

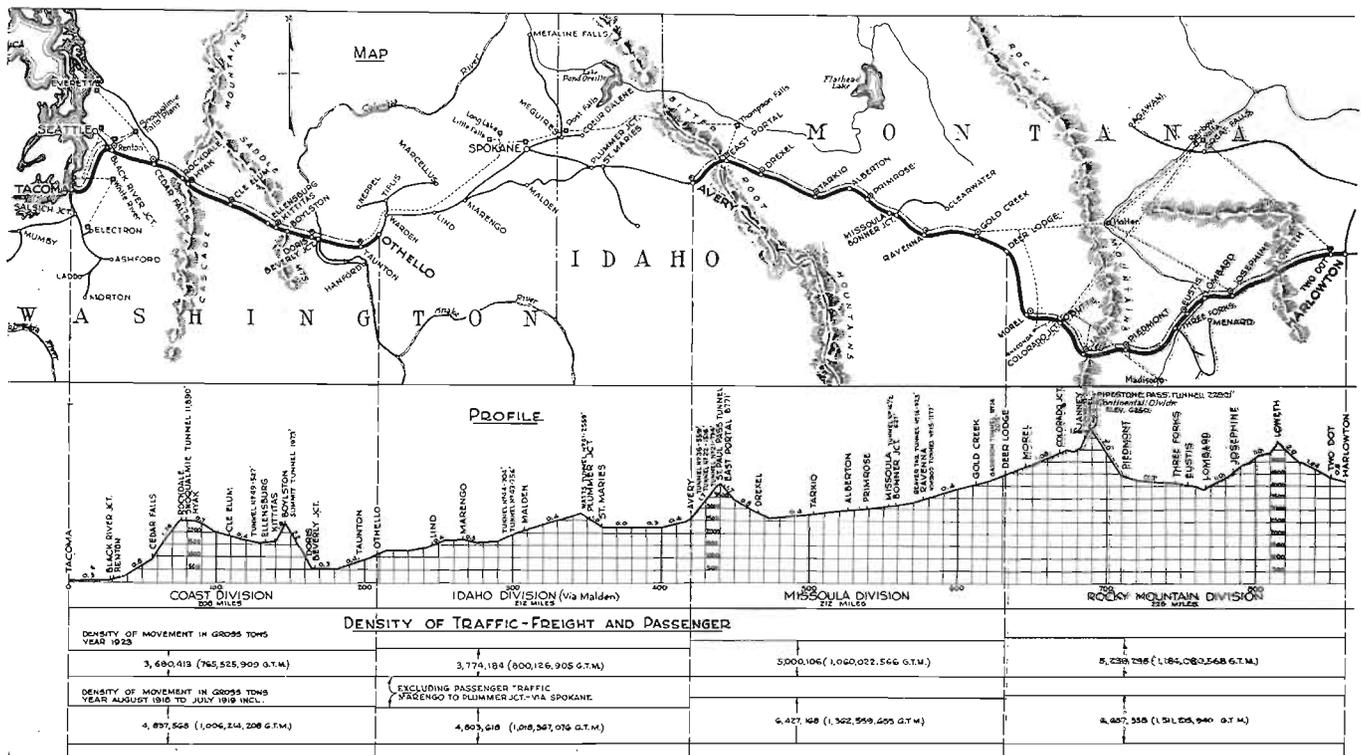
# St. Paul's Electrification Shows Economies Over Steam

*A study of comparative costs on 648 miles of line indicates saving for electric operation*

**A**FTER nearly nine years of operation on 438 miles of its 648 miles of electrified lines and nearly five years of service on the remaining 210 miles the Chicago, Milwaukee & St. Paul has made a detailed study of the comparative cost of operation electrically with that of previous operation with steam power which shows a marked saving from electrification. The report, signed by H. E. Byram, president, was prepared under the direc-

and above interest and carrying charges has been \$12,400,007.

The St. Paul started the electrification of its line in the Rocky Mountains in 1914. The first section, passing over the Big Belt and the Rocky mountains between Harlowton, Mont., and Deer Lodge, including 226 miles of first main and 66 miles of other tracks, was placed in service in April, 1916. The Missoula division, passing over the



Map, Profile and Traffic Density Chart of Electrified Territories

tion of W. W. K. Sparrow, vice-president, by Chester Oliphant, assistant comptroller, in consultation with R. Beuwkes, electrical engineer. It indicates that on a net additional investment for electrification of \$15,625,739, as explained in detail later, the saving to date over

Bitter Root range between Deer Lodge, Mont., and Avery, Idaho, and including 212 miles of first main and 62 miles of other tracks, was placed in electric operation in November, 1916.

This project, comprising a total of 438 miles of main

TABLE I—VARIATIONS IN TRAFFIC AND SAVINGS RESULTING FROM ELECTRICAL OPERATION, FIGURED ON PRICE LEVELS OF 1923

Years	Harlowton to Avery—Electrical operation began April and Nov., 1916		Othello to Tacoma—Electrical operation began March, 1920		All electrified sections	
	Volume of traffic—gross ton-miles, freight and passenger	Net savings by electrification	Volume of traffic—gross ton-miles, frt. and pass.	Net savings by electrification	Volume of traffic—gross ton-miles, frt. and pass.	Net savings by electrification
1916	1,639,054,000	†\$1,098,166	1,639,054,000	\$1,098,166	1,639,054,000	\$1,098,166
1917	2,677,097,000	1,641,369	2,677,097,000	1,641,369	2,677,097,000	1,641,369
1918	2,759,178,000	1,734,687	2,759,178,000	1,734,687	2,759,178,000	1,734,687
1919	2,894,063,000	1,888,037	2,894,063,000	1,888,037	2,894,063,000	1,888,037
1920	2,710,745,000	1,679,623	*691,674,000	*\$249,003	3,402,419,000	1,928,626
1921	1,812,714,000	658,651	664,238,000	12,363	2,476,952,000	671,014
1922	2,109,868,000	996,485	734,121,000	103,301	2,843,989,000	1,099,786
1923	2,247,102,000	1,152,508	746,405,000	119,285	2,993,507,000	1,271,793
1924	2,129,426,000	1,018,721	691,476,000	47,808	2,820,902,000	1,066,529
Total		\$11,868,247		\$531,760		\$12,400,007

†Tonnage and savings for 6½ months.  
\*Tonnage and savings for 9 months.

line from Harlowton to Avery, covered what was previously four steam engine districts with intermediate terminals at Three Forks, Deer Lodge and Alberton. The Belt mountains are crossed at Summit, 45 miles west of Harlowton, at an elevation of 5,795 ft., with a one per cent grade 14 miles long on the eastern slope and a similar grade 44 miles long on the western slope. The length of this latter grade presented one of the most serious problems encountered in this installation. The Rocky mountains are crossed at Donald, 124 miles west of Summit and 18 miles east of Butte, at an elevation of 6,350 ft. The eastern slope includes 20.8 miles of two per cent grade and the western slope 10 miles of 1.66 per cent grade. The third district between Deer Lodge and Alberton descends continuously westward on a maximum grade of 0.4 per cent. The crossing of the Bitter Root mountains is made at Roland, Idaho, at an elevation of 4,200 ft. The summit is reached by 12 miles of 1.7 per cent grade on the eastern slope and 24 miles of 1.7 per cent grade on the western slope. Over 6,250 ft. of rise and fall is overcome between Harlowton and Avery.

As would be expected in such mountainous country, the curvature is heavy, the maximum degree of curve being 10 deg. There are 36 tunnels between Harlowton and Avery, 16 of which are on the western slope of the Bitter Root mountains. The longest is the St. Paul Pass tunnel at the summit of the Bitter Root mountains, 8,751 ft. in length.

The traffic each way daily consists of two heavy trans-

continental passenger trains with occasional special passenger and milk trains, and an average of four tonnage freight trains with a local freight every second day. The freight traffic amounts to about 15,000 gross tons daily. Under ordinary conditions the prevailing tonnage is eastbound and consists largely of grain, lumber and other dead freight. Normally one time freight is able to handle all eastbound expedite business. Westbound, nearly all of the traffic consists of merchandise and other time freight.

With steam locomotives a 2,000-ton train was hauled up one per cent grades with one Mallet road engine, helpers being added on the heavier grades. Seven engines were held in this service on the Rocky Mountain division, as compared with an average of 23 road engines.

The St. Paul secured the coal used between Harlowton and Avery from company mines located on its line at Roundup, Mont. In 1923 the coal for the Rocky Mountain division cost an average of \$3 per ton at the point of use. During 1915 oil was used as locomotive fuel on the Missoula division, the oil being hauled from Puget Sound points. The oil equivalent to a ton of coal cost about \$3.65 laid down at the point of use in 1923.

The electrification of the Coast division, from Othello, Wash., to Tacoma was placed in operation in March 1920. This territory includes 208 miles of first main and 72 miles of side and yard tracks, and passes over the Saddle mountains and the Cascade mountains. The summit of the Saddle range is at Boylston, altitude 2,390 ft.,

TABLE II—OPERATING EXPENSES DIRECTLY AFFECTED BY CHANGE IN POWER—HARLOWTON TO AVERY

I. C. C. accts.	Classification of expenses—Description (2)	Steam operation— Costs of the year 1915 adjusted to the price levels of 1923			Electrical operation— Actual costs of the year 1923		
		*Variable		*Constant	*Variable		*Constant
		Freight (3)	Passenger (4)	frt. and pass. (5)	Freight (6)	Passenger (7)	frt. and pass. (8)
	Maintenance of way and structures:						
201	Superintendence .....			\$94,472			\$95,208
231	Water stations .....			23,800			
233	Fuel stations .....			9,930			
235	Shops and enginehouses .....			42,383			33,927
249	Signals and interlockers .....			52,131			47,671
255	Power substation buildings .....						1,530
257	Power transmission systems .....						2,913
259	Power distribution systems .....						40,763
261	Power line poles and fixtures .....						18,379
271	Small tools and supplies (for M. of Elec. Prop. only) .....						847
	Total maintenance of way and structures .....			\$222,716			\$241,238
	Maintenance of equipment:						
301	Superintendence .....			\$120,194			\$105,440
306	Power substation apparatus .....						19,163
308-11	Locomotive repairs—Train .....	\$687,824	\$218,725		\$190,390	\$135,349	
308-11	Locomotive repairs—Switch .....	37,105			12,510	77	
314-17	Brake shoe and rigging, wheel and draft rigging wear .....	21,352	11,622				
326	Trolley maintenance cars—Only .....						2,757
	Total maintenance of equipment .....	\$746,281	\$230,347	\$120,194	\$202,900	\$135,426	\$127,360
	Transportation:						
371	Superintendence .....			\$70,240			\$61,407
377	Yardmasters and yard clerks .....			17,055			17,055
378	Yard conductors and brakemen .....	\$61,533			\$27,174	\$166	
379	Yard switch and signal tenders .....			1,189			548
380-81	Yard enginemen—Yard motormen .....	39,644			17,990	110	
382-84	Fuel for yard locomotives—Yard switch, power purchased .....	43,315					9,489
383	Yard switching power produced .....						1,053
385	Water for yard locomotives .....	1,257					
386	Lubricants for yard locomotives .....	777			394	1	
387	Other supplies for yard locomotives .....	808			302	1	
388	Enginehouse expense—Yard .....	12,431			4,131	25	
389	Yard supplies and expenses .....			712			328
392-93	Train enginemen—Train motormen .....	400,421	121,341		231,352	77,778	
394-96	Fuel for train locomotives—Train power purchased .....	886,009	270,693				754,231
395	Train power produced .....						87,135
397	Water for train locomotives .....	24,939	7,556				
398	Lubricants for train locomotives .....	14,534	3,360		9,979	4,811	
399	Other supplies for train locomotives .....	19,018	5,381		4,831	2,470	
400	Enginehouse expense—Train .....	142,283	66,330		42,341	40,531	
401	Trainmen .....	317,041	94,649		197,067	94,649	
402	Train supplies and expenses (Train—Light and heat) .....						12,883
404	Signal and interlocker operation .....			40,841			31,517
	Total transportation .....	\$1,964,010	\$569,310	\$130,037	\$535,561	\$233,425	\$962,763
	Work train expense—All other than included above in M. of W. & S. adjusted to 1923 work train-miles .....			\$74,721			\$62,415
	Totals for operating expenses directly affected (Gr. Tot. Stm. \$4,057,616; Gr. Tot. Elec. \$2,501,088) .....	\$2,710,291	\$799,657	\$547,668	\$738,461	\$368,851	\$1,393,776
	Gross ton-miles in thousands—the work performed (Gr. Tot. Stm. 2,178,631; Gr. Tot. Elec. 2,247,102) .....	1,758,726	†419,905		1,827,197	419,905	
	Cost per 1,000 gross ton miles .....	\$1.54105	\$1.90438		\$4.0415	\$8.7842	

\*"Variable"—Expenses considered to vary practically directly with volume of traffic: "Constant"—Expenses considered to remain practically constant for all volumes of traffic within a reasonable range.  
†The actual for the period, 354,054,000, adjusted to the tonnage of electrical operation as the difference rests solely in the number of cars per train: Expenses adjusted to conform.

while at the Snoqualmie tunnel, the summit of the Cascade range, the altitude is 2,562 ft. The maximum grade of 2.2 per cent extends for 12 miles from Doris to Boylston. The maximum grade on the west slope is 1.74 per cent on 19.2 miles between Rockdale and Cedar Falls.

The direct-current-overhead-trolley type of electrification is used. Twin trolley construction is employed to avoid sparking. Current is purchased at taps in the high tension lines along the right-of-way and transmitted to sub-stations where it is stepped down from three-phase alternating current at 100,000 volts to a working voltage of 2,300 and thence converted through motor generators to direct current at 3,000 volts for distribution on the trolley. The motors of the locomotives are so constructed as to act as generators when descending grades, thus returning current to the line and controlling the speed of trains without mechanical braking.

The complete locomotive equipment for the electrified territories consists of 13 passenger, 42 freight and 4 yard locomotives. The tractive effort of these locomotives varies with the time required to pull up the trade. The equivalent number of steam locomotives necessary would be 133 freight, 23 passenger and 10 switching locomotives.

Since the electrification was placed in service marked

fluctuations in the volume of traffic have been caused by the war time peak and by the slump in 1921. During 1915, the last year of steam transportation on the Harlowton-Avery section, this territory handled 2,178,631,000 gross ton-miles of passenger and freight traffic. The electrification was completed in November, 1916. The years 1917-1920 saw the peak traffic, the maximum occurring in 1919, when 2,894,063,000 gross ton-miles were handled. After the slump in 1921, when only 1,812,714,000 ton-miles were carried, the curve again began to rise and in 1923 the load amounted to 2,247,102,000 ton-miles which is approximately equal to that of 1915. For the purpose of a study of steam and electrical operation the years 1915 and 1923 are compared.

On the Coast division the electrification was placed in full service in May, 1920. The year ending July 31, 1919, was therefore chosen as the steam period for comparison with the year 1923 as the electrical period. However, in this case the steam period included a traffic of 1,014,511,000 ton-miles, considerably larger than the electrical operating year with only 746,405,000—a situation favoring steam operation to some extent in the comparison.

The cost of steam operation for the year 1923, if this form of operation had been employed on these electrified

TABLE III—OPERATING EXPENSES DIRECTLY AFFECTED BY CHANGE IN POWER—OTHELLO TO TACOMA

I. C. C. accts.	Classification of expenses—Description	Steam operation— Costs of the year, August, 1918 to July, 1919, inclusive, adjusted to the price levels of 1923			Electrical operation— Actual costs of the year 1923		
		*Variable		*Constant	*Variable		*Constant
		Freight (3)	Passenger (4)	frt. and pass. (5)	Freight (6)	Passenger (7)	frt. and pass. (8)
	Maintenance of way and structures:						
201	Superintendence .....			\$48,295			\$49,777
231	Water stations.....			8,273			
233	Fuel stations.....			5,215			
235	Shops and enginehouses.....			16,234			12,513
249	Signals and interlockers.....			33,202			31,343
255	Power substation buildings.....						2,047
257	Power transmission systems.....						5,179
259	Power distribution systems.....						19,723
261	Power line poles and fixtures.....						11,066
271	Small tools and supplies (for M. of Elec. Prop. only).....						365
	Total maintenance of way and structures.....			\$111,219			\$132,013
	Maintenance of equipment:						
301	Superintendence .....			\$31,105			\$22,306
306	Power substation apparatus.....						7,891
308-11	Locomotive repairs—Train.....	\$326,467	\$129,174		\$78,549	\$60,703	
308-11	Locomotive repairs—Switch.....	24,141			2,658		
314-17	Brake shoe and rigging, wheel and draft rigging wear.....	18,000	7,000				
326	Trolley maintenance cars—Only.....						714
	Total maintenance of equipment.....	\$368,608	\$136,174	\$31,105	\$81,207	\$60,703	\$30,911
	Transportation:						
371	Superintendence .....			\$35,097			\$34,126
377	Yardmasters and yard clerks.....			6,708			3,268
378	Yard conductors and brakemen.....	\$40,560			\$10,038		
379	Yard switch and signal tenders.....			2,047			578
380-81	Yard enginemen—Yard motormen.....	25,629			6,396		
382-84	Fuel for yard locomotives—Yard switch, power purchased.....	24,763					2,714
383	Yard switching power produced.....						447
385	Water for yard locomotives.....	602					
386	Lubricants for yard locomotives.....	506			105		
387	Other supplies for yard locomotives.....	526			44		
388	Enginehouse expense—Yard.....	6,845			1,186		
389	Yard supplies and expenses.....			314			62
392-93	Train enginemen—Train motormen.....	233,323	69,674		92,224	38,095	
394-96	Fuel for train locomotives—Train power purchased.....	493,807	186,446				\$319,634
395	Train power produced.....						53,301
397	Water for train locomotives.....	11,710	4,548				
398	Lubricants for train locomotives.....	5,606	1,758		4,804	2,171	
399	Other supplies for train locomotives.....	7,211	2,778		3,485	1,999	
400	Enginehouse expense—Train.....	45,959	29,252		14,554	16,127	
401	Trainmen.....	264,338	60,644		107,183	47,698	
402	Train supplies and expenses (Train—Light and heat).....					7,723	
404	Signal and interlocker operation.....			19,248			1,380
	Total transportation.....	\$1,161,385	\$355,100	\$63,414	\$240,019	\$113,813	\$428,510
	Work train expense—All other than included above in M. of W. & S. adjusted to 1923 work train-miles.....			\$50,452			\$39,676
	Totals for operating expenses directly affected (Gr. Tot. Stm. \$2,277,457; Gr. Tot. Elec. \$1,126,852).....	\$1,529,993	\$491,274	\$256,190	\$321,226	\$174,516	\$631,110
	Gross ton miles in thousands—the work performed (Gr. Tot. Stm. 1,014,511; Gr. Tot. Elec. 746,405).....	805,830	±208,681		537,724	208,681	
	Cost per 1,000 gross ton miles.....	\$1.89865	\$2.35419		\$.59738	\$.83628	

\*"Variable"—Expenses considered to vary practically directly with volume of traffic: "Constant"—Expenses considered to remain practically constant for all volumes of traffic within a reasonable range.

†Constant up to a total of 906,097,000 gross ton miles for freight and passenger services; thence increased in freight service as estimated necessary for greater volumes of traffic: (The amount to be added at 1,014,511,000 G. T. M. is \$38,307.00.)

‡The actual for the period, 186,232, adjusted to the tonnage of electrical operation as the difference rests solely in the number of cars per train due to difference in train routing: Expenses adjusted to conform.

sections, is based upon the actual cost of steam operation for the last 12 months that such operation was in effect, adjusted to the costs prevailing in 1923. The sections were electrified at different times and have different physical and traffic characteristics, as well as different investment costs. For these reasons the report deals with the cost of steam and electrical operations on each section separately.

Under either method of operation some costs, within reasonable limits, remain constant while others vary with the volume of traffic. Because of the total tonnage moved in each year being different, the unit cost, or cost per gross ton-mile for the tonnage handled in the selected years of steam operation is not comparable with the cost per gross ton-mile for the tonnage handled in the year of electrical operation. In order, therefore, to make an accurate comparison and determine the differences in cost between the two methods of operation, the costs as

case of the Rocky Mountain and Missoula divisions, where there was little variation in the volume of tonnage as between the selected years of steam and electrical operation, are within practical limits, a true assumption, and that any possible variation would be slight and of no consequence. In the case of the Coast division where the tonnage in the year of electrical operation was very low in comparison with that of the steam period, any variation from the assumption made would have the effect of making the unit costs of electrical operation for the higher tonnages as shown in this report greater than they should be, and be. Due to the difference in the cost levels obtaining in the different years in which the property not common to both uses was acquired, there is a considerable difference in the investment cost of such property. As interest and depreciation charges on all property used solely for either operation are in this report charged against the form of operation to which they apply, it is just as necessary to a true comparison of cost to restate such investment costs for a period having the same cost levels as it was to restate the cost of labor and material used in operation.

This has been done, using for the electrical property the actual cost figures and for the steam property no longer in use on the electrified sections and which consequently has either been released for use on other divisions of the railroad, or retired from service, what such property would have cost new at the time of the purchase and installation of the electrical property.

No savings have been credited to electrical operation which are not susceptible of direct ascertainment, as for example, the possible increased revenue due to the release of equipment used in the transportation of coal when these divisions were under steam operation, better utilization of freight equipment due to faster movement, less wear and tear on road and equipment, less station expenses affected by the number of trains required to handle a given tonnage, or increase in passenger revenue due to the attractiveness and greater comfort of travel under electrified operation.

**Savings Resulting from Electrical**

**Operation—Cost Level of 1923**

Table I shows for the years since the beginning of electrical operation the net savings from electrical operation, using for steam operation the actual costs for the last 12 months of such operation, adjusted to the costs obtaining in 1923; and for electrical operation, the actual costs as determined for the year 1923. The net savings shown are obtained by deducting from the savings in operating expenses the carrying charges of interest and depreciation on the additional investment required by electrification. This additional investment amounts to \$15,625,739, as shown in detail later.

From this table it will be seen that for the year 1923, with its comparatively low tonnage, the net savings from electrical operation of the two sections amounted to \$1,271,793. For the minimum tonnage so far experienced, which was in the year 1921, the savings amounted to \$671,014. The maximum tonnage handled so far was in the year 1919. If the section from Othello to Tacoma had been under electrical operation during that year the savings for the two sections would have amounted to \$2,355,199. The total accrued net saving by electrification aggregates \$12,400,007, or slightly more than three-fourths of the cost of the electrification.

**Operating Expenses Directly Affected**

**by Change in Power**

Statements of the costs of electrical and steam operation as collected from the detail work sheets, together with certain traffic, fuel and locomotive statistics used or given consideration with the costs, are shown in Tables

TABLE IV—INVESTMENT IN AND CARRYING CHARGES ON THE PROPERTY PECULIAR TO EACH MODE OF OPERATION—HARLOWTON TO AVERY (438 Roadway miles)

Items	Investment	Carrying charges		Total
		Interest 5%	Depreciation S. F. Basis 6%	
Steam operation—Fixed property:				
Fuel and water stations, cinder pits, etc.....	\$630,000	\$31,500	\$16,695	.....
D. C. signal system.....	†.....	.....	.....	.....
Totals, fixed property....	\$630,000	\$31,500	\$16,695	\$48,195
Locomotives:				
Freight (incl. all pusher work service locomotives).....	\$2,470,628	\$123,531	\$28,165	.....
Passenger .....	356,039	17,802	4,059	.....
Switch .....	78,598	3,930	896	.....
Totals, locomotives.....	\$2,905,265	\$145,263	\$33,120	\$178,383
Totals, steam property..	\$3,535,265	\$176,763	\$49,815	\$226,578
Electrical operation—Fixed Prop-erty—				
Roadway buildings.....	\$89,545	\$4,477	\$2,382	.....
Power substation buildings..	535,157	26,758	3,361	.....
Power substation apparatus..	1,859,353	92,968	21,383	.....
Power transmission system...	715,181	35,759	5,435	.....
Power distribution system....	2,890,615	144,531	23,269	.....
Power line poles and fixtures.	1,091,721	54,586	50,110	.....
A. C. signal system.....	†197,446	9,872	1,374	.....
Engr.—Int. during construction and miscellaneous....	325,671	16,284	3,354	.....
Maintenance equipment.....	37,000	1,850	422	.....
Sub-total .....	\$7,741,689	\$387,085	\$111,090	\$498,175
Rental of transmission lines—				
Credit .....	.....	Cr.\$2,760	.....	Cr.\$2,760
Totals, fixed property....	\$7,741,689	\$384,325	\$111,090	\$495,415
Locomotives:				
Freight (incl. all pusher and and work service locomotives) .....	\$2,881,112	\$144,056	\$32,845	.....
Passenger .....	927,408	46,370	10,573	.....
Switch .....	111,564	5,578	1,272	.....
Totals, locomotives.....	\$3,920,084	\$196,004	\$44,690	\$240,694
Totals, electrical property..	\$11,661,773	\$580,329	\$155,780	\$736,109
Increase in carrying charges—				
Account electrification.....	.....	.....	.....	\$509,531

\*Electrical operating property at actual cost 1914-15-16: Steam operating property priced as of the costs obtaining during the same period (1915).  
 †Net increase in investment chargeable to electrification included under electrical operation.

developed for the traffic of any one year had to be adjusted to conform to the volume of traffic of the other years. This adjustment was made by separating the costs between those items which, within practical limits for the range of tonnage under consideration, vary directly with the volume of traffic and those which remain constant.

When this has been done it is a simple matter to state the cost of steam operation for the tonnage of the year of electrical operation, and similarly the cost of electrical operation for the tonnage of the years of steam operation. The only assumption made in this adjustment is that the costs as separated between constants and variables have true varying and constant characteristics which, in the

II and III. The selection accounts used was made after a careful study of the expenditures under each of the primary accounts of the operating classification. Some of the accounts excluded as not being affected by the change in power are without doubt affected to some extent, but the effect is so slight as to be negligible in comparison with the effects produced by other causes. For example, "Maintenance of Track" is an expense unquestionably affected to some extent by the class or kind of power, but the effects from other causes such as weather, availability of money, cycles of renewals of parts, maintenance programs, labor conditions, etc., are so much greater and so impossible of exact ascertainment for elim-

data were available which would enable the brake shoe wear to be determined with any accuracy for the condition of continuous and long application which, under steam operation, occurs on mountain grades. Therefore, a wear figure, believed at least to be conservative, of one pound of wear per 100,000,000 foot-pounds of energy dissipated was used. There is also a saving in draft rigging and braking apparatus and in wheel wear, all of which are, for evident reasons where cars move over many divisions, indeterminable. The amount of savings on account of these items was assumed to be the same as that resulting from the reduction in brake shoes wear. This is believed to be conservative.

Costs of electric power are based upon a minimum total payment corresponding to the respective kilowatts for which the railway company in 1923 had exercised option for the different sections. Where these respective amounts of kilowatts are not sufficient to handle the increased traffic, power cost has been increased on the basis of the additional kilowatts required.

TABLE V.—INVESTMENT IN AND CARRYING CHARGES ON THE PROPERTY PECULIAR TO EACH MODE OF OPERATION—OTHELLO TO TACOMA (208 Roadway miles)

Items	Investment	Carrying charges		Total
		Interest 5%	Depreciation S. F. Basis 6%	
<b>Steam operation—Fixed property:</b>				
Fuel and water stations, cinder pits, etc.	\$507,010	\$30,421	\$13,436	.....
D. C. signal system	612,000	36,720	6,793	.....
Totals, fixed property	\$1,119,010	\$67,141	\$20,229	\$87,370
<b>Locomotives:</b>				
Freight (incl. all pusher and work service locomotives)	\$2,133,785	\$128,147	\$24,348	.....
Passenger	430,231	25,814	4,905	.....
Switch	144,224	8,653	1,644	.....
Totals, locomotives	\$2,710,240	\$162,614	\$30,897	\$193,511
Totals, steam property	\$3,829,250	\$229,755	\$51,126	\$280,881
<b>Electrical operation—Fixed property:</b>				
Roadway buildings	\$114,215	\$6,853	\$3,027	.....
Power substation buildings	452,808	27,168	2,875	.....
Power substation apparatus	1,476,964	88,618	16,985	.....
Power transmission system	549,521	32,971	5,072	.....
Power distribution system	2,190,401	131,424	16,822	.....
Power line poles and fixtures	966,563	57,994	40,596	.....
A. C. signal system	780,000	46,800	8,658	.....
Engr.—Int. during construction and miscellaneous	621,519	37,291	7,645	.....
Maintenance equipment	27,000	1,620	308	.....
Sub-total	\$7,178,991	\$430,739	\$101,988	\$532,727
Rental of transmission lines—Credit	.....	Cr.\$25,842	.....	Cr.\$25,842
Totals, fixed property	\$7,178,991	\$404,897	\$101,988	\$506,885
<b>Locomotives:</b>				
Freight (incl. all pusher and work service locomotives)	\$3,065,280	\$183,917	\$34,944	.....
Passenger	1,035,690	62,141	11,807	.....
Switch	48,520	2,911	553	.....
Totals, locomotives	\$4,149,490	\$248,969	\$47,304	\$296,273
Totals, electrical property	\$11,328,481	\$653,866	\$149,292	\$803,158
Increase in carrying charges—Account electrification	.....	.....	.....	\$522,277

\*Electrical operating property at actual cost 1917-18-19: Steam operating property priced as of the costs obtaining during the same period (1918).

ination, that the expense can only be classified as not being affected by change in power. Work train expenses have been separated and included as expenses directly affected by changes in power for several reasons, one of which is that certain stand-by losses under steam operation are eliminated by using electric motors in work train service. The costs of the two periods have been adjusted to the same amount of work train service.

As the price levels of labor and material were not the same for the periods of electrical and steam operation, it was necessary to bring the costs to the same level so that a true comparison could be made. To this end the costs of the steam periods have been restated as of the electrical period and hence all the operating expense costs in this report are for the price levels of 1923.

With respect to the savings through the use of regenerative electric braking, it was found that no existing

### Separation of Affected Operating Expenses Between Constant and Varying Items

The total tonnage moved in the selected years, or any year that could have been selected, for steam operation was not the same as the tonnage moved in the year of electrical operation. Therefore, in order that the costs of electrical and steam operation might be stated for different volumes of traffic, within a reasonable range of the tonnage which has been handled over these divisions, without which a correct comparison between the cost of steam and electrical operations could not be made, the costs affected by a change from steam to electrical operation were separated between those which within reasonable limits remain constant for different volumes of traffic, because they are not connected with the direct movement of traffic, and those which on account of being connected with the movement of traffic vary directly with the volume of traffic. The expenses which within practical limits vary directly with the volume of traffic have been separated further between passenger and freight service, as such expenses can be directly assigned. With these separations in the expenses, the costs of operation for the volumes of traffic dealt with in this report may be obtained readily. It is only necessary to multiply the gross ton-miles of each service at any volume point by the respective unit costs developed, and to the sum of the products so derived add the total constant cost.

### Carrying Charges on the Investment

The property here considered is the power equipment and the facilities and appurtenances directly related thereto—as, for example, in steam operation, the fuel and water stations and in electrical operation, the transmission and distribution systems, sub-stations, etc. The signal systems are also included as it was necessary to change out the direct current systems for the alternating current systems on account of the electrification.

Investment for the property peculiar to electrical operation was taken as of the actual cost of installation—on the Coast division, as of the prices obtaining in 1918 (1917 to 1919); on the Rocky Mountain and Missoula division, as of 1915. The carrying charges computed upon the investments and included as cost are interest and depreciation. The interest rate has been taken at the rate paid by the St. Paul during the different periods of installation—for the Coast division 6 per cent and for the Rocky Mountain and Missoula divisions 5 per cent. Depreciation has been computed upon the sinking fund basis, using an interest rate of 6 per cent.