central stations. Mr. Murphy's argument tended to show that it would pay to electrify railways even if the generators in central stations are steam-driven, and certainly if they are water-power driven, on account of the entire conservation of coal.

"Steam Locomotives consume 25% of all coal mined every year," he said. "Electric locomotives can save two thirds of that coal when their electrical energy comes from stationary steam plants; water power can make them save it all.

"Still smarting from the sufferings of two successive winters' fuel shortages, caused primarily by inadequate transportation facilities, we should prevent, if possible, recurrences of such serious and trying experiences.

Use 30% of Canadian Coal

"No argument is required, I think you will agree, to support the contention that eliminating the need for coal at a considerable distance from the mine is a greater measure of relief, and of true conservation, than increasing mine production and thereby adding more load to the already overburdened railways. Reducing coal consumption automatically relieves or releases men and apparatus all along the route from the mine to the consumer; it also relieves the route itself from some of its congestion.

"So eminent an authority as E. W. Rice, the president of the American Institute of Electrical Engineers, addressing that body in New York in February, 1918, made the following statement:

"'It is really terrifying to realize that 25% of the total amount of coal which we are digging from the earth is burned to operate our steam railroads—and burned under such inefficient conditions that an average of at least 6 pounds of coal is required per horse-power-hour of work performed. The same amount of coal burned in a modern central power station would produce an equivalent of three times that amount of power in the motors of an electric locomotive, even including all the losses of generation and transmission from the power station to the locomotive.'

"Mr. Rice went on to say that 150,000,000 tons of coal, nearly 25% as he said, of all the coal mined in the United States, were consumed in steam locomotives last year.

"Here in Canada steam locomotives consumed about 9,000,000 tons—30% of the 30,000,000 tons of coal imported into and mined in this country. Our 9,000,000 tons cover, I believe, wood and oil consumed on steam locomotives; some 49,000,000 gallons of oil are covered by the Canadian record. But, in the United States figures, 40,000,000 barrels of oil, 15% of the total oil output, are not included.

Of Interest to Fuel Controllers

"The total conservation of—the elimination of the necessity for mining—those great quantities of fuel would be secured if all the railways were operated electrically and if the electrical energy were generated from water power. Modern steam central stations can save from 50% to 66% of the coal now used in steam locomotives if the latter are discarded and electric locomotives used instead.

"With such possibilities for fuel conservation in sight may we not soon expect to learn that the fuel controllers in both countries have asked the railways, and that the railway managers have asked their engineers:—'How many of these millions of tons of coal can you save—when will the good work of railway electrification begin?'

"It is said our fuel shortages were due to a combination of bad weather and inadequate transportation. As we cannot control the *weather* our attention and efforts must be directed to the *transportation* portion of the difficulty. Railway electrification will reduce coal consumption, coal haulage and the mining of coal; it will also greatly improve traffic conditions; electrification, therefore, seems to be the solution of the problem. Under these circumstances it may not be out of place to recite in general terms what electrification has actually accomplished on some notable railways.

"Railroading in the mountains is the most strenuous kind of railway work. The examples which I have chosen cover mountain sections. The Butte, Anaconda & Pacific Railroad, by electrification, is said to have increased its ton-milage 35% and at the same time decreased the number of trains, and their incidental expenses, 25%. The time per trip was decreased 27%. It is said their savings in the first year's operation, after electrification, amounted to 20% of the total cost of electrification. That railway buys power from water power plants.

Regenerative Electric Braking

"On the Norfolk & Western Railway power is obtained from their own steam station. Twelve electric locomotives have replaced 33 Mallets of the most modern and powerful type. The tonnage has been increased 50%. Electrification obviated the necessity for double tracking. The salvage value of the released steam engines was 45% of the cost of electrification. Electric locomotives make 8 times as many miles per-train-minute-delay as the steam engines. Their terminal lay-overs average only 45 minutes and they are double-crewed every 24 hours. Pusher engine crews have been reduced from 8 steam to 4 electric. Pusher engines or locomotives have been reduced from 7 steam to 2 electric. Steam locomotives used to 'fall down' in cold weather—the electrics always 'stand up,' they are really more efficient, in cold weather. At the New York Railroad Club meeting last year their electrical engineers stated that:—'coal wharves, spark pits, water tanks and pumps as well as roundhouses and turntables have disappeared from the electric zone. Our track capacity has been doubled. Our operating costs have been reduced. From an engineering, an operating and a financial viewpoint our electrification has been a success.' Speaking of the value of regenerative electric braking they went on to say:—'The use of the air brake is practically eliminated, it is only used to *stop* trains; it is regrettable we are unable to put a dollars and cents value on this great asset; to appreciate it properly one must have had experience with the difficulties of handling 90 car trains with air. Trains of 103 cars are now taken over the summit, 12 to 20 times every day, down the 2.4% grade without even touching the air. We never broke a train in two or slid a wheel. It is done so nicely we wouldn't spill a drop of water out of a glass in the caboose.'

Cruising Radius Is Doubled

"The 440 route miles of Chicago, Milwaukee & St. Paul Railway which have been electrified will soon be augmented by 450 miles more. Nearly 900 miles of railway and about 33% in addition for passing-tracks, yards, industrial tracks and sidings will soon represent the extent of this great railway electrification. Among the advantages secured by this railway on its electric sections are the following:—The 'cruising radius' of each electric locomotive is twice that of the steam engine. Sub-divisional points, where freight crews and steam locomotives were formerly housed and changed, have been abolished; the passenger crews' runs are now 220 miles instead of 110. For railway purposes, these stations do not now exist; 7 or 8 miles of track at each old station have been taken up; 'through freights' do not leave the main line track at all at these points; shops and roundhouses have disappeared, along with their staffs, and one electrician replaces the whole old shop and roundhouse force. An electric locomotive has made 9,052 miles in one month. Although schedules have been reduced the electrics have 'made up' more than 2½ times as many minutes as steam engines running on the old schedules —'time' which had been lost on other divisions; 29% of electric passenger trains made up time in this manner. On a milage basis alone the operating costs of the electrics are less than one half the steam engine costs. Freight traffic increased 40% shortly after electrification—double-tracking would have been necessary to handle such increased business under steam operation. An average increase of 22% in freight tonnage, per train, has taken place. One electric handles about 3½ times as many ton-miles as a steam engine; the reduction in time in handling a ton-mile is 30%; faster and heavier trains have accomplished these results; the number of trains has not been increased. About 11½% of the energy used by the railway is returned to the line in