boilers were extremely discouraging, and it was only after considerable development work in methods of combustion, extending over many years, that it was found possible to maintain the rate of combustion necessary to give good steaming results with the use of this fuel. Even now, due to the use of steam jets, and the necessity for sanding flue sheets to remove unconsumed carbon, etc., it is a most wasteful practice as far as utilization of heat value in the fuel is concerned.

In stationary practice the introduction of natural gas under boilers required special regenerative features and, until the firebox had been properly arranged, practically no evaporation results were obtained.

PART VI

POSSIBILITIES OF CONSERVATION OF FUEL BY RAILWAY ELECTRIFICATION

By W. D. BEARCE

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The most potent factors in the conservation of fuel during the last twenty years have been: (1) the development of water power, (2) the concentration of the production of power from fuel in central stations where the most economical methods may be utilized, and (3) the distribution of power electrically. There is still much to be done in the way of replacing inefficient isolated power plants of various kinds and sizes with electric power. From the point of view of fuel conservation the most important field remaining for the more extended use of electricity is on the railways. One-fourth of all the coal mined in the country, as well as a considerable quantity of oil, is consumed by steam locomotives. The locomotive is an isolated power plant of low efficiency, and the only excuse for its continued existence is the cost of electrification. Data are now available which show that in one case, cited by the author, an electrified railway has earned 20 per cent annually on the investment.—EDITOR.

According to the classification of the U. S. Geological Survey, the steam railroads are the next to the largest consumers of coal products in the United States, their requirements being exceeded only by the group of industries classed as "Industrial Steam Trade."* Out of a total production of more than half a billion tons of bituminous coal, the steam roads are charged with the consumption of 135,000,000 tons, or 27 per cent. The railroads also consume 6,735,000 tons of anthracite, or 7.7 per cent of the total production.

The report of the Interstate Commerce Commission gives figures for the fiscal year ending June 30, 1916, showing a total of 63,862 steam locomotives in service. These engines are operating over 259,211 miles of route, or a total of 394,944 miles on a single track basis The transportation systems represented by these figures operated every type of railway from light infrequent service roads to heavy transcontinental freight and passenger haulage. Locomotives vary in size from small switchers up to the heavy freight engines weighing 300 tons or more.

Figures on the consumption of fuel oil for steam locomotives indicate that oil burners consumed a total of more than 42,000,000 barrels for the year 1916. These locomotives were operated over nearly 32,000 miles of track in twenty-one states.

At the present prices of the crude product, it is probably somewhat more expensive to operate with oil than with coal, although in some cases the reduced damage from forest fire offsets the extra cost. Many of the western roads, however, on account of the proximity of government reserves are required to use oil over long distances. Large amounts of fuel oil are required by the United States navy, as well as by large numbers of merchant ships, and the supply of the principal product of the oil refineries in the shape of gasolene hardly equals the demand. It is, therefore, quite as important to save fuel oil as to conserve the supply of coal.

The number of electrically operated railways is small in comparison to those operating by steam, totalling only 47,000 miles, or 10½ per cent of the total trackage. The rolling stock includes 80,000 passenger motor cars, more than 1000 express motor cars, and about 540 electric locomotives. The coal consumption per mile is small, however, when compared with that required by steam locomotives. In fact, it may be conceded that the traction systems of our large cities, such as New York, Boston, Chicago, and others, are operated on a most efficient basis as far as coal consumption is concerned. Many cities, such as Buffalo, Baltimore, St. Louis, and San Francisco, are supplied to a large extent from hydroelectric plants, and thus require little if any coal for their operation. This is also the case with a large

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* This classification covers a wide range of consumers including the following: large mills, factories, central power stations, pumping plants, and brick and cement burners.

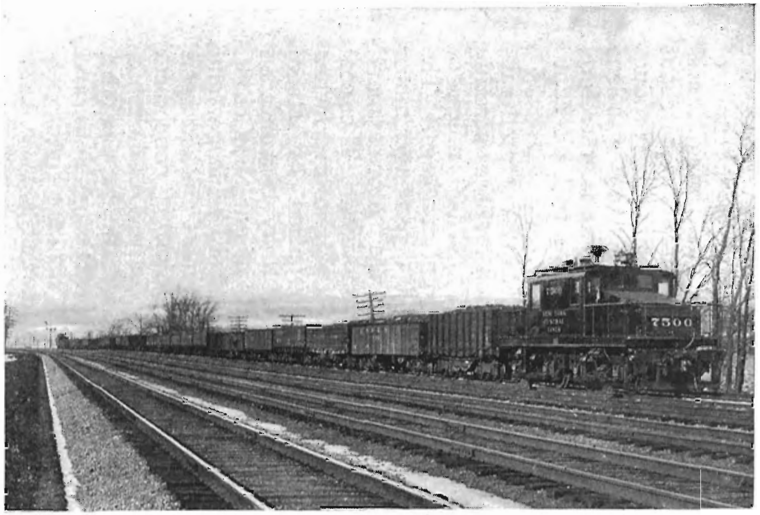


Fig. 1. 100-ton, 600-volt Locomotive on the Detroit River Tunnel Electrification

Fig. 2. 130-ton, 600-volt Direct-current Gearless Locomotive Coupled to the Twentieth Century Limited on the Electrified Division of the New York Central Railroad

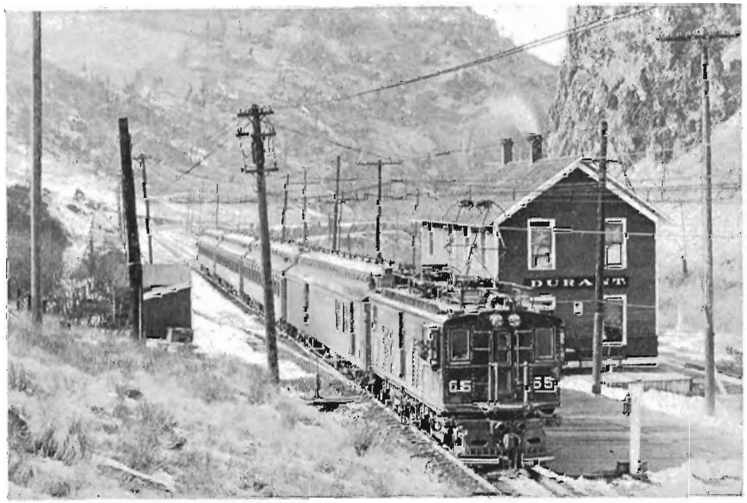


Fig. 3. 80-ton, 2400-volt Locomotive on the Butte, Anaconda and Pacific Railway

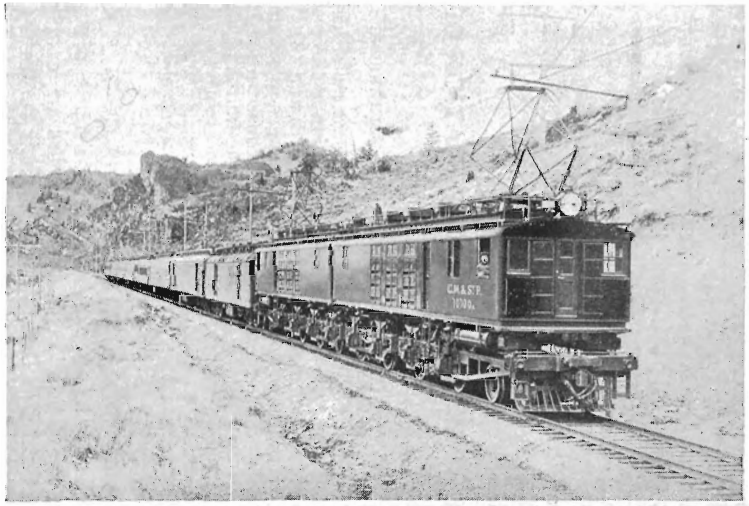


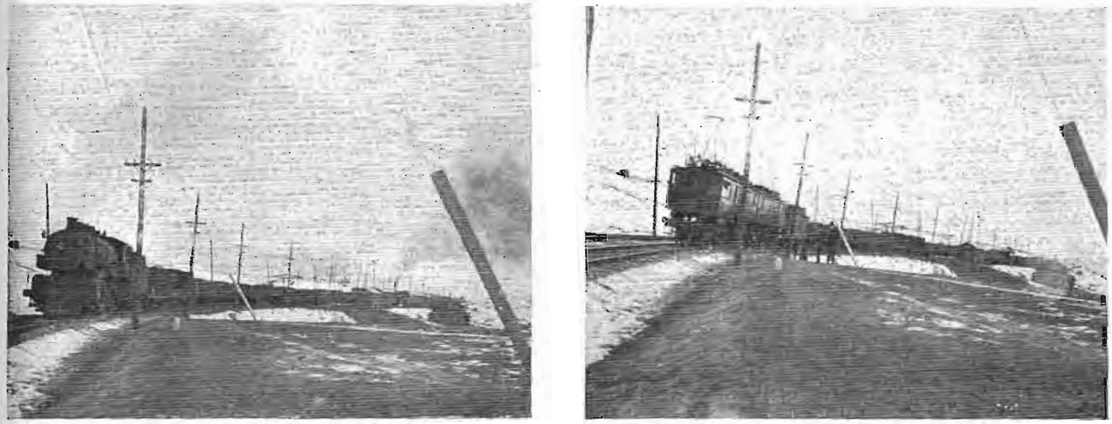
Fig. 4. 300-ton 3000-volt Direct-current Locomotive on the Chicago, Milwaukee and St. Paul Railway

number of small interurban roads throughout the country. Taking into account the large amounts of hydroelectric power utilized and the efficient use of coal in the power plants of the large electric railway systems, it is obvious that if our steam railroads were operated on the same efficient basis tremendous savings of coal would result.

It is evident, therefore, that the most significant economies should be secured by reducing the 27 per cent of the total output now required by steam engines used on our great railway systems. Some improvement in efficiency is being secured by modernizing large numbers of engines of the older types and by discarding obsolete engines for up-to-date equipment. Competent engineers, however, are satisfied that the greatest reduction in coal consumption could be obtained by the electrification of a great many of our railroads which are large consumers of coal. The results obtained on various roads in the United States during the past twenty years have amply demonstrated the feasibility and desirability of electrification.

It is a remarkable fact that ample water powers exist within easy transmission distance of practically all the great railways of the northwestern United States and Canada. Many of these powers are undeveloped owing to the absence of a market for power and in some cases because of their location on government lands. By the development of these water powers, electricity could be delivered to the right-of-way of all the trans-mountain railways of the northwest for a distance of 1000 miles from the Pacific Coast. The use of fuel for railroad trains would thus be entirely eliminated, saving thousands of tons of coal and many barrels of fuel oil.

In European countries, where the high price of coal and its scarcity have furnished added incentive, railway managements are vigorously pushing plans for electrification. In Italy and Switzerland the coal situation is acute, and plans are well matured for the utilization of the vast water powers in order to become independent of foreign coal supply in emergencies such as the present war. These plans contemplate not only the electrical operation of the railroads but the electrification of industrial plants as well.



Figs. 5 and 6. Exhibition Test of Chicago, Milwaukee and St. Paul Locomotives on 1.66 per cent Grade near Janney Substation. Three steam locomotives operating at 9–10 m.p.h. with 2000 tons trailing; two electric locomotives operating at 15–16 m.p.h. with 3000 tons trailing

In addition to the actual saving in coal resulting from electrification of the existing steam railroads, the experience of main line railroads now operating electrically demonstrates that an increased capacity of track is made available by the increased train loads and the greatly increased operating speeds. Furthermore, under steam operation, the fuel coal has to be transported over the road as non-revenue tonnage from the mines or from the point of delivery on the right-of-way to the various coaling stations, thus occupying the tracks and engines which might otherwise be used in the production of revenue. A non-revenue movement which is much more difficult to reduce to actual figures, however, is the hauling of this same coal in the engine tenders. This movement of company coal in cars and on tenders, together with water for steaming purposes, is estimated by Mr. A. H. Armstrong* in the case of mountain divisions of a trunk line railway (sections now

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* See General Electric Review, November, 1916, p. 1009.

in the most immediate need of electrification) as 10 per cent of the total gross ton-miles carried over the rails. Under these conditions the electric locomotive, due to freedom from coal and water requirements, is inherently capable of hauling 10 per cent more average train tonnage with no increase of weight upon the driving axles.

Data are now available for several railway systems showing that the cost of conversion to electrical operation in the case of roads with a reasonable amount of traffic is amply justified from the financial standpoint. The Butte, Anaconda & Pacific Railway, which was electrified in 1913 at an initial cost of $1,201,000, showed a total net saving per year over steam operation of $242,300, exceeding 20 per cent upon the entire cost of electrification. In addition to this definite money saving the road secured a greatly increased capacity and a great improvement in the service. These facts being well established, it is quite within reason that the Federal Government should take steps to conserve the existing supply of coal and fuel oil by assisting to finance such electrifications as competent engineering authorities should be able to show will make the greatest saving in fuel.

In order to establish a definite ratio of comparison between the efficiency of the steam locomotive and the electric systems, data from various roads have been compiled showing that as an average figure seven pounds of coal on the steam locomotive tender is equivalent to a kilowatt-hour of electricity on the alternating-current switchboard at the power-house. A kilowatt-hour of electrical energy can be produced in a modern power plant with two and one-half pounds of coal. This means that it requires seven pounds of good coal on a steam locomotive to haul the same amount of net tonnage as could be handled with an electric locomotive by burning two and one-half pounds of coal in an up-to-date power house. It is necessary to use net tonnage figures to

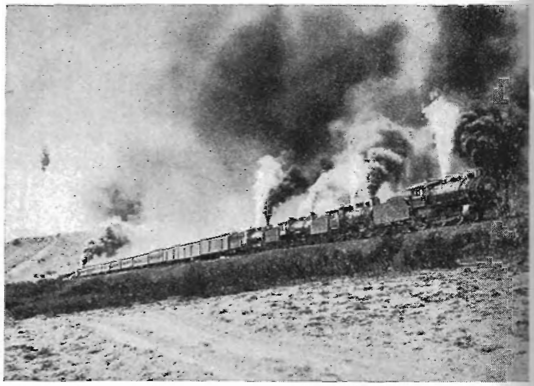

Fig. 7. Passenger Train on a Mountain Grade Hauled by Five Steam Locomotives

POWER CONSUMPTION OF ELECTRIFIED RAILROADS IN UNITED STATES AND EQUIVALENT COAL SAVING

Railroad	Trolley Voltage	Miles Electric Track	Steam or Water Power	Kilowatt-hour Consumption per Year at Power Station	Equivalent Coal in Tons at 7 Lbs.	Tons of Coal Saved per Year
Long Island R.R.	600 D-C.	208	Steam	78,652,000	275,280	183,500
New York Central Elec. Div.	600 D-C.	.253	Steam	92,000,000	322,000	215,000
New York, New Haven & Hartford	11,000 A-C.	531	Steam	90,500,000	317,000	212,000
Penn. R.R.—N.Y. Terminal	600 D-C.	97	Steam	49,347,000	172,715	115,000
West Jersey & Sea Shore R.R.	600 D-C.	150	Steam	30,018,400	105,000	70,000
Butte, Anaconda & Pacific	2,400 D-C.	90	Water	23,408,270	82,100	82,100
Erie R.R.—Rochester Div.	11,000 A-C.	38	Water	1,894,860	6,315	6,315
So. Pacific—Oakland, Alameda & Berkeley Div.	1,200 D-C.	138	Water	27,844,800	97,457	97,457
Baltimore & Ohio	600 D-C.	8	Steam	7,014,000	24,549	16,400
Grand Trunk—St. Clair Tunnel	3,300 A-C.	12	Steam	3,396,453	11,880	7,900
Detroit River Tunnel	600 D-C.	20	Steam	7,431,000	26,000	17,300
Gr. No. Ry.—Cascade Tunnel	6,600 A-C. 3-phase	7	Water	4,080,000	14,280	14,280
Boston & Maine—Hoosac Tunnel	11,000 A-C.	21	Steam	7,727,000	27,045	18,000
Norfolk & Western	11,000 A-C.	90	Steam	50,410,552	177,000	118,000
Penn. R.R.—Paoli Div	11,000 A-C.	95	Steam	23,400,000	82,040	54,700
Chicago, Milwaukee & St. Paul Ry.	3,000 D-C.	600	Water	134,400,000	470,400*	470,400*
		2358		608,124,335	2,129,021	1,643,652

* Oil burning locomotives were used on a large part of the sections now electrified, so that this figure is tabulated for comparative purposes only. Three and one-half barrels of oil are ordinarily considered as equivalent to a ton of coal.

secure a fair basis of comparison, since there is a much greater percentage of non-revenue freight with steam than with electric haulage owing to the handling of company coal for the steam locomotive.

These assumptions are based on a good quality of coal both on the locomotive and in the power station. Experience has demonstrated that there is no economy in attempting to use low-grade fuel on the locomotive, but with stationary boilers and equipment it is possible to materially reduce the cost of power by burning low-grade coal. For purposes of comparison, the ratio of 7 to 2½ is a conservative figure.

On systems where hydroelectric power can be used practically the entire coal consumption of a road may be conserved by electrification. Where steam power stations are required, nearly two-thirds of the present coal consumption may be saved.

In the table on page 862 there are 2358 miles of track which has been converted from steam to electric haulage. Figures for the kilowatt hours consumed have been tabulated and the equivalent coal calculated on the basis of 7 lb. of coal per kilowatt-hour. These figures represent the amount of coal that would be required were these electrified roads operating with steam engines. Assuming that all of this coal would be saved where water power is used, and two-thirds where electricity is produced in steam stations, the amount of coal saved is calculated in the adjoining column.

While the total track miles included in the table is less than one per cent of the steam road mileage of the United States, it should be noted that the calculated savings exceed a million and a half tons of coal or equivalent fuel oil as a result of electrical operation. The most conspicuous savings are shown by the Chicago, Milwaukee & St. Paul electrification which has secured a saving of fuel equivalent to nearly half a million tons of coal per year. The electrification of the Cascade division of this road consisting of 221 miles of track is being pushed vigorously and when in operation will also add 364,500 barrels of oil to the saving now being made.

The Operation of Railway Substations without Attendants

By W. D. Bearce

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The author gives a brief historical review of the progress made during the past three years in the equipment of automatic substations for railway service. While about thirty automatic railway substation equipments are under construction at Schenectady, the following description is mainly confined to railway systems which are now actually operating attendantless substations.—Editor.

The automatic railway substation, as it is being equipped today in rapidly increasing numbers, was first put into commercial operation about three years ago in the stations of the Elgin & Belvidere Electric Company near Chicago. After one of these stations had been tried out, the other two stations operated by this company were also equipped for automatic operation.

The operation of substations without attendants was first tried out by the Detroit Edison Company and the equipment installed in 1912 was a forerunner of the present automatic station. This installation consisted of a 500-kw. synchronous converter connected to the lighting system in the city of Detroit for the purpose of maintaining the proper voltage in the outlying districts. A new station was installed instead of additional feeder copper and was controlled by the operator of the main alternating-current supply station. Control was effected entirely from this main station over the 4400-volt, three-phase, alternating-current line. A similar installation was made in 1914 by the New South Wales Government Tramways in one of the outlying substations of Sydney, Australia. The scheme of control was quite different, however, the starting, shutting down, etc., being effected by the use of pilot wires. This station, however, was connected to a railway load and was subject to the fluctuating peaks common to railway service.

As a matter of general information, it should be stated that the stations installed at Detroit and in Sydney were of the remote control type while that put in operation on the Elgin & Belvidere system was strictly automatic. The automatic equipment is essentially different from the remote control system in that the machines are started up connected to the line and shut down without the assistance of an operator either in the station or in any remote station. These