From Frey, History of NP locos (U of M, 1970)

financial aspects of electricity. The old three-phase system did have the advantage of repaying power through the regenerative braking principle. When the locomotive was going downhill it was possible for it to generate electricity and return it to the generating plant. For instance, a 2,500 ton freight train decending a 2 per cent grade had to dissipate 4,700 horsepower.[49] Thus, it is easy to see the attractiveness of a three-phase system which carried the negative, positive, and return phase allowing regenerative braking.

Good discussion Electrification

The Milwaukee Road utilized electrification in a different manner. In 1909, the Milwaukee Road appointed one of William Rockefeller's men, John D. Ryan, to its Board of Directors. Ryan, who had numerous interests in the underdeveloped waterpower of the northwest, was a strong advocate of railroad electrification. The General Electric Company had already been making a study of the feasibility of electrifying the Milwaukee Road over some of the difficult mountain divisions in Montana, Idaho, and Washington. The railroad also engaged an independent agency to make a study. The final recommendation of both reports was to electrify. When the decision of where to acquire the electrical power was discussed, Ryan was able to convince the Board of Directors to purchase power from local utility companies rather than having the railroad construct its own independent power supply. Ryan, of course, owned considerable amounts of

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[49] August Derleth, The Milwaukee Road: Its First Hundred Years (New York: Creative Age Press, 1948), p. 190.

stock in most of the local power companies. The initial decision was to electrify 438 route miles between Harlowton, Montana, and Avery, Idaho. At 30 mile intervals, sub-stations were constructed to reduce the 100,000 volt, three-phase alternating current to 3,000 volts of direct current supplied directly to the locomotive.[50]

Apparently, the Milwaukee was pleased with the initial results of electrification because in January of 1917, the Board authorized further electrification between Othello and Tacoma, Washington, a distance of 207 miles. Within eight years the company was able to estimate that it had saved about $12,400,000 because of electrification.[51]

After some reflection, it is probable that the Milwaukee fared less successfully in electrification than did the Great Northern. Although the monetary savings of the Great Northern cannot be estimated accurately, it is conceivable that because of the extremely difficult grades they faced (up to 4 per cent) and the long tunnels at the summit of the Cascades, the Great Northern from 1909 to 1956 probably saved about $10 million by electrifying.[52] However, even these savings were probably

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[50] August Derleth, The Milwaukee Road: Its First Hundred Years (New York: Creative Age Press, 1948), p. 190.

[51] Ibid., p. 191.

[52] Northern Pacific Railway Company, Mechanical Department, "Report on Electrification of the Great Northern," dated May 21, 1929, GMS File 2384, Box 599, Como. Also, an interview with G. L. Ernstrom, April 8, 1967.

generous since the traffic density of the Great Northern frequently was not sufficient to utilize the equipment on hand, and in both 1927 and 1956 the company dismantled or sold at great loss equipment in which useful life had not been exhausted.[53] For the Milwaukee there is little doubt that electrification was a money-losing investment. Despite the additional tons the electric locomotives were able to carry and regardless of the pleasure of the passengers who were no longer bothered with cinders over the 650 miles of the Milwaukee, the railroad, in the final analysis, did not have enough traffic density to support electrification. The direct cost of stringing the catenary for 650 route miles came to almost $35 million.[54] The indirect costs, primarily the interest on the bonds, came to about $1.1 million per year. Maintenance per year cost about $250 per mile and taxes cost about $200,000 per year, primarily on the electrified improvement. The cost of motive power was higher initially, but the maintenance per locomotive mile was considered lower than for a steam locomotive of equivalent horsepower.[55] Thus, the costs of electrification on the Milwaukee were:

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[53]Northern Pacific Railway Company, Mechanical Department, "Report on Electrification of the Great Northern," dated May 21, 1929, GMS File 2384, Box 599, Como. Also, an interview with G. L. Ernstrom, April 8, 1967.

[54]Derleth, p. 198.

[55]The cost per horsepower was about 20 per cent higher for an electric locomotive than it was for a steam locomotive. However, the electric locomotive showed up to 90 cents per mile savings in maintenance costs.

Table 13

Total Cost of Electrification[56]

Total costs of changes and additions to fixed plant to electrify. . . .	$22,900,254
Interest costs for eight years.	8,800,000
Maintenance costs	325,000
Taxes	1,600,000
Depreciation	200,000
Total cost to electrify for 8 years	$33,825,254

The company estimated that the savings from electrical operation over steam operation for the first eight years of total electric operation (1917-1925) was $12,400,000. This saving was realized because of reduced maintenance costs on the electric locomotives and the increase in train tonnage over the electrified divisions. However, it would have taken between 21 and 22 years for the electrified portion to cover the relatively fixed costs had they remained fixed. By 1939 the company would have been making a considerable amount of money from the electrified portion of the Milwaukee. Unfortunately, the Milwaukee Road's figures did not come close to telling the entire story. Within 20 years the cost of maintenance on the electric locomotives had increased and it was necessary to replace them in many

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[56]Most of the cost estimates were taken from an article by George J. Sennhauser, entitled "Why We Don't Electrify," Trains, December 1962, pp. 40-44, who wrote the article in reply to an earlier article by Thomas M. C. Martin, entitled "We Should Have Electrified 15 Years Ago," Trains, April 1962, pp. 18-23. These articles taken together present an excellent pro and con argument on the electrification controversy. Both are written by electrical engineers whose practical experience and knowledge of theory combine to present some interesting points.

cases with newer and more expensive locomotives. The cost per mile of maintenance on the electrical wiring system also increased. In fact, it would be far more accurate to reduce the cost of electrifying to a yearly figure, which might be done accepting the following facts: (1) a 50 year life for the additions and changes to the fixed plant and a depreciation at the rate of 2 per cent per year;[57] (2) the electrification of the Milwaukee was financed by bonds at 5 per cent due in 2014.[58] The additional cost per year to electrify would then be reflected by Table 14.

Table 14

Estimated Cost of Electrification[59]

Total cost of changes and additions to fixed plant to electrify.	$22,990,254
Annual depreciation	440,000
Annual interest costs	1,100,000
Annual maintenance costs.	225,000
Annual taxes.	220,000
Total annual cost to electrify fixed plant.	$ 1,985,000

To offset this annual cost with savings traceable to locomotive maintenance and increased train length over the electrified portion of the line, it was necessary to operate about 21 trains per day over the entire length of the 650 route miles of

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[57] Sennhauser, p. 43.

[58] Derleth, p. 198.

[59] Statistics and method taken from the Sennhauser article, p. 43.

electrified railroad. The Milwaukee Road never had such traffic density.[60] An estimate of between $250,000 and $325,000 loss per year on the electrified portion of the Milwaukee does not appear to be out of line considering the reduction in traffic over the western portion of the system during the 1920's. Indeed the company was plunged into a most perilous situation financially because of the tremendous expenses of the western extension of the railroad. Instead of keeping this deficit down, the electrification appears, in retrospect, to have helped the financial deterioration of the railroad.

The Northern Pacific had been studying the possibilities of electrification since the time of the First World War. In May of 1917, a carefully drawn-out plan for electrifying the mainline over the Rocky Mountains was presented to the General Mechanical Superintendent. This plan proposed electrifying the entire passenger and freight mainline from Billings to Butte, Montana, a distance of 472 route miles. The reason was primarily because of the difficult grades encountered over this territory. Electric locomotives had some distinct advantages over steam locomotives in mountain operations. Since they did not have to carry their own power generating supply, there was more room available for traction-increasing devices. In tunnels, the electrics were not bothered by smoke and gasses as were

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[60] The average locomotive miles per year over the Milwaukee between Harlowton-Avery and Othello-Tacoma was about 2,100,000 given the most optimistic amount of traffic. About 14 to 16 trains operated over the line daily, again given the most favorable amount of traffic.

steam locomotives. Finally, if the three-phase system of electrification was used, it was possible to borrow some electricity and return it as the locomotive proceeded downgrade. The plan even included a series of drawings for proposed passenger, freight, and switching locomotives. Apparently the Milwaukee Road system of electrification was to be used. A three-phase system, depending heavily on the regeneration process for reducing the costs of converting to electricity, was specified and public power was to be used at 25 cycles.[61]

One of the first disappointments the company experienced was the discovery that the amount of electricity regenerated was not as high as expected. Total costs of the electrical power per year was estimated at $926,980 of which only $95,622 worth could be regenerated. The total bill for electricity for an average year was $831,358.[62] Such a reduction put immediate questions into the minds of officials considering electrification. As the Northern Pacific had time to observe the electrification of both the Great Northern and the Milwaukee, they gradually came to the conclusion that long distance electrification on the Northern Pacific would meet the same problems as it was facing on the Milwaukee--not enough traffic density. In 1916, the Northern Pacific had a total of 2,961,460

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[61] Northern Pacific Railway Co., Office of the Chief Engineer, "Blueprint for Proposed Electrification," dated May 1, 1917. Copy in possession of Mr. Ray Morrow of the Northern Pacific Railway Company.

[62] Ibid.

locomotive miles over the trackage to be electrified from Billings to Missoula.[63] This was substantially more than the Milwaukee had, but it was still about a million miles short of breaking even if electrification should be installed.[64] The problems of equipping repair shops, training maintenance staffs, and purchasing surplus parts also added to the disadvantages of electrification.

Some years later, in the late 1920's and early 1930's, the Northern Pacific considered using the Great Northern method and electrifying only a short portion of its mainline where the grades were heaviest and the tunnels were most irritating for steam locomotives. That, of course, was the section of line between Auburn and Yakima, Washington, including Stampede Tunnel. Although studies were completed, the company again failed to view the proposals favorably. The Northern Pacific did carry the studies far enough to determine that traffic density was not sufficient to realize substantial savings.[65]

When the Northern Pacific decided to forego electrification, it adopted a policy of providing large steam locomotives to power the trains over the steepest portion of its mountain runs. The Z-3 and Z-4 Mallets, slow though they were, handled most of the freight assignments primarily as helpers from the 1920's down to the time they were replaced by diesels. In the late

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[63]Northern Pacific Railway Company, Mechanical Department, "Memorandum on Electrification," dated January 15, 1918. ME File 45A, Box 91, Como.

[64]Sennhauser, p. 43.

[65]Interview with G. L. Ernstrom, March 25, 1968.