (Chicago: Chicago, Milwaukee and Puget Sound Railway Company, 1911), 21.
[148] Field, 114.
[149] "Electric Link in St. Paul Extension," *The New York Times*, September 28, 1907, 12.

To haul the tonnage on the Pacific Coast Extension and its branches, the Milwaukee utilized over four hundred steam locomotives. The railroad pushed the limits of steam locomotive technology in the Rocky Mountains, using oil burning 2-6-6-2 steam locomotives, typically known as Mallets in the railroad industry, on freight trains. The Mallets were powerful locomotives and operated well in other regions, but served poorly in the Rocky Mountains. The severe grades, ranging up to 2 percent, and several ten-degree curves resulted in slow operating speeds, usually no more than eight miles per hour. Additionally, temperatures sometimes reached lows of forty degrees below zero during the depths of winter, resulting in engine failures or the inability to generate steam. The Milwaukee needed more powerful and reliable locomotives to make the operations in the Rockies a greater success and profitable.

In February 1910, C. A. Goodnow, assistant to the vice president of the Milwaukee, inspected the Great Northern's Cascade Tunnel electrification with the CM&StP's electrician and master mechanic. The Milwaukee men confided to Reinier Beeuwkes, GN's supervisor of the electrification work at the tunnel (and later the Milwaukee's electrical engineer in charge of its electrification), that the CM&StP was considering a major electrification project, but wanted to confirm the major investment in electric traction would be justified. The GN was not handling full freight trains under electricity at the time of Goodnow's visit. Goodnow and his men, however, left the Cascade Tunnel impressed with the GN's, and Beeuwkes's, work.[150]

After Goodnow's Cascade Tunnel visit, the Milwaukee further explored its electrification plans. The Milwaukee brass approved a study of electrification between

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[150] Reinier Beeuwkes, Letter to Dr. Cary T. Hutchinson, from Scenic, Washington, February 20, 1910, Box 2, B-13-6-1-9-2, RBC.

Harlowton and Deer Lodge, Montana, located thirty-seven miles north of Butte. In July 1910, GE released its study and indicated the total cost of electrifying the Rocky Mountain Division at $4,003,000.[151] The study also predicted an average savings of $643,300 per year over the current steam operations, resulting in a 16 percent return on the $4 million investment in electrification.[152] Based on the results of the study, the costs justified investment. Early in 1913, the Milwaukee announced the decision to electrify the Three Forks-Deer Lodge subdivision over the Rocky Mountains.[153] The Milwaukee was going to take the plunge into electrified railroading, becoming the first major railroad to install an extensive electrification project based solely on cost savings.

Planning the Electrification

The Milwaukee had to come up with a source of electricity to operate its trains. Early on, Montana was the site of hydroelectric technology advancement . Hydroelectric power development in Montana started during the early 1880s when a businessman from Minneapolis, Paris Gibson, noticed the Missouri River fell almost seven hundred feet between Great Falls and Fort Benton, a distance of forty-eight miles.[154] By the early twentieth century, there were several major companies producing hydroelectric power in Montana, including the Butte Electric and Power Company; the Madison River Power Company; the Great Falls Water Power and Townsite Company; and the Missouri River Power Company. The Missouri River Power Company attracted great attention in engineering circles when it became the first to transmit more than 50,000 volts over a

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[151] General Electric, *Chicago, Milwaukee & Puget Sound Railway Engineering Report on the Electrification of the Rocky Mountain Division*, July 11, 1910, Milwaukee Road Archives, <http://milwaukeeroadarchives.com/Electrification/EngineeringReport1910.pdf>, accessed July 28, 2009, 16.
[152] Ibid., 46.
[153] Jim Scribbins, *Milwaukee Road Remembered* (Minneapolis: University of Minnesota Press, 2008), 138.
[154] Fredric L. Quivik, "Early Steel Transmission Towers and Energy for Montana's Copper Industry," *Montana: The Magazine of Western History*, 38, no. 4 (Autumn 1988): 67.

long distance – sixty-five miles from the Missouri River near Helena to Butte.[155] During the same time the mining industries around Butte grew more dependent on a reliable source of electricity, as well. John D. Ryan immediately set out to find an electrical power source for the mining interests.

Ryan was born in 1864 in Michigan's Upper Peninsula near Houghton. In 1890, he followed his older brother, William, to Denver where he honed his promotional skills as a lubricating oil salesman. After Ryan inherited his brother's assets upon his death around 1900, he invested in the Daly Bank & Trust Company in Butte in 1901, becoming bank president within a year. After gaining considerable stature in the Butte business community, Ryan was named Anaconda Company president in 1905 and, three years later, was elected to the Amalgamated Copper Company's board of directors.[156] During 1908 he also became involved with Montana's burgeoning hydroelectricity business.

The railroad magnate James J. Hill owned the Great Falls Water Power and Townsite Company. Hill grew impatient waiting for his investment on the Missouri River to mature and sold the company to Ryan in 1908. Next, Ryan's engineers designed a new dam and powerhouse at Rainbow Falls, 130 miles north of Butte.[157] The Rainbow Falls hydroelectric plant opened in 1910 and had the highest generating capacity in Montana. The Rainbow Falls generators created 6,600 volts, which were boosted to 102,000 volts and sent to Butte via high tension wires, becoming one of the first transmission systems of its kind in the United States.[158]

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[155] Ibid., 68.
[156] Carrie Johnson, "Electrical Power, Copper and John D. Ryan," *Montana: The Magazine of Western History*, 38, no. 4 (Autumn 1988): 26-28.
[157] Quivik, 69.
[158] Ibid.

Ryan catered mostly to industries and mining companies that were eager to electrify their operations. One of the first major contracts Ryan secured was with the Anaconda Company to provide power for a new electrolytic zinc plant at Great Falls around 1910. Ryan, however, was enthusiastic to create more business for his hydroelectric plant and targeted the Milwaukee as a potential customer for his company's product. Ryan focused on securing an electrification contract with the Milwaukee. In 1909, Ryan was appointed to the Milwaukee's board of directors. Three years after his appointment to the Milwaukee's board, the railroad came to an agreement with Ryan's Great Falls Power Company on a 99-year power contract. In 1913, the railroad entered a similar contract with the Thompson Falls Power Company, of which Ryan also had an interest.[159]

While Ryan's inclusion on the boards of the power companies and the railroad appears as a conflict of interest, he withheld from wielding undue influence on the Milwaukee board members during the debates concerning electrification. As a member of the Milwaukee board of directors, Ryan advised the executives on the economies of railroad electrification, especially those obtained from buying the power from a central station rather than generating the electricity in its own plants. Ryan did act, however, in the power company's interest in making the contracts for the CM&StP.[160] Therefore, Ryan's influence on the Milwaukee board concerning the issue of electrification was advisory in nature, while his true interests laid in securing the best contract possible for the power companies. Besides, the railroad initially purchased land along its right-of-

[159] August Derleth, *The Milwaukee Road: Its First Hundred Years* (New York: Creative Age Press, 1948), 189-190.
[160] Ibid., 190.

way to generate electricity and construct substations, leading one to believe the railroad intended to electrify once electrical engineers perfected the technology.

With the power contract secured, the Milwaukee sought proposals for the initial Three Forks to Deer Loge electrification. In 1914, the General Electric Company, having designed a distribution system that worked well for the Butte, Anaconda, and Pacific Railroad, submitted a proposal. General Electric's engineers were careful in recommending a three thousand-volt DC distribution system. First, the system was similar to the BA&P's 2,400-volt DC system. Although the Milwaukee's locomotives would be operating at approximately 20 percent greater voltage than the BA&P's 160-ton locomotives, GE engineer A. H. Armstrong believed adopting the higher voltage did not "over step the limits of conservative engineering as reflected by the operating and designing experience" of the era.[161] In addition, GE engineers thought "no other combination of distribution system and locomotive construction offered the same promise of reliability, efficiency and general adaptability to meet all the requirements of freight and passenger main line operation."[162] The 3,000-volt, DC system was a successful, proven power distribution system and, therefore, there was no need to experiment with any alternatives. Additionally, the Milwaukee had better motive power options if they opted for 3,000-volt DC, including geared axle motors like the BA&P used and gearless motors, which were successful on the New York Central's electrified suburban passenger

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[161] A. H. Armstrong, Letter to C. A. Goodnow. July 9th, 1914, Schenectady, NY. General Electric Company's "Proposal for Electrification of Rocky Mountain Division, Three Forks-Deer Lodge" Papers, K. Ross Toole Archives, Maureen and Mike Mansfield Library, The University of Montana-Missoula,1.

[162] General Electric Company, *Chicago, Milwaukee & St. Paul Railway Puget Sound Lines Proposal for Electrification of Rocky Mountain Division, Three Forks – Deer Lodge* (Schenectady, NY: General Electric Company, 1914), K. Ross Toole Archives, Maureen and Mike Mansfield Library, The University of Montana-Missoula, 6.

service in New York.[163] Furthermore, GE's engineers were experienced with 3,000-volt DC systems. While a 6,000-volt DC system could be practical for railroad use, it would be novel and there would most likely be a number of delays in implementing the higher voltage system. Besides, GE's operating success and factory tests on a 3,000-volt DC system meant it could "make guarantees of performance that we have every reason to believe can be immediately fulfilled without subjecting your Company (the Milwaukee) to the expense and annoyance of perfecting new and untried types of apparatus."[164] The 3,000-volt DC system would be the most prudent choice for the Milwaukee.

GE's proposal to the Milwaukee estimated the grand total for the installation would be $3,397,242.[165] This included all electrical apparatus, materials, labor, substation buildings, overhead, and track construction. It did not include, however, the cost of transforming the line's block signals from direct current to alternating current, which was necessary to prevent interference. The proposal also did not allow for contingent or unexpected expenses other than the 10 percent added to outside construction work, and it assumed that no abnormal labor conditions, such as a strike, would be encountered.[166] Milwaukee executives approved GE's proposal and authorized work to begin the following year.

Construction

The Milwaukee began installing the distribution and transmission systems between Deer Lodge and Alberton, Montana (thirty miles northwest of Missoula), on July 24, 1915. The railroad started first by distributing poles for both systems along the line

[163] Ibid., 9.
[164] Ibid. 10.
[165] Ibid., 13.
[166] Ibid.

and having crews follow behind to erect them. Next, in November and December, crews began bonding and stringing feeder wires. Bonding stopped for the winter on December 11, however, because of bad weather, and picked up again the following April. By April 1916, crews started installing the trolley wires. Experiencing few difficulties despite a harsh winter and heavy traffic volumes, all work on the distribution and transmission systems between Deer Lodge and Alberton was completed on August 20, 1916.[167]

Meanwhile, installation crews started work on the route between Alberton and Avery, Idaho in October 1915. This stretch of track, however, proved to be one of the most difficult for construction crews to install the distribution and transmission system:

> West of St. Regis the line is one succession of curves, tunnels and viaducts, the longest tunnel being through the Bitter Root Mountains at East Portal. Because of the deep snow in the Bitter Roots poles could not be distributed until the spring of 1916. As soon as the snow disappeared sufficiently in May 1916, the work on trolley pole erecting was started each way from East Portal. As soon as possible thereafter trolley and feeder stringing crews arrived and started to build both ways down the mountain. Progress was extremely slow due to heavy freight traffic, tunnel lining work trains at St. Paul Pass tunnel, and the distance between sidings on the mountain side. In many instances a crew could not build one mile of trolley per week.[168]

The crews also experienced set backs due to avalanches, clearing timber, and spending time to prepare extra surveys of Forest Department lands where transmission lines made short cuts. The installers persevered and completed the distribution and transmission systems on February 23, 1917.

The railroad also installed the power distribution system. Engineers constructed the power transmission lines, carrying 100,000 volts, from the hydroelectric power plants and generally followed the Milwaukee's right-of-way, which allowed the railroad's

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[167] Electrification Department, "Cost Harlowton, Mont. To Avery, Ida.," *Electrification Costs*, Chicago, Milwaukee & St. Paul Railway Company, Circa October, 1917, 148, Box 13, B-13-10-18-9-1, RBC.
[168] Ibid.

electrical department to inspect and maintain the lines more easily. In some cases, however, engineers constructed the lines on private land in order to save distance or because of physical conditions.

The transmission line poles were constructed with some of the best materials in the Northwest. Engineers installed wood poles made from Idaho cedar and utilized cross arms of Washington fir. The railroad preferred these materials for its poles, since each wood provided sufficient strength under extreme load conditions and offered good protection from wind, snow, and sleet. Each pole was approximately forty-five to fifty feet in height, depending on the grading, and spaced 300 to 450 feet apart.[169] The spacing provided enough distance to connect the wires without putting too much strain on the poles.

The Milwaukee used two technological advances on its transmission and overhead contact systems. First, the railroad used special wiring techniques on its transmission lines. Wires tend to sag based on variations in temperatures and lengths of span. To avoid overstraining during harsh weather conditions, engineers carefully calculated the wires for various lengths.[170] The railroad also selected wires that could handle the extreme conditions of the Rocky Mountains. The actual mechanical strength of the wires averaged 5,220 pounds even though the Milwaukee's engineers assumed the maximum stress under the worst conditions possible would be 2,500 pounds.[171] The wires also retained mechanical strength when the railroad opted not to solder when splicing or jointing the wires. Soldering heats and softens the wires, which in turn

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[169] R. E. Wade, "The Transmission System of The Rocky Mountain and Missoula Divisions Electrification," *The Milwaukee Railway System Employees' Magazine*, 3, no. 5 (August 1915): 12.
[170] Ibid., 13.
[171] Ibid., 14.

reduces mechanical strength. Instead, the railroad passed the wires to be joined through a special tubular copper sleeve, which improved the joint's aesthetic qualities, as well as its electrical and mechanical properties.[172]

Second, the Milwaukee revolutionized the overhead contact system design. The system comprised of a messenger wire, which is located immediately above and supported the trolley wires. Where the Milwaukee departed from convention, however, was the addition of a second trolley wire. The wires hung side by side and used staggered hangers, allowing the wires to move vertically and horizontally. This meant a flexible section of wire always contacted the locomotive's current collector.[173] Such an installation permitted the current collector to gather more electricity at a higher speed and without sparking.[174] Additionally, the ground-breaking system provided improved current flow despite differences in track quality and locomotive sway.

Substations

The Milwaukee built fourteen substations along its electrified district in the Rocky Mountain and Missoula Divisions and spaced them an average distance of thirty-three miles apart.[175] Varying the distances between the substations any more than thirty-three miles would have increased the costs, since larger machines or copper sizes would have been necessary. Engineers built the substations with the most modern of construction methods. Each of the permanent structures utilized a concrete foundation, a brick superstructure, and concrete roofs supported by steel purlins and trusses.[176] The

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[172] Ibid.
[173] R. E. Wade, "The Feeder and Overhead Contact Systems of the Rocky Mountain and Missoula Divisions," *The Milwaukee Railway System Employes' Magazine*, 3, no. 6 (September 1915): 15.
[174] Ibid.
[175] F. B. Walker, "The Substation Plants of the Rocky Mountain and Missoula Divisions," *The Milwaukee Railway System Employes' Magazine*, 3, no. 7 (October 1915): 12, RBC.
[176] Ibid.

substations also featured two rooms, one for the transformers and another for the motor generators. Because the substations had a secondary function as depots, the generator room featured a substation operator's office, ticket counter, and waiting area, as well. In addition, since most of the substations were located in remote mountain locations, the Milwaukee built bungalow style houses at each location, allowing the substation operators and their families to live together full-time.

The substations' main purpose was to receive the 100,000-volt AC electricity supplied by the power plants via the transmission lines and convert it to 3,000-volt DC power for the electric locomotives. The 100,000-volt AC power initially passed through the substation's transformers, which stepped down the current to 2,300 volts AC using oil switches. The transformers needed oil switches to prevent the great flash, which could be dangerous for substation operators, that would follow if opened in the air.[177] About sixty-five barrels of oil were used to cool the oil switches and the complete transformer weighed twenty-eight tons.[178]

After stepping down the power to 2,300 volts AC in the transformers, the electricity flowed to the motor generators. The Milwaukee ordered nine 1,500-kilowatt and twenty-three 2,000-kilowatt DC motor generators from General Electric.[179] The motors generators turned the 2,300-volt AC current delivered from the transformers into the 3,000-volt DC current needed to propel the Milwaukee's electric locomotives. Each of the substations contained a minimum of two motor generators, but some substations contained more. For example, the substations at Piedmont and Janney were equipped

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[177] Ibid, 11.
[178] Ibid., 12.
[179] F.C. Helms and C. M. Fulk, "Description of the 1500- and 2000-kw., 3000-volt D-C. Motor-Generator sets of the Chicago, Milwaukee, & St. Paul Railway," *GE Review* (November 1916): 980.

with three 1,500-kilowatt motor generator sets and the East Portal substation, the largest in the electrified district, was equipped with three 2,000-kilowatt motor generator sets. Steeper grades and longer distances between substations required railroad officials to construct larger substations at these locations. All of the remaining substations between Harlowton and Deer Lodge used two 2,000-kilowatt motor generator sets.[180] The GE motor generators were revolutionary. Engineers fabricated the motor generators for 3,000-volt DC operation, which no other railroad had used before. In addition, GE designed the motor generators for heavy overloads during direct operation and reverse operation, when regenerative braking was in use, providing greater evenness in the varying load factors throughout the day.[181]

The Milwaukee incorporated an important technology into its substations: GE's recently developed high-speed circuit breakers. Ordinary switchboard circuit breakers required 0.1 to 0.15 seconds to take effect. The Milwaukee's circuit breakers could be released in 0.003 seconds, several times faster than typical circuit breakers.[182] While a tenth of second may not seem like a long time, the use of high-speed circuit breakers was an important safeguard that prevented extensive damage to the Milwaukee's generating equipment. After the substations stepped down and converted the power from 100,000-volts AC to 3,000-volts DC, the energy flowed from the substation to the feeder wires and into the overhead contact wires, where it was delivered to the locomotives.

Locomotives

The Milwaukee contracted with GE to provide forty-two new electric locomotives.

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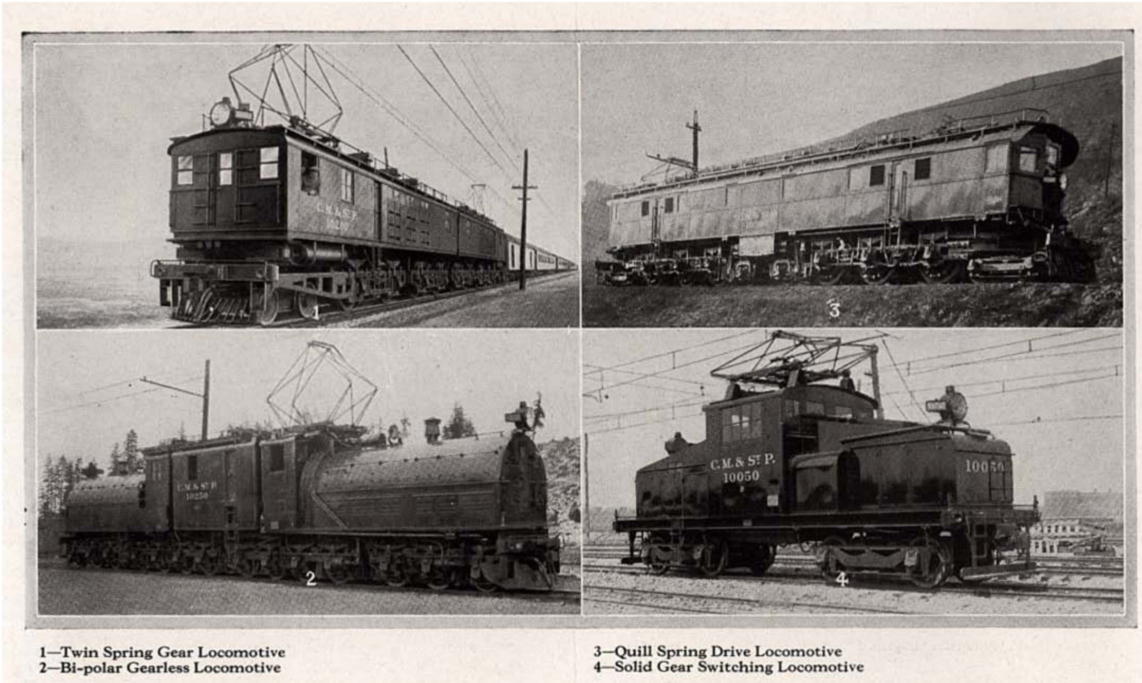
[180] Walker, 12.
[181] F.C. Helms and C. M. Fulk, 980.
[182] C. H. Hill, "High Speed Circuit Breakers for Chicago, Milwaukee & St. Paul Electrification, *General Electric Review*, 21, no. 9 (September 1918): 623.



Examples of the Milwaukee's electric locomotives, circa 1920 (Advertising Ephemera Collection - Database #A0573 [pages 21-22], Emergence of Advertising On-Line Project, John W. Hartman Center for Sales, Advertising & Marketing History, Duke University Rare Book, Manuscript, and Special Collections Library, <http://library.duke.edu/digitalcollections/eaa/>).

On September 25, 1915, the first shipment was made of what the Milwaukee billed as "The Most Powerful Electric Locomotive Ever Built." The CM&StP, like proud parents of a newborn child, flaunted the new motors. Throngs of spectators gathered to examine the latest in technology from General Electric. An estimated 10,000 people gathered near Chicago Union Station on October 6, 1915, to view the locomotive.[183] Over 25,000 spectators marveled at the new technology as the motor made its way west through Milwaukee, Minneapolis, Butte, Seattle, and other cities along the line.

GE supplied the Milwaukee with some of the most technologically advanced locomotives on the market. The 3,440 horsepower, 3,000-volt, DC locomotives, classified by the Milwaukee as EF1's, utilized axle-mounted, 396-horsepower GE-253

[183] E.S. Johnson, "The First 3,000-Volt Locomotive for the Chicago, Milwaukee & St. Paul Railway Company," *General Electric Review*, 18, No. 12 (December, 1915): 1157.

motors, which were the largest geared motors available.[184] Additionally, the locomotives were among the largest ever built, weighing in at 288 tons and 112 feet in length. Because the locomotives were so long, the carbodies and motors were mounted on duplicate sections and coupled together. If necessary, the complete locomotive could be uncoupled from its duplicate parts and be used separately for lighter service in marshaling yards or local passenger service. Each locomotive had a maximum tractive effort of 132,500 pounds, providing ample strength to power the Milwaukee's trains across the Rockies.[185] The Milwaukee used the EF1's in both freight and passenger service (classified as EP1 for passenger service); twelve of the forty-two locomotives were geared for passenger train operation.

Instead of using trolleys, the Milwaukee outfitted the EF1 with pantographs to collect the overhead current. Trolleys were common on lighter electric lines, such as streetcars and interurbans. The former steam railroads, however, preferred using pantographs.[186] There were several advantages to using pantographs to collect current from the overhead wires. The train crew would not have to raise or lower a pantograph when changing directions. Pantographs did not have wheels that train crews needed to replace when passing over crossings or switches. In addition, trolley wheels broke easily, which damaged frogs. Crews found it difficult to replace trolley wheels at night or during inclement weather, as well. Furthermore, pantographs were safer than trolleys, because pantographs never left the wires, resulting in fewer opportunities for the train to

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[184] E. D. Priest, "The Motor Used on the 300-ton Locomotives of the Chicago, Milwaukee & St. Paul Railway," *General Electric Review* (November 1916): 937.

[185] A. F. Batchelder, "The Mechanical Features of the Locomotives of the Chicago, Milwaukee & St. Paul Main Line Service," *General Electric Review* (November 1916), 929.

[186] One notable exception to pantograph use was the Great Northern's Cascade Tunnel electrification. GN experimented with trolleys for its three-phase, AC locomotives when the electrification opened, but, due to several problems with trolley damage, eventually converted its locomotives to pantographs.

break in two. Finally, the power supply never cut off when switching tracks while using pantographs.[187] Given that the Milwaukee's electric trains operated under the extreme topographical and weather conditions in the Rocky Mountains, using pantographs was a wise decision.

Regenerative Braking

The Milwaukee pioneered the use of regenerative braking in DC-propelled locomotives. Regeneration occurred when the electric locomotive recovered energy on descending grades. When a train using steam or diesel locomotives descends a grade, the stored energy created by gravity has to be dissipated and is typically done so with air brakes. General Electric, the builder of Milwaukee's locomotives, found a way to turn the motors into generators. The motors, therefore, absorb the descending train's energy and convert it to electricity.

One of the functions of regenerative braking is to slow down the train without using air brakes. Braking a conventional train in mountainous territory stresses the brake shoes on the freight cars, which can cause them to overheat. Regenerative braking prevents overheating, since the air brakes are unnecessary to stop the train. In addition, regenerative braking reduced the stress on drawbars and couplings, because the entire train was bunched behind the locomotive and held to the same speed.[188] This makes for a smooth and easy descent compared to the uneven speed and jerkiness of slowing down using air brakes.

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[187] Reinier Beeuwkes, Letter to Alex Stewart, regarding the use of pantographs on trolley wires in Cascade Tunnel (1st page missing), December 29, 1909, Box 2, B-13-6-1-9-3, RBC.

[188] W. D. Bearce, "The Electrification of the Mountain District of the Chicago, Milwaukee & St. Paul Railway," *General Electric Review* (November 1916): 927.

The other major function of regenerative braking was to produce electricity that could be returned to the overhead system on descending grades. Engineers estimated that a steam train weighing 2,500 tons descending a 2 percent grade at seventeen miles per hour wasted 3,500 kilowatts, or 4,700 horsepower, of energy.[189] An electric locomotive using regenerative braking while hauling the same train on a descending grade sent the power that otherwise was wasted on a steam-powered train back into the overhead wires. The electricity was used to power other trains along the line. If no other trains were operating to absorb the power generated by a descending train, the power passed through the substations and converted from direct current to alternating current. From there, the electricity would either be sent into the railroad's transmission lines or be given back to the Montana Power Company (the company that bought John D. Ryan's Great Falls Water Power and Townsite Company in 1912). The railroad received a credit for any surplus power absorbed into the MPC's power grid.

Since regenerative braking had never been tried on a DC locomotive, CM&StP officials were still uncertain if it would work when the Milwaukee's electrification opened. The Milwaukee tested the locomotives on the Butte, Anaconda, and Pacific's electrified lines on November 13, 1915. Locomotive 10201 operated a train consisting of sixty-five ore cars, one caboose, and one business car - a total weight of 4,943 tons - from Rocker Station (three miles west of Butte) to the railroad yard at Anaconda, Montana, a distance of approximately twenty-two miles, without the use of air brakes.[190] With several officials from GE, the BA&P, and the CM&StP onboard for the historic test run, George Spaulding, traveling engineer for the Milwaukee, guided the train downgrade at a

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[189] Ibid.

[190] "Test of Rengerative Braking," *The Milwaukee Road Employe's Magazine*, 3, no. 9 (December, 1915): 21.

speed of twenty-five miles per hour and slowed the train to four miles per hour upon approaching Anaconda Yard and returned 2,100 kilowatts of power to the substation in the process.[191] Company officials onboard the train noticed no jarring action and the train was not in any danger of breaking in half during the test run. The test run was extremely successful, proving DC locomotives could be equipped with regenerative braking technology just as easily as AC motors.

Light Signals

Electrification also affected the railroad's signaling technology. Initially, the Milwaukee used DC, right-hand semaphore signals on 135 miles of the 440-mile electrified district. These signals proved disadvantageous to the new operations. Semaphore signals used colored lenses, which passed back and forth in front of a light to indicate the signal, and a blade attached to the lens indicated which position the signal was in if the light was burned out. Installation of wires along the right side of the track reduced clearance for the blades and obstructed the engineer's view of the semaphore signals, which were also installed on the right side of the track. Additionally, the 3,000-volt, DC used to propel the trains interfered with the DC track currents operating the semaphores, causing the signals to malfunction. Due to these problems, light signals were necessary in the electrified zone.[192]

Light signals were well-suited for service on the Rocky Mountain Division. They did not need as much clearance as semaphore signals and could be located inside the trolley poles where the view was obstructed less. Additionally, the gray and brown colors of the rocks on the mountainsides generally made a good background for light

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[191] Ibid.

[192] L. B. Porter, "Light Signals on C., M. & St. P.," *Railway Signal Engineer*, 10, no. 9 (September 1917): 256.

signals compared to semaphore signals. Since curves on mountain ranges are generally shorter, light signals, using deflecting prisms to spread the light through a wide angle, could be easier for the engine crew to view than a semaphore signal, as well.[193] Therefore, the Milwaukee adopted light signals for its electrified territory.

Former CM&StP ABS light signal at Missoula, MT, March 24, 2009 (Photo by the Author).

Adding light signals also paved the way for the completion of an automatic block system, or ABS. In an automatic block system, sections of the mainline between sidings or stations are divided into blocks, which are generally about one to two miles in length, or the stopping distance of a train. The signals are controlled by the weight of the train. A home signal, located at the beginning and end of each siding, controls the distant signals, which are located at the beginning and end of each block between a pair of sidings. When a train leaves the siding to enter the mainline headed for the next siding or station, other trains behind it will not be allowed to proceed until the first train clears the first block. Once the first train completely clears the block at full speed, a following train may approach the previously occupied block at a slow, or restricted, speed. ABS permitted more trains to traverse a given section of the mainline instead of waiting for the station agent at the next station to confirm that the first train arrived safely before the second train could proceed. ABS also delayed the costly expense of double tracking, such as in the Milwaukee's case, by increasing capacity on single track lines 20 percent.[194]

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[193] Ibid.
[194] Everett Edgar King, *Railway Signaling*, 1st Ed. (New York: McGraw-Hill Book Company, 1921), 249.

United Switch & Signal Company provided the signaling equipment for the Milwaukee and the road's signal engineering department handled the installation process. By September 1919, the CM&StP replaced all of the DC semaphore signals and an additional twenty-mile stretch of track west from Butte to Finlen, Montana, was placed in service. When the installation was finally completed at an estimated cost of $683,000, the Milwaukee's mainline had continuous ABS light signals from Harlowton, Montana, to Seattle and Tacoma, a distance of 886 miles.[195]

Divisional Organization

Electrification also prompted the reorganization of the divisional structure at the Milwaukee. Before electrification, the Rocky Mountain and Missoula Divisions operated separately and each were approximately two hundred miles in length. The divisions needed to be short because steam locomotives could not operate over long distances without needing maintenance. Each division had its own personnel, including one superintendent, dispatchers, and trainmasters, among others . There were also two freight subdivisions with individual engine terminals for steam locomotive maintenance and a separate helper service for train operating across steep mountain grades. Since electric locomotives could operate longer distance without requiring maintenance, the Milwaukee changed the divisional organization.

After electrification in 1916, the Milwaukee combined the two divisions to form the Rocky Mountain-Missoula Division. As part of this process, the railroad made several personnel changes and modified the division's organizational structure. For example, the CM&StP combined the two divisions under one superintendent. The trainmasters' positions for each division were abolished and the trainmasters became

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[195] L. B. Porter, "Light Signals on C., M. & St. P.," 256.

assistant superintendents. Additionally, the railroad retained only one dispatcher for the entire division.[196]

Because the work of installing and operating an electrified railroad system was very different from the traditional steam operations, the CM&StP hired Reinier Beeuwkes to fill the position of electrical engineer. Beeuwkes graduated from Johns Hopkins University in 1899 with a degree in electrical engineering. From 1899 to 1902 he participated in the GE Schenectady Test in upstate New York, where he performed electrical generator tests on several projects. Beeuwkes also worked on the New York Central and Hudson River Railroad electrification project as an assistant electrical engineer in 1904 and was the electrical engineer in charge of the Great Northern's Cascade Tunnel electrification in 1908. In 1911, Beeuwkes moved on to supervise the installation of a telpherage system at the Missouri-Kansas-Texas Railroad's Freight House, in St. Louis, Missouri. The telpherage system, designed to carry cargo on small overhead cranes to different parts of the Freight House, was the first of its kind installed to handle freight at railroad terminal.[197] When the CM&StP hired Beeuwkes as the railroad's electrical engineer in 1914, he directed the new Electrical Department and consulted the Milwaukee's executives and divisional officers in all matters pertaining to the electrical installation and operation.[198]

The railroad also created entirely new positions and departments pertaining to electrification. For example, the Milwaukee needed substation operators. The Electrical

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[196] Chicago, Milwaukee & St. Paul Railroad Electrical Department. *Report on the major changes in the divisional organizations of the Electrified Divisions of the C. M. & St. P. Ry. due to electrification*, February 26, 1923, Box 9, B-13-10-16-10-1, RBC, 3.
[197] "M., K. & T. Freight House at St. Louis," *Railway Age Gazette*, 50, No. 25 (June 23, 1911), 1647.
[198] Chicago, Milwaukee & St. Paul Railroad Electrical Department, *Report on the major changes in the divisional organizations of the Electrified Divisions of the C. M. & St. P. Ry. due to electrification*, 2.

Department recruited men from the construction force to operate substations because of their familiar with the electrification process. In addition, the Milwaukee created a position for a load dispatcher. The Electrical Department needed a load dispatcher with a technical education and someone familiar with hydroelectric plant operations.[199] The load dispatcher also instructed and advised the train dispatcher and substation operators on how to space train movements in order to prevent overloading the power distribution system. Moreover, the CM&StP formed a department pertaining to the maintenance of trolley and transmission systems. The department consisted of two crews, one assigned to each of the former Rocky Mountain and Missoula Divisions. Each consisted of a foreman, three linemen, and one helper. Because the Electrical Department conducted fewer electrical repairs during the winter months, a lineman was dropped from the crew.[200] The Electrical Department also supplied the crews with a self-propelled gas-electric car (operated by an engineer, conductor, and brakeman) to troubleshoot problems with the transmission line and trolley distribution systems that could be repaired quickly.

Electrification resulted in greatly reduced dependency on engine terminals. During steam operation, the Milwaukee situated engine terminals approximately every sixty miles at locations such as Harlowton, Montana (the eastern terminus of the Rocky Mountain-Missoula Division), Three Forks, Piedmont, Butte Yard, Deer Lodge (the middle of the Rocky Mountain-Missoula Division), Alberton, and Avery, Idaho (the western terminus of the Rocky Mountain-Missoula Division). Of these, only Harlowton, Deer Lodge, and Avery hung on to their engine terminals - with Deer Lodge becoming the main electric locomotive repair shop. The CM&StP executives abandoned the rest of

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[199] Ibid., 3.
[200] Ibid., 7.

the engine terminals and eliminated most of the fuel and water facilities located at intermediate points.[201]

At the main repair shop in Deer Lodge, the locomotive maintenance forces had to be reorganized. For a time a master mechanic familiar with steam locomotives was in charge of the shop and he had an assistant who formerly was in charge of a shop on another railroad that used electric locomotives. Since the master mechanic did not adapt well to the new technology, CM&StP officials reassigned him to another shop on a steam-operated division and the assistant became the new master mechanic at Deer Lodge. Shortly thereafter, the new master mechanic tailored the shop's maintenance forces to the electric motor's needs. For example, he organized a small group of electrical inspectors and men, primarily recruited from interurban railroads, experienced in maintaining electric locomotives.[202] These workers did most of the general repairs that the locomotives required. The master mechanic created positions for other specialized tasks, as well. These positions included armature winders, who wrapped new wire around the electric locomotives generators during major repairs, and "motor packers," who did nothing but lubricate and pack motor bearings and other electrical equipment.[203]

Coast Division Electrification

After successfully opening the electrification in the Rocky Mountains, the Milwaukee pursued the electrification of its Cascade and Coast Divisions, a 208-mile stretch between the Washington cities of Othello and Tacoma. This section of the Milwaukee's mainline had tough grades, reaching over 2 percent in some places, and severe weather conditions similar to those of the Rocky Mountain and Missoula

[201] Ibid., 2-3.
[202] Ibid., 15.
[203] Ibid., 15-16.

Divisions. Additionally, officials concluded that the traffic volume of four to six freight trains daily each way as well as the operation of two luxurious passenger trains, the *Columbian* and the *Olympian*, justified the electrification expense.[204] Since the Milwaukee's electrified operations were proving successful in the Rocky Mountains from an operational standpoint, the railroad's executives decided to electrify this rugged portion of track to Puget Sound. On March 5, 1920, the Milwaukee officially began operating its Coast Division on electricity.

There was nothing particularly unusual about the design of the Coast Division electrification that differentiated it from the Rocky Mountain and Missoula Divisions. The CM&StP built the substations to the same specifications with a few minor differences. The one major exception, however, was that each generator in the substation now had a high-speed circuit breaker instead of one for the entire station.[205] However, one of the oddities of the substation construction process was that, to speed up the process of electrifying the Coast Division, the Milwaukee contracted with both General Electric and Westinghouse to build substation equipment. Westinghouse equipped the Taunton, Doris, and Kittitas substations, while GE equipped the remaining five substations.[206] One other variation was that the new locomotives on the Coast Division were outfitted with their own high-speed circuit breakers, greatly reducing the opportunities for damage to the electric motors. The Coast Division electrification on the whole, however, was a duplication of the original undertaking with only minor variances.

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[204] E. S. Johnson, "Electrification of the Coast and Cascade Divisions of the C., M. & St. P. Ry.," *General Electric Review*, 23, no. 4 (April 1920): 263.
[205] Ibid., 267-268.
[206] "Opening the New Electrification District," *The Milwaukee Railway System Employes' Magazine*, (circa January 1920): 13.

The Milwaukee utilized two sources for its electrical power on the Coast Division. On the western portion of the line the Milwaukee contracted with Puget Sound Traction, Light and Power Company. The PSTL&P operated three hydroelectric plants in Western Washington, one each on the White, Puyallup, and Snoqualmie Rivers. The total output of all the power plants was 114,533 horsepower, with an additional 45,000 horsepower available from an auxiliary steam plant, if necessary.[207] Meanwhile, the Washington Water Power Company supplied power on the eastern half of the Coast Division from its Long Lake Plant northwest of Spokane. From this plant the power company constructed a 113-mile transmission line to the Taunton substation.[208] The two companies' hydroelectric plants supplied more than enough energy for the Milwaukee's needs.

Motive power on the Coast Division came in the form of twelve EF1 freight motors (which were originally EP1 passenger motors re-geared for freight service) from the Rocky Mountain Division and five new passenger locomotives from GE. The railroad classified the new passenger motors as the EP2. The EP2's were 3,000-volt DC locomotives, weighed 265 tons, and rated at 3,240 hp, making them the most powerful locomotives in the world.[209] GE designed the locomotives differently from the previously purchased motors on the Rocky Mountain and Missoula Divisions. The locomotives were of the bi-polar gearless type, meaning that the motor armatures were mounted on the axles.[210] Engineers considered "the chief advantage of this method of construction (mounting the motor armatures on the axles) was the great simplicity of mechanical design, which eliminated all gears, armature and suspension bearings,

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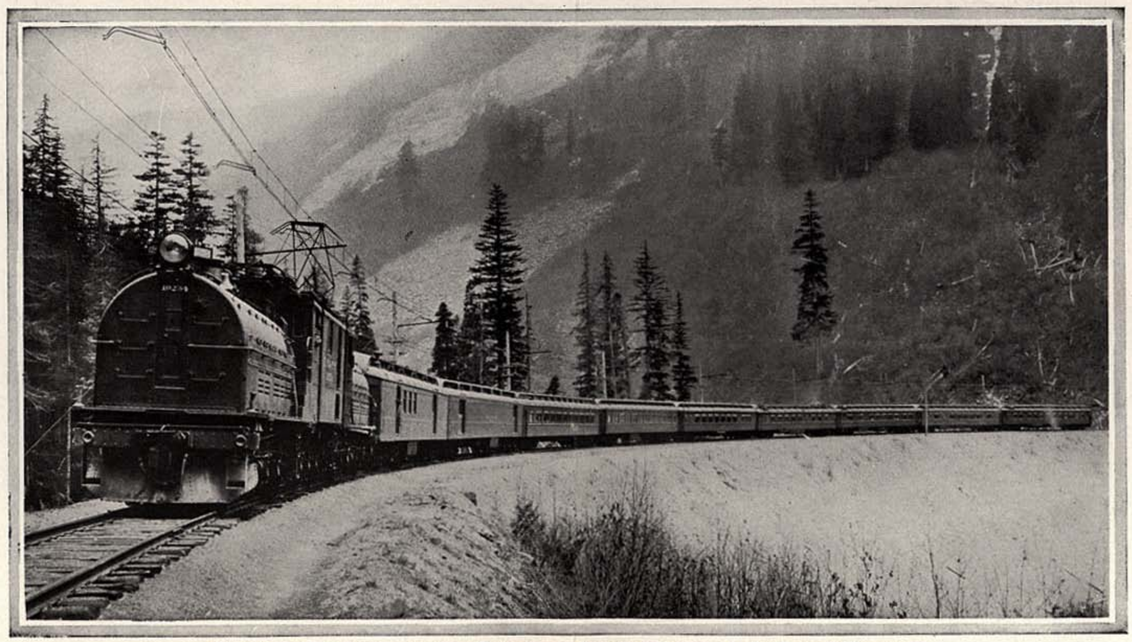
[207] "Six Rivers Speed Milwaukee Train Across Cascades," *Seattle Post-Intelligencer*, 77, no. 113 (March 6, 1920), Home Ed., 5.
[208] Johnson, 270.
[209] "Engine 10251," *The Milwaukee Employes' Magazine* (January 1920), 6.
[210] Ibid.



The "Olympian" Transcontinental Train operated by electric power, in the Cascade Mountains

One of the Milwaukee's gearless "bi-polars" handling the *Olympian* through Washington's Cascade Mountains, circa 1920 (Advertising Ephemera Collection - Database #A0573 [pages 5-6] Emergence of Advertising On-Line Project, John W. Hartman Center for Sales, Advertising & Marketing History, Duke University Rare Book, Manuscript, and Special Collections Library <http://library.duke.edu/digitalcollections/eaa/>).

jackshafts, side-rods or other transmitting devices."[211] Gearless motors were popular with the locomotive crews and maintenance personnel at the New York Central, which utilized such locomotives on its suburban passenger service in New York City. Locomotive crews found the motors easier to operate than steam locomotives, while maintenance personnel preferred the simplicity of the electric motor, which allowed for inspection without having to remove any parts. With fewer moving parts, locomotive maintenance costs on the NYC were reduced and reliability greatly improved. Gearless motors on the Milwaukee's passenger service would be a good fit.

Gearless motors were also better adapted to passenger service than geared locomotives. The gearless motors were more efficient because they did not have a gear

[211] Ibid.

drive. Since passenger trains generally made fewer stops and operated at higher speeds, gearless locomotives used in this service could obtain 10 percent greater efficiency from its motors at fifty miles per hour.[212] The Milwaukee's new bi-polars also operated smoothly at higher speeds. GE coupled the locomotives' trucks in a manner to prevent lateral oscillation. If a train operating at high speeds oscillated as it passed over a track, it caused track damage, resulting in higher maintenance costs and lower operating speeds. The bi-polars' coupling method allowed for high operating speeds of sixty-five miles per hour or greater, which were ideal for the Milwaukee's crack passenger trains, the *Columbian* and the *Olympian*.

The last remaining EP2 "bi-polar" in existence, number E-2, is preserved at the Museum of Transportation, St. Louis, MO (Photo by the Author).

The transfer of the former EP1's to the Coast Division for freight service meant new passenger locomotives for the Rocky Mountain and Missoula Divisions, as well. The Milwaukee purchased ten passenger locomotives from Baldwin-Westinghouse in 1920. Rated at 4,200 horsepower and weighing in at 275 tons, they were the largest, most powerful locomotives in the world.[213] The CM&StP classified the locomotives as EP3's and nicknamed them "Quills" because of their quill drives, which reduced the

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[212] Ibid., 9.
[213] F. W. Shepard, "The Milwaukee Electrification," *The Milwaukee Employes' Magazine* (April 1920): 12.

weight sitting above the axles.[214] The Quills quickly became popular with locomotive crews because of their handling performance, but their poor design qualities were a headache for maintenance personnel who often had to repair broken axles and cracked wheels. Despite their major design flaws, the Quills would continue to operate on the Rocky Mountain Division into the 1950s.

Conclusion

The Milwaukee's electrification project was an impressive, well-constructed undertaking. The railroad built a state of the art distribution system using the finest materials. Engineers installed a new automatic block signaling system to protect the right-of-way. The General Electric locomotives used on the line pioneered regenerative braking on DC-propelled motors. The electrification altered the way management staffed the railroad line and closed steam locomotive facilities. All of this occurred while only taking just under a year and a half to construct the electrification. The Milwaukee immediately felt the impact of its electrified service on the Rocky Mountain and Missoula Divisions. Within a few short months, each division was operating exclusively on electric motors. The operational advantages, as well as the public relations benefits, would be significant.

[214] American-rails.com, "The Milwaukee Road Quills, Class EP-3," <http://www.american-rails.com/quills.html>, accessed July 1, 2009.

Chapter 5

The Milwaukee Electrification's Benefits and Drawbacks

The wait was finally over. With the first engine division of 112 miles completed between Three Forks and Deer Lodge, Montana, the Milwaukee energized its trolley system on November 30, 1915. The next day, the CM&StP ran a train consisting of an electric locomotive and business cars over the line. On December 8, the Milwaukee made an exhibition run for the railroad's top brass and local leaders. A party congregated at the 1.66 percent grade at Janney to watch two trains labor over the pass. One train consisting of 3,000 tons and two electric locomotives effortlessly climbed the grade at a speed of fifteen miles per hour, surely delighting the assembled party. Meanwhile, another train followed carrying 2,000 tons and hauled by two of the road's "L" series steam locomotives and the help of one Mallet pusher.[215] Despite carrying less weight and using more locomotives, the train struggled through the tough grade over Janney at ten miles per hour. The electric motors outperformed their steam counterparts, proving their worth from the beginning.

On December 9, 1915, the Milwaukee hauled its first passenger train, the *Olympian*, under wires between Butte and Piedmont, Montana. The CM&StP began regular electrified operations of both its freight and passenger trains during December. The railroad removed the final steam locomotives from the Rocky Mountain and Missoula Division in July 1916. Almost immediately railroad executives noticed a shift in operation improvements and extolled the virtues of electrification to the public.

[215] "Formal Opening of the St. Paul Electrification," *Railway Electrical Engineer*, January, 1916, RBC.

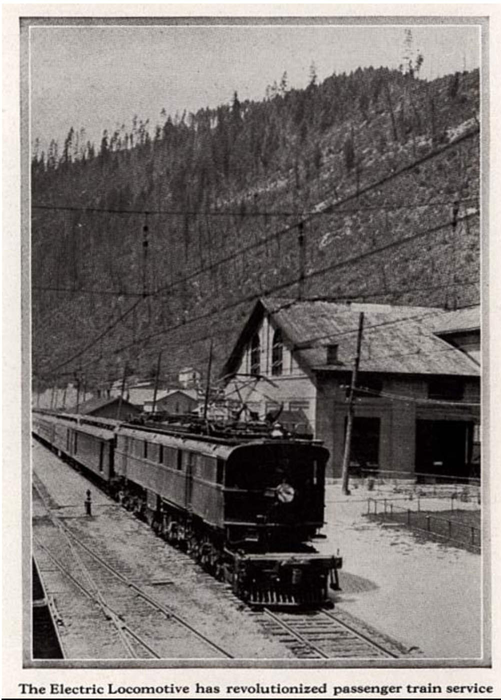
Operational Benefits

The weather extremes in the Rocky Mountains had less of an effect on the electrics than the steam locomotives. The electrics performed just as well during the hot and dusty Montana summers as they did during cold and snowy Montana winters. During the winter of 1914-1915 severe weather lowered temperatures to forty-five degrees below zero. Snow also played a factor, with two feet of fine, dry snow commonplace.[216] Although there was only partial electric operation during this period the Milwaukee's electrics outperformed the road's steam locomotives. In one instance the railroad dispatched an electric locomotive in forty-degree below zero weather to fetch two steam operated freight trains that died on the mainline east of Three Forks as passenger trains were approaching in each direction. C. A. Goodnow, assistant to the CM&StP president, noted, "In five minutes from the time the inquiry was first made the electric locomotive, manned by the Superintendent and engineer, was moving out on the main track toward the stalled trains." [217] The superintendent and engineer, with the aid of an electric locomotive, cleared the inoperable freight trains. Both passenger trains traversed the mainline on time, thanks to the help of the electric motors.[218] The electric locomotives did not need to wait for steam pressure to build up in its boilers before it could operate; the engineer just had to raise the pantograph and it was ready for operation.

The Milwaukee's operating efficiencies improved under electric power. The CM&StP limited steam-operated trains to eight miles per hour and 1,700 tons; under

[216] W. S. H. Hamilton, "The Operation of Locomotives in Service on the Chicago, Milwaukee & St. Paul Railway," *General Electric Review* (November 1916): 957.
[217] C. A. Goodnow, "Some Practical Results Obtained by Electrification on the Chicago, Milwaukee & St. Paul Railway," *General Electric Review* (November 1916): 912.
[218] Ibid.

electric power, electric locomotives hauled 3,000-ton trains and twice the speed.[219] The increased speed and capacity along the mainline also improved the freight train schedules in the electrified territory. The railroad reduced running times by five to six hours under electric operation. Additionally, the CM&StP management eliminated the locomotive inspection at Three Forks that steam engines required, since electric motors were more reliable. Discontinuing the locomotive inspection cut the overall scheduled time in half, with the results being increased freight train capacity.[220] Furthermore, the railroad needed fewer helper locomotives to assist freight trains climbing the tough Rocky Mountain grades. Moreover, the passenger trains did not require helpers, reducing operating costs and improving schedules.



A Milwaukee passenger train barrels past one of the line's substations, circa 1920 (Advertising Ephemera Collection - Database #A0573 [page 20], Emergence of Advertising On-Line Project, John W. Hartman Center for Sales, Advertising & Marketing History, Duke University Rare Book, Manuscript, and Special Collections Library <http://library.duke.edu/digitalcollections/eaa/>).

Electrification also slightly improved the Milwaukee's passenger train schedules. In 1914, steam locomotives handled train number fifteen in the Rocky Mountain, Missoula, and Coast Divisions in twenty-five hours and ten minutes. In 1925, under wire, the same train made the schedule in twenty-two hours and twenty-five minutes through the same divisions. All four passenger trains operating these same divisions operated a

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[219] Ibid., 910.
[220] Hamilton, 966.

total of one hundred hours and thirty-one minutes in 1914 under steam operations. Electrification shaved six hours and thirty-six minutes from the schedule by 1925. The four passenger trains operating west of Mobridge, South Dakota, had combined running times of 185 hours in 1914, compared to 182 hours and 8 minutes in 1925, saving 2 hours and 52 minutes.[221] Electrics reduced schedule times during the period approximately 2 percent, offering a small benefit to the time-sensitive traveler.

The new motors also provided safety benefits. Train crews reported fewer drawbar pull incidences compared to trains operated with steam locomotives, meaning the electric locomotives maintained enough power at a constant speed to prevent trains from breaking apart. Locomotive crews also enjoyed a spectacular view of the track ahead, since the cab was located at the front of the electric locomotive. On steam locomotives the boiler obstructed the engineer's view, resulting in poor sightlines, especially during winter months and in tunnels.

Electric motors also benefited the environment. The Milwaukee saved a significant amount of natural resources using electrified trains. Railroad engineers estimated using hydroelectric power on the Milwaukee's electrified divisions would save 300,000 tons of coal and 40 million gallons of fuel oil annually.[222] Electric locomotives also reduced the risk of forest fires, since they did not spew sparks or cinders that kindled blazes in the Cascade and Bitterroot Mountains.

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[221] Chicago, Milwaukee & St. Paul Railway Electrification Department, "Comparison of Steam and Electric Passenger Train Schedules, 1914 vs. 1925," Seattle, Wash., Sept. 29, 1925, Box 9, B-13-10-16-8-1, RBC.

[222] W. A. Scott, "Chicago, Milwaukee & St. Paul Railway Completes Electrification of Pacific Coast Division," *Electrical Review*, 76, no. 12 (March 20, 1920): 496.

The Milwaukee's Perception of Electrified Railroading

The Milwaukee's public relations department painted the electrification as a new epoch in the world of railroading. According to one of the railroad's advertisements, "There is only one other event in railroad history that compares with the electrical achievement of the Chicago, Milwaukee & St. Paul Railway – and that was the first trip of the first steam locomotive." [223] The public relations department believed the steam locomotive, the mainstay of nineteenth century railroading, was on its way out. The advertisement further stated, "When the first train ran over the electrified trackage of the main line of the Chicago, Milwaukee & St. Paul Railway, drawn by an electrical locomotive, the electrical era in railroading was ushered in – the last word in scientific transportation."[224] Electric motors were the dazzling new technology of the twentieth century prepared to replace its smoke-belching counterparts.

To underscore further the prominence of the new technology, the public relations department pitted the Milwaukee's new electrics against the road's steam locomotives in dramatic shoving matches. At least two of these events occurred: one in Erie, Pennsylvania, on the GE test track in 1919, and another on a stretch of track between Kent and Auburn, Washington, on March 6, 1920. In each instance crowds gathered to watch the shoving matches as two mighty steam locomotives were coupled to the electric locomotive. When signaled, the engineers on the steam and electric locomotives started shoving each other. The steam locomotives started strong, pushing the electric locomotive backwards a short distance. As the electric motor received more current,

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[223] Chicago, Milwaukee, & St. Paul Railway, *The Dawn of the Electrical Era in Railroading: The Electrification of the Mountain District of the Chicago, Milwaukee, & St. Paul Railway*, (Chicago: Poole Brothers, 1916), 4.
[224] Ibid.

however, the steam locomotives were no match for the electric. The engineer on the electric locomotive could open the throttle to add more power instantly, giving it more horsepower immediately. On the other hand, the steam engines built up power gradually, giving the electric motor an instant advantage during a tug-of-war with a steam locomotive. "The steam engines slowly but surely lost momentum and finally came to a complete stop," reported the *Milwaukee Railroad System Employe's Magazine*, "still with their throttles wide open, puffing and chugging as under extraordinary strain."[225] Finally, the electric motor prevailed, pushing the struggling steam locomotives backward while under full power. The *Milwaukee Railway System Employe's Magazine* declared, "the exhibit was probably unique in the annals of electrification, and was virtually a tug of war between three monsters of iron and steel."[226] The new motive power clearly showed its superiority in front of the watchful eye of the public.

The Milwaukee's employees enjoyed a great sense of pride in knowing that the Milwaukee was a pioneer in the field of electric traction. Scientists, engineers, and railroad executives worldwide focused their attention on the opening of the electrified territory. One railroad employee bragged that, because of the Milwaukee's electrification, the Rocky Mountain Division was "the most renowned division in the world."[227] S. D. Roberts, another Milwaukee employee, proclaimed that the chief executive of the Milwaukee had:

> …The vision to see the transcendent importance of electrification – his was the influence that interested the directorate to expend millions on it.

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[225] "Engine 10251," *The Milwaukee Railroad System Employes' Magazine,* January, 1920, 10.
[226] Ibid.
[227] George H. Waugh, "The Rocky Mountain Division," *The Milwaukee Railway System Employes' Magazine*, 3, no. 12 (March 1916), 24.

> His was the judgment in planning and the persistence in carrying out the vast work. It will stand as one of the master conceptions of the century.[228]

Roberts also played out the importance of every department involved in the electrification process, from the publicity department to the construction crews. Because of the railroad's advances in electrifying transportation, the Milwaukee would take a lofty place among the railroad pioneers when the history of transportation is written.[229]

The CM&StP considered electrification to be a triumph of man over nature. The Rocky Mountains were a formidable natural barrier that steam locomotives struggled to conquer. Using electric motors, powered with electricity created by the rushing streams originating in the Rocky Mountains themselves, the Milwaukee was able to tame the steep mountain grades in Western Montana like no other transportation technology before. C. A. Goodnow, one of the Milwaukee's executives, claimed, "it is a fair statement to say that the use of electric locomotives, so far as easy and uniform operation is concerned, has practically eliminated the grades of the Continental Divide."[230] The Rocky Mountains were no longer a great hindrance to transportation.

A. J. Earling, the Milwaukee's president, told Montana residents that electrification was the way to open up the vast resources of Montana. Earling believed that the city of Butte confirmed its great interest in developing the unlimited resources of Montana when its residents turned out in large numbers to witness the first Milwaukee passenger train leave the city under electric power. While the Great Northern and Northern Pacific passed through Montana on their way to the Pacific Northwest, Earling thought the executives of those railroads largely misread the state's potential in

[228] S. D. Roberts, "Doing Your Part in Electrification," *The Milwaukee Railway System Employes' Magazine*, 4, no. 2 (May 1916), 11.
[229] Ibid.
[230] Goodnow, 910.

developing resources. The president assured Butte residents that the Milwaukee would be second to none in developing the state's potential agricultural resources, predicting that within the next decade Montana would "produce more small grains than any state in the Union." [231] The Milwaukee voiced its commitment to developing Montana's resources and backed it up with the investment in electrification.

The railroad prophesized how people of the future would view the Milwaukee's use of electric motors. The editor of the *Milwaukee Railway System Employes' Magazine* predicted that, one hundred years from now, the Chicago, Milwaukee, and St. Paul's electrification would be assured its place in history at the forefront of the technology. "If the picture of electric locomotive 10200 should be displayed, in that future time, with its queer looking pantagraph (sic) atop of it, it will probably meet with the same derisive smiles as now are bestowed on the pictures of the ancient steam engines," stated the editor, "but, like them, it will also receive its due share of honor as a pioneer in the forward movement of human affairs." [232] Despite looking different from future electric locomotives, the railroad's pioneering efforts in electric traction would, nonetheless, be recognized one hundred years later.

Public Perception of the Milwaukee's Electrification

The railroad received supportive and congratulatory messages from prominent individuals worldwide during and after the construction process. C. A. Goodnow reported that the railroad received letters from the German government and from the world's greatest engineers and scientists when the Milwaukee made its electrification

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[231] Carpenter Kendall, "A Handwriting on the Wall," *The Milwaukee Railway System Employes' Magazine*, 3, No. 11 (February 1916): 7.
[232] Ibid., 6.

plans.[233] Thomas Edison and Nikola Tesla both considered the electrification as a "grand wedding of science and business."[234] Wealthy industrialist Theodore Vail compared the Milwaukee's revolution in transportation similar to the way electricity produced at a central station transformed industrialization.[235] The international business and scientific community appreciated the prominence and scope of the CM&StP's electrification project.

The business community held a great celebratory banquet in honor of the new technology. On December 8, 1915, the Milwaukee held test runs between steam and electric traction on the grade near Janney, Montana. Afterwards, more than two hundred businessmen and railroad executives gathered at the Silver Bow Club in Butte to commemorate the successful test runs of the electric locomotive.[236] The *Butte Miner* exclaimed, "Never was there such a setting for a banquet."[237] An elaborate display contained a series of electrically-lighted dioramas of water power development in Montana, a miniature water power plant with water running over the mill race, and a model electric train running on a table.[238] After dinner, President Earling, Montana Power Company President John D. Ryan, and other prominent individuals spoke eloquently about the Milwaukee electrification, captivating the banqueters. The CM&StP enthralled the business community with the new technology and showed its appreciation to the Milwaukee executives in a grand fashion.

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[233] "Power of Milwaukee to be Changed Soon," *The Anaconda (MT) Standard*, March 25, 1914.
[234] Kendall, 7.
[235] Ibid.
[236] "Achievement of Milwaukee Means Much for Montana Say Speakers at Banquet," *Butte Daily Post*, December 9, 1915.
[237] "Brilliant Banquet Celebrates Triumph," *The Butte Miner*, 53, no. 81 (December 9, 1915), 1.
[238] Ibid.

Meanwhile, the Milwaukee grabbed the headlines with its new form of motive power. The press predicted the new technology would replace steam locomotives. After the test runs near Janney, the *Anaconda Standard* described the event as the "last gasps of steam."[239] Some news outlets thought the Milwaukee's electrification marked the beginning of a radical new era in transportation. The *Butte Daily Post* exclaimed that the successful electric motor test runs were "epoch-marking."[240] Similarly, The *New York Times* described the CM&StP's opening of the Rocky Mountain Division electrification as "an epoch in transportation."[241] When the first *Olympian* departed Renton Junction, Washington, under electric power on March 5, 1920, on the newly electrified Coast Division, the *Seattle Post-Intelligencer* stated that "with this epochal departure came the actuality of the electrical era in Pacific coast railroads, … supplanting the 'iron horse' of steam."[242] Newspapers emphasized the Milwaukee's importance in transportation history.

Film crews also visited to document the electrification. During the test runs at Janney in December 1915, motion picture crews from Pathe and Hearst-Selig filmed the trains "to flash the news in every theater of the country."[243] The railroad also used film to promote the electrified lines. In 1916, the railroad's Passenger Department produced a film focusing on the Milwaukee's "progressiveness" and the highlights of the beautiful scenery along the electrified route.[244] Any Milwaukee agent could request the movie,

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[239] "Electric Test is Successful," *The Anaconda (MT) Standard*, December 9, 1915, 1.
[240] "Electricity Wins in Epoch-Marking Test on Milwaukee Line," *The Butte Daily Post*, 3, no. 293 (December 8, 1915), 1.
[241] "Electric Trains Over the Rocky Mountains," *The New York Times*, April 23, 1916, Magazine Section, SM9.
[242] "Six Rivers Speed Milwaukee Train Across Cascades," *The Seattle Post-Intelligencer*, 77, no. 113 (March 6, 1920), 1.
[243] *Butte Post*, December 11, 1915, 16.
[244] Roberts, 13.

which targeted prospective passengers and shippers, and show it in a local movie theater for free.

Some foreign nations sent dignitaries to visit the Milwaukee's electrified lines to gain a better understanding of the new technology on display. In 1918, the Orleans, the Midi, and the Paris-Lyons-Mediterranee railroads of France proposed to electrify 10,000 kilometers of track. on November 14, 1918, the French Ministry of Public Works, Transports, and Merchant Marine resolved to send a delegation to the United States to inspect electrified railroad lines. Thirteen delegation members, comprising of French professors, railroad engineers, and electrical engineers, left Paris on April 15, 1919, to visit the United States. A. Maudit, a member of the delegation wrote:

> The principal duty of this mission was to find out, on summing up all the information gained by the study of the Swiss and Italian Electric railways on the [sic] side, and the American on the other, if a system of electric traction existed for large systems distinctly superior to all others and able to be adopted to the exclusion of all others by all the different companies interested for the projected electrification in the center and the south of France.[245]

The delegation toured several railroads, including the New York Central, the New Haven, the Long Island, the Norfolk and Western, and the Milwaukee, as well as several interurban lines.

Upon the delegation's return to Paris on July 22, the members were most impressed with the Milwaukee's electrification. A. Maudit spoke for the delegation when he stated, "We studied with particular care this installation of the Chicago, Milwaukee, & St. Paul, and all the members were unanimous in considering that this electrification, by

[245] A. Maudit, "Summary of the Report Rendered Addressed to the Minister of Public Works by the Mission Sent to America to Study the Electrification of the Great Railway Systems," extract from the *Official Journal of the French Republic*, translated by Allen Mulford, August 13, 1919, Box 15, B-13-12-24-2-1, RBC, 4.

far the most important in the world, was at the same time, greatly superior to all others on account of the excellence of its technical operation from all points of view."[246] The delegation thought highly of many aspects of the electrification, including the Milwaukee's substations. The French were impressed with the use of preparatory protectors on the commutators and high speed circuit breakers on the mainline, which eliminated flash over during short circuits.[247] Additionally, Maudit wrote favorably of the Milwaukee's electrics:

> The locomotives are very easy to run, and operate perfectly, the series direct current motor being of all others the ideal motor for traction work, as has long been shown by the experience of tramways and suburban railways. They are capable of regenerative braking, marvelously regulated, which assures the most flexible progress on down grades, and occasions an important economy of power, the tires of the wheels and the brake shoes.[248]

The delegation was also amazed with the insignificant amount of interference between the DC distribution system and the AC telegraph and telephone lines. The technical soundness of the Milwaukee's electrification astonished the French visitors so greatly, Maudit declared that, "he does not hesitate to formally conclude in favor of the adoption of this system, and he believes it to be actually the only system suitable for the electrification of large traction lines."[249]

The Milwaukee's electrification became a model that other railroads in the United States followed. To comply with Cleveland's smoke abatement laws, the Cleveland Union Terminal developed a 3,000-volt, DC system in 1925. In 1930 the Delaware, Lackawanna, and Western Railroad developed a similar electrification system on its lines

[246] Ibid., 8.
[247] Ibid., 9.
[248] Ibid.
[249] Ibid., 10.

in New Jersey. The Milwaukee's concept also was well received abroad. The Mexican Railway completed a sixty-four-mile, 3,000-volt DC system in 1928. Additionally, railroad engineers in Brazil, Chile, Argentina, Spain, and France employed concepts of the Milwaukee electrification on their own lines.

Costs and Drawbacks

Although the Milwaukee reaped many benefits from the electrification, the initial investment set the railroad back a lot of money. The Milwaukee's Electrification Department pegged the cost of labor and materials for the Rocky Mountain and Missoula Divisions at $7,907,648.66. The grand total, which includes the cost of locomotives, was estimated at $13,134,225, an astronomical sum for its time.[250] The railroad, despite the enormous expense related to electrifying the Rocky Mountain Division, forged ahead with stringing wires across the Coast Division in 1919.

The total cost of installing the Coast Division electrification between Othello and Tacoma amounted to $6,301,387.42, or an average cost of $30,135.76 per route mile. The total cost included the trolley system, transmission system, substation layout, right of way, telephone and telegraph line changes, and engineering. Compared to the Rocky Mountain and Missoula Divisions, however, the Milwaukee paid almost double the amount of installation costs per route mile. This was due to the increased demand for labor and basic materials during World War I. Additionally, there was the cost for new motors. Ten Westinghouse freight locomotives, five GE Bi-polar passenger locomotives,

[250] Chicago, Milwaukee, & St. Paul Railway Electrification Department, "Costs of Electrification Harlowton to Avery, Totals to March 31, 1920," Box 9, B-13-10-16-6-1, RBC.

and two GE switching locomotives were purchased for a total of $3,044,209.16.[251] In addition, the railroad delayed electrifying its branch line into Seattle. The 8.8 mile route between Black River Junction and Seattle was electrified in 1927 at a remarkably lower total cost of $102,063.[252]

By spending $22,581,884.58 on electrifying 656 miles of its routes, the Milwaukee executives hoped the increased capital cost would reflect a big reduction in operating expenses. Electrification did result in a reduction of maintenance costs for the railroad. The Milwaukee saved 46 percent on freight car maintenance costs, as well as 19 percent on passenger car maintenance costs between steam and electrified operations.[253] Additionally, while eastern steam railroads were paying on average forty-nine cents per mile to maintain electric locomotives,[254] between 1924 and 1929 the Milwaukee had the lowest average electric locomotive maintenance costs of any major steam railroad electrification at 6.65 cents per mile, which was almost half the average cost per mile of the remaining railroads.[255] During steam operations on the Coast Division the railroad spent $3,007,480.82, or $0.00299 per gross ton mile, on operating costs, while

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[251] Chicago, Milwaukee & St. Paul Railway Company Electrification Department, "Statement of Costs for Electrification of the Coast Division of the C. M. & St. P. Railway, Extending From Othello to Tacoma, Washington," Seattle, Washington, 1923, RBC.
[252] Chicago, Milwaukee, St. Paul & Pacific Railroad Office of the Electrical Engineer, "Cost of Electrification – Black River Jct. to Seattle, Wash.," Seattle, Washington, November 29, 1933, Box 9, B-13-10-16-8-1, RBC.
[253] Chicago, Milwaukee & St. Paul Railway Company, "A Study of the Relative Cost of Steam and Electrical Operation," B-13-10-16-25-1, RBC, 19.
[254] W. D. Bearce, "Abstract of 'Appendix C' of Superpower Report on the Electrification of Railroads," *General Electric Review*, 25, No. 2 (February 1922): 90.
[255] Electrification Department, "Electric Locomotive Maintenance Costs for Various Railroads, Years – 1924 to 1929, Inclusive," Chicago, Milwaukee, St. Paul and Pacific Railroad Company, Seattle, Washington, March 31, 1931, RBC, B-13-10-16-18-1, 1.

$2,125,071.01, or $0.00282 per gross ton mile, was expended on operating costs under electric operations.[256]

Electrification of the Rocky Mountain and Missoula Division reduced operating expenses. Gross ton mileage on the two divisions was considerably higher between 1916 and 1924, with a low of 1.639 billion in 1916 and a high of 2.894 billion in 1919, while most years topped over two billion.[257] Because of the increased traffic volumes between Harlowton, Montana, and Avery, Idaho, the Milwaukee reduced expenses with electrified operation. According to a study published in *Railway Age*, the Milwaukee saved $11,868,247 on its Rocky Mountain and Missoula Division electrification during its eight and a half years of operation, based on 1923 price levels.[258] At this pace and under this accounting method, the railroad's total electrification investment in actual dollars would pay for itself in about sixteen years, making economic sense for the Milwaukee. The Milwaukee's decision to electrify looked more brilliant than ever before.

Due to low traffic volume on the Coast Division, however, the Milwaukee's electrification actually lost money. To break even on operating costs, based on the actual expenditure of electrifying the Coast Division during the inflationary World War I period, the Milwaukee estimated that the railroad needed to perform 758 million gross ton miles of work per year on its electrified Coast Division lines.[259] Under steam operation on the division between August 1918 and July 1919 the Milwaukee performed over a billion gross ton miles of work. Between August 1920 and July 1921, when the Coast Division

[256] Chicago, Milwaukee & St. Paul Railway Company, "A Study of the Relative Cost of Steam and Electrical Operation," 22.
[257] "St. Paul's Electrification Shows Economies Over Steam," *Railway Age*, 78, No. 9 (February 28, 1925), 514.
[258] Ibid.
[259] Chicago, Milwaukee & St. Paul Railway Company, "A Study of the Relative Cost of Steam and Electrical Operation," 3.

was running primarily under electricity, traffic on the Milwaukee declined after the conclusion of World War I to 752,735,888 gross ton miles, indicating a slight loss on electric operation.[260] Between 1922 and 1924, the Coast Division's gross ton miles only decreased further, falling below 700 million in 1924.[261] Had the Milwaukee installed the electrification at the same time or immediately following the Rocky Mountain Division electrification, the railroad could have reduced operating costs on the Coast Division significantly during the steam operation period of 1918-1919, as well as saved a substantial amount of money on labor and materials that were caused by the effects of World War I. If built at the same prices as the Rocky Mountain and Missoula Divisions just a couple of years earlier, the Milwaukee would only need to operate 604 million gross ton miles on the Coast Division to break even.[262] In that case, the Coast Division's electrification would have easily justified the expense.

Additionally, the Milwaukee never electrified the 210 miles of mainline between Avery, Idaho, and Othello, Washington, an area commonly referred to as "The Gap." This stretch of track between the two electrified divisions was not a high priority for electrification since it was generally flatter and straighter. Steam engines operated well in "The Gap," meaning the railroad had less incentive to electrify the line. In 1921, the railroad dropped its electrification plans for "The Gap" because of the lack of traffic, trouble raising capital, and because freight and passenger trains used different routes near Spokane.[263] In later years, however, the Milwaukee's executives realized that not

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[260] Ibid.
[261] "St. Paul's Electrification Shows Economies Over Steam," 514.
[262] Chicago, Milwaukee & St. Paul Railway Company, "A Study of the Relative Cost of Steam and Electrical Operation," 4.
[263] Rodney A. Clark and John J. Fell, Jr., *The Milwaukee Electrification - A Proud Era Passes*, Supplement of *The Milwaukee Road Magazine*, July-August 1973, Milwaukee Road Archives, <http://milwaukeeroadarchives.com/Electrification/AProudEraPasses.pdf>, accessed July 29, 2009, 7.

electrifying "The Gap" resulted in poor motive power flexibility, since the electrics could only operate on the bookends of a 900-mile route between Harlowton, Montana, and Tacoma, Washington, with steam, and later diesel, locomotives required to haul trains through "The Gap."[264]

Despite the losses on the Coast Division and the decision not to electrify "The Gap," overall the electrification did save enough money to justify the cost. The CM&StP drastically reduced locomotive and rolling stock maintenance costs. Because the railroad purchased new steam locomotives before the lines were electrified, the electrics freed up these newer engines for service in the Midwest and allowed the Milwaukee to retire older steam locomotives. In addition, the entire electrification system paid for itself within twenty years and lasted well beyond initial projections. The electrification, from a financial standpoint, became a success.

Although the Milwaukee's electrification proved its superiority over steam, universal adoption in the field was impossible. Even E. W. Rice, Jr., electrical engineer and president of the General Electric Company, had his doubts about universal adoption as the Milwaukee strung wires along the Coast Division. When asked if he believed all United States railroads would adopt electrification, "frankly, no," Rice said. "I realize that the task of electrifying all of the steam railroads of the country is one of tremendous proportions," Rice stated, "It would require under the best of conditions many years to complete and would demand the expenditure of billions of dollars."[265] At a time when operating expenses were going up and freight rates were staying the same, there was little opportunity for railroads to save money for such a massive capital investment.

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[264] Ibid.
[265] "Milwaukee Railroad Proceeding Rapidly With Preparations for Substituting Electricity for Steam as a Motive Power on Coast Division," *Seattle Post-Intelligencer*, April 27, 1919.

Despite the electric locomotive's ability to improve capacity, most railroads had no need to increase it. Ton miles on American railroads increased from 76 billion in 1890 to 255 billion in 1910. After World War I, however, railroads received less traffic. Ton miles decreased from 414 billion in 1920 to 375 billion in 1940.[266] Railroads hauled fewer materials after World War I and, after 1930, the Great Depression further reduced tonnage. The sharp decline in tonnage resulted in lower profits for railroads, putting the enormous capital costs of electrification out of reach.

Moreover, steam locomotive builders produced larger, more efficient steam locomotives. The Lima Locomotive Works of Lima, Ohio, developed the 2-8-4 wheel arrangement "Berkshire" locomotive with a larger firebox in 1924. These locomotives hauled greater tonnage and were more efficient than the 2-8-2 Mikados of two decades earlier. After the Berkshires appeared, other powerful new steam locomotives emerged, including 2-10-4's and the American Locomotive Company's 4-8-4 "Northerns."[267] The new "superpower" steam locomotives quickly appeared on railroad lines across the United States. Crews enjoyed running them because they were powerful and railroad executives liked that they were well-suited for the high speed operation they craved.

The more efficient steam locomotives, however, would eventually lose ground to the diesel-electric locomotive. A single diesel-electric locomotive provided less horsepower than an electric locomotive or steam engine. A diesel-electric, however, could be lashed together with other diesel-electric locomotives and, using the principles applied to multiple-unit trains, could be operated by one engineer in the lead locomotive.

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[266] Association of American Railroads, *U.S. Freight Railroad Statistics*, January 15, 2008, < http://www.aar.org/PubCommon/Documents/AboutTheIndustry/Statistics.pdf>, accessed October 27, 2009, 2.

[267] Brian Solomon, "The American Steam Locomotive," (St. Paul: Motorbooks International, 1998) 83, 91.

The diesel-electric locomotive's flexibility allowed railroads to use the right amount of power to haul virtually any train. Additionally, they started up quicker and were far simpler to maintain than steam locomotives. Despite lacking the power of an electric locomotive, the diesel-electric engine did not require the costly installation of overhead wires or a third rail. The diesel-electric provided the advantages of an electric locomotive, but without the extraordinary capital costs of installing a power distribution system.

The first diesel-electrics were used in switching services in major terminals starting in the 1920s. In 1936, the Union Pacific and the Chicago, Burlington, and Quincy Railroads equipped their new streamlined passenger trains with sleek diesel locomotives. The big breakthrough, however, occurred in 1939 when the Electro-Motive Division of General Motors introduced the FT. After going on a lengthy United States tour, the FT proved popular with railroad executives and locomotive and maintenance crews. Before the railroads purchased a significant number of the new FT's, World War II put a temporary halt to new diesel locomotive building.

After the war, however, diesel locomotive production ramped up. In 1946, EMD introduced its E-series passenger locomotives and launched the F3 for freight service. American railroads jumped at the chance to cut costs and improve performance by "dieselizing" their locomotive fleets. By 1960, all major U. S. railroads had made the transition from steam to diesel.

Dieselization also meant the demise of many electrified railroads in the United States. With diesels offering many of the benefits electric locomotives provided over steam locomotives at a fraction of the cost, many of the electrified lines constructed in the pre-World War II era were deemed unnecessary. By 1959, electrification was gone from the Southern Pacific, the Boston and Maine's Hoosac Tunnel, the Baltimore and Ohio's Howard Street Tunnel, the New York Central's Detroit River Tunnel, the Great Northern's Cascade Tunnel, the Grand Trunk's St. Clair Tunnel, Cleveland Union Terminal, the Norfolk and Western, and the Virginian.[268] The Butte, Anaconda, and Pacific held out until 1967.

The Milwaukee electrics kept going as long as they could. When the electrification was installed, it was only expected to last about thirty years. Reinier Beeuwkes, the Milwaukee's electrical engineer from 1914 to 1947, however, predicted that, with the exception of the poles and fixtures, "the depreciation period or life of the apparatus, it seems to me, will be governed by the question of obsolescence rather than any replacement due to wear and tear."[269] Beeuwkes was right; with modest upgrades and new locomotive purchases, the system lasted well beyond the projected thirty-year lifespan. Nonetheless, the writing was on the wall for the Milwaukee's electrified service. Between 1972 and 1974 the Milwaukee leased ninety new EMD SD40-2 diesel

The Milwaukee's abandoned mainline through Montana during the summer of 2009 (Photo Courtesy: Carlos A. Schwantes).

[268] Middleton, 420-421.
[269] Reinier Beeuwkes to G. J. Bunting, General Auditor, Chicago, Illinois, November 24, 1916, Box 9, B-13-10-16-8-1, RBC.

locomotives for use on the Pacific Coast Extension.[270] The SD40-2 was reliable and was similar in horsepower to the EF1's and the newer "Little Joe" electrics purchased in the late 1940s. Additionally, after a sixteen-month study, the Milwaukee determined that the existing 656 miles of electrification needed replacement and installing electrification in the gap between Avery, Idaho, and Othello, Washington, was necessary to make the line more successful. The total cost of purchasing new locomotives, replacing the current electrification system and bridging the gap would cost $45 million.[271] With the railroad teetering on the edge of bankruptcy, the cash-strapped Milwaukee executives believed the investment was unwise. In 1972 the Coast Division wires were de-energized. Thanks to the 1973 oil embargo, however, the Rocky Mountain Division electrics hung on a little longer. On June 16, 1974, the Milwaukee concluded electrified service on the Rocky Mountain Division.[272] The Milwaukee's electrification was finally obsolete.

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[270] Frederick W. Hyde, "The Milwaukee Road" (Denver: Hyrail Productions, 1990), 136.
[271] William J. Quinn, Letter to Senator Warren G. Magnuson, November 13, 1973, Milwaukee Road Archives, <http://milwaukeeroadarchives.com/Electrification/QuinntoMagnusonLetter11131973.pdf>, accessed July 8, 2009.
[272] Milwaukee Road News Bureau, Press Release, May 23, 1974, Milwaukee Road Archives, <http://milwaukeeroadarchives.com/Electrification/Announcement05231974.pdf>, accessed July 8, 2009.

Chapter 6

CONCLUSION

The Milwaukee's electrification was a success in several ways. First, the railroad used the best technology available on the market. General Electric designed the power distribution system to high standards using the latest in electrical engineer knowledge, including the high-speed circuit breakers found in all of the substations. GE also developed the most powerful locomotives ever created for the Milwaukee's freight and passenger operations. Furthermore, CM&StP executives equipped the line with automatic block signals, the most sophisticated and efficient signaling system available. Technologically, the Milwaukee electrification met the highest standards.

Second, the electrification transformed the CM&StP's operations. The electrification reduced transit times of its freight and passenger trains. Electric locomotives operated at the flick of a switch and were ready for service much faster than steam locomotives. Trains no longer had to stop at engine terminals every one hundred miles for a locomotive inspection. In addition, electrification eliminated several engine terminals and abolished duplicate positions in train dispatching. The Milwaukee also created an Electrification Department to oversee the Milwaukee's pioneering efforts in railroad electrification. Operations improved on the CM&StP, thanks to the electrification.

Third, the Milwaukee received a great deal of praise from numerous outlets. The media highlighted the electrification in the newspapers and film, bringing much public attention to the Milwaukee. Businesses in Montana greeted the Milwaukee executives with a banquet after the electrification's completion. Scientists the world over congratulated the Milwaukee on its achievement. The railroad could boast of itself as a pioneer in steam railroad electrification, a definite morale booster for the Milwaukee's employees. The media and public lavished the Milwaukee with flattering remarks during the opening of the electrification.

Fourth, the Milwaukee's electrification reduced costs. Unfortunately, the Coast Division electrification lost a small amount of money immediately after World War I, since the electrification was installed during a period of increased inflation and because the traffic dropped after the war. Coupled with the savings from the Rocky Mountain Division, however, the Milwaukee reduced costs with electrified operations. The railroad also benefited from the lowest maintenance costs per mile of any electrified railroad in the nation.

The Milwaukee's electrification project was technologically sound, improved operations, generated favorable publicity, and reduced costs. Nonetheless, the Milwaukee, pioneers in developing electrification over several steam divisions for the purpose of economics, did not revolutionize the railroad industry. First, tonnage decreased after World War I. The demand for the railroads' services decreased after the war. In addition, greater competition from shipping companies using the Panama Canal and the rising trucking industry cut into freight traffic. Automobile usage also rose, precipitating a decline in passenger traffic. While using electric locomotives to increase capacity had the benefit of increased efficiency, steam railroads could not afford the cost of installing expensive new equipment during a period of decreasing traffic. As the railroad's received less income for hauling freight and passengers, the capital costs of installing electricity became too much to bear for United States railroads.

Second, technological improvements to steam locomotives after World War I and the introduction of the diesel locomotive in the 1930s made electrification a costly, unnecessary investment. The powerful new steam locomotives staved off the electrics with their increased horsepower and lower capital costs. When the diesel-electric came along in the late 1930s, the days of the steam locomotive (and electric) were numbered. The diesel-electric provided most of the benefits of an electric locomotive and was a cheaper alternative to both steam and electric. By the 1960s virtually all of the major United States railroads with electrified operations eliminated them in favor diesel-electrics.

The promise of electricity fulfilled the expectations in virtually all other aspects of our daily lives. Americans utilized electricity in several different capacities, from the factory to the home. It revolutionized the way people communicate, work, recreate, and travel. Electricity also fulfilled the promises of increased economy and efficiency for the Chicago, Milwaukee, and St. Paul and other railroads. The decrease in traffic, along with the capital costs of electrification and the technological advances in locomotive design during the twentieth century, however, made the electric motor virtually obsolete in railroad operations. Railroads decreased their electrical usage for moving trains. The last vestiges of electric passenger trains continue to operate in the Chicago area and along Amtrak's Northeast Corridor between Boston and Washington, DC, where they still maintain an integral role in transporting commuters and vacationers alike. Freight railroads, however, carried virtually no freight on electrically-operated trains in the United States. An era of electric railroading passed, leaving the promise of electricity in American railroading unfulfilled.

The Future

Thirty-five years have passed since the Milwaukee wires came down, but, the economies of electrification are again being discussed in railroad circles. Oil prices in recent years have been extremely volatile. On July 11, 2008, crude oil reached a record high of $147.27 a barrel.[273] Prices, however, have dropped off dramatically since reaching those record highs, hovering around $65 a barrel during the summer of 2009. On the other hand, if oil prices climb again, mainline electrification of North American railroads may become a viable alternative.

One railroad, the Burlington Northern Santa Fe, is in a good position to consider electrification. Electric utilities are studying the idea of generating wind power in Colorado and transmitting the electricity to California.[274] Sending the power to California, however, presents the major problem of acquiring right-of-way for the transmission lines. BNSF may have a solution: allowing the utilities to transmit power along its right-of-way in exchange for electricity to operate its freight trains. The railroad already leases its transcontinental rights-of-way to fiberoptic companies in exchange for communications and data transmission capacity.[275] Therefore, it would not be much of a stretch to think the railroad and the utilities could become partners in transmitting electricity.

While this solution could be a major benefit to both utilites and BNSF, several issues need to be worked out. For example, major engineering issues, such as installing

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[273] Mark Shenk, "Crude Oil Rises as Traders Are Caught in End-of-Month Squeeze," *Last Updated: October 31, 2008 16:52 EDT* <http://www.bloomberg.com/apps/news?pid=20601072&sid=a1yLGuDS_HNk&refer=energy>. Accessed April 23, 2009.

[274] William C. Vantuono, "Time to Revisit Electrification?", *Railway Age*, September 2008. Accessed Electronically at <http://findarticles.com/p/articles/mi_m1215/is_9_209/ai_n29476448/>. Accessed April 23, 2009.

[275] Ibid.

catenary, creating a power grid, and modifying tunnels and bridges, need to be addressed. Additionally, the railroad needs to figure out how many miles of track to electrify. BNSF would have to identify all of the potential engineering issues and determine if they could be straightened out before the railroad could electrify.

Another issue is the locomotives. Currently, BNSF operates an all-diesel locomotive fleet. If the railroad chose to operate a portion of its lines with electricity, would the locomotives be electric or a hybrid of electric and diesel locomotives? It would all depend on how many lines BNSF wanted to electrify and in what time frame. Running electric-only engines on electrified track sections would either mean changing out locomotives when a train reaches that area, or converting large sections of the network and equipment all at once.[276] BNSF would prefer a dual-mode locomotive, which is currently in use on Metro-North's commuter train service in New York, but the technology would need more time to develop for freight service.

Finally, it all comes down to economics. BNSF's Chairman, President and CEO, Matt Rose, stated the price tag to electrify all BNSF mainline tracks could be $10 billion, including what the carrier would need in dual-mode locomotives.[277] If the price of oil returns to July 2008 price levels, electrification would be justifiable. If prices remain around $65 a barrel, however, diesel locomotives will remain BNSF's preferred motive power. Although BNSF believes that, from an environmental and public policy standpoint, the electrification would be a success, the project will not proceed without government support. "You hear everybody talking about a carbon-constrained world,

[276] John D. Boyd, "Challenges Loom for Electric Ideas." *The Journal of Commerce Online - News Story*, April 13, 2009, <http://www.joc.com/node/410837>. Accessed April 23, 2009.
[277] John D. Boyd, "BNSF Eyes Route to Electric Trains," *The Journal of Commerce Online - News Story*, April 13, 2009, <http://www.joc.com/node/410836>. Accessed April 23, 2009.

and a carbon-priced world," Rose said, "Railroads are so efficient from a carbon standpoint in terms of a truck, but we still have an opportunity in terms of electrification. But I just think the capital burdens are so enormous when we're talking about this that it's really going to have to be a federal vision, with some federal funding."[278] In the early twentieth century, the Milwaukee thought the economic benefits of electrification would justify the cost. As for the BNSF, almost a century later, the question of whether or not electrification would economically benefit the railroad is still tough to answer.

[278] Ibid.

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