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ECONOMIC RESULTS OF DIESEL ELECTRIC MOTIVE POWER ON THE RAILWAYS OF THE UNITED STATES OF AMERICA

By H. F. BROWN, Ph.B., Fellow A.I.E.E.

1961 · VOLUME 175 · NUMBER 5

ECONOMIC RESULTS OF DIESEL ELECTRIC MOTIVE POWER ON THE RAILWAYS OF THE UNITED STATES OF AMERICA*

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Part I: Economic Conditions and General Statistical Data

INTRODUCTION

THIS STUDY OF THE ECONOMICS of diesel motive power is based mainly on data contained in the 'Statistics of Railways of the United States' published annually by the Interstate Commerce Commission, hereinafter referred to as I.C.C.

The decisions by the various railways to make the change from steam to diesel power were based largely on the operating economies made by the relatively few units placed in yard and in road service during the period 1935–46. These economies appeared so large in comparison with the costs of existing steam operation at that time, that the question of steam *versus* diesel has been regarded as a closed issue, and of but academic interest in the United States of America since 1950.

However, by 1955 it was becoming evident that a number of factors pertaining to the economics of diesel operation had not been fully known as early as 1945–50. Today, with nearly twenty years of diesel operation, these factors can be more clearly defined. During these years, and for at least two decades prior to these years, other important factors have been shaping railway economics in the United States.

The problem, in this study, has been not only to isolate the motive power statistics, which are quite complete for both steam and diesel motive power, but also to show enough of the general operating and traffic data to enable the identification and evaluation of these other important economic factors, the results of which have been often attributed to diesel operation.

In the final analysis made in this study, the costs of the actual diesel operations for the year 1957—the latest available at the time this study was made—are compared with the similar costs of hypothetical operations with equivalent steam power, of modern design and of the same average age, sufficient in numbers and capacity to handle the same amount of traffic. Such steam power, of necessity, would have been installed, had the diesel not been available. By such a comparison, many of the other contemporaneous factors which have confused the true picture of diesel operating economies are eliminated.

This study is not to be construed as advocating a return to steam operation. Its sole purpose is to determine the economic position of diesel motive power with respect to other types whose economics are known, or yet to be determined.

TRAFFIC

The railways of the United States of America grew steadily and contributed largely to the development of the country, up to about 1920. Then the increasing growth of automotive highway traffic began to divert the short-haul passenger traffic to the highways. As highways were rapidly improved, more of the passenger traffic, and then the short-haul freight traffic was diverted.

With the loss of most of the short-haul traffic, the railways began to abandon service on branch lines and to reduce the 'local' train service on the main lines by eliminating stops at the smaller communities. This eliminated many of the short, slower trains, both passenger and freight, leaving the remaining long-haul traffic on fewer, heavier trains.

These trends started as far back as 1920, but have been increasing more rapidly since 1945.

Between 1930 and 1940 the country went through a serious business depression which affected not only the railways, but all business and employment generally. All traffic on the railways, both passenger and freight, dropped to levels lower than those attained in 1910.

The depression was immediately followed by the 1939–45 war. During 1941–46, traffic returned to the railways, and rose to volumes never achieved before, or since. Much of this traffic was due to the restricted use of automotive fuel for highway traffic, as a war emergency measure.

The MS. of this paper was received at the Institution on 15th December 1959. For a report of the meeting, in London, at which this paper was presented, see p. 318.

* *This paper is a necessary datum for a forthcoming paper dealing with the economic results of the electrification of parts of certain class I railways in the United States of America.*

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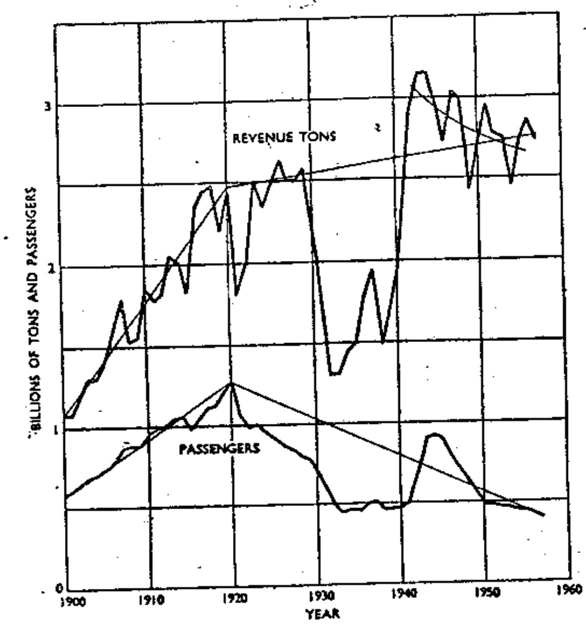
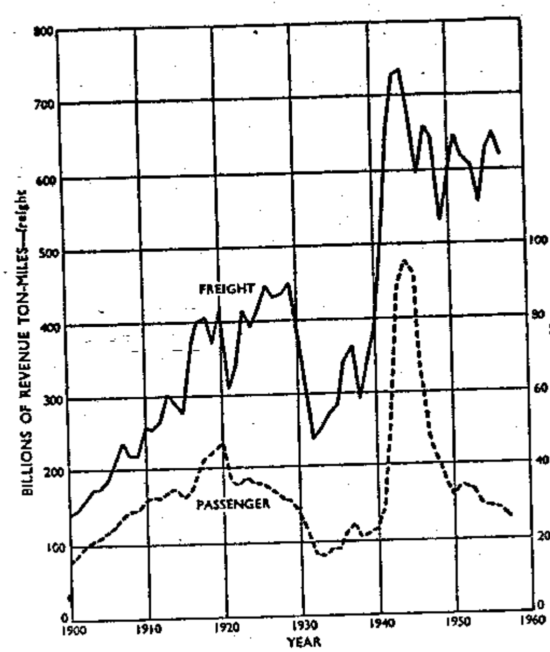


a Revenue tons and passengers carried.



b Revenue ton-miles and passenger miles.

Fig. 1. Traffic. All classes I and II railways

Since the war, railway passenger traffic declined further owing to increasing diversion of the short-haul traffic to the highways, and of the long-haul traffic to the airways. Railway freight revenue-tons are still declining (Fig. 1*a*), but revenue ton-miles remain at a high level owing to the increasing length of haul (Fig. 1*b*).

Since 1920, the miles of road operated by the class I railways has declined more than 10 per cent. The number of passenger cars has declined more than 40 per cent, and the number of passenger trains has declined approximately 60 per cent.

The traffic pattern is shown graphically in Fig. 1. Traffic has been the most influential factor in motive power requirements and operation, as well as in railway operating expenses and earnings.

MOTIVE POWER REDUCTION

The number of locomotives on the United States railway increased steadily until 1924, in which year there wer 69 486 locomotives in service on all the classes I, II, and II railways. Their average tractive capacity has steadily in creased up to the present time (Fig. 2). Except for the wa years, the number has steadily declined since 1924, and i still declining.

The necessity for longer and fewer trains to reduc operating expenses created the demand for motive pow of greater horsepower. Motive power, by itself, did n create the longer trains.

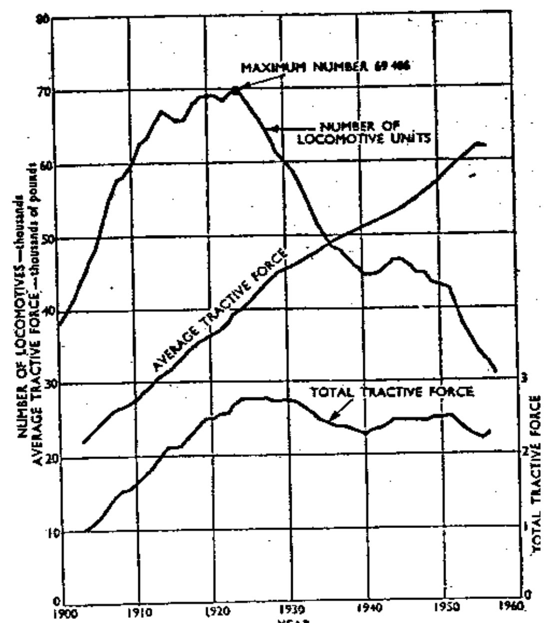


Fig. 2. Motive power in service on all railways in the United States of America

Classes I, II, and III.

The advances in engineering, technology, and manufacturing between 1915 and 1935 were able to increase the maximum horsepower capacity of steam locomotives from 1500 h.p. to single units of 5000 h.p. Since 1935, maximum steam locomotive capacity has been further increased to nearly 7000 h.p. for special operations (Fig. 3).

The acquisitions and retirements of locomotives on the class I railways over the past 50 years are shown in Fig. 4. Ever since 1922, long before the advent of diesel power, retirements have exceeded acquisitions each year by a ratio greater than two to one, except during the war years. New

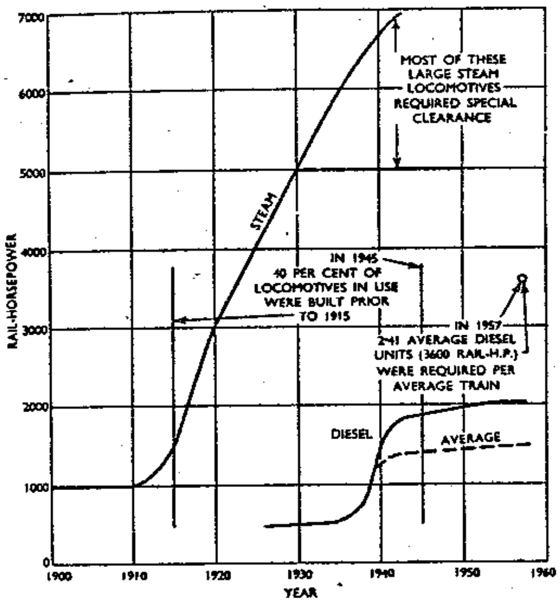


Fig. 3. Development of maximum locomotive rail horsepower

Available at rim of driving wheels.

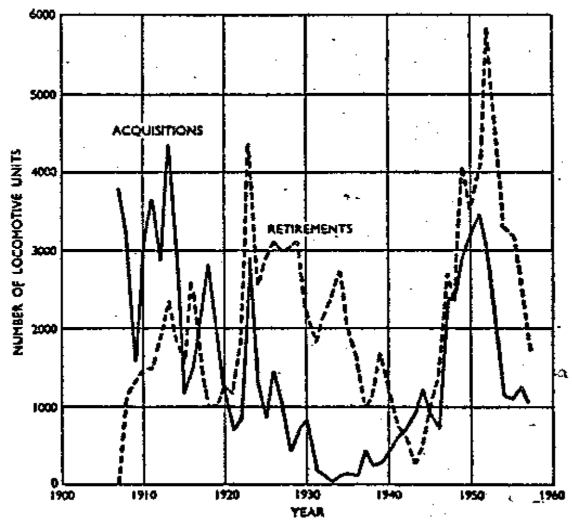


Fig. 4. Locomotive acquisitions and retirements on all class I railways from 1907 to 1957

All types, steam, electric, diesel and other.

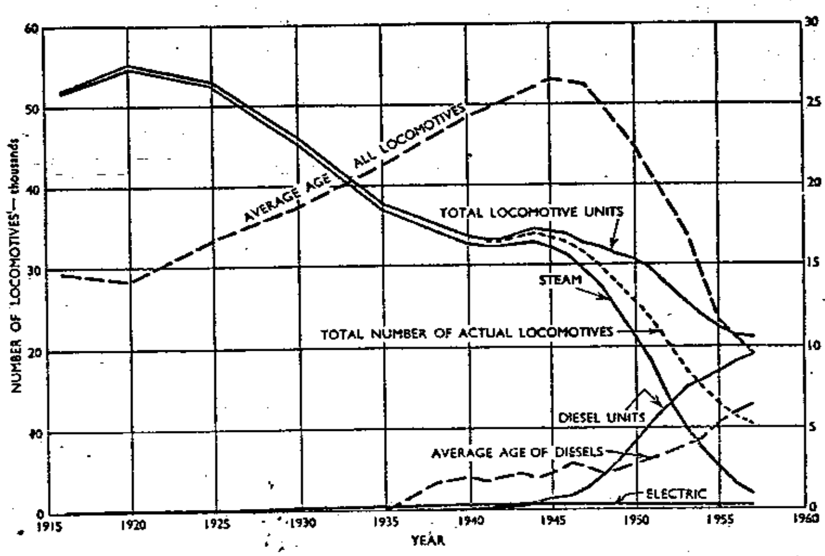


Fig. 5. Road locomotives on all class I railways

locomotive capacity doubled during the life of the old units retired, and fewer locomotives were required for the declining traffic. This trend has continued unaffected by, and certainly not initiated by, the change in type of motive power.

Nearly 50 per cent of the motive power was either unserviceable or stored during the depression. Very little new power, therefore, was acquired during those years, and little new power could be acquired during the war years.

At the end of the 1939–45 war, *more than 40 per cent* of all the motive power still in service consisted of locomotives built prior to 1915, and well over 31 years old. This equipment was small in capacity, completely worn out, and long overdue for replacement. Never before in the history of American railroading had the motive power been permitted to become so old and so inadequate in such large numbers.

ROAD, OR LINE-HAUL MOTIVE POWER

The decrease in total number of locomotives in road, or line-haul service on the class I railways since 1920 is shown in Fig. 5. The change in numbers of the three principal types, steam, electric, and diesel, and the change in average age for the diesels and for the whole group are also shown. The relatively small amount of electric motive power is quite apparent.

The change in total number reflects the changes in traffic patterns and in operating methods, together with the gradual change to motive power of greater capacity.

Particular attention is called to the change in the average age.

YARD AND SWITCHING (SHUNTING) MOTIVE POWER

Similar data are shown for yard and switching locomotives in Fig. 6.

A large reduction in number is shown between 1925 and 1940 due to the same causes that influenced road power.

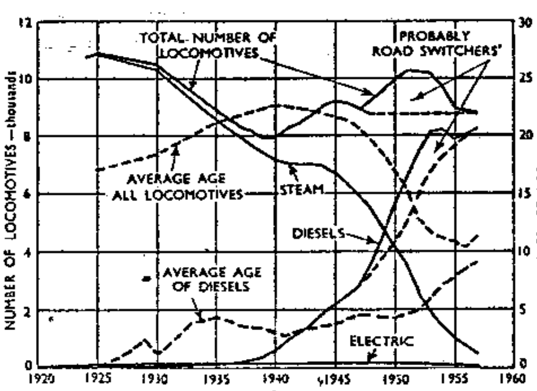


Fig. 6. Yard and switching (shunting) locomotives on all class I railways

There were not sufficient electric or diesel locomotives in yard service prior to 1940 to cause this reduction in number. The reduction made during the depression was restored during the war, mainly with diesel units.

A substantial increase in number is indicated from 194; to 1953, due to the inclusion with yard power of a larg number of diesel units known originally as 'road switchers' By 1956 most of these had been properly reclassified as roa locomotives.

The change from steam to diesel power has not reduce the number of yard locomotives required, which remaine in 1957 at about 8800 units, approximately the same as i 1935, 1943, and 1948.

OPERATION

Motive power performance during the period under revie is indicated by the train-miles, shown in Fig. 7.

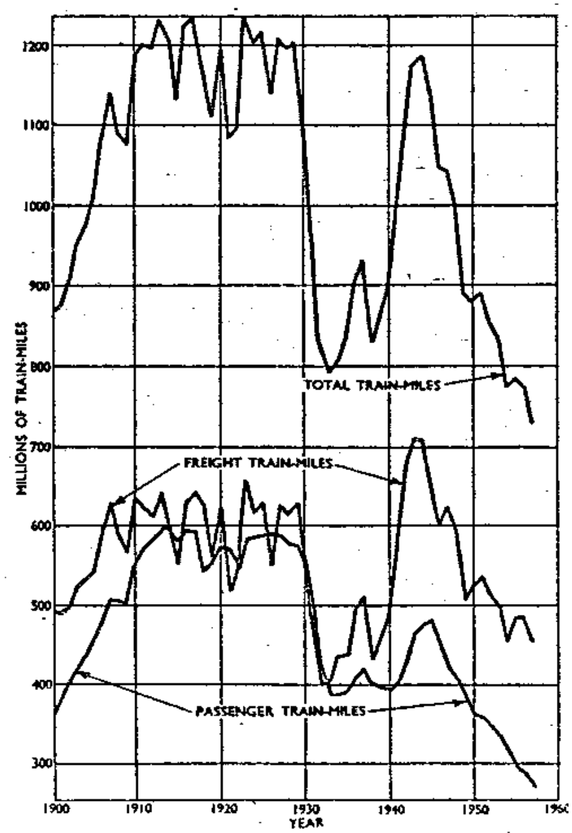


Fig. 7. Train-miles

All classes I and II railways.

Locomotive-miles per train-mile (average locomotiv per train), car-miles per train-mile (average cars per train and ton-miles per train-mile (average tons per train) a shown in Fig. 8.

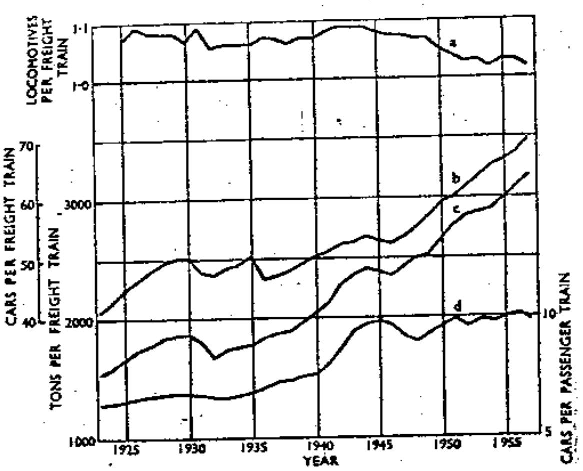


Fig. 8. Locomotive-miles, car-miles, and ton-miles per train mile

a Locomotive-miles per freight train-mile (average locomotives per freight train).
b Car-miles per freight train-mile (average cars per freight train).
c Gross ton-miles trailing per freight train-mile (average tons per freight train).
d Car-miles per passenger train-mile (average cars per passenger train).

TOTAL RAILWAY OPERATING EXPENSE

Total railway operating expenses and revenues have in general followed the traffic pattern. Nothing indicates that the change in type of motive power since 1940 has had a bearing on either of these items, unless unfavourably. Operating expenses have increased at a greater ratio than operating revenues.

This fact is indicated by the operating ratio, which is the ratio of total railway operating expense to total railway operating revenue, shown for all classes I and II railways in Fig. 9. The average operating ratio since 1945 is higher than for any similar previous period except 1918–22, when

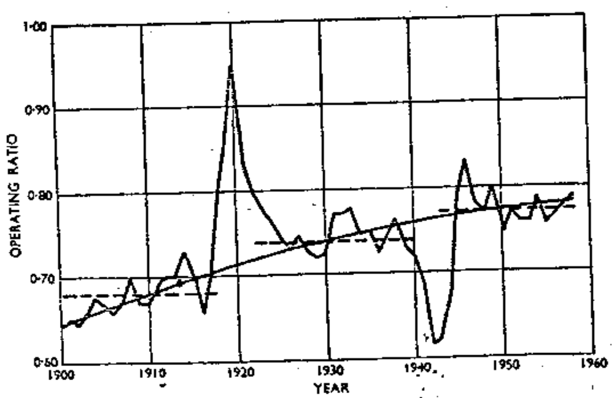


Fig. 9. Operating ratio, all classes I and II railways

all railways were under Federal Administration as a war measure.

All items of railway operating expense are classified in six major groups by the I.C.C. These are:

I Maintenance of way and structures
II Maintenance of equipment
III Traffic
IV Transportation
V Miscellaneous
VI General

The sum of all these group expenses is the total railway operating expense.

Maintenance of way and structures, maintenance of equipment and transportation comprise more than 90 per cent of the total operating expense.

The total railway operating expenses for all class I railways as a group from 1916 to 1957 are shown graphically in Fig. 10 in billions of dollars.

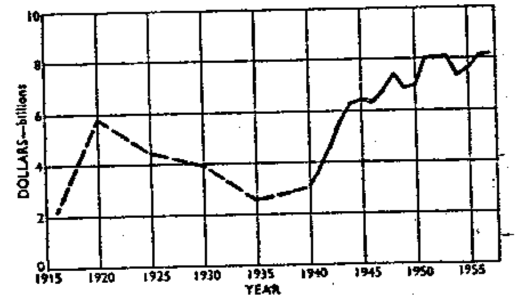


Fig. 10. Total railway operating expense, all class I railways

MOTIVE POWER OPERATING AND MAINTENANCE COSTS

The I.C.C. statistics show separately for road locomotives and yard locomotives the following items of expense involved with motive power on the class I railways:

(1) Locomotive repairs
(2) Fuel, including electric power where used
(3) Wages of enginemen
(4) Engine house expenses
(5) Water
(6) Lubricants
(7) Other locomotive supplies
(8) Depreciation

Repairs and depreciation are items of maintenance of equipment expense. All others are items of transportation expense.

All of the above itemized costs for road locomotives, with the exception of depreciation, are shown in Table 1*a* in millions of dollars, for the years 1916, 1920, 1925, 1930, 1935, 1940, and for each year thereafter to 1957. Each item is also shown as a 'ratio cost', or as a proportionate part of

Table 1a. Cost of operating and maintaining road locomotives (excluding depreciation)

All class I railways

Costs as incurred in millions of dollars

Year	Total railway operating expense	Operating ratio	Repairs				Fuel and power			Engine men	Engine house ex-pense	Water	Lubri-cants	Other supplies	To
			Steam	Diesel	Other	Total	Fuel	Power	Total						
1916	2211	65·38	150·7		0·7	151·4	192·6	2·9	195·5	129·0	36·3	12·6	3·6	3·5	53
1920	5831	94·38	512·0		4·1	516·1	566·0	8·5	574·5	268·0	124·9	26·1	8·7	10·4	152
1925	4540	74·10	388·5		2·7	391·2	340·5	8·2	348·7	229·4	83·1	21·7	7·5	6·4	108
1930	3931	74·43	293·5		3·8	297·3	237·8	9·9	247·7	204·6	69·1	20·0	7·2	4·7	85
1935	2593	75·11	191·6		4·0	195·6	173·1	11·3	184·4	149·8	41·0	14·3	5·7	2·8	58
1940	3089	71·90	230·1		8·0	238·1	210·8	15·2	225·0	171·0	46·1	16·2	7·5	3·2	70
1941	3664	68·53	284·4		10·5	294·9	259·5	16·2	275·7	204·3	52·5	17·8	9·3	3·9	85
1942	4601	61·63	342·5		14·0	356·5	335·8	18·3	354·1	262·6	69·8	21·3	12·0	5·1	108
1943	5657	62·48	411·7		19·0	430·7	432·4	19·6	452·0	295·1	88·9	24·7	14·6	6·1	131
1944	6282	66·57	474·2		28·3	502·5	473·8	21·3	495·1	321·9	111·2	27·3	16·2	7·2	148
1945	6418	72·10	461·8		34·4	496·2	462·8	21·3	494·1	317·2	110·7	26·8	16·8	7·5	146
1946	6357	83·35	451·7		40·9	492·6	452·5	21·4	473·9	328·5	115·8	26·1	16·0	7·2	146
1947	6797	78·27	453·5		59·9	513·4	545·7	23·2	568·9	334·3	120·7	27·6	18·7	8·3	159
1948	7472	77·26	441·4		89·7	531·1	643·8	25·0	668·8	365·7	129·7	28·1	21·3	8·9	175
1949	6892	80·32	334·9		126·0	460·9	479·5	23·4	502·9	329·7	119·4	24·0	19·7	7·9	146
1950	7059	74·52	316·4		162·7	479·1	472·4	22·6	495·0	338·9	119·6	22·1	19·2	8·1	148
1951	8041	77·39	326·9		215·6	542·5	494·7	22·4	507·1	378·8	136·3	22·2	21·5	9·7	161
1952	8053	76·11	243·9		265·5	509·4	436·3	22·5	458·8	374·3	129·8	18·3	21·5	9·2	152
1953	8135	76·29	173·5		303·5	477·0	409·6	22·4	432·0	365·8	119·8	14·7	21·3	8·8	143
1954	7384	78·80	86·4	299·6	16·6	402·6	356·4	22·8	379·2	346·2	106·4	9·5	20·9	8·1	127
1955	7646	75·66	65·3	323·3	18·2	406·8	364·5	23·1	387·6	365·8	101·6	3·1	22·3	8·2	129
1956	8108	76·85	55·0	365·0	19·8	439·8	374·5	23·3	397·8	385·9	105·5	2·0	24·9	8·7	136
1957	8228	78·42	30·9	377·4	20·7	429·0	366·7	23·2	389·9	388·3	104·2	5·3	27·2	8·8	135

Table 1b. Cost of operating and maintaining road locomotives (excluding depreciation)

All class I railways

Dollar costs converted into 'ratio costs'

(Proportion of total railway operating expense)

Year	Total railway operating expense	Repairs	Fuel	Engine men	Engine house expense	Water	Lubricants	Other supplies	Tota
1916	2211	0·0686	0·0885	0·0584	0·0164	0·0057	0·0016	0·0016	0·24
1920	5831	0·0886	0·0986	0·0460	0·0214	0·0045	0·0015	0·0018	0·26
1925	4540	0·0864	0·0770	0·0505	0·0183	0·0048	0·0016	0·0014	0·24
1930	3931	0·0757	0·0630	0·0521	0·0176	0·0051	0·0018	0·0012	0·21
1935	2593	0·0755	0·0713	0·0555	0·0158	0·0055	0·0022	0·0011	0·22
1940	3089	0·0770	0·0724	0·0554	0·0149	0·0052	0·0024	0·0010	0·22
1941	3664	0·0805	0·0752	0·0557	0·0143	0·0049	0·0025	0·0011	0·23
1942	4601	0·0775	0·0770	0·0570	0·0152	0·0046	0·0026	0·0011	0·23
1943	5657	0·0762	0·0800	0·0521	0·0157	0·0044	0·0026	0·0011	0·23
1944	6282	0·0801	0·0790	0·0513	0·0177	0·0044	0·0026	0·0011	0·23
1945	6418	0·0774	0·0770	0·0494	0·0173	0·0042	0·0026	0·0012	0·22
1946	6357	0·0775	0·0745	0·0517	0·0182	0·0039	0·0025	0·0011	0·22
1947	6797	0·0755	0·0836	0·0492	0·0178	0·0041	0·0028	0·0012	0·23
1948	7472	0·0710	0·0895	0·0489	0·0174	0·0038	0·0029	0·0012	0·23
1949	6892	0·0669	0·0730	0·0480	0·0179	0·0035	0·0029	0·0012	0·21
1950	7059	0·0680	0·0701	0·0480	0·0170	0·0031	0·0027	0·0012	0·21
1951	8041	0·0676	0·0631	0·0472	0·0170	0·0028	0·0027	0·0012	0·20
1952	8053	0·0633	0·0570	0·0465	0·0161	0·0023	0·0027	0·0011	0·18
1953	8135	0·0587	0·0532	0·0450	0·0148	0·0018	0·0026	0·0011	0·17
1954	7384	0·0546	0·0514	0·0470	0·0145	0·0013	0·0028	0·0011	0·17
1955	7646	0·0532	0·0507	0·0479	0·0133	0·0004	0·0029	0·0011	0·16
1956	8108	0·0542	0·0491	0·0476	0·0130	0·0002	0·0031	0·0011	0·16
1957	8228	0·0522	0·0475	0·0472	0·0127	0·0006	0·0033	0·0011	0·16

Table 2a. Cost of operating and maintaining yard locomotives (excluding depreciation)

All class I railways

Costs as incurred in millions of dollars

Year	Total railway operating expense	Repairs	Fuel	Engine men	Engine house expense	Water	Lubricants	Other supplies	Total
1916	2211	e26·55	34·42	37·82	11·18	2·35	0·62	0·72	113·66
1920	5831	e89·1	109·32	96·70	45·55	4·74	1·69	2·05	349·16
1925	4540	e68·0	67·23	88·93	30·53	4·40	1·35	1·46	261·9
1930	3931	e51·9	45·66	83·55	25·18	3·97	1·18	1·16	212·6
1935	2593	34·35	30·61	57·2	15·15	2·97	0·88	0·73	141·89
1940	3089	41·44	36·08	75·4	17·5	3·3	1·31	0·9	175·9
1941	3664	53·63	43·94	91·86	19·96	3·63	1·67	1·11	215·8
1942	4601	60·22	52·03	113·4	25·3	4·0	2·15	1·35	258·45
1943	5657	73·5	62·56	124·4	31·2	4·36	2·57	1·56	300·15
1944	6282	82·45	66·32	136·7	37·5	4·6	2·8	1·8	332·17
1945	6418	80·9	65·85	135·4	37·0	4·6	2·9	1·9	328·6
1946	6357	84·1	66·77	147·7	38·6	4·4	2·9	1·9	346·3
1947	6797	91·0	82·37	157·8	40·8	4·75	3·5	2·25	382·5
1948	7472	100·1	97·57	180·0	45·6	5·0	3·9	2·5	434·7
1949	6892	81·9	69·86	164·7	39·7	4·2	3·4	2·2	366·0
1950	7059	84·4	66·95	179·9	39·1	3·9	3·3	2·1	379·65
1951	8041	93·2	67·05	216·4	42·9	4·0	3·7	2·4	429·65
1952	8053	90·5	55·88	209·7	39·1	3·3	3·7	2·3	429·40
1953	8135	86·2	50·35	214·0	36·3	2·7	3·6	2·2	421·25
1954	7384	73·8	43·07	208·9	31·0	2·0	3·4	1·9	364·1
1955	7646	74·5	42·76	219·5	29·3	1·6	3·7	1·95	373·3
1956	8108	82·8	45·31	237·2	30·3	1·44	4·0	2·16	403·2
1957	8228	84·1	43·42	242·7	29·9	1·14	4·44	2·18	407·9

e Estimated. Costs were included with road locomotives.

Table 2b. Cost of operating and maintaining yard locomotives (excluding depreciation)

All class I railways

Dollar costs converted into 'ratio costs'

(Proportion of total railway operating expense)

Year	Total railway operating expense	Repairs	Fuel	Engine men	Engine house expense	Water	Lubricants	Other supplies	Total
1916	2211	0·0120	0·0156	0·0171	0·0051	0·00107	0·00028	0·00033	0·0514
1920	5831	0·0153	0·01875	0·0166	0·00781	0·00081	0·00029	0·00035	0·0599
1925	4540	0·0150	0·0148	0·0196	0·00673	0·00097	0·00030	0·00033	0·0577
1930	3931	0·0132	0·0116	0·02125	0·00641	0·00101	0·00030	0·00029	0·0541
1935	2593	0·01325	0·0118	0·0221	0·00584	0·00115	0·00034	0·00028	0·0548
1940	3089	0·0134	0·01169	0·0244	0·00567	0·00107	0·00043	0·00029	0·0572
1941	3664	0·01463	0·0120	0·0251	0·00545	0·00099	0·00046	0·00030	0·0589
1942	4601	0·0131	0·0113	0·0247	0·0055	0·00087	0·00047	0·00029	0·0563
1943	5657	0·0130	0·01106	0·0220	0·00552	0·00068	0·00045	0·00028	0·0530
1944	6282	0·01313	0·01055	0·0216	0·00598	0·00073	0·00045	0·00029	0·0530
1945	6418	0·0126	0·01025	0·0211	0·00576	0·00072	0·00045	0·00030	0·0513
1946	6357	0·0132	0·0105	0·0232	0·00608	0·00069	0·00046	0·00030	0·0545
1947	6797	0·0134	0·0121	0·0232	0·00600	0·00070	0·00052	0·00033	0·0563
1948	7472	0·01335	0·01306	0·0241	0·00608	0·00067	0·00052	0·00033	0·0581
1949	6892	0·0119	0·01013	0·0239	0·00576	0·00061	0·00049	0·00032	0·0532
1950	7059	0·01195	0·0095	0·0255	0·00555	0·00055	0·00047	0·00030	0·0538
1951	8041	0·0116	0·00835	0·0269	0·00534	0·00050	0·00046	0·00030	0·0535
1952	8053	0·01122	0·00694	0·0261	0·00485	0·00041	0·00046	0·00029	0·0534
1953	8135	0·0106	0·0062	0·0264	0·00447	0·00033	0·00044	0·00027	0·0518
1954	7384	0·0100	0·00583	0·0284	0·00421	0·00027	0·00046	0·00026	0·0494
1955	7646	0·00975	0·0056	0·0288	0·00383	0·00022	0·00048	0·00026	0·0489
1956	8108	0·0102	0·00559	0·0292	0·00374	0·00018	0·00049	0·00027	0·0497
1957	8228	0·01022	0·00528	0·0295	0·00363	0·00014	0·00054	0·00027	0·0496

the total railway operating expense for the year in which it is incurred, in Table 1*b*.

The itemized costs for yard locomotives are shown similarly in Tables 2*a* and 2*b*.

TREATMENT OF COST FIGURES

An economic factor affecting all expenses and revenues has been the decline in the purchasing value of the dollar over the period studied. This 'inflation factor' distorts the direct comparison of costs incurred over a term of years.

By converting all dollar costs into 'ratio costs', that is, as proportionate parts of the total railway operating expense, the 'inflation factor' appears nearly equally in the numerat and denominator of the ratio, and is approximately cancell out, leaving the basic factors which are comparable.

Ratio costs of any item may be compared year after ye to determine whether they are rising, falling or stationa thereby enabling their change to be more readily relat to the economic factors causing the change.

The totals of the items of road locomotive operati expense for each year, presented as 'ratio costs' in Table 1 are shown in Fig. 11. The graph of the total number of ro locomotives in service is also shown for comparison. It evident, and logical, that the operating costs have decrease in general, as the number of locomotives has decreased.

The three largest items of road locomotive operati expense shown in Table 1 are repairs, fuel, and engine me Their ratio costs are shown in Fig. 12*a*, and comprise abo 90 per cent of the total shown in Fig. 11. The remaini four items of engine house expense, water, lubricants, a other supplies, are shown to a larger scale in Fig. 12*b*.

The totals of the items of yard locomotive operati expense for each year, presented as ratio costs in Table 2

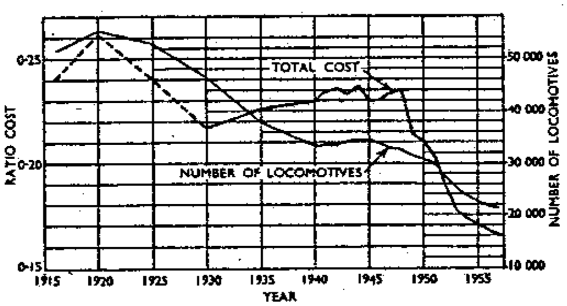
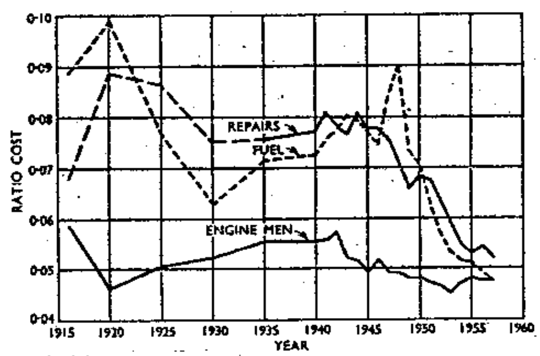
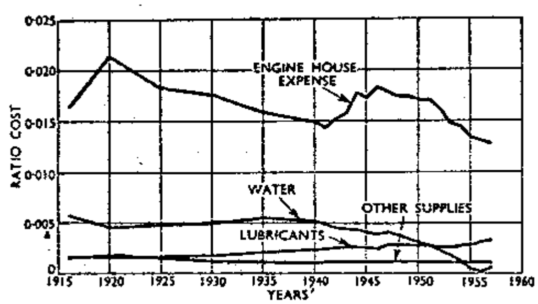


Fig. 11. Total cost of operating and maintaining road locomotives on all class I railways

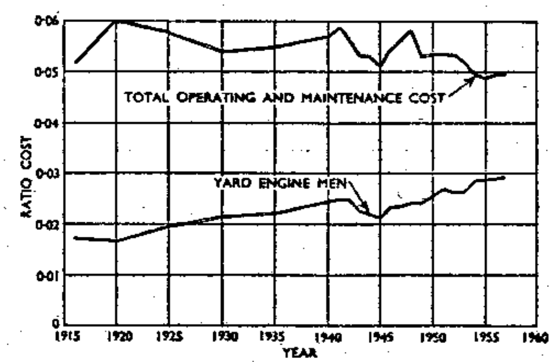


a Repairs, fuel, and engine men for road locomotives.

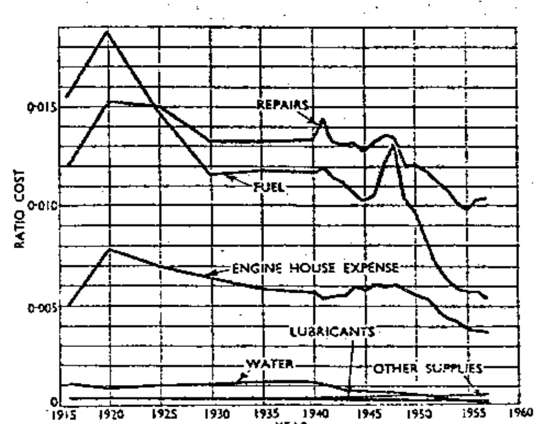


b Other itemized costs of operating road locomotives.

Fig. 12. Costs on all class I railways



a Total cost of operating and maintaining yard locomotives, also cost of yard engine men.



b Other itemized costs of operating yard locomotives.

Fig. 13. Costs on all class I railways

are shown in Fig. 13*a*. Also shown are the costs of yard engine men, the largest single item of yard locomotive operating expense. The ratio costs of the other six items are shown to a larger scale in Fig. 13*b*.

FACTORS INVOLVED IN TRENDS OF LOCOMOTIVE EXPENSE ITEMS

The trends in the graph of each item of locomotive expense are due to some factors common to all, combined with special factors in some items.

All items vary with the number of locomotives in service.
All items may vary with the type of motive power used.
Special factors of importance in specific items are:

Repair costs will also vary with the age of the equipment and at a different rate for each type.

Fuel costs will also vary with trends in the fuel market.

Cost of engine men will vary with the number of locomotives (not units) used per train, separately manned; with the total weight on drivers, and with change in wage rates.

Engine house expense will also vary with traffic, as short runs and branch line operations have been eliminated with their engine terminals; also if steam and diesel power are being operated simultaneously.

Where several factors are acting simultaneously to shape the trends, careful analysis must be made to ensure that each factor involved is quantitatively identified. Many of the claims of economies attributed to the diesel locomotive have been made erroneously because this analysis has been overlooked or ignored.

DEPRECIATION

Depreciation is an accounting charge for the cost of the equipment spread over its service life. It should equal, during the life, the original cost less the ultimate scrap value.

Although by I.C.C. ruling an item of operating expense under maintenance of equipment, depreciation cannot be properly converted to a ratio cost since it is not a function of operation but of investment.

A correct depreciation rate is essential to prevent depletion of assets when renewals become necessary. A rate based on a 30-year life has been generally used for steam and electric locomotives, although many of these have been retained in service longer.

When diesel locomotives were introduced, it was assumed they would have service life characteristics similar to electric locomotives, reduced somewhat by the known shorter life of the internal combustion-type prime mover. A depreciation rate based on a 20-year life for road power, and a 25-year life for yard power of this type was approved by the I.C.C. The I.C.C. does not establish depreciation rates. It approves such rates established by the railways based on proper supporting data.

More recently, studies based on accumulated experience relative to obsolescence and to rise in repair costs with age of diesel power indicate an economic life of but 12–14 years for road power and about 18 years for yard power. The road locomotives of this type rebuilt or remanufactured within the past few years have been between 11 and 16 years old. Such rebuilt equipment must appear on the books as new units, for by a ruling of the I.C.C., when more than 50 per cent of the original cost is spent in any one year for repairs, that equipment must be retired and charged to the depreciation reserve.

It is becoming apparent that the depreciation charges included with the present operating expenses are not adequate to properly maintain the equipment depreciation reserve, and that in some cases the diesel retirements may have to be charged to the profit and loss account.

The evidence is now rather well established that the diesel locomotive has about one-half the service life of a steam or electric locomotive in the same service.

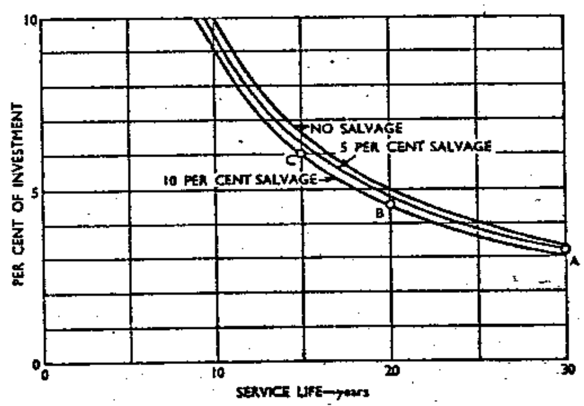


Fig. 14. Annual depreciation charge in per cent of investment

A Steam and electric locomotives.
B Yard diesel locomotives.
C Road diesel locomotives.

The annual depreciation charge, on a 'straight line' basis becomes larger as the service life decreases, as shown in Fig. 14. Depreciation rates used in this study are 3·16 per cent for all steam and electric locomotives; 6 per cent for all road diesels, and 4·5 per cent for yard diesels.

The advantage of equipment having a long economic life is apparent.

INTEREST CHARGES

Interest on the unamortized cost of equipment, while not an item of operating expense, is a proper item to be considered in an economic study of motive power. A conservative rate of 2 per cent of the investment, per year, over the service life is used in this study.

Taxes and insurance are additional fixed charges to be considered. These charges are relatively small, and are not uniform on all the railways, nor isolated in the statistics. They have been omitted in this study.

INVESTMENT IN MOTIVE POWER

The changes in investment in locomotives on the class I railways from 1941 to 1957 are shown in Fig. 15. This information is unavailable in the I.C.C. statistics prior to 1941. Although the total number of *locomotives*, as dis-

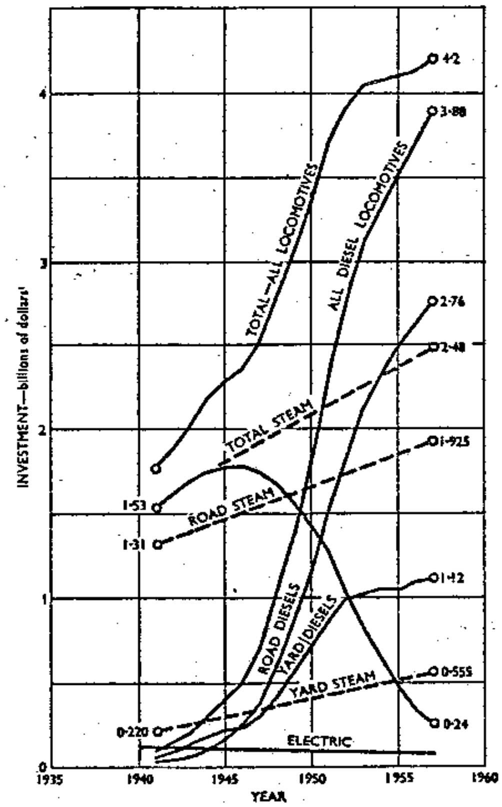


Fig. 15. Investment in locomotives, all class I railways

tinguished from *units*, in 1957 was less than one-third the number in 1941, the total investment has increased 2·4 times. In 1957, the investment in road diesel motive power was \$2760 million, and for yard diesel power, \$1120 million.

A large increase in investment for motive power servicing facilities, shops, engine houses (sheds), water and fuel stations, has also been made since 1941, shown in Fig. 16 amounting to more than \$400 million.

The calculated hypothetical investment for the equivalen number of modern steam locomotives required to perform the service of diesel locomotives in 1957 is shown by th

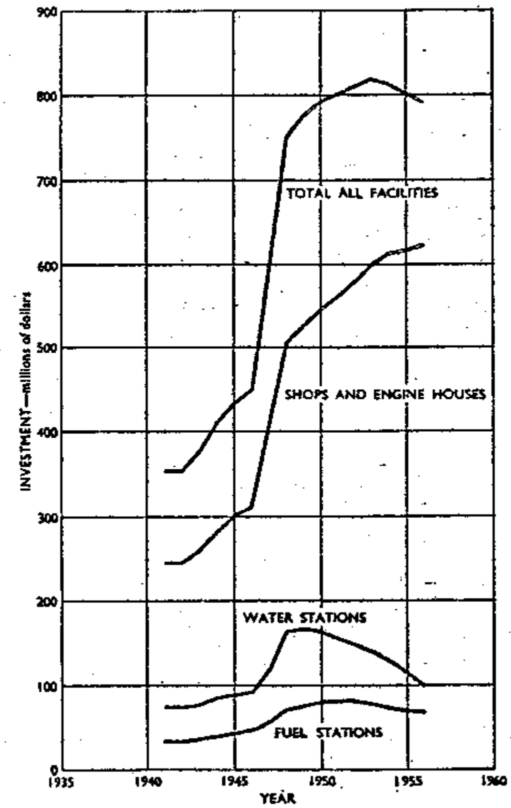


Fig. 16. Investment in motive power facilities

light broken lines in Fig. 15 as \$1925 million for road loco motives, and \$555 million for yard locomotives*.

All investment costs have been influenced by the 'in flation factor' previously mentioned.

The value of long-life investments is enhanced durin periods when the currency is being devaluated.

* *See the Appendix for method of calculation.*

Part II: Economic Results of Diesel Electric Locomotive Operation

THE CHANGE FROM STEAM TO DIESEL MOTIVE POWER

The diesel electric locomotive made its initial appearance on the United States railways in yard service in 1925, but fewer than 100 such units were acquired during the next ten years. By the end of 1939, there were about 435 diesels in yard service and about 90 in road service—too few to have any noticeable effect on the general railway economy.

After the 1939–45 war, the automotive industry started an active campaign to sell the diesel locomotive to the American railways. The time was most opportune because of the age and general worn-out condition of the steam motive power.

The first road diesels were used in preferred passenger service on long runs, and on lines having stiff gradients. It was quickly found that in such service this new motive power could be used to the limit of its availability, which was quite high.

High annual milages per unit were being made. Grades could be negotiated without the former 'helper' service required. Fuel costs were low, with diesel oil then at 4 cents per gallon. Thermal efficiencies were about four times better than steam in road service, and up to ten times better in yard service. Maintenance costs of this new power compared with the old steam power were quite low.

The steam locomotive almost immediately became outmoded by the testimony of its former manufacturers, then all competitively engaged with the automotive industry in the manufacture of diesel power. About 8000 diesel locomotives had been acquired prior to 1949. During the years 1949–52, more than 12 500 units were acquired; and since 1952, about 7000 more have been acquired up to the end of 1957. No steam locomotives have been built in the United States since 1953. One of the largest manufacturers stopped building steam locomotives in 1948.

The class I railways are all operating today with most of their motive power relatively new, compared with that in service prior to 1945.

BASIC DIFFERENCES: STEAM AND DIESEL ELECTRIC MOTIVE POWER

Diesel locomotives have operating characteristics fundamentally different from those of steam locomotives. These must be understood before the operating economies can be appraised. Diesels are more nearly like electric locomotives, limited, however, by the capacity of their own power plant.

The steam locomotive develops its maximum horsepower at near its full speed. At starting, the boiler can generate steam faster than the cylinders can use it. The cylinder pressure and wheel diameter determine the maximum starting tractive force, within the limits of adhesion. At high speed, the boiler horsepower determines the tractive force.

The diesel engine is a constant-horsepower machine. With its electric drive, which is simply a 'torque converter', the engine can be operated at full speed at starting, and nearly its full horsepower can be converted into tractive force, also within the limits of adhesion.

Tractive force and horsepower are related to each other through the speed, by the well-known equation

$$T = \frac{\text{h.p.} \times 375}{V}$$

(where T is the tractive force, lb., and V is the speed, mile/h).

The tractive force therefore falls off rapidly as the speed increases.

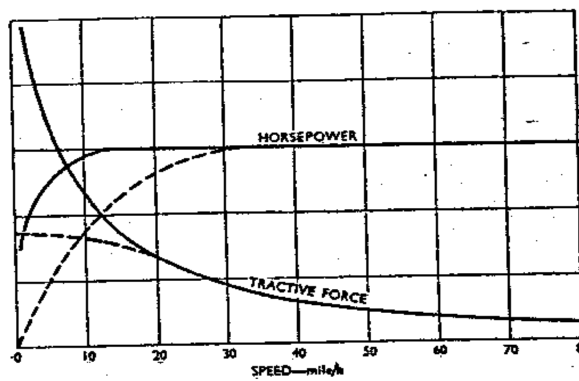


Fig. 17. Comparative horsepower and tractive force, steam and diesel locomotives of same maximum horsepower

– – – – Steam.
——— Diesel.

The relative horsepower and tractive force curves of a diesel, and of a steam locomotive having the same maximum horsepower are shown in Fig. 17. The diesel has greater tractive force up to about 25 mile/h. Above this speed both locomotives have equal tractive force. This would be, however, a relatively small steam locomotive.

The comparative horsepower and tractive force curves for a diesel and a steam locomotive having equal weight on drivers are shown in Fig. 18. In this case more horsepower can be built into the steam locomotive than into the diesel. The diesel still has a higher starting tractive force up to about 6 mile/h, but above 20 mile/h the steam locomotive has double the tractive force of the diesel.

American manufacturers have not been able to build a single diesel unit having much more than 2000 h.p., delivered to the rim of the driving wheels. The average diesel locomotive will produce about 14 h.p. per ton of its weight.

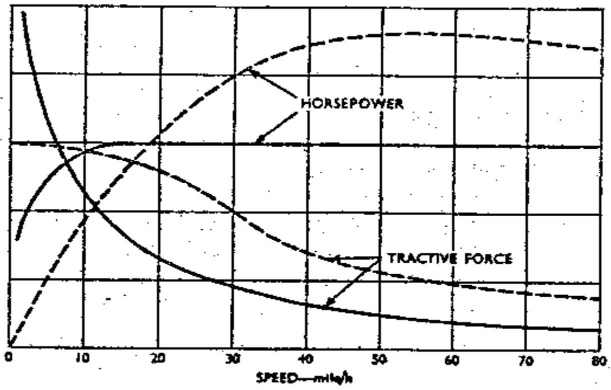


Fig. 18. Comparative horsepower and tractive force, steam and diesel locomotives of same weight on drivers

— — — — Steam.
———— Diesel.

The superior performance of the diesel at slow speeds is one reason why it was adopted so rapidly in switching and yard service, where speeds average but 6 mile/h. The diesel became popular also on the railways having heavy mountain grades, because by slowing down, the diesel can increase its tractive force to a greater extent than can a steam locomotive.

Starting tractive force, however important, is but a short part of the time of the total road performance. Horsepower is required for speed, and single diesel units cannot produce the horsepower that modern steam or electric locomotives can supply in single units.

The tractive force rating usually given for any locomotive is that for starting. This can be quite misleading in the comparison of types, for it overrates the ability of the single diesel unit. The important tractive force required in road service is that for accelerating and moving the train load at the schedule speed. This requirement is independent of type of motive power. Any locomotive can usually keep moving any train it can start. The criterion is, 'Can it bring that train up to the desired speed, and in the desired time?'

THE TRUE NUMBER OF LOCOMOTIVES

The I.C.C. statistics for 1957 show that it required 2·08 diesel units per average passenger train, and 2·59 diesel units per average freight train. The average for all trains in road service was 2·41 units. The tractive force of any of these combinations *at the running speed* is well within the capacity of most of the modern steam power remaining in either passenger or freight service in 1957.

This leads to the interesting conclusion that it has required more motive power units of the diesel type to perform the present transportation service on the class I railways than would have been required had modern ste locomotives been purchased in their stead. The ac number of diesel *locomotives* in road service in 1957 not the 18 959 diesel *units* given in the statistics, but this number divided by 2·41, which is 7870 locomotive

The true reduction in number of locomotives caused the traffic losses, and the changes in operating patterns methods made to meet these losses is shown in Fig. 5 the dotted graph, which departs from the solid graph numbers in 1941 and drops to 10 330. This is the theoret total number of all road locomotives in service in 1957.

AVAILABILITY: DIESEL AND STEAM LOCOMOTIVES

New diesel locomotives have an availability as high 90 per cent. Modern steam power has an availability o least 60 per cent when new. The availability of all mo power is reduced as it becomes older.

Availability is of no great value beyond the utilizat that can be made of the motive power. The high utilizat made of the diesel power in selected service during its ear years has been reduced, as diesels increased in numbers.

This is indicated in Table 3 by the approximate ann milage shown for diesel locomotives, which dropped fr 101 000 in 1953 to 86 500 in 1957.

To establish a basis for comparison of operating costs investment, it may be assumed that the number of mod steam locomotives equivalent to the road diesel *locomoti* is inversely proportional to their availabilities. This assun tion is favourable to the diesel.

Then 7870 times 1·5 or 11 800 steam locomotives wo be the hypothetical equivalent of the 18 959 diesel units road service in 1957.

EFFECT OF DIESEL OPERATION ON NUMBER OF TRAINS AND TRAIN-MILES

It is claimed that the large reduction in the number trains as indicated by the reduction in train-miles since 1 in Fig. 7 has been due to the multiple-unit operation diesel units, which has enabled the operation of longer faster trains in both freight and passenger service. This turn has allowed a large reduction in the number of trai thereby making large savings in operating labour. T claim is given great emphasis by the diesel manufactur and considerable credence by the general public.

It does seem plausible to relate the large drop in tra miles after 1946 to the known substitution of diesels steam, as shown in Fig. 5, during this same period. Nev theless, a little analysis will show that these two facts not at all related to each other.

Consideration of Fig. 3 shows that at least two die units are required to perform the service of the largest ste power installed between 1920 and 1930, and up to 5 u to equal the largest steam locomotives built after 19 Ever since the introduction of diesel motive power in r service, the multiple-unit operation of two or more u has been a necessity to equal the horsepower of the ste

Table 3. Diesel operating statistics 1953–57

All locomotive- and train-miles in millions

	1953	1954	1955	1956	1957	1953 against 1957 Increase, per cent	1953 against 1957 Decrease, per cent
Freight							
Diesel locomotive-miles	375	391	428	446	438	17	
Diesel unit-miles	921	964	1054	1113	1134	23	
Units per locomotive	2·46	2·46	2·46	2·50	2·59	5·3	
Diesel train-miles	358	374	409	424	417	16	
Total freight train-miles	492	447	476	475	447		10
Cars per train	64·0	65·6	66·2	67·6	70·0	9·3	
Gross tons per train	2870	2900	3000	3100	3220	12·3	
Train-miles per train-hours	18·2	18·7	18·6	18·6	18·8	3·5	
Passenger							
Diesel locomotive-miles	244	251	244	243	233		5
Diesel unit-miles	493	506	497	502	483		2
Units per locomotive	2·02	2·02	2·04	2·07	2·08	3	
Diesel train-miles	239	246	239	239	229		4
Total train-miles, locomotive propelled	302	288	271	261	245		23
Total passenger train-miles	333	317	299	290	275		21
Cars per train	10·0	9·7	10·1	10·3	9·8		2
Train-miles per train-hours	39·1	39·5	39·8	40·0	40·2	3·5	
Total							
Diesel locomotive-miles	619	642	671	689	671	9	
Diesel unit-miles	1413	1470	1551	1615	1617	14·5	
Units per locomotive	2·29	2·29	2·31	2·35	2·41	5	
Train-miles, all	826	764	776	766	722		15
Diesel							
Average miles per locomotive, thousands	101	95·0	93·5	91·5	86·5		17

locomotive replaced. Multiple-unit operation is not a virtue, except where 'double-heading' or 'helper service' can be eliminated, or reduced. It does provide also for some flexibility for maintenance.

There are two possible explanations for the large drop in train-miles since 1946:

(1) The increase in cars-per-train and in tons-per-train shown in Fig. 8 could be caused by the consolidation of two or more trains into one much longer train, with a reduction in the number of train-miles. This would call for an increase in the number of diesel units per locomotive nearly proportional to the reduction in the number of train-miles, in order to justify the above claim.

(2) The same increase in cars-per-train and in tons-per-train, with the same reduction in train-miles could be due to the withdrawal of the many short trains on branch lines and to loss of the short-haul traffic on the remaining trackage. The remaining traffic would be handled by trains of no greater maximum length than before, yet the total cars-per-train and tons-per-train would show a rise in Fig. 8 due to the elimination of the shorter trains which made up the average. In this hypothesis, the number of diesel units per locomotive would show only a slight increase.

Data on diesel unit-miles are not available prior to 1953. In Table 3 are shown the diesel operated train-miles, locomotive-miles, and diesel unit-miles in freight and in passenger service for the years 1953–57 inclusive. Freight train-miles decreased 10 per cent during this period, gross tons per train increased 12·3 per cent, and cars per train 9·3 per cent. Units per locomotive, however, increased only 5·3 per cent. These statistics indicate improved operating skill in the loading of cars and trains, but this is independent of the type of motive power.

In passenger service, train-miles (locomotive-propelled) decreased 23 per cent, cars per train decreased 2 per cent, but units per locomotive decreased only 3 per cent.

It is quite obvious from Table 3 that the data fits explanation (2) rather than explanation (1), and that this entire claim for the diesel is invalid.

The average of 10 cars per train in passenger service, and 70 cars or 3200 gross tons per train in freight service are no greater than could have been handled by any average steam or electric locomotive remaining in service in 1957.

Table 3 also indicates that the diesel, *per se*, has not been responsible for the slight increase in average speed shown. It is probable that this increase is due to the elimination of slower trains and intermediate stops, together with improved dispatching and signal systems. Also, the elimination of passenger trains allows faster average freight train speeds.

ANALYSIS OF LOCOMOTIVE OPERATING EXPENSE ITEMS

Repairs

Road locomotives

The graph of repair costs shown in Fig. 12*a* is a function of numbers, age, and type of motive power.

The ordinates of the 'number' curve and the corresponding ordinates of the 'age' curve in Fig. 5 were multiplied together to make a composite curve of both these factors. This composite curve and the repair cost graph are compared in Fig. 19, which leave little doubt that these two factors dominate in repair costs.

The rise in repair costs with age for steam locomotives has been recognized for many years. In Fig. 20 is shown the result of a study of steam locomotive repair costs which

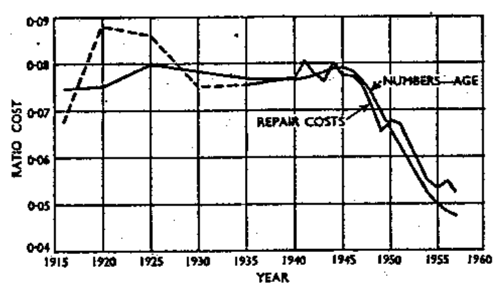


Fig. 19. Road locomotive repair costs, all class I railways compared with the numbers–age graph

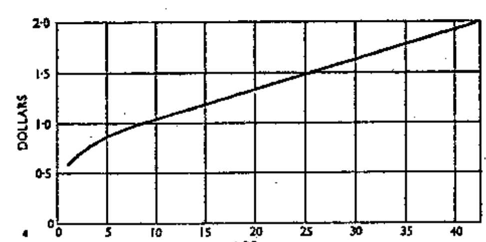


Fig. 20. Cost of steam locomotive repairs in dollars per 10 000 h.p.-mile unit

From report of Federal Co-ordinator of Transportation, June 1934. Costs are approximately 1929 level.

appeared in a statement of the Federal Co-ordinato Transportation in 1934. This graph is based on a re cost survey covering about 66 per cent of all the st locomotives of all sizes and types in use on the cla railways during 1927–29.

The rise in repair costs with age for diesel locomotiv often debated and denied on the basis that after 'h repairs' the running repair costs drop to former low le When the costs of these 'heavy repairs' are spread *pro* over the intervening period between such heavy overh the total costs of repairs will be found to rise continuo with age.

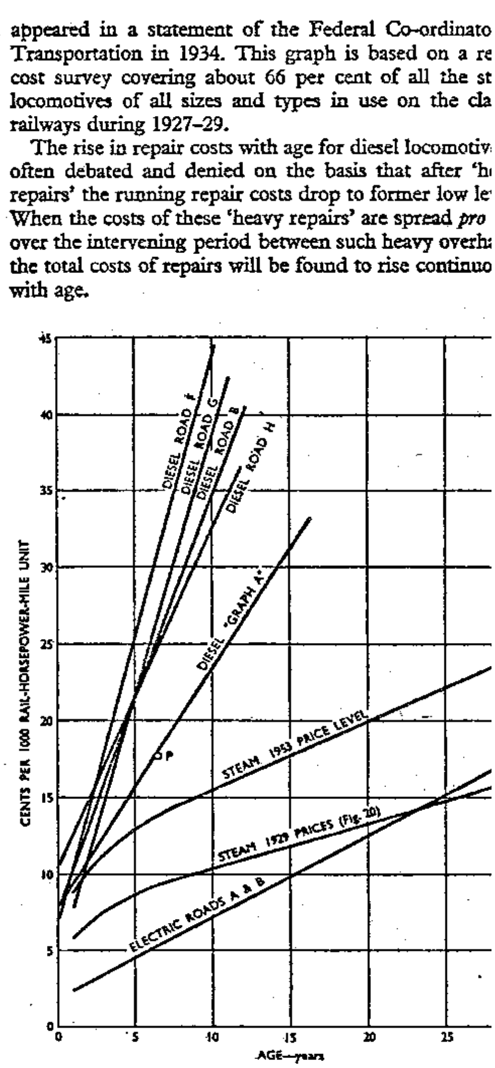


Fig. 21. Comparison of steam, diesel, and electric loc motive repair costs on basis of 1953 price level

In Fig. 21 are shown comparative repair costs in c per 1000 rail-h.p.-miles, related to age, for steam, di and electric locomotives. The steam curve is the ordinator's Curve' from Fig. 20, adjusted from 192 1953 price levels. The electric graph is from costs on class I railways operating similar electric motive p designed around 1938. The diesel graphs are from stu made in 1955 of repair costs related to age of more 3000 diesel units of all ages up to 12 years (on seven cl railways). All costs are shown in 1953 price levels.

The graph marked A is based on calculated diesel repair costs for an economic life of 15 years. Point P is the calculated repair cost in cents per 1000 rail-h.p.-mile incurred by all the road diesel power on the class I railways in 1957, adjusted to the 1953 price level. The average age of this diesel power was 6·6 years in 1957. The point P falls almost exactly on the graph A, at 17·8 cents.

Steam repair costs at age 6·6 years are 78 per cent of diesel repair costs shown in graph A. Road diesel repair costs in 1957 were $377·4 million. Equivalent steam power of the same age, to perform the same number of horsepower-miles, would cost $377·4×0·78 or $293 million.

Yard locomotive repair costs

It can be shown that the graph of repair costs in Fig. 13*b* also follows a composite 'number-age' curve made from data in Fig. 6. In 1957, diesels in yard service had an average age of 9 years. The ratio of steam to diesel costs (graph A) in Fig. 21, in the 9th year is 0·695. Yard diesel repair costs in 1957 were $76 million. Steam locomotives of same number and age would cost $76×0·695 or $52·8 million.

Fuel costs

The graph for fuel costs in Fig. 12*a* is a function of numbers, type of motive power, and trends in the fuel market. It shows a greater drop in the final 5 years than shown in the repair cost graph. Without question this is due to the change in type of motive power.

Diesels in road service have an average thermal efficiency of about 26 per cent, compared with 6 per cent for steam. In Fig. 22 are shown comparative costs, on a B.t.u. basis, of fuel used by the class I railways between 1939 and 1957. Although diesel oil is a high-cost fuel, the higher thermal efficiency of the diesel engine makes it lower in cost than coal for the same work performed. The cost of diesel fuel used in road service, adjusted for ratio of efficiencies has averaged 79·2 per cent of coal costs on a B.t.u. basis during the past 10 years.

The cost of fuel for all road locomotives was $366·7 million in 1957, exclusive of $23·2 million for electric power. Diesels were 88 per cent of total road power, using this proportion of the fuel cost, which is $323 million. This is 79·2 per cent of the cost of coal for equivalent service, which would have been $408 million, making the total fuel bill $451·7 for equivalent steam operation.

In yard service, with lower load factors and higher stand-by losses, the ratio of efficiencies is approximately 15 per cent for diesel and 1·5 per cent for steam, or ten to one. Diesel fuel costs, adjusted for ratio of efficiencies in yard service, have averaged 34·3 per cent of the cost of equivalent coal on a B.t.u. basis during the past 10 years.

Diesel fuel cost $40·5 million for yard operation in 1957. This is 34·3 per cent of the cost of $118 million for coal for the same service with steam locomotives. Diesel operation was 95 per cent of the total yard operation. The total fuel and power bill was $43·4 million in 1957. With equivalent steam operation, this would have been $121·4 million.

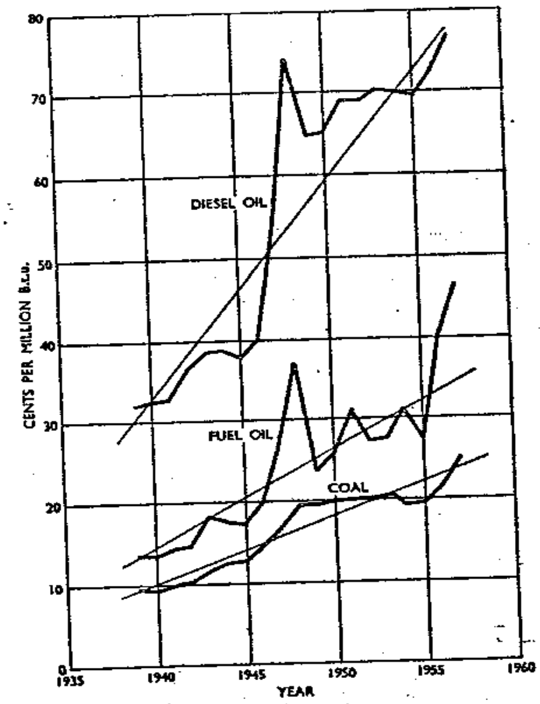


Fig. 22. Comparative cost of fuels used on class I railways, on B.t.u. basis

Assumed B.t.u. content: coal 12 500 per lb; fuel oil 149 000 per gal; diesel oil 138 000 per gal.

Engine men

The graph for engine men in Fig. 12*a* is a function of the reduction in number of locomotives, the weight on drivers, and increase in wage rates.

In Fig. 8, locomotive-miles per train-mile shows a reduction from 1·07 in 1940 to 1·02 in 1957. This 5 per cent reduction is probably in 'double-heading' and 'helper service', and can be credited to diesel operation. This can also mean a 5 per cent reduction in engine men.

Engine men in road service cost $388·3 million in 1957. On the above basis, they would have cost 5 per cent more with steam operation, or $407·7 million. No statistical data are available for the additional cost of engine men with diesel operation due to increased weight on drivers.

No savings in the cost of engine men ($242·7 million) is indicated in yard service. This is one example where savings which might be made with diesel or electric motive power cannot be made because of working agreements. The second engine man (fireman) performs no essential function on switching locomotives of these types. Nearly $100 million could be saved annually by their elimination.

Engine house expenses

The graph for engine house expenses in Fig. 12*b* reflects largely the reduction in number of locomotives, branch line terminals, and traffic and, to a lesser extent, the change in type of motive power. The rise between 1941 and 1954 reflects war traffic and operation of dual types of power.

In the graph for this item in yard service, shown in Fig. 13*b*, the downward trend since 1950 must be assigned to the change in type of motive power. Costs in 1950 are the same as in 1941, at 0·0055 as a ratio cost. In 1957 this ratio cost was 0·0036, a reduction of 0·0019, which amounts to $15·6 million.

The ratio of road diesel units to yard units in 1957 was 2·3 and the ratio of hypothetical steam road locomotives to road diesel units is 0·623. It may be assumed that the savings in engine house expenses in road service for diesels over steam would be $15·6×2·3×0·623, or $22·3 million. This is about $4 million greater than would be estimated by taking the drop shown in Fig. 12*b* for the period 1940–57.

Water

There can be no question that the diesel is saving almost the entire cost of water. Assuming the cost of $5·3 million in 1957 was for the 1942 steam locomotives still in road service, the cost of water for 11 800 steam locomotives would be $5·3 times the ratio of 11 800 to 1942 or $32·2 million.

In yard service, there were 455 steam locomotives still in service in 1957 and the water cost was $1·1 million. Had all the 8227 yard diesels been replaced with steam, the water cost would have been $1·1 times the ratio of 8227 to 455, or $19·8 million.

Lubricants

In the diesel locomotive, some of the lubricants are consumed with fuel. The costs of lubricants are higher than for other types of motive power.

Most lubricants are products of petroleum, which has increased in cost 2·4 times since 1940 (see Fig. 22). Lubricants cost $7·5 million for 33 700 steam and electric road locomotives in 1940. The equivalent steam and electric locomotives in 1957 would be 14 300, or 42·5 per cent of the 1940 number. The costs of lubricants in 1957 on the basis of above assumptions would be $7·5×2·4×0·425 or $7·7 million, a very slight increase compared with the actual cost in 1957 of $27·2 million.

Lubricants for yard service locomotives cost $1·3 million in 1940. Multiplied by the assumed rise in cost, this would be $3·1 in 1957, compared with the actual cost of $4·4 million.

Other locomotive supplies

The cost of other supplies has not been materially affected by the change in type of motive power. These costs were $8·8 million in 1957, for road locomotives, and $2·2 million for yard power.

Summary of savings with diesel electric moti power

The summary of savings for all the items of locomoti operating expense is given in Table 4, together with t comparative total investment and the fixed charges. T shows that the diesel locomotives, *in toto*, made operati savings of $137·0 million compared with the assum equivalent steam operation, on the basis of 1957 costs. I each year in retrograde prior to 1957, the savings would correspondingly less.

The total investment is $1·8 billion greater for the diese and the fixed charges are $165·5 million greater than for t equivalent steam locomotive investment, exceeding t operating savings by $28·5 million.

In road service alone, the investment in diesels and p rated facilities is $1135 million more than for the equival modern steam power. Diesel operation is $49·7 mill cheaper than steam operation, but fixed charges amount $71·6 million more than the operating savings.

In yard service alone, the investment in diesels and p rated facilities is $665 million more than with equival steam power. Diesel operation is $87·3 million cheaper th with steam operation, and fixed charges are only $4 million greater than for steam, making a net overall sav of $43·1 million. This is 6·6 per cent return on the $6 million increase in investment.

Quite obviously, the savings realized by diesel operat in yard service have not been realized in road operati It is clear in the development of the analysis just why t has not been possible. Nothing can be found in this analy to justify the claim so often made that the diesels are p ducing a 30 per cent return on their investment. If this w true, such large savings would become apparent in lo operating ratios, and in increased earnings.

EARNINGS

Each one of the class I railways is a private enterp operated primarily for a profit. In Fig. 23 are shown the t capital stock outstanding, common and preference, gether with the amount of stock paying dividends, and total amount of dividends paid, for all the classes I and railways. It is clear by comparing with Fig. 1 that earni are closely related to traffic.

The increase in dividends since 1940 does coincide w the change in type of motive power; but to relate these facts is wholly unwarranted. Earnings for this period lower, with a greater traffic volume, than in the pe 1925–30, when all the motive power was steam and elec

OTHER CONSIDERATIONS

Although the diesel is a cleaner type of motive power t the steam locomotive, it still requires expensive ventila equipment in long tunnels and is excluded from opera in large enclosed or built-over urban terminals. Any sav resulting from the through diesel operation of former s electrified sections in tunnels are included in the ger statistical data studied.

Diesel locomotive design has proved, as electric locomotive design has proved in Europe, that high speeds can be safely made with locomotives having small-diameter driving wheels without the necessity of idle leading axles. Thus all of the locomotive weight may be used for adh:sion.

Small-diameter driving wheels, and lower centre of gravity do produce greater track and rail stresses. Rail 'burns' from slipping driving wheels are more prevalent with diesel operation than with former steam. It is often claimed that the change from steam to diesel has reduced

Table 4. Comparative costs diesel operation versus *operation with equivalent modern steam on basis of 1957 costs*

All figures in millions of dollars

	Diesel		Steam	
	Cost	Saving	Cost	Saving
Road power				
Repairs:				
Diesel and equivalent steam	377·4		293	84·4
Other	51·6		51·6	
Fuel:				
Diesel and equivalent steam	366·7	85	451·7	
Other	23·2		23·2	
Engine men	388·3	19·4	407·7	
Engine house expense	104·2	22·3	126·5	
Water	5·3	26·9	32·2	
Lubricants	27·2		7·7	19·5
Other locomotive supplies	8·8		8·8	
Total road locomotive expense	1352·7	153·6	1402·4	103·9
Net operating savings		49·7		
Yard power				
Repairs:				
Diesel and equivalent steam	76		52·8	23·2
Other	8·1		8·1	
Fuel:				
Diesel and equivalent steam	40·5	77·5	118	
Other	3·4		3·4	
Engine men	242·7		242·7	
Engine house expense	29·9	15·6	45·5	
Water	1·1	18·7	19·8	
Lubricants	4·4		3·1	1·3
Other locomotive supplies	2·2		2·2	
Total yard locomotive expense	408·3	111·8	495·6	24·5
Net operating savings		87·3		
Total expense, road and yard	1761·0		1898·0	
Total net operating savings		137·0		
Investment				
Road locomotives	2760		1925	835
Yard locomotives	1120		555	565
Total locomotives	3880		2480	1400
Facilities (pro-rated 300 road, 100 yard)	400			400
Total investment	4280		2480	
Net saving in investment				1800
Fixed charges				
Depreciation of equipment:				
Road	165·6		61·0	104·6
Yard	50·4		17·5	32·9
Interest on undepreciated equipment:				
Road	55·2		38·5	16·7
Yard	22·4		11·1	11·3
Total fixed charges, equipment	293·6		128·1	165·5
Total, all charges road	1573·5		1501·9	71·6
Total, all charges yard	481·1	43·1	524·2	
Total, all charges road and yard	2054·6		2026·1	28·5

Return on differential in investment for yard operation, 6·6 per cent.

the cost of track maintenance. Maintenance of way costs have been carefully examined over the period studied to verify this claim. No indication can be found that the change in type of motive power has produced any savings in this field. Such costs have increased slightly.

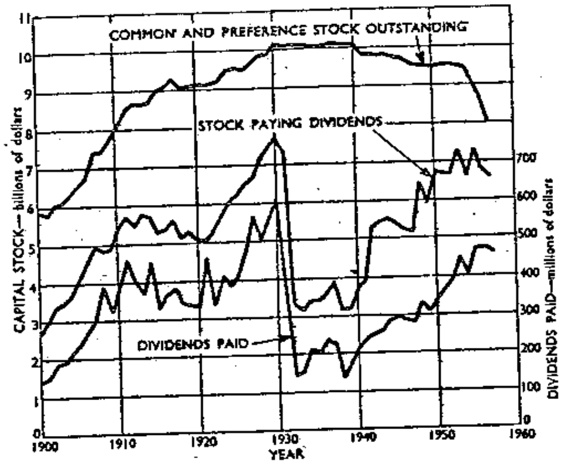


Fig. 23. Capital stock and dividends paid, all classes I and II railways

During the period since 1940, railway management has been beset with many serious problems, including increased competition with subsidized carriers, loss of traffic, rising costs, and higher operating ratios. To solve these problems management has changed operating methods, made large investments in new motive power, cars, and facilities, in improved freight terminals and yards, in new signals and dispatching systems, and in general improvements in way, and in maintenance methods.

In this period the total investment in the classes I and II railways has been increased $9 billion, or more than one-third. Of this increase, motive power and facilities have accounted for $2·5 billion; new cars, $4 billion; with all other improvements accounting for the balance of $2·5 billion. The investment in diesel motive power has been the most spectacular, and has had the greatest amount of publicity.

To claim, however, that the diesel is responsible for all the operating economies made since 1935, or even 1945, is to belittle the skill of management, and to expropriate the credits due to these other investments.

Such claims cannot be made equitably for any one factor. All have made their contribution.

This study simply states that the all-embracing economies claimed for diesel motive power on the class I railways of the United States, as a whole, do not appear in the statistical record.

The diesel locomotive has not 'revolutionized' America railway economics. In road service, diesel motive power h added to the financial burden of the railways.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the valuable editori assistance of Mr. Alfred G. Oehler, Consulting Editor *Railway Age*, and Jacob Stair, jun., consulting engineer wi Gibbs and Hill, Inc., in the preparation of the text.

Tables 1*a*, 2*a*, 3, and diesel costs in Table 4 are compil directly from the I.C.C. statistics. Tables 1*b* and 2*b* a calculated from Tables 1*a* and 2*a* respectively.

Figs. 1, 2, 4–10, 15, 16, and 23 are plotted fro I.C.C. statistical data.

The average age in Figs. 5 and 6, the ratio costs in Figs. 1 12*a* and *b*, 13*a* and *b*, and 19, and fuel costs in Fig. 22, a calculated from I.C.C. statistics.

Fig. 3 is compiled from locomotive encyclopaedias a other published data relative to steam and diesel locomoti characteristics.

Diesel and electric locomotive maintenance costs sho in Fig. 21 are from studies made in 1953 and 1955 in whi the author collaborated.

Depreciation costs given in the I.C.C. statistics were always itemized for the different types of motive power, a are not used for reasons stated in the text.

Figs. 17 and 18 are from *The Steam Locomotive*, by Ral P. Johnson, published by Simmons-Boardman in 1945.

APPENDIX

HYPOTHETICAL INVESTMENT IN STEAM POWER EQUIVALENT TO EXISTING DIESEL POWER

Road locomotives

Existing number of diesels (1957), 18 959 units.
At 1500 h.p. average, 28 500 000 h.p.
These units make 18 959/2·41 or 7870 locomotives.
Assume the number of equivalent steam locomotives is inver proportional to their availabilities.
Then 7870×90/60, or 11 800 steam locomotives will required.

28 500 000 h.p.×90/60 is 43 000 000 h.p.

Assume 1953 as average year of purchase.
In 1929, steam locomotives cost approximately $30/h.p.
1929 prices times 1·49 equal 1953 prices.
Steam locomotives would cost $45/h.p.* in 1953, assu manufacturing would have been continued.

43 000 000 h.p.×$45/h.p. is $1925 million.

Yard locomotives

Existing number of diesels in 1957, 8227 units.
At 1500 h.p. average, 12 250 000 h.p.
At $45/h.p., $555 million.

Total investment	road	$1925
	yard	555
	total	$2480 m

* *Actually, the last few steam locomotives made in the United in 1952 and 1953 did cost approximately this amount.*

interruptions during the past few months due to breakdowns associated with the locomotive. Recently, motorists driving into Montreal had seen five commuter trains held up head-to-tail due, he had been informed, to a scavenge-blower-bearing failure on the engine of the leading train.

So far as it had been possible to ascertain, those five failures were due to the following causes:

(1) Failure of a scavenge blower bearing.
(2) Failure of a heat exchange component.
(3) Failure of an electrical component.
(4) Failure of an electrical controller.
(5) Failure due to overheating.

The low thermal efficiency of the steam locomotive certainly called for improvement, but it appeared that the higher efficiency obtained from the diesel-electric locomotive was penalized by the introduction of unacceptably high maintenance costs and a very questionable degree of reliability in service.

Possibly a compromise solution would be the use of the diesel combustion process in association with a turbo-mechanical drive. That could be met by gasifiers such as the crank system successfully installed in locomotives in Sweden, or the free piston gasifiers installed in locomotives in France and, also, in the United States of America. Of those two alternatives the free piston system would appear to offer some advantage over the crank system, as the use of multiple gasifiers would ensure 100 per cent availability.

Both systems offered the advantages inherent in the use of a turbine as torque converter, giving a performance comparable to that of electric drive without the accompanying penalty in the way of some 15 per cent transmission losses. There was no limitation to the size of locomotive, apart from those imposed by loading gauge and permanent-way restrictions.

It was surprising that the only active development of the gasifier locomotive in Europe was in two countries committed to a policy of full electrification, and it would have been expected that the country which spent money investigating such developments as the Ljungstrom turbo-locomotive, the Kitson-Still hybrid, the open cycle gas-turbine, and other less promising developments to have paid more attention to the gasifier-turbine compound engine with its much higher potential, in regard to both immediate benefits and long-term prospects.

Mr H. G. McClean, B.Sc. (Eng.) (*Member*), wrote that those who, like himself, had had substantial experience of dieselization both in the United States and on railways overseas, must feel that the paper presented a misleading picture of the results of dieselization of American railroads, now substantially completed.

Based on I.C.C. statistics for United States railroads as a whole, together with some diesel-electric costs for selected railroads, which readers were asked to assume were typical, and finally some steam costs (all highly presumptive), the author had reached the conclusion that the merits of dieselization on United States railways were largely imaginary; that the publicized statements of its benefits were erroneous; and that dieselization had not been an economic advantage.

Those findings were those of the author alone and were not representative of those of United States railroads, either collectively or individually, and were in conflict with published statements of practically every United States railroad president.

Having established to his satisfaction that modern steam power would have been more economic than diesel, the author had withdrawn from advocating a return to steam operation, leaving a vacuum, presumably to be filled by a recommendation for electrification in his subsequent paper.

It seemed desirable, therefore, to withhold full comment until the author's presentation was complete. But some of his conclusions must be contested immediately as they might otherwise be highly misleading.

The United States railroad system comprised rather more than 100 class I railroads operating primarily for profit, deriving their revenue and profit almost wholly from handling freight, and engaged in intensive competition, both with road haulage, and with one another. Equally, the locomotive builders were aggressive competitors. It was reasonably certain that any decisions made as to the operation of those railroads would each be taken individually by the management of that railroad, based on the figures for that railroad, and for that railroad only.

If the author's presentation was correct, then the fine managements of those many railroads (and of the locomotive builders) were, without exception, by implication incompetent to a point which would constitute negligence, and all those railroads had, by the author's paper, been deliberately misled in their policy of dieselization by the erroneous claims of the locomotive manufacturing industry.

Locomotive repair costs. Essentially, had the author attempted to justify his presentation on the basis of the diesel locomotive repair costs presented in Fig. 21, and especially the rate of increase with age.

Those were figures for some selected railroads, and the slopes of the curves were, of course, particularly sensitive to the accuracy of values at about the 10-year life. The slope of the author's curve was unreasonably high.

In Fig. 28, superimposed on the author's Fig. 21, were values for locomotive repair costs from another large United States railroad, well known, and early active in dieselization. Those values were actual costs, not adjusted to 1953 price levels. Such adjustment, obviously, would tend to make the rate of rise with age even less. It would be seen that those figures were very much below those on the author's chart.

However, the figures would be equally misleading if they were used to develop generalized statements since the values were most likely well below the average for most railroads.

Fig. 28 showed for that same railroad the curves for repair costs for successive additions to their locomotive fleet and confirmed the general form of the curves.

It might be repeated that each individual railway would

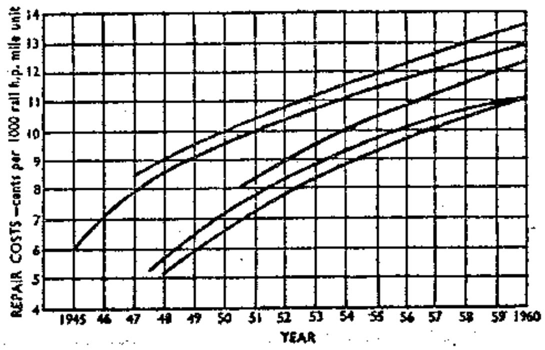


Fig. 28. Diesel-electric locomotive repair costs for a United States railroad

Actual values not adjusted to 1953 price levels.

make its decisions on motive power based on its own cost figures.

It was, furthermore, possible to dispute the author's figures by citing statements made publicly by most United States railroad presidents in placing on record the economic benefits of dieselization.

In May to July 1955, there had been correspondence in the American railroad press on the increase with age of maintenance costs of steam and diesel locomotives. At that time Mr. John M. Budd, the President of the Great Northern Railway (a railway which was electrified through the Cascade Tunnel) wrote, '. . . Those who are trying to sell electrification to the railroads have made the same assumptions . . . that there is a constant rise in the unit mile cost of maintaining Diesel locomotives. We have taken exception to that theory and believe have pretty definite proof that it will not stand careful examination. . . . An analysis of carefully kept figures on a unit basis for 92 F–T Diesel locomotives gives definite indication of a cycle in repair costs per unit mile. . . . We made heavy repairs to these locomotives after about an 8-year life. In the following year the cost of repairs per unit mile dropped back to about the same level as that attained in their third year of life, which was slightly higher than the repair costs for the locomotives when they were new. . . . We anticipate our repair costs per unit mile will level off.'

That railway's experience, 1955–60, had confirmed the accuracy of Mr. Budd's forecast, with unit repair costs following the same general curve superimposed on the author's Fig. 21.

Fuel costs. Fig. 22 showed comparative costs of fuel on a B.t.u. basis. That was perhaps unfortunate in that it might lead the reader to imagine that the cost of fuel under dieselization had been higher than steam locomotives, coal-fired or oil-fired.

However, the author's text suggested fuel costs for road locomotives was $367,000,000 in 1957 when coal would have cost $408,000,000; and even so his method of calculation might be questioned as unfavourable to diesel.

Depreciation and obsolescence. The author had implied that the depreciation allowance allocated to diesel locomotives when they were originally purchased was inadequate. On the information then available, the assumed life of a road locomotive was generally 20 years, and there was ample evidence to indicate that the locomotive was, and was going to be, a satisfactory piece of operating equipment at that age.

But he was critical because the manufacturers, by an active programme of continuous product improvement, with the encouragement of the railways, had made it possible to establish economic justification for replacement or remanufacture of the locomotive before it had reached its 20-year life. Constant product improvement had made it possible to increase the capacity of the equipment by the order of 3–4 per cent per annum average, but with lower maintenance costs.

It was a perfectly legitimate and desirable commercial practice, both for a railroad as for any economic undertaking, to purchase equipment on a well-chosen value of depreciation, but subsequently to seek to obsolete that equipment by something more efficient in less than its assumed full life. There would frequently be a tax advantage to the user in so doing.

Long economic life frequently involved technical stagnation. One of the great demerits, surely, of electrification was that it froze the product in the form in which it was installed because that required such a high first-cost investment. Clearly, the United States locomotive manufacturers were going to try to improve their product at such a rate that the railways would be encouraged to scrap and buy new with economic advantage in so doing.

Traffic. The graphical presentation of traffic in Fig. 1 might tend to be misleading unless it were emphasized that 85 per cent of the revenue of the American railroads came from freight traffic, and that, by and large, that was the only traffic of importance. The statistics, as presented, might give the impression that passenger traffic was more important than it was. The exceptions, such as the New Haven Railroad, with which the author was associated, were far from typical.

In Part II there was a reference to the activity of the automotive industry in promoting the sales of diesel-electric locomotives, perhaps with an implication that that was an improper promotion and 'campaign' when the economic claims justifying the purchase of diesel locomotives were inaccurately presented.

For the benefit of the uninformed, perhaps it would have been desirable that the author should have made it plain that the reference to the automotive industry should not be taken to imply that automotive manufacturing facilities were converted to locomotive manufacture.

The diesel locomotive activity in the United States was initiated by a group of men who spent the whole of their lives in railway motive-power activity and who latterly became associated with an automobile manufacturer who provided necessary additional management, philosophy techniques, and means, especially in the area of skills in volume manufacture of standard units.

Assumed steam locomotive costs. The author assumed a steam locomotive cost of $45 per horsepower in 1953 and a typical size of locomotive having 5000-rail h.p. It would be helpful if he would indicate the weight, wheel arrangement, boiler, and grate of a typical locomotive of the class that he had in mind. Experience had shown, in his opinion, that it was difficult to make a proper comparison between the power of a steam locomotive and a diesel locomotive for regular day-in day-out operation. The output from the diesel locomotive varied but little from day to day or year to year, but there was a substantial difference between the performance of a steam locomotive in a new trial (when most of the published tests were conducted) and the average of its performance in day-in day-out service. On the latter basis a steam locomotive having 5000-rail h.p. was a very big locomotive.

Large-horsepower single-locomotive units. The author had stated that American manufacturers 'have not been able to build' single units of much more than 2000 h.p. That statement presumed that the several United States manufacturers believed that it was desirable to attempt to build such units but did not know how to do so. In fact, most of those manufacturers had held the belief that the retention of the multiple unit concept of smaller units was a better policy for both operator and manufacturer, and experience confirmed their view.

It was the author's presumption that they could not have done so had they made the attempt. In fact, one manufacturer had produced a larger unit. He was not now actively in the United States railroad locomotive business.

Economic results of dieselization. The author's basic conclusion was that dieselization had been a mistake. 'Nothing indicates that the change in type of motive power since 1940 has had a bearing on—operating expenses—unless unfavourably'. That sweeping statement was completely in conflict with the conclusions of every railroad in the United States, without exception. It would be possible to quote almost every United States railroad president to the contrary in statements made at one or other of the annual meeting reports of the past 10 years. The statements were in no way invalidated by the fact that there had been a rise in operating ratios, and the author, in effect, had subsequently disproved his own statement by his reference to the saving in fuel cost alone. If any reader was in doubt he should seek opinions direct from individual railroads.

But perhaps the best refutation of the author's statements came from the action of the Norfolk and Western Railroad. That was a large eastern railroad, heavily engaged in hauling coal and with, therefore, every incentive to use motive power energized by coal, whether steam locomotives or electrification. Some 100 miles of that railroad had been electrified through a mountainous area handling heavy traffic in 1914. The railroad had abandoned the electrification in 1951.

Thereafter it had operated a fleet of modern steam locomotives in a way which was well known and admired throughout the world as a classically fine steam locomotive operation. In 1955 the Norfolk and Western Railroad had made the decision to buy their first diesel locomotive, and in 1958 had decided on complete dieselization. At the time of that decision they had a background of previous experience of electrification. They had excellent comparative operating costs for steam locomotives, possibly the best figures in the United States, and equally, as late starters, they had available to them from all the other railroads that had been dieselized, data on the results of dieselization on those lines to supplement their own diesel experience. The President of that railway, speaking at Roanoke 9th February 1960, said, 'Our dieselization programme was a major factor in enabling us to improve our operating performance so substantially in 1959'. No more outstanding example is available to disprove the author's statement 'Diesel motive power has added to the financial burden of the railways'.

Many persons would reserve further comment until they had read the author's subsequent paper on electrification.

Mr P. A. McGee, Mem. A.S.M.E. (Ventnor, N.J.), wrote that the great merit of the paper was the presentation in one paper of important operating data from I.C.C. records. It, however, suffered from the inclusion of unnecessary and confusing details.

Perhaps the chief error was the omission of important operating and cost indices and their substitution by the author's unsupported opinions which were largely refuted by available data and the substantial operating railroad records.

The extraordinary increase in class I railroad yearly operation expenses from 3 billion to 6 billion dollars per year in the short period 1940–45 was naturally the cause of great concern to United States railroad management. Millions of dollars were spent by railroads and manufacturers between the late 1930's and middle 1950's in designing and testing all kinds of direct steam and steam-electric power and gas and solid-fuel turbines.

The results of those tests and the conclusions drawn from them by the most competent and experienced talent available were no secret and were well known to United States railroad management.

The author's assumption of a mysterious hypothetical steam locomotive for a comparative cost study with diesel power was, to put it mildly, quite unconvincing.

The author had stated that after the first flush of successful diesel performance that doubts had arisen as to whether the economies which developed with diesel power were not the result of other factors which, he stated, was a natural development. From his own continued association with responsible railroad personnel and a close study of current operating results—and as could be shown from the record of recent diesel purchases—that erroneous opinion appeared to be confined to the author and his associates at 32nd Street and Church Street, New York.

There was no monopoly in the application of any particular power on United States railroads. If there was a better steam or a better gas-turbine or electric locomotive, all that was required was to produce it; and there would undoubtedly be a ready response by manufacturers, coal, and residual oil suppliers, and the railroads.

The substitution of diesel for steam power was the result of an extensive operating study which would continue as long as operating records were available. The purchase of some $3,900 million of diesel power, as mentioned by the author, required the approval of 110 Boards of Directors and the financing support of banking, financing institutions, and insurance companies throughout the United States.

He himself had had an extensive experience in railroad electrification and diesel operation since its introduction in 1937, and it so happened that he had prepared, at the end of 1957, a record of diesel performance between the years 1941 and 1956.

Statistics were invariably tedious. He had, however, reduced his 1957 study to include only the essential operating indices and costs, with particular reference to fuel, maintenance, engine men, and engine house expenses. He believed that they would be found to be informative and very interesting.

Table 5 with operating details for all class I motive power and freight movement at 5-year intervals from 1941 to 1956 and the available data for 1959 were reduced to 16 items. Those 16 items gave the full pertinent data of total operating costs and comparative costs of actual steam and diesel power for the approximate 220 000 miles of class I railroads.

Item 1 Gross ton-miles (G.T.M.) of trailing freight was fairly uniform from 1946 to 1959.

Item 2 The freight G.T.M. per freight train hour supplied the most significant operating indices of freight movement. It explained the whole tempo of freight movement and what must be its operating cost basis. From 1941 to 1959, that index improved by nearly 90 per cent.

Items 3 and 4 gave the relative G.T.M. of freight hauled by steam and diesel power. In 1941 freight diesel operation was insignificant and in 18 years was over 98 per cent.

Item 5 Total operating expenses which were approximately $3000 million in 1940 doubled to $6,000 million in 1945. In the following 14 years with double the basic material and labour cost, the total increase in operating cost with diesel power was limited to the same amount, $3,000 million dollars. That control of operating cost, as would be shown, was largely caused by the improved operating rate of item 2 and the fuel cost item 13.

Item 6 The large contribution in national taxes should be noted by critics of the profit motive.

Table 5. Summary of certain United States of America class I railroad operating data for 1941–56 by P. A. McGee on 12–9–1957, to show the influence of diesel power on the performance indices; operating expenses with increased costs

Item	Subject	1941	1946	1951	1956	1959
1	Total freight G.T.M., billions	1,195	1,361	1,440	1,447	1,300
2	Freight G.T.M. per train hour	33,000	37,057	46,407	57,102	61,926
3	Percentage operated by steam	97·5	88·0	45·6	9·0	0·3
4	Percentage operated by diesel	0·2	9·7	52·5	89·1	98·2
5	Operating expenses, millions of dollars	$3,664	$6,357	$8,041	$8,106	$9,077
6	Taxes in millions of dollars	$547	$498	$1,203	$1,121	$1,048
7	Average yearly compensation per employee	$2,045	$3,068	$4,133	$5,102	$6,100
8	Ratio of average yearly compensation per employee, basis 1941	1·0	1·5	2·0	2·5	3·0
9	Ratio of cost of rails; freight cars; signal equipment	1·0	1·2 to 1·4	1·8 to 2·1	2·2 to 2·7	
10	Basic cost per h.p. typical 130-ton diesel railroad unit	$90	$93	$108	$101	$94
11	Fuel unit cost:					
	steam coal per ton	$2·3	$3·6	$5·00	$5·7	$6·4
	steam oil per gallon	2·1c.	3·0c.	4·6c.	5·4c.	4·9c.
	diesel oil per gallon	4·5c.	5·5c.	9·5c.	10·2c.	9·8c.
12	Fuel and power total road and yard:					
	steam coal, million tons	98	100	48	8·5	0·3
	steam oil, million gal.	3484	3878	2031	180·0	
	diesel oil, million gal.	186	511	2262	3581	
	electric, million kWh.		1893	1672	1566	
13	Fuel 1000 G.T.M. per $1·00 cost:					
	steam coal	6,250	3,900	3,030	3,087	2,570
	steam oil	4,700	3,470	2,140	1,959	2,376
	diesel	12,250	10,250	6,420	5,299	5,165
	electric	3,800	3,700	3,300	2,959	2,457
14 •	Fuel and power total cost all services, million $	$322	$518	$562	$441	$419
	Fuel and power total cost all services, million $ *at 1959 unit cost*	$855	$912	$652	$436	$419
15	Locomotive maintenance road and yard	314	576	635	512	
	Locomotive maintenance road and yard, million $ *at 1956 unit cost*	635	721	634	512	
16	Engine house and engine men road and yard, million $	369	632	744	759	
	Engine house and engine men road and yard, million $ *at 1956 rates*	924	1,260	1,160	759	

Items 7 and 8 The average employee compensation increased by one billion dollars every 5 years. Its effect on items 2, 15, and 16 should be noted.

Items 9 and 10 The increase in material costs was less than labour increase items 7 and 8. A very interesting development in diesel power showed practically no increase in cost on a h.p. basis over the years since diesel road power was applied.

Item 11 All fuel costs had increased about 100 per cent in the 14-year period. Its effect on items 13 and 14 should be noted.

Item 12 Total fuel quantities. This item deserves the special attention of all railroads of the world. In 10 years 1946–56 the application of diesel power saved over 90 million tons of coal; 3700 million gallons residual oil; 330 million kWh with an increase of about 3000 million gallons of diesel fuel. On the basis of 1959 unit costs, that represented a saving of approximately half a billion dollars per year. The total amount of diesel fuel required with practically 100 per cent diesel operation was considerably less than the total residual oil consumed in 1946 with about 18·5 per cent of the total freight movement.

Item 13 G.T.M. per $1 fuel cost. That important index, not commonly published with year statistics, confirmed the savings mentioned in items 12 and 14.

Item 15 Locomotive maintenance. That item represented for recent years about 30 per cent of total equipment maintenance and with succeeding years and more labour content in freight and passenger-car maintenance would become progressively less. At 1956 maintenance rates, diesel power for 1946 showed a yearly saving of about $200 million.

Item 16 Engine house and engine men. Those very important cost items were practically all employment compensation and very sensitive to the requirements of locomotive servicing and the crew costs which were largely influenced by item 2. At 1956 rates, the diesel power showed a saving in 1946 operating cost of over half a billion dollars.

Table 5 did not by any means represent the complete savings derived with diesel power. The large potential savings in maintenance of way was not included which, without going into details, might exceed those of maintenance of equipment. Nor were the very large savings with the extensive closing down of the mandatory tunnel, terminal, and grade electrifications included.

The total out-of-pocket savings of approximately $1,200 million per year with diesel operation as developed in Table 5, however, sufficiently refuted any opinion or suggestion that diesel motive power, with a claimed investment of $3,880 million dollars, represented any financial burden to the United States class I railroad system.

An investment which paid for itself in less than 3½ years, and thereafter saved probably over a $1500 million per year, spoke for itself.

Mr J. E. Owen (Doncaster) wrote that on p. 265, under Locomotive Expense Items, the author had dealt with the subject of depreciation and had stressed the importance of using a correct depreciation rate in the accounting process. That rate was shown to be dependent on the economic life of the asset, and figures of 30 years and 12–14 years were quoted for the economic life of steam and main-line diesel locomotives respectively. That economic life was determined largely by three considerations: (1) The increasing cost of maintenance as the life of the asset was prolonged. (2) Technical obsolescence. (3) Non-technical considerations, such as, for example, Company policy, the incidence of taxation, or, in the author's words on p. 265, 'a ruling of the I.C.C.'

There was little doubt that the rate of increase in maintenance costs would be somewhat greater in the case of the diesel engine than the steam engine, and the diesel engine was probably more vulnerable to technical obsolescence. Already, particularly in Germany, a strong movement could be seen away from electrical transmissions to various systems of hydromechanical transmission. But he questioned whether those two things alone were sufficient to reduce the economic life of the diesel locomotive to only 14 years.

He would like the author to state to what extent that relatively short life of 14 years or thereabouts had been due to entirely non-technical considerations which might have been used to support a 'scrap and build' policy.

The importance of the depreciation figures in that case could scarcely be over-stressed, since it appeared on reference to Table 4, column 4, that the saving of 71·6 million dollars attributed to steam traction became in fact a saving of 11 million dollars to diesel traction if the same rate of depreciation had been applied to both steam and diesel locomotives.

exhausted, and must be pursued. The railways of the ~~United~~ States, however, had no joint research ~~organization~~ for that type of development and must ~~look to~~ the manufacturing industry to produce ~~such a locomotive~~ That industry had no incentive to ~~destroy~~ their present renewal part business or to ~~produce~~ equipment having a longer life between ~~renewals.~~

In regard to Mr Owen's query relative to the extent the short life of diesel-electric motive power had been due to non-technical considerations, such as company policy, incidence of taxation, or rulings of regulatory bodies such as I.C.C., it was his considered opinion that those factors had had little bearing on the retirements made to date, shown in Fig. 30. That figure confirmed the short economic and service life, regardless of analysis of statistics. Increasing repairs with age and obsolescence had been the real factors.

Several railways had attempted to rebuild diesel locomotives in their own shops, as steam locomotives once were, but it had been found to be usually too expensive. The heavy overhaul of a steam locomotive was not greatly different from its original manufacturing procedure, and nearly all large railways had shops with trained labour and supervision to handle such procedure. In fact, several large railways built their own steam locomotives.

An entirely different type of motive power had then entered the scene. The former shops, facilities, machines and type of skilled labour were all rendered inadequate—all had to be replaced by something different (see Fig. 16). On that new equipment new unit assemblies replaced an entire assembly on which a lesser item had failed. After removal the faulty item was found and replaced and the assembly awaited another replacement. There came a time, with age and service, when too many units and assemblies were out of service because too many items needed attention. Few shops equipped for simple part renewals or unit assembly replacements could cope with complete heavy overhauls, except in special cases. One diesel manufacturer, as part of his 'service' to the railways, had even designed the shops for their repair up to that point. For the final heavy overhaul, after about the twelfth year, he said, 'let us rebuild it'. But he would not tear down and rebuild it in kind. It must always be a 'later model' like an automobile, not only with increased capacity, but with greatly changed appearance. 'Streamlining', once the trade-mark of the diesel locomotive, had become old style—obsolete. Even the underframe, or car-body, as it was called in American railway parlance (Sir Ralf Emerson in his discussion had called that the hull), was no longer adequate. So the old unit was perforce—retired—sold back to the manufacturer for a small fraction of its original cost. In time, a new (i.e. rebuilt!) unit was received in return, costing more than the original unit, and which must be paid for anew, on the 'chattel mortgage' basis.

An important question being asked today in the United States by all consumers of modern automobiles, household appliances, even railroad motive power, was, 'how much built-in obsolescence is there in this apparatus when it is purchased new?' It was a legitimate question and a serious one.

Mr McClean had found that the paper presented a 'misleading picture' to one like himself having substantial experience of dieselization in the United States and on oversea railways. He himself had had a little *railway* experience in both areas. He quite understood that Mr McClean, from his position as Manager of Export Sales of the largest American manufacturer of automotive highway vehicles and railway diesel motive power, could not be otherwise than at wide variance with the paper at every point possible.

In the second paragraph of his discussion, he had correctly, and with precise wording, summarized the conclusions reached in the paper. To state, however, that 'those findings were those of the author alone', however complimentary that might be intended, indicated that he had been more attentive to the sales than to the performance of railway motive power in the United States during the past few years. That again was to be expected from his position.

Three times in his discussion he had invoked all the United States railroad presidents to support his opinions against those expressed in the paper. A poll of opinion could hardly be accepted as conclusive evidence. If he actually could show from his own or from any other investigations, evidence to refute that offered in the paper, it would seem more factual than to 'call upon all the gods at once' to blast that base traducer of the good name of the American diesel.

Possibly he felt that the gods were on his side in that matter. About three years earlier the diesel manufacturing company he represented, in a series of front-cover advertisements on the leading American railway weekly magazine, had honoured in turn many of the prominent railway presidents. Their portraits were presented in colour over the trade mark of the manufacturer, with the caption, 'Men who have built the future of the American Railroads' (obviously, no doubt, by purchasing diesels from the sponsor).

Few railroad presidents in the United States had achieved that position of responsibility because they were motive power experts. For a large railway supplier to couple their names in that manner with its product might have been dramatic sales promotion, but it could be considered to be pointing in too many directions in these days when the sale ethics of so many large American business enterprises were under fire. He would simply point out to Mr McClean that that action of his company had possibly placed those busy officials in a position where to call upon them for testimony in that matter, either pro or con, might be somewhat embarrassing to them.

Mr McClean had then made a serious charge, which he himself could not accept and must counter:

> 'If the author's presentation was correct' (and the author will continue to endeavour to show that it is) ... 'then the fine managements of those many railroads (and of the locomotive builders) were, without exception, *by implication* incompetent to a point which would constitute negligence, and that all those railroads had, *by the author's paper*, been deliberately misled in their policy of

dieselization by the erroneous claims of the locomotive manufacturing industry.'

He wished it to be clearly understood: that the association of all those ideas in that statement was made by Mr McClean. He himself had made no *implications* of any kind in the paper. He had been extremely careful *not* to couple any 'claims found to be erroneous' with any 'locomotive manufacturing industry'. No statements of any kind had been attributed to any individual or group, unless it was clearly on the record.

Mr McClean apparently had read into the paper in too many places, ideas that he had *not* said, written, thought, or 'implied'. Every statement had been given careful thought, because the paper was contrary to a number of prevailing opinions. Further on in his discussion under the heading '*Traffic*', he had again made similar charges, associating with the word 'campaign', his own words 'improper sales promotion' and 'claims justifying the purchase of diesels were inaccurately presented'.

Since Mr McClean had introduced all those pointed statements to the attention of the readers, he believed that they should be correctly informed *from the record* (part of which had been published only recently) as to just what the 'locomotive manufacturing industry' did tell the railway industry about dieselization in those early days. It now became a vital part of his reply to Mr McClean's entire discussion, and threw entirely new light on the subject of the paper. It placed him on much firmer ground, and Mr McClean very much on the defensive.

He had already shown in his reply to Lt-Col. Fell's remarks, exactly what the Vice-President of the Baldwin Locomotive Works, speaking 'on behalf of the three recognized locomotive builders in this country', had told the railway industry in 1935. The performance records, as shown in the paper, seemed to show that the ideas expressed by Mr Binkerd at that time were not only sound, but prophetic.

At that same meeting in 1935 he had also made the additional statement:

> 'Therefore, the field of probable profitable application of the Diesel locomotive is pretty generally indicated at work speeds not exceeding 10 miles an hour.'

That forecast to the railways was also confirmed by the statistical record which the paper presented.

In those statements the managements of the (then) leading locomotive manufacturers, who, with the collaboration of the leading electrical manufacturers, had been making diesel locomotives for yard service since 1925, electric locomotives since 1905 and steam locomotives since the earliest days of their production in the United States, gave the railways their best advice concerning the *economies* to be expected from the diesel, in comparison with steam power. Why should they have tried to expand the sales of a product they honestly believed would not be as economic as steam? Its first costs and its maintenance costs would be much higher. No one could say that the railways were 'deliberately misled' by 'erroneous claims' made by any one of the steam locomotive manufacturers. The fact that some of them were no longer in the locomotive manufacturing business in no way invalidated the advice given. It had been confirmed as sound advice by the subsequent performance.

Quite recently, and quite timely for the present discussion, he had received a booklet* sent out to all the shareholders of the automotive and diesel manufacturing corporation with which Mr McClean was associated. In that, there was a short chapter entitled 'Steam *versus* Diesel', which was so germane to the discussion that he wished to quote two consecutive paragraphs from it verbatim. They showed the sales approach of that manufacturer, *by its own acknowledgement*, with the railways relative to its sales promotion of diesels:

> 'Looking back after the many years Diesel locomotives have been in service, the advantages of Diesel power as compared to steam power, for locomotives, are obvious. The record speaks for itself. But in the early years of the Diesel locomotive industry, it was necessary to dramatize these advantages even to prospective customers who were not steam-engine minded.
>
> 'Among other sales tools, a method of selling was developed, and is in use today, called an economic study. Based on the performance record of Diesel electric locomotives of all types that were in service, it was possible to project the economies and return on investment of replacing all steam power with Diesel electric equipment. These studies became the standard method of selling in 1946, because a return on the investment of upwards of thirty per cent per year could be shown in comparison with steam operations.'

There was disclosed for the first time to himself, and he now shared it with the reader, the source of the claim, made all those years, for the 'thirty per cent per year return on investment'. It really *was* made by that manufacturer in 1946 to *dramatize* the product they wanted to sell. To call an economic study a 'sales tool' developed in 1945 to promote the sales of diesel locomotives, was akin to saying the mariner's compass was developed by the Cunard Line to promote trans-Atlantic travel.

It should be noted that the 'thirty per cent savings per year' in no case had been the *actual* savings made by the diesels installed, but in every case were the *estimated* savings which could be made, if *all* the railways were dieselized. That was *estimated* to be $550,000,000 in 1946 in the booklet referred to above.

It should also be noted in his reply to Mr Cantlie relative to the number of diesels in service, that about 58 per cent of the diesels were in yard service in 1945 (on which year any *estimate* of diesel performance would have had to be based in 1946). No doubt those had made notable savings.

Also should be noted, from Figs. 31 and 32, the quite small percentage of total diesel operation which must be 'magnified' to become the total, in 1945–46.

It was curious to note also that in 1957, with but 69 per

* G.M. Corporation 1961, p. 8, 'The Electro Motive Story'.

cent of the motive power, and the corresponding reduction in train performance, those *estimated* savings over steam operation had grown to $1,000,000,000 (Mr McGee now stated that in 1959 they were $1·5 billion).

There was no longer any wonder in his own mind why, in his search through all the statistical records of actual operating performance, he could find no substantiation of those 'dramatized' *estimates*.

No railway electrical engineer, with any knowledge at all of economics, would ever suggest that *all* the railways of the United States be electrified. That would be nonsense. Neither should have any locomotive manufacturer ever suggested that *all* the railways be dieselized, except for their own profit motives. There were many places in the United States where it would have been far more economic to electrify. There were many places where diesel operation was without doubt the proper and economic method to use, just as in every other country in the world. There was a proper and economic place for steam operation, as demonstrated by a number of railways, until steam could no longer be obtained or maintained. The place for each type could still be found by economic studies that were *not* dramatized sales tools.

Not content with the elimination of steam, one diesel manufacturer had continued its dramatic 'sales-tool' studies of existing electric operation in comparison with substitute diesel operation, with the script written in red ink for the electric, and in what appeared to be letters of glittering gold for the diesel.

The Interstate Commerce Commission, reporting recently on the wretched state of affairs of one railroad, which had received and *acted* on such a dramatized 'sales-tool' study, described it quite aptly as 'a mirage'.

Locomotive repair costs

Under that subject, Mr McClean had presented Fig. 28 as evidence that repair costs shown in the paper were not typical.

Those had the appearance of 'cumulative' repair costs. That was a method of keeping repair costs, devised by the manufacturer, to disguise the true rise. Cumulative costs had one-half the actual rate of rise with age.

He had then stated that those 'would be equally misleading' (as those shown in Fig. 21), 'since the values were most likely well below the average for most railroads'. (As indeed they were.) Why then should such figures be presented as evidence? Why not show just what the 'typical costs' were, if he had them. The costs shown in Fig. 28 were as far below graph A in Fig. 21, as the graphs B, F, G, and H were above graph A. Graph A was calculated for a 15-year life (used in the comparison with steam power). The slope of graphs B, F, G, and H indicated economic lives of from 12 to 14 years, and were confirmed by retirements shown in Fig. 30.

He had then cited a statement from a railway president to the effect that diesel repair costs on his road 'levelled off'. That was even contrary to Fig. 28. It was of interest to note that on that president's railway, 87 diesel units had been retired up to the end of 1959. That was exactly the number in service on that railway at the end of 1946, 13 years before, thus again confirming Fig. 30 which, *per se*, confirmed Fig. 21.

One interesting point was noted in Fig. 28: the graph for the latest unit (or group) starting in 1950–51 had a steeper rate of rise than the graph for the earliest unit (or group) starting in 1945. That was to be expected, if the engine had been given a higher rating. The materials would be working harder, and the repair costs would rise at a greater rate. Since all costs in any one year were comparable, adjustments for price levels would have no effect on that relationship. That was poor evidence of lower repair costs due to 'product improvement'.

Fuel costs

To Mr McClean Fig. 22 was 'unfortunate' and misleading because it presented fuel costs on a B.t.u. basis so that they might be equitably compared. That figure was simple and factual and would mislead no intelligent person when considered with the text it was designed to illustrate.

He had referred to the actual fuel cost in 1957 of $367,000,000, as being 'suggested' in the text. That cost was shown in Table 1*a*. He thought that the method of calculation, shown fully in the text, of $408,000,000 for equivalent coal 'might be questioned as unfavourable to diesel', but he had failed to submit any evidence to support his statement, or even to outline his ideas of a method more favourable to the diesel.

Depreciation and obsolescence

No one, in the period 1942–50, had any reason to question the 20-year life that had been agreed upon jointly by representatives of the railways and the manufacturers with the I.C.C., for accounting purposes. The line-haul units in service at that time were too new. By 1953 there were a few scattering indications that some might have a shorter life, possibly 15 years. As late as 1954 he had used the 20-year life in a technical paper*.

He agreed with Mr McClean that 'there was ample evidence to indicate that the locomotive . . . was going to be a satisfactory piece of operating equipment *at that time*'. There was no 'implication' in the paper otherwise.

Mr McClean had then attributed to him statements not made in the paper: (The author) . . . 'was critical because the manufacturers, by an active programme of continuous product improvement, with the encouragement of the railways, had made it possible to establish economic justification for replacement or remanufacture of the locomotive before it had reached its 20-year life.' By that phraseology he was stating that the railways had figuratively said to the manufacturer(s), 'we know our locomotives are only 12 years old, and we can use them just as they are for another 8 years, but we know they are obsolete from what you have

* BROWN, H. F. and KIMBALL, R. L. 1954 *Amer. Inst. elect. Engrs*, Paper No. 54-29, 'A Reappraisal of the Economics of Railway Electrification: How, When, and Where Can it Compete with the Diesel-Electric Locomotive'.

told us. Please take them back and rebuild them to be like the two you sold us this year. They are bigger, and we will only have to use three instead of four.'

If Mr McClean, or his company, believed *any* railroad in the United States was in a financial position to do that with their motive power, unless it had become inoperable or too expensive to continue to repair, they had become self-deluded by their own philosophy. Railway traffic had declined, and was continuing to decline. On most railroads three old units could do the work of four formerly required, in general, if they were at all operable and could still be maintained.

That 'continuous product improvement' mentioned was simply the continuous effort of the manufacturer to improve a design of engine, possibly obsolete, in order to produce a part of greater capacity per unit that the railways had been continuously requiring. It was also highly significant and unfortunate that most of that 'product improvement' was not made until the railways were more or less completely dieselized, after 1953.

The fact was still clear, that diesel motive power had not been retired or 'rebuilt' (i.e. replaced) until it had become badly worn out and incapable of further use. The diesel locomotives as presently manufactured in the United States, simply and factually, did not have a long life.

The railway industry, in spite of Mr McClean's fantastic statement about long life involving 'technical stagnation' was still entitled to the long life equipment it formerly had, in *any* type—steam, electric, or diesel—and must have it if it expected to survive under present-day competition.

'Technical stagnation a great demerit of electrification'! That statement would surely raise the eyebrows of every railway electrical engineer in every country in Europe, if not all over the world! Mr McClean was viewing technical progress through the wrong end of the opera glasses supplied with every one of his 'dramatized sales tools'. Possibly one of the best examples of 'technical stagnation' was the diesel locomotive as manufactured in the United States today.

Why otherwise would two of the progressive railways in the United States be importing from Europe a number of 4000-h.p. diesel units having hydraulic drive? Why otherwise would one American manufacturer have recently developed a high horsepower unit with every detail newly designed toward reduced maintenance? (The fact that that manufacturer had been unable to sell any was another part of the story.)

Traffic

If Mr McClean were an experienced railway man instead of a diesel sales executive, he would recognize that Fig. 1 (which he thought misleading) was a fair representation of traffic on the American railways in so far as its relation to the subject of the paper was concerned; which was *not railroad revenue*, but diesel motive power economics.

Traffic must be hauled, as offered or as scheduled, regardless of type of service. Revenue had little bearing on type of railway motive power. Passenger traffic must be provided with motive power the same as freight, in accordance with the train milage to be performed. Train-miles were the units for which the motive power operating officers must provide. In fact, diesel motive power was used in passenger service for several years before it was used in freight service. Mr McClean had possibly forgotten that.

The most casual glance at Fig. 7 would show that for the past 30 years, in spite of losses to the automotive traffic on the highways, the American railways had continued to operate considerable passenger train milage. As late as 1957, it was 60 per cent of the freight train milage. That had required its fair share of diesel motive power. With that in mind, Fig. 1 would mislead no one who understood railway operations in the United States.

His introduction of 'sales promotion of diesel locomotives' at that point had already received sufficient commentary. The relationship of that subject to *traffic* seemed to be significant to Mr McClean.

Next, for some reason not made clear, he had stated,

'For the benefit of the uninformed, perhaps it would have been desirable that the author should have made it plain that the reference to the automotive industry should not be taken to imply that automotive manufacturing facilities were converted to locomotive manufacture.'

Again nothing was stated or implied concerning that in the paper, nor did he himself see any bearing it had on diesel economics. However, since Mr McClean had introduced the subject, he wished to quote another statement made by Dr Th. Thelander, on p. 29 of his paper already referred to under his reply to Mr Warder. That had a pertinent bearing on the entire discussion and on the subject:

'It should be observed that the extensive use of diesel-electric traction in the United States is in a not inconsiderable degree to be attributed to the topography of that country. In the inland, the trains perform daylong runs extending over broad tracts of flat, open country, which are practically free from difficult upgrades. In the mountainous regions of the East and the West, on the other hand, the character of railway traffic is different. In these regions, the railway men make a virtue of necessity. They utilize the ability of diesel-electric locomotives to develop a great draw-bar pull at a low speed as the trains are slowly hauled up the steep grades. This causes great losses of time, but they are of little importance since they are largely made up for on the wide-stretching plains.

'In spite of the circumstance that the train schedules are thus adapted to the topography, the unproductive locomotive weight in the United States often amounts to such a substantial part of the total train weight that the economic aspect of American diesel-electric traction appears to be debatable. Contrary to what one is sometimes led to believe, this statement holds true regardless of the structure of the train service, which is characterized by a large proportion of very heavy trains in the United

States. In fact, the draw-bar pull required at the draw-bar of the locomotive per ton of weight of cars remains unchanged irrespective of whether the trains are heavy or light, and is dependent only on the speed and on the lay of the land. Therefore, it seems as if the widespread use of diesel-electric traction in the United States were determined by financial factors rather than by engineering and economic considerations.

'If we take this broader view of American diesel-electric traction, then we discover several noteworthy circumstances. We find that very large industrial resources which had been tied up in the manufacture of diesel-electric generating sets for submarines during the Second World War were turned to account by using such sets in railway traction. Furthermore, we realize that diesel-electric traction has enabled the railways to make full use of the production and the distribution of fuel oil, which are well developed in the United States. Moreover, it is possible that some commercial banks which are interested both in railways and in industries tend to favour diesel-electric traction as a business link which induces the former to become important customers of the latter. Finally, it may be presumed that those engaged in high finance prefer to keep their capital in the form of liquid or floating assets, which are readily available for speculation, rather than convert a large part of the capital into permanent or fixed assets. The whole constitutes an intricate and peculiar pattern, which might deserve a detailed analysis.'

That was a most concise and accurate summarization of diesel-electric traction on the railways of the United States. It was as accurate today as when written in 1956.

He had already outlined, at the outset of the closing remarks and in his reply to the discussion of Lt-Col. Fell, just where and by whom the original development of the diesel-electric locomotive in the United States was started; Mr McClean's remarks to the contrary notwithstanding.

Assumed steam locomotive costs

His assumption of $45 per h.p. and the average size of assumed equivalent steam locomotives, had already been discussed in his reply to Mr Cock, Mr Lambe, and Sir Ralf Emerson and as shown in Table 6. The average horsepower of steam units was shown to be 3650 and not 5000. Mr McClean had asked him to 'indicate the weight, wheel arrangement, boiler and grate area of a typical locomotive of the class that he had in mind'. There would be about as many types as there were at present of diesels. If Mr McClean would avail himself of a copy of 'Steam's Finest Hour'*, he would find all those details of the several types of steam locomotives that doubtless would have been continued.

No single diesel unit now operating in the United States would ever be able to equal the life and performance during its life of a classic steam locomotive built by Alco for Timken in 1930, originally called 'The Four Aces'. Purchased, shortly after being demonstrated on all the major railways of the country, by the Northern Pacific and renumbered 2626, it was finally retired and scrapped in 1957 after 27 years of service in which it was operated 2 225 000 miles—an average annual milage of 84 000.

In so far as regular day-to-day performance of motive power was concerned, diesels could be just as erratic as steam, even after skilled technicians took over, as Mr Fuller had already pointed out. To inject just a bit of humour, he understood that in England during the past winter, owing to a diesel failure on one important train (which could happen to most any type of motive power), an old popular song was reworded, '*Pop Goes the Diesel*!'

Large horsepower single locomotive units

The paper was misquoted by the omission of the final clause—'delivered to the rim of the driving wheels'. If Mr McClean wished to presume that the wording of the paper 'have not been able to build' signified *that they do not know how to build*, it was his and not the author's presumption. If the American manufacturer(s) really did know how to build more horsepower into a single unit, to meet the demand for such, *which had existed from the start of their use*, they had limited that ability to the statement which had appeared unvaried, except for model number, in their advertising for the past five years: 'Added capacity enables three VP-60's to replace four older units!' Meanwhile the traffic on the railways was declining so that three of the older units, had their useful life been longer, could have handled the traffic anyway.

The fact that one manufacturer did make larger capacity diesel units was connected by Mr McClean to the fact that he was no longer in the United States railroad locomotive business. That seemed to have a sinister portent, when considered with his prior statement that 'most of those manufacturers had held the belief that the retention of the multiple unit concept of smaller units was a better *policy for both operator and manufacturer*'. That had a familiar ring to many Americans—'What's good for the (Automotive Industry) is good for the Country!'

A final bit of evidence of what the railroads desired in motive power capacity was shown by the approaching acquisition of the European-made 4000-h.p. units with hydraulic drive (to which reference had been made). In connection with that, a statement was recently made to him by a well-informed railway motive power expert of long years of experience: 'This is the first time locomotives have been purchased by *the motive power department* of any United States railroad in twenty years'. That would seem to agree with Dr Thelander's opinions expressed at the end of his second paragraph quoted above.

Economic results of dieselization

Nowhere had he stated that dieselization had been a mistake. The first paragraph in the paper under the heading 'Total Railway Operating Expense', made simple statements

* MORGAN, D. P., editor, 1959 'Steam's Finest Hour' (Kalmbach Publishing Co., Milwaukee).

of fact which when intelligently read would mislead no one. Expenses and revenues had gone up as traffic had increased, and had declined as traffic had declined. Expenses had increased at a greater ratio than revenue, so the operating ratio, in general since the war, was higher than before the war. It would be nonsensical to relate an increase in revenue, so obviously related to traffic, to a change in type of motive power. But if there had been any relationship in that direction and since expenses had continued to rise in a greater ratio, then that bearing of motive power on the operating ratio would be unfavourable. It was definitely stated, however, that the change in type of motive power had had little bearing on either of those items. Indeed the final study made as a check, and shown in Table 4, confirmed that statement. There was very little difference between the actual cost with diesel and the calculated cost with steam in the overall picture with yard service and line service combined—both of which were in the operating ratio.

The present study had been based on the performance of motive power on *all* the class I railways of the United States *as a whole*. The statistics of *no one specific railway* had been selected and applied as representing the whole.

There was no question in his own mind that the diesel had been highly successful and economic on a number of railways. By the same token it had been unsuccessful and uneconomically applied on others, since the *average*, for all the railroads, by the study, had been about an even break. Why should any railway president be called upon to endorse or reject any opinions on that subject? Dieselization was not only a *fait accompli*, but there was no other type of motive power he could buy, unless he looked overseas.

Britain had more than a dozen locomotive manufacturers, most of which would make any type called for. She was fortunate in having so many to choose from for her railway motive power needs. Among all the pros and cons of Government operation there was a definite advantage to the Nation's economy in having a solid national organization of trained engineers and specialists in every branch of railway operation, engineering and motive power, who neither presented nor accepted an economic study as a 'sales-tool'.

Mr McClean had cited the 'action of the Norfolk and Western Railway as the best refutation of his (the author's) statements'. That was quite agreeable to him, who had been a small shareholder in that well-managed railway for many years, and was quite familiar with its operations. It was one of the few financially sound railways in the United States because its principal traffic, coal, could not be diverted to automotive vehicles on the highways. The experience of that railway with its motive power, steam, electric and diesel, was an excellent epitome of the whole subject under discussion.

For years that railway had built its own steam motive power which was outstanding in its performance. But there was a short, difficult section of single-track line, having a 2·2 per cent grade against their prevailing heavy traffic in the mountains. That was further complicated by a long tunnel, creating a serious 'bottleneck' on their otherwise two-track line. Electric operation of that section was installed in 1914 for helper service of the through traffic. Also for complete electric operation of the heavy coal trains from the various gathering yards over the summit of the grade to the main departure yard. From thence heavy steam power could take the trains down grade to the seaport terminal. That electrification was paid for out of earnings; created no additional debt; satisfactorily solved the operating problems; and was just another part of smooth, economic railway operation.

Like all railway electrification installed in the United States in those early days, it had been necessary to install its own power plant for its operation. Railway loads were far too heavy to be assumed by the small isolated industrial and lighting plants then existing. By 1950, after 35 years of exceptionally severe operation, including the 1941–45 war traffic requirements, the power plant and the electric motive power had reached the end of their economic life. Both required replacement.

The diesel manufacturers were immediately on their doorstep, dramatic sales-tools in hand, to convert them to the 'modern way' of operating their railway. Their motive power officials, being excellent steam locomotive manufacturers as well as operators and maintainers, had been quietly collecting the facts concerning diesel operation from their associates on the connecting lines—of which there were many. They compared the 'dramatized version' with the facts collected and saw further that their own steam costs were below either version of diesel costs.

That railway being principally engaged in coal haulage, and having excellent steam locomotives, had elected to retain their steam operation. They spent a considerable sum out of earnings to construct an entirely new double-track line over a new route through the mountains. That had much more favourable grades and a larger, shorter, double-track tunnel, all of which replaced the former single-track section that had required the electric operation. They had then returned to complete through operation with steam at speeds that were higher than the fixed-speed induction-motor type of electric locomotives had been capable of performing. All that was accomplished with no increase in debt and at about the same cost as new electric motive power and power supply.

In 1955 there was a sharp increase in the coal export business to Europe. Additional motive power was required —and soon. Their steam motive power had increased in age and was becoming more expensive to maintain. More especially since all other steam locomotive manufacturing had ceased, even the various small replacement details, formerly easily obtained from suppliers, were no longer available. The Norfolk and Western Railway had *no decision to make* by comparing motive power costs. *They had no choice.* They could no longer build, maintain or purchase steam. They had no time to study and develop the new commercial frequency electrification for 60-cycle operation which would be required. They purchased diesels from the two manufacturing companies and it cost them approximately \$86,000,000. That was more than they wished to divert from the unappropriated earned surplus. So, like all the other railways, these were purchased by means of 'equipment trust certificates'.

He had a copy of the speech made by the President of that railway, referred to by Mr McClean, relative to dieselization. Of course he had to explain the expenditure of that large sum in the best light to the shareholders. He could not be criticized by anyone for what he had to do, nor were his statements incorrect. New diesels had saved materially in maintenance costs, compared with the much older steam power now retired. Also, diesel oil was much cheaper at the present time than the very high grade, high B.t.u. content Pocahontas coal, formerly used. The N. & W. was enjoying the palmy days of initial diesel operation, as other railways were doing in 1950–53.

But all costs do not appear in operating costs or operating ratios. And that was the part censored in all the 'dramatized versions'. The N. & W., which for years had been free from debt except for a very small mortgage bond issue, largely covered by a sinking fund accumulation, was now *for the first time in its history*, burdened with a large debt represented by equipment obligations. It was paying off that debt at the rate of $5,662,000 per year on the principal, plus annual interest charges of $1,700,000, a total of $7,362,000. (Those sums were all taken from the 1960 record before its merger with the Virginian.)

The main point to note was that by the time that debt was paid, the equipment would be worn out and that, or a larger debt, would have to be renewed for replacement motive power. There was no denying that the financial burden on that railway had been increased by more than $7,000,000 annually, because of its *necessity* of adopting diesel motive power. That financial burden must be carried until a type of motive power having a much longer life took its place. The fact that that particular railway could, at the present time, assume that debt without too much drain on earnings had no bearing on the thesis.

The statement made in the paper that 'diesel motive power has added to the financial burden of the railways' was not disproved by the evidence of the N. & W., submitted by Mr McClean.

He submitted that Mr McClean had not produced *any* evidence at all to show that any statements in the paper were 'highly misleading'.

Mr McGee thought that he had made some serious omission 'of important operating and cost indices' and had substituted unsupported personal opinions 'largely refuted by available data and the substantial operating railroad records'. He also, for some reason, thought that he had used 'a mysterious hypothetical steam locomotive for a comparative cost study with diesel power', and was 'mildly unconvinced'.

For the benefit of the reader, it should be stated that Mr McGee was a valued friend of his, regardless of opinions, and had been almost from the start of their respective careers. Their occupational paths had diverged in or about 1937 when Mr McGee had became associated with the automotive-diesel manufacturing industry.

Mr McGee had submitted, to correct the errors and omissions in the paper, Table 5, which really was a valuable addition to the whole subject. There was displayed, for the reader's benefit, the manufacturers' concept of an economic study, dramatized as it should be as a sales-tool. That would be discussed item by item, so that the reader might decide for himself the comparative value of the evidence presented by himself and by Mr McGee's Table 5 and his analysis.

Table 5 started with the year 1941 and gave values for every fifth year thereafter, including 1959. He himself had started originally with the year 1940 but had soon found that it was essential to obtain a longer 'backsight' because other factors besides the mere change in type of motive power were involved. He had not the advantage of 1959 figures in the paper, for it was completed in that year and he could not give firm figures much later than 1957. The tables and figures in the paper were self-explanatory as to the period reviewed.

Item 1. Freight gross ton-miles

He had indeed omitted to show that item—the pattern was so nearly identical with the revenue ton-miles shown in Fig. 1*b*, it was considered unnecessary. It was shown graphically, however, in the discussion in Fig. 34.

There was no mention whatever in Table 5 of passenger train operating statistics. Evidently Mr McGee and Mr McClean were in agreement that the costs of that service were unimportant because the revenues were so small. He, in spite of his former connection with a large passenger-carrying railroad (as Mr McClean had pointed out), thought from his study that the related statistics and costs of diesel motive power in that service should also be included. The passenger ton-miles were therefore included in Fig. 34.

Item 2. Freight gross ton-miles per train-hour

That, according to Mr McGee, and to many railroad statisticians, was held to be 'the most significant of operating indices of freight movement'. He himself had also been impressed by that 'statistical average' until he 'broke it down' as shown in Fig. 31, to show whether the rise was due to any particular type of motive power or to some other cause. Particular attention was directed to the group of graphs in Fig. 31 enclosed in the bracket labelled 'gross ton-miles per train-hour'. The statistics shown in Table 5 could be located on the graph composed of the fine dots marked AVG. The rise in that graph was the 'tempo of freight movement' that Mr McGee and the statisticians extolled. What had caused that rise, the change to diesel motive power? If so, why should graph S, for steam, rise; or graph E, for electric, rise? And why should both rise with the drop in train-miles? The performance of the diesels, graph D, were much lower in 1958 than in the period 1945–50, and even slightly below the AVG. line. Electric had outperformed the diesel since 1951 and even steam had outperformed the diesel after 1957.

He submitted that all that rendered item 2 valueless for the use Mr McGee intended to make of it in item 5. The

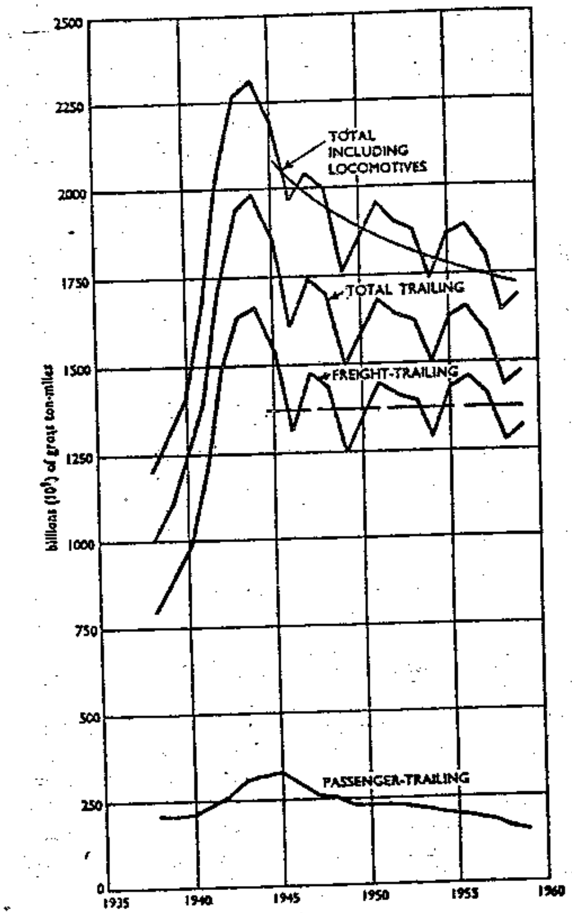


Fig. 34. Gross ton-miles, all class I railways
Source: I.C.C. statistics.

importance of the rise in that 'statistical average', shown along the line AVG. which had been held for a number of years to be due to the change in type of motive power, and which had been given a leading role in the 'dramatized version', had been 'miscast' to say the least. Change in type of motive power had had no important effect.

His analysis of that group of statistical graphs, which was also applicable to the two other groups of graphs in Fig. 31, was:

As diesels were acquired for freight service, soon after 1949, they lost their position in special or preferred service and began to assume more of the everyday work of steam motive power. Gross ton-miles per train-hour dropped because many of those trains were lighter and many were slower. Meanwhile the character of freight traffic was slowly changing. Branch-line traffic slowly disappeared. Local short-haul traffic on the main lines also slowly declined, both being taken over by the automotive traffic on the highways. Those slower steam trains with lighter tonnage slowly dropped out of the aggregate ton-miles and train-hours, and steam gross ton-miles per train-hour rose. The older, lighter steam motive power was retired leaving only the newer, heavier steam power. As the shorter trains disappeared more diesel power was released, or acquired, to equal the capacity of the heavier steam power then growing old. So that beginning about 1955, the diesel unit-miles, per locomotive-mile and per train-mile, began to rise as indicated by the two short graphs in Fig. 31. Then the gross ton-miles per train-hour again began to show in the diesel performance. Finally, by 1957 only the heaviest steam power and the electric power was left undieselized because the diesel could not equal their performance while they remained in service. Much of that steam power was, without doubt, that remaining on the Norfolk & Western.

That analysis was offered as evidence because it seemed to fit all the facts. It was probably embarrassing to Mr McGee because it invalidated the use of items 2 and 5 as he intended. And, as would be shown, some of the other items would be affected if that analysis was sound. It rendered the 'index improvement of nearly 90 per cent' somewhat without value in so far as being related to motive power.

Items 3 and 4. Percentage operated by steam and percentage operated by diesels

That was given in Table 5 in gross ton-miles. He had shown similar percentages graphically in Figs. 31 and 32, expressed in train-miles. There was very little difference between the two units used, as might be seen from plotting the values given in Table 5 on Fig. 31.

Item 5. Operating expenses, in millions of dollars

That was shown more completely in Tables 1a and 2a; also graphically in Fig. 10. If, as Mr McGee claimed, the rise after 1945 was controlled at all by item 2, it certainly *was not due to any change in type of motive power*, as Fig. 31 would show. The major factor involved in rise or fall in total operating expense was traffic. That was one thing that all railroad presidents did know—if traffic volume was good, operating expenses must be increased to handle it. If it was poor, expenses must be cut.

The effect of each item of motive power expense on total operating expense was shown in the ratio costs in Tables 1b and 2b. The effect of fuel cost (item 13) was given in those tables and shown graphicallly in Figs. 12*a* and 13*b*.

Item 6. Taxes

That was of general interest but had no real bearing on the subject of the paper.

Items 7 and 8. Average compensation per employee, and its index on basis of 1941 as unity

Those items were also of interest, but not too relevant to his presentation where *index costs had been purposely avoided to prevent distortion*. All labour cost involved in motive power expense had been included for each year since 1940 in such items as repair costs, wages of engine crew, and engine house expenses, in Tables 1a and b and 2a and 2b.

They were also a part of items 15 and 16 in Table 5. Items 7 and 8 could not be used at all with item 2 as Mr McGee had suggested, unless certain parity factors, almost impossible to calculate, be applied. For example, how would Mr McGee apply item 7 to AVG. G.T.M. per train-hour shown in Fig. 31, say, for the year 1951? And if an 'influence factor' of item 7 could be found for 1951, would he say that by dividing by two he would get that same 'influence factor' for 1941, or by multiplying by 1·5 he would get that same factor for 1959? (That was apparently the operational use of item 8.)

He did not believe items 7 and 8 had any bearing on, or could be applied to, item 2 in Table 5.

Another point unexplained was the use of the year 1941 as the unity index base year for labour costs in item 8 and material costs in item 9.

Items 9 and 10. Ratio of cost of rail, cars, signal equipment and basic cost per h.p. Typical 130-ton diesel railroad unit

Both items 9 and 10 were also of general interest but not too relevant to the subject of the paper except as material costs affected repair costs, which were all included in Tables 1 and 2, a and b.

Examination of the average ratio cost of materials selected, as shown in item 9, seemed to indicate that materials *had* increased about on the same ratio as labour, in spite of Mr McGee's statement that materials had risen less.

Mr McGee had erred in citing costs of $94 per h.p. for typical 130-ton diesel units in 1959. That cost, according to the 1959 I.C.C. Annual Statistics (p. 29, Table 37), was for a rebuilt unit. On p. 27 of the same volume, in Table 37, 'New Units', there was an entry of 279 multiple-purpose units, type B–B, 1750 h.p. Avg. wgt. per unit of 131 tons, Avg. cost per unit, $196,078. That gave a cost per h.p. of $112. The corrected cost, applied in Table 5, item 10, indicated that diesels, like everything else, had been increasing in cost.

Item 11. Fuel unit costs

That information was shown in a different way in the paper in Fig. 22. It would be discussed further under item 12.

Item 12. Fuel and power total, road and yard

The total costs of fuel consumed had been shown in Tables 1 and 2. He agreed that for that discussion the amount of each type of fuel consumed was important and submitted Fig. 35 to show in graphical form the total fuel used on the class I railways from 1939–59. Mr McGee called world-wide attention to the fact that diesel oil consumption in 1956–59 with close to 100 per cent diesel operation was less than the fuel oil consumption used in 1946 for only 18·5 per cent of the total freight movement and, therefore, enormous sums, which he roundly estimated at one-half billion dollars, had been saved. Even Fig. 35 would seem to indicate that the entire amount of coal had been saved.

Once more, *parity* of performance must be observed,

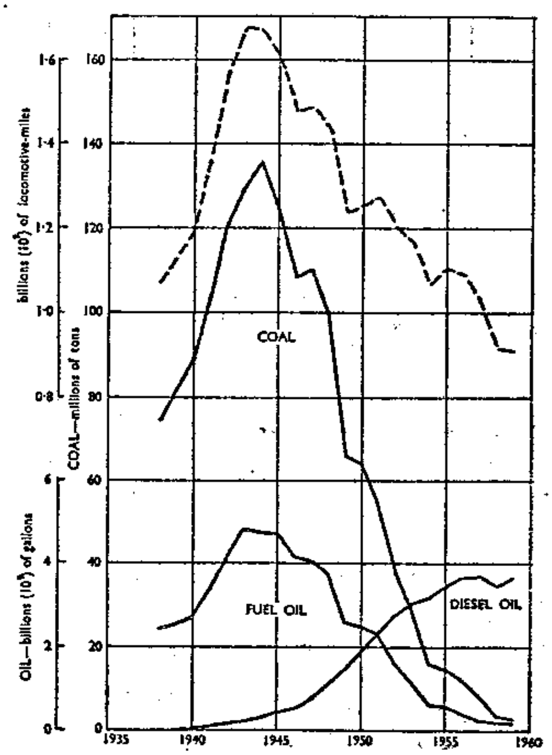


Fig. 35. Fuel consumed on all class I railways and its performance

Source: I.C.C. Annual Statistics.

– – – – Performance: total locomotive miles, freight, passenger and shunting.

before such savings could be claimed. He or the reader might say that since the total freight gross ton-miles shown in item 1 and in Fig. 34 seemed to be about the same over the ten-year period, approximate parity of performance had been observed. When the total tonnage moved was considered with passenger trains and locomotives themselves included, Fig. 34 showed a drop of at least 10 per cent over that period. That was not all. The tonnage shown in Fig. 34 for passenger trains could not be compared with the tonnage for freight movements, in considering fuel consumption. Because of being higher speed, the fuel consumption per ton-mile would be much greater. Immediately, 'gross ton-miles' became a poor yardstick for measuring fuel consumption. (It became more obvious why neither Mr McClean nor Mr McGee liked to include passenger service.) Train-miles or even locomotive-miles might be a better measure, *provided* the character of train-miles had remained the same over the years. But even that had been changing, as might be seen from Figs. 8, 31, and 32; and he still held that very little in the change in character of the trains from year to year had been due to change in *type* of motive power. As stated in the paper, the increase in train weight had demanded increased *capacity* in the motive power and that was all.

It became apparent that parity of performance was affected by too many factors to be blithely converted from one year to another by the simple application of index factors, as had been done, not only by Mr McGee but by all believers in the 'dramatized version'.

In so far as fuel cost savings were concerned, he had arrived at the conclusion that savings could be determined only by taking the actual fuel consumption in any one year and determining as closely as possible the actual work performed by that fuel. On the general assumption that 6 per cent of the B.t.u. content of all the coal and fuel oil consumed in that year represented the work done by the steam locomotives, and that 26 per cent of the B.t.u. content of all the diesel fuel consumed represented comparable work done by the diesel locomotives, and adding those amounts of what might be called 'useful B.t.u.'s' for each year, the diagram shown in Fig. 36 was obtained. That was for line-service motive power only, as yard power would require different thermal efficiency factors. The statistics did not permit going back further than 1921. The similarity of Fig. 36 to Fig. 1, and more especially, Fig. 7 (train-miles) was to be noted.

From Fig. 36 (or from the tabulated figures from which it was plotted) might be calculated *in any one year* the fuel savings made by the substitution of one type of motive power for another type.

For example, in 1959, the fuel used was nearly all diesel fuel. Had the *same line-haul train services* been performed by steam locomotives, the cost of the steam fuel would be calculated thus:

> By construction, Fig. 36 showed 26 per cent of the actual diesel fuel consumed, in B.t.u. Then the actual B.t.u. consumption was 100/26 or 3·84 times that amount, which at the cost per million B.t.u. shown in Fig. 22 for 1959 was *M* dollars. If the fuel consumption shown in Fig. 36 for 1959 had been from coal it would have been, by assumption (and by construction if any coal had been used), 6 per cent of the total amount of coal consumed, which would be 100/6 or 16·7 times that amount of B.t.u. shown for the year. That multiplied by the cost per million B.t.u. for coal shown in Fig. 22 for 1959 would be *C* dollars. Then *C* dollars minus *M* dollars was the saving in fuel cost made by diesel operation in comparison with steam, using coal as a fuel, and *for that year only*. The same method of calculations could be applied for any year, but the calculations made for 1959, or for 1956, or for 1946, could not be multiplied by any cost index, or other factor, to obtain the savings in another year, because *all* the performance parity factors were not known.

That method was used by himself in calculating the fuel savings shown in Table 4 for the year 1957.

The soundness of that reasoning was left with the reader, to decide for himself. Since he believed that reasoning was sound, then item 13 was shown to have little meaning of value, and the second line of item 14 was shown to be completely wrong, both in logic and in values shown.

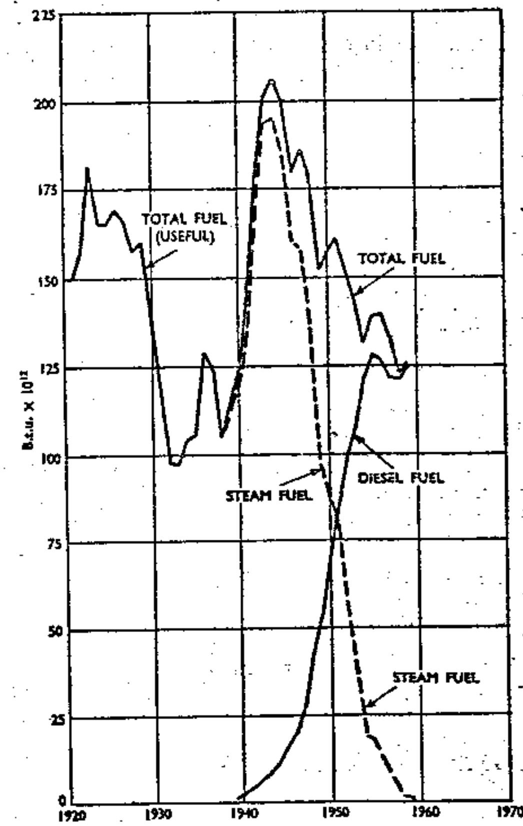


Fig. 36. Calculated useful portion of all fuel consumed in moving all freight and passenger trains on all class I railways

The graph is virtually fuel required independent of motive power type.

Basis of calculation: all fuel consumed taken from I.C.C. annual statistics.

Assumed B.t.u. content: coal, 25 000 000 per net ton; fuel oil, 149 000 per U.S. gal; diesel oil, 138 000 per U.S. gal.

Assumed thermal efficiencies: steam locomotives, 6 per cent; diesel locomotives, 26 per cent of total fuel consumed.

Six per cent of all steam fuel in line-haul service is added to 26 per cent of diesel fuel. All switching fuel excluded.

Item 13

Those 'Statistical Averages', as mentioned above, had little real value because not only was the purchasing value of the dollar changing from year to year, but the fuel cost of producing 'ton-miles' was changing each year, due to entirely different factors, and would not be equally comparable for different types of motive power in any year. That highly 'dramatic' index was so completely meaningless when applied to electric operation that attention must be called to it. The electric power costs from which the '1000 G.T.M. per $1·00 cost' were compiled were from all the railways using electric power for *any* type of traction service, most of which was for commuter passenger service, with poor load factor, with correspondingly high unit costs per kWh. Only three electrified railways were operating any electric freight haulage today—Pennsylvania, 'Milwaukee' and N. & W. (formerly Virginian), all having fairly low electric power costs. Nevertheless, the statisticians included every electrified railway, with the exception of the metropolitan rapid transit lines (and even one of those), in calculating that 'index cost' for hauling freight by electric power. He was in full agreement with those who had mentioned in their discussion the care required in using statistics.

Mr McGee, however, had stated that item 13 confirmed the savings he had shown in items 12 and 14.

Item 14. Total fuel and power cost of all services

Those costs in dollars were shown in Tables 1a and 2a. The second line of that item was fully discussed under item 12.

Item 15. Locomotive maintenance, road and yard

The cost in dollars had been shown in Tables 1a and 2a. The treatment of those costs as 'ratio costs', shown in Tables 1b and 2b, with their comparison to numbers and age as shown in the paper, took more account of parity than was shown in Mr McGee's 'index' comparison. No explanation was given why 1956 had been selected as the 'base' year. That made three base years in Table 5, for making the desired distortion of the dollar costs.

Item 16. Engine house and engine men, road and yard

The dollar costs were all shown separately in Tables 1a and 2a. The application of index costs from one year to another to that item was particularly meaningless. In the example of engine-crew wages, that item should be treated for each year, as fuel costs were. In any one year, the change in type of motive power would have little effect on crew wages. It unfortunately cost as much for engine crews for diesel operation as for steam, except for a small additional amount for helper service, shown in Fig. 8 to be about 5 per cent in 1957 and for which full credit was given in Table 4. Actually, crew wages had increased considerably for diesel operation due to their being based on 'weight on drivers'. That was too difficult to calculate, so it was omitted (as being favourable to diesel) in the paper.

The application of index costs to engine-house expense was also without meaning or value. The number of engine houses had declined principally because of branch-line abandonments. Each line abandoned removed at least one, and often two, engine houses. The number of employees in the remaining houses had possibly declined. The effect of change in type of motive power on engine-house expense had been given more than its proper value in the paper for reasons shown in the calculations.

Relative to savings in maintenance of way and structures expense that Mr McGee estimated to be in excess of $200 million annually: little more could be said than was stated in the paper and the reply to Mr Cantlie.

However, in 1959 with nearly 100 per cent dieselization, the total maintenance expense of roadway, track, tunnels and all supporting structures was approximately $702 million including $120 million for total superintendence. That was 0·0911 of the total railway operating expense. In 1948 with at least 75 per cent of the steam operation still in the picture and with the lingering effects of the heavy war traffic, those costs were approximately $848 million, including $83 million for total superintendence. That was 0·1133 of the total railway operating expense. A drop of $146 million was indicated which was 0·0222 expressed as a ratio cost.

The ratio costs of all expenses charged to 'maintenance of way and structures' had been:

1940	16·08
1945	20·01
1950	18·24
1955	18·15
1959	16·05

In other words, in so far as maintenance of way costs were concerned, they were right back to what they were before the war and before dieselization.

To allocate all of the $146 million difference between the 1959 and the 1948 cost indicated above to the change in type of motive power, was to entirely overlook:

(1) Reduced track milage.
(2) Longer and heavier rails.
(3) The growing milage of welded rail joints.
(4) The improved track maintenance machines and methods.
(5) Fewer trains.
(6) Reduced maintenance on branch lines pending abandonment.

to mention but a few of the factors which had contributed to the drop of 0·0222 in those ratio costs.

Mr McGee could be assured that maintenance of way engineers had been just as busy, if not far busier, than had the diesel manufacturers in improving their contribution to reduced railway operating expenses. Finally, there was no total of $200 million in the entire picture.

In regard to 'large savings with the extensive closing down of the mandatory tunnel, terminal and grade electrifications' Mr McGee had mentioned, if those had been of sufficient magnitude to be outstanding, they had all been included somewhere in the motive power expenses shown. The major costs of those might be found in reduced engine-house expenses. The electric operation abandoned in the United States appeared impressive when listed, but the kilowatt-hours of energy consumed in railway electric traction had declined very little from 1940 to date. Any savings from the abandonment of those various small installations, if they could be isolated, would be microscopic in the total railway operating expense.

He submitted that Mr McGee had presented in Table 5 little important information not shown in the paper, *except* *that* he had taken the reader behind the scenes, had shown how the 'dramatization' had been staged, the backgrounds shifted, and the principal characters spot-lighted. He had greatly enlightened the author himself who had no real concept, when he had started his search for the *facts*, how or where they turned into *fiction*.

The reader having now seen for himself the 'dramatized version' of the Economic Results of Diesel Electric Motive Power on the Railways of the United States of America, and how they had been calculated in Table 5, could continue to accept that version if it appealed to him. There was certainly 'more money in it'. (But who had received it?) He himself had no mission to make converts to his analysis or thinking.

It was always of interest to uncover the origin of folk-lore and mythology, but no one gained popularity by upsetting old beliefs. He could only say, with the crusaders of old, '*Magna est veritas, et praevalebit!*'

Before closing the discussion, he wished to add one or two final thoughts. If his analysis was sound, and he believed it was, otherwise he would not have spent all that effort on the study—he was not implying, nor was it to be inferred, in any way, that those who had made other analyses, or who held other views, had not been just as sincere and convinced that their views and convictions were sound and correct. No one could go out and do missionary work against his own beliefs, nor try to sell a product against his own convictions.

Without question, the diesel was *sold* to the railways of the United States. Those who sold it *believed* in it, and did an excellent sales job of *convincing* the railways that it *was* all that it appeared to be during those early years. They still believed in it, and neither he nor anyone else could convince them they were wrong. That was as it should be, for the diesel had its merits as a fine type of railway motive power and there were many places throughout the world yet awaiting its economic application.

One thing was quite apparent. Sooner or later, the railways of the United States must wake up to the fact that they must do a little thinking for themselves about more economic motive power. The manufacturers had no incentive or *obligation* to do that thinking for them. They were in business to make profits, and they had been far more clever than the railways had been in that effort during the past quarter century. (Actually some of their profits had been at the railways' expense.) For every million ton-miles the railways lost to the automotive traffic on the highways (and that was where most of it had gone and was still going), the automotive industry made possibly fewer diesel locomotives, but a great many more automotive highway vehicles. They could not lose—nor was it really necessary for them to change the *status quo*—unless some of the railways started to wake up and decide they really did require some more economic, longer life, single-units with higher capacity at all speeds, that cost much less to maintain and much less in first cost.

Motive power was not *sold* to the railways in Europe. They studied their needs, specified their desires, and *bought* their motive power. There was a large difference. The same was true in the United States until there was no further demand for steam. The American railways could, if they really wanted to, put themselves back into that position again. And they must, if they wished to continue in business as free enterprises. Possibly a move in that direction had already been started by the acquisition of some foreign-made diesels.

He could not refrain from stating that as a result of the study, he was more than ever convinced that the diesel had been misapplied to a considerable amount of milage of the American railways. It was well known that 50 per cent of the traffic was handled on about 10 per cent of the American railway milage. That required also about 50 per cent of the motive power capacity. That traffic could be handled, just as it was in Europe, far more economically with electric operation. *Fifty per cent of the traffic, handled more economically*, was really something to think about and to look for. But the railroads would not be able to get any American locomotive manufacturer to help them in their search for that. There was no real incentive in that for any such manufacturer, and for some, it could be to their disadvantage. The railways must make that search for themselves, as they had in every country in Europe, and as England was doing today.

If the paper stimulated any serious thinking along those lines at home, it would have served a further, unexpected purpose.

He could not feel otherwise than honoured, and not a little complimented, by the discussion, both pro and con, the paper had elicited. He had felt that the results of the research he had made on the subject over a number of years might be of sufficient interest to others to be made a matter of record. He had no concept when the paper was completed in September 1959, that he would have the honour of presenting it to the Institution, or that it would arouse the interest that had been shown.