RAILWAY-MOTOR-CAR TRAFFIC.

BY MR. T. HURRY RICHES, *Vice-President, OF CARDIFF,*
AND MR. SIDNEY B. HASLAM, *Associate Member, OF CARDIFF.*

In this Paper the authors propose to deal as far as possible with the question of Railway-Motor-Cars, and it must be understood that they are seeking to give facts as to the best means of dealing with local and branch line passenger traffic, as being a commercial question as well as an engineering one. Clearly the best method of conveying passengers is that one which yields the best results in the balance sheet, and at the same time gives satisfaction in other ways. The opinion held by most locomotive engineers, and by a large number of electrical engineers, on the broad and general question of railway electrification, is that for suburban close traffic only is it justifiable. It is suggested and maintained that the electrification of branch and main line traffic will, as a general rule, result in a loss to the railway company, as the load-factor at the power-station will be a very poor one, owing to the intermittent traffic. On the other hand, suburban traffic, especially if in thickly populated areas, calls for a more frequent service and a greater acceleration of speed than is attainable with ordinary passenger trains. It is not only desirable but is quickly becoming a necessity that, if the suburban railway system is to hold its own with

municipal tramway competition, a frequent service with high acceleration must be established in suburban districts. It was to meet this competition that one or two attempts were made to produce self-contained cars on various lines in the early part of the last century. While these cars were more or less a success, the requirements were not then great enough to encourage continuation.

It may not be out of place to mention here that in 1873 or 1874 a Mr. Rowan designed and built self-contained steam-cars, for which he could find no sale in this country. His cars were however taken up to a certain extent abroad, notably in Austria and Switzerland. In 1902, however, the competition of street cars in the suburban districts, especially around London, became more acute, and caused the railway companies to give serious thought to the matter; and railway motors were introduced by the London and South Western Railway Co. as an experiment. This proved so far successful, that the Great Western Railway Co. and the Taff Vale Railway Co. followed by building cars for trial upon their railways to fulfil the requirements of a more frequent service upon sections in certain districts where traffic was light. It was obviously impossible to run such a frequent service with ordinary trains as being too expensive, the running expenses and the capital outlay involved being too great in proportion to the passengers carried. It was then seen that the solution of the difficulty lay in self-contained cars, and the question of what motive power to use then arose; steam or electricity, and if electricity, which of the many methods of application would be employed. Many people doubtless think that electricity is the only panacea for everything, but the problem is, of course, purely one of commercial results. The authors hope later on to prove, by giving comparative figures, that for lines where the service is necessarily light and intermittent, and where the distances to be run are several miles, the power-house would need to be large in proportion to the average work done; and where heavy gradients have to be worked, the peak-load would be large in proportion to the average and minimum, and rapidly fluctuating therefrom. The necessarily large units, which would have to be provided in the generating station to meet

this maximum motor power and high peak-load, would be large, and consequently the capital outlay would be out of proportion to the work done.

The first railway to move in the direction of self-contained car traffic was the London and South Western Railway Co., which placed a steam-car on their line between Fratton and Southsea in 1903. This car, which was equipped with small cylinders and a vertical boiler, was fairly successful, and encouraged the idea that progress in this direction promised a solution of the problem. The next railway company to move was the Great Western Railway Co., who adopted the 4-wheel coupled type, the boiler being vertical and the engine being placed under the car. This car, which had to contend with heavier gradients than the car of the London and South Western Railway Co., was necessarily more powerful.

About the same time, or immediately afterwards, the Taff Vale Railway Co., who had for some time been considering the various possible methods of treating this problem, put their first car on the rails, Fig. 1 (page 654) and Fig. 3, Plate 70. This car, which was different in several important features from those previously mentioned, was deemed so far satisfactory that six more were ordered. Owing to the heavy gradients to be overcome, namely, 1 in 40, it was necessary that more provision should be made for dealing with these heavy gradients than had previously been made in cars. The engine and boiler of this car were made separate from the carriage-body, while the leading wheels of the 4-wheeled bogie, which carried the engine and the leading end of the car, were made the driving wheels. The boiler was of a design shown on drawings, Figs. 5 and 6, Plates 71 and 72, giving a large heating surface (in comparison with the small space occupied by the boiler), and therefore fulfilling that most essential requirement of raising steam rapidly. The engine was of the outside cylinder type, carried beneath the boiler, while a novel feature of the car was the ease with which the body could be detached from the engine. The next railways to deal with the subject were the North Eastern, Great North of Scotland, Great Central, and the Great Northern, and it is proposed to deal with these and other types later.

FIG. 1.—*Steam-Car, Taff Vale Railway, 1904.*

To seat 12 First- and 40 Third-Class Passengers.

Heating Surface, 338·5 sq. ft. Grate area, 8 sq. ft. Water, 550 gallons. Working Pressure, 160 lbs. per sq. inch.

FIG. 2.—*Steam-Car, Taff Vale Railway, 1905.*

To seat 16 First- and 57 Third-Class Passengers.

Heating Surface, 464·84 sq. ft. Grate area, 10 sq. ft. Water, 550 gallons. Working Pressure, 180 lbs. per sq. inch.

(For Details of Boiler, see Plates 71 and 72.)

Before coming to the actual experience of the authors and the reasons which caused the adoption of steam-cars on the Taff Vale Railway, the authors wish to point out that this is not done with any idea of comparison with other systems, but given merely as first-hand information. The Taff Vale Railway Co. have a certain branch, which, owing to the paucity of passengers as a general rule, was not as profitable to work as was desired, and it was to this branch that attention was first drawn for any better and cheaper method of working. To be sure of getting the best results, careful comparisons were taken of the cost, both capital and running, of steam and electricity, the latter of which was subdivided as follows:—

1. Self-contained cars, that is, worked with secondary batteries.
2. Third-rail system.
3. Overhead system; (1) with bonded rail return; (2) with new return rail.
4. With lead and return rails.

With a view to gaining experience in the methods obtaining abroad, one of the authors visited Belgium, France, and Germany, and also collected information from all parts of the world where electricity was being used for railway traction, and the matter was thoroughly gone into. Various makers were asked to tender for the different classes of equipments, and the cost was carefully summarised. It was at once seen that the expenses of sections 2, 3 and 4 were much too costly; the manufacturers and contractors, in fact, preferring not to quote for these, on account of this great initial expense. The cost of a car with dynamo, driven by a petrol-engine with accumulators for working in parallel with the generator when necessary to overcome stiff gradients, was also considered. The outlay for this was however enormous, as the equipment, besides the above, also comprised a milking booster and two 75-H.P. motors, and caused the scheme to be abandoned.

The idea of a car run by current from secondary batteries was however given more consideration, and one of the authors visited Belgium and Swansea, and examined the cars used there, which at that time were run by storage batteries. The gross weight, without

passengers, of each car was 45 tons and 19 tons 7 cwt. respectively, and the seating accommodation was in Belgium 50-60, and at Swansea 42 inside, 57 outside. The capacity of the batteries was 140 ampère-hours, and the normal discharge rate 20 ampères at Swansea and 250 ampère-hours with discharge rate of 125 ampères in Belgium.

The general conclusion arrived at on the subject of battery cars was not favourable, as their first cost, namely, £4000-£5000, was high, and their maintenance was also excessive, while their weight and periods of inactivity when charging (a time equal to their period of activity) were all features which did not compare favourably with steam-cars.

The results of the costs of the other sections are given in Table 1, and the running cost of an ordinary train is also given as a comparison, as well as the actual cost of the self-contained steam-car.

These figures were based on the original design of the Taff Vale Railway Co.'s car to hold 52 passengers, their latest design holding 70. The conclusion drawn from these figures was, that unless the service is very frequent, that is, a train every few minutes, and the maximum distance from the power-house short, the steam service is better and more economical than the electrical. The question of taking current from a supply company in preference to installing generating plant was also thoroughly considered, and there is no doubt that when the amount of current or load factor fluctuates much, or where the power is originally small, the supply company can work at a considerably cheaper price per unit. Again, if the distance is great, that is, if the start and finish of that part of the line which is to be electrified are some way apart, a considerable point in favour of the power supply is raised, as the current could be supplied at two or three points along the line, thereby doing away with and saving a considerable voltage drop and the resultant losses and the increased outlay. In the question of steam and electricity the subject of control has also to be considered.

It is worthy of remark that even those railways which have gone in for the electric system have mechanical braking on their cars in

(Continued on page 662.)

TABLE 1.—Comparative Costs.

Details.	Cost of original system. Small Engine and Train.	Secondary Battery.		Third-rail System from Supply Co.	Steam-Cars.
		Own Power Supply.	From Supply Co. at 1d. per unit.		
I.—Single Car.	£	£	£	£	£
Capital Cost .	1/3 engine } 733 per day } Carriages . 1,775 2,508	Car complete 4,000 Generating } 1,150 Station } 5,150	Car . . 4,000 Transformers 100 4,100	Car . . 1,350 Preparing 6 } 7,136 miles of rails } 8,486	Car . . 2,100
Interest at 4 %	£ 100	£ 206	£ 164	£ 339	£ 84
Maintenance } Wages, etc. }	975	716	542	680	251
Total . .	4,075	922	706	1,019	335
Giving at 11,000 miles per annum a cost per mile of }	23·45d.	20·02d.	15·4d.	22·11d.	7·74d.
II.—2 Cars. Cost per mile .	—	19·6d.	15·3d.	16·3d.	—
III.—3 Cars. Cost per mile .	—	19·4d.	15·2d.	14·1d.	—

TABLE 2 (continued on opposite page).

Comparison of Details of Various Steam-Cars.

Railway.	Figs.	No. of Passengers.		Length over all.	Size of Cylinders.		Weight on Bogies.	
		First.	Third.		Diameter.	Stroke.	Motor.	Trailing.
G. W. Ry.	—	61		ft. ins. 70 0	ins. 12	ins. 16	tons. 26·9	tons. 16·25
T. V. Ry. (Old type.)	1 & 3	12	40	58 8	9	14	25	10·85
(New type.)	2 & 4	16	57	70 3½	10½	14	30·7	11·25
G. N. Ry. of Scotland.	7	46		50 0	10	16	40	
G. C. Ry.	11	16	34	61 6	12	16	29·75	14·8
L. & N. W. Ry.	14-16	48		57 0	9½	15	27·4	16
S. E. & C. Ry.	17	56		64 11¼ (over buffers)	10	15	24·5	14
G. S. & W. Ry. of Ireland.	13	6	48	50 0	8¾	12	12·2	20·3
Canadian Pacific Ry.	18	52		72 0 car frame.	10	15	58-60	
G. N. Ry. of Ireland.	19	20	39	61 6	12	16	25·5	15

(continued on next page) TABLE 2.

Comparison of Details of Various Steam-Cars.

Grate Area.	Total Heating Surface.	Diameter of Wheels. Motor Bogie.	Water Capacity.	Tractive Force.	Boiler Details.
sq. ft.	sq. ft.	ft. ins.	gallons.	lbs.	
11.54	659.24	4 0	450	6,912	Vertical 4 feet 6 inches diameter with cone top—160 lbs. pressure. 458 tubes $1\frac{1}{2}$ inch diameter.
8.0	338.5	2 10	550	4,269.17	Two barrels with 152 $1\frac{1}{2}$ -inch diameter tubes and smoke-box each. 160 lbs. pressure.
10.0	464.84	3 6 (driving) 2 10 (trailing)	550	5,292	Two barrels with 232 $1\frac{1}{2}$ -inch diameter tubes and smoke-box each. 180 lbs. pressure.
9.0	500	3 7	660	4,465	Vertical multitubular type. 150 lbs. pressure.
13.0	610.36	3 9	550	7,680	Vertical boiler. 150 lbs. pressure.
6.38	317.27	3 9	455	4,210	Loco. type. 175 lbs. pressure.
8.8	381.5	3 7	400	4,480	Loco. type Belpaire fire-box. 160 lbs. pressure.
8.4	367.66	2 9	430	2,360	Loco. type, 309 $1\frac{1}{2}$ -inch outside diameter tubes. 130 lbs. pressure.
—	600 (about)	3 6	740	2,500	Return tubes boiler. 160 lbs. pressure.
11.5	653.1	3 9	550	6,720	Vertical multitubular. 420 $1\frac{1}{2}$ -inch outside diameter tubes. 175 lbs. pressure.

TABLE 2 (continued on next page).

Comparison of Details of Various Steam-Cars.

Railway.	Figs.	No. of Passengers.		Length over all.	Sizes of Cylinders.		Weight on Bogies.	
		First.	Third.		Diameter.	Stroke.	Motor.	Trailing.
Missouri Pacific Railway.	—	64		ft. ins. 78 0	ins. ins. 11 12		tons. tons. 58	
Port Talbot.	21	61		77 4 buffers.	12 16			
G. N. Ry.	26	53		65 8½ buffers.	10 16		27·3	15·15
L. & S. W. Ry. (Last type car.)	32	40		50 0	10 14		21·7	10·6
Glasgow & S. W. Ry.	33	—		57 0	9 15		—	—
L. B. & S. C. Ry.	34	48		57 3 buffers.	8½ 14		22·05	12·075
L. & Y. Ry. (New cars.)	37	56		66 5	12 16	Made their first two cars to		
							32·7	14·8
N. Staffs. Ry.	38	46		50 5 buffers.	8½ 14		20·875	11·675

(concluded from opposite page) TABLE 2.

Comparison of Details of Various Steam-Cars.

Grate Area.	Total Heating Surface.	Diameter of Wheels. Motor Bogie.	Water Capacity.	Tractive Force.	Boiler Details.
sq. ft.	sq. ft.	ft. ins.	gallons.	lbs.	
—	—	3 6	2,000	6,966	Water tube. 250 lbs. pressure.
13.1	660	3 0	600	8,700	Loco. type. 170 lbs. pressure.
9.5	382	3 8	560	5,120	Loco. type. 175 lbs. pressure.
6.75	347	3 0	485	3,889	Locomotive type. Fire-box fitted with water-tubes.
—	—	3 6	—	—	Loco. type. 142 tubes, 1½-inch outside diameter.
7.0	369	3 8	450	3,230	Loco. type. 242 tubes, 1½ in. outside diameter.
the Taff Vale Railway Company's specification.					
9.4	509	3 7½	550	7,530	Loco. type. 4 feet 3 inches diameter barrel, 199 1½-inch outside diameter tubes. 180 lbs. pressure.
7.0	368	3 8	450	3,305	Loco. type. 180 lbs. pressure.

preference to electrical, and it is generally held that the steam-cars are, as a whole, more amenable to requirements and more easy to control. The usual system of braking on electrical railway cars is one or another of the ordinary air or vacuum brakes, the pump being driven by a small electric motor.

It was while these results were being arrived at that the London and South Western Railway Co. placed their steam-car on the rails. The Taff Vale Railway Co., having satisfied themselves that the steam-car was undoubtedly the most economical for their purpose, then designed and placed one on the rails, suitable for carrying the above-mentioned 52 passengers at a maximum speed of 25 miles per hour, and having a capacity of acceleration of 30 miles per hour in 32 seconds. This speed of 25 miles per hour, however, was found to be insufficient, and the greater speed, which had to be and was attained, caused at first some considerable trouble in axle-heating. Since then the journals of the driving wheels have been increased in length to $10\frac{1}{2}$ inches instead of 7 inches, and with other small alterations the car now attains a speed of 35 miles per hour with ease. The comparison of the weights, sizes, and general details of the best-known cars may be of interest, and are therefore given in Table 2 (pages 658-661).

The following points which cannot be tabulated are worthy of notice:—

Great Western Railway Car.—The trailing pair of wheels of the motor bogie are the driving wheels, and are coupled to the leading pair. The cylinders, which are fixed outside the frame, have balanced slide-valves, while the motion is of the Walschaerts type. The cars are lighted by means of 20-c.p. incandescent-gas lamps, the gas being stored in cylinders attached to the underframe. Hand and vacuum brakes are fitted to each bogie, and can be operated from either end of the vehicle, while electrical communication is provided between the motor and driver's compartments. The water-tank, which holds about 450 gallons, that is, sufficient to take the car 30 miles including stops, is attached to the underframe. The main frame of the coach body runs the whole length of the car and includes the engine and boiler.

Taff Vale Railway Car (Figs. 1 and 2, page 654, and Plates 70-72).—As previously mentioned, the leading pair of wheels are the driving wheels, the cylinder being fixed between the leading and trailing pairs outside the frame. The valves are operated by an ordinary link motion with rocking shaft. The compartments are heated by steam from the engine with warmers of acetate of soda, and the lighting is done by Pintsch's system of oil gas. Steam and hand-brakes are provided on the motor bogie, while there is a hand-brake in the car bogie, the latest type being also fitted with vacuum brakes. The conductor can communicate with the motorman by means of an electric bell, and can also shut off steam and sound the whistle. The motor is capable of travelling at 35 miles per hour on the level, and can ascend a gradient of 1 in 40 at a speed of 20 miles per hour. This car can be driven from either end, and all operations except starting can be performed from the guard's compartment. A distinct feature of the car is the ease with which the engine can be taken from the coach body, 20 minutes being ample time for this work, while it can be put under in the same time.

Great North of Scotland Railway Car (Fig. 7, Plate 72, and Figs. 8 and 9, Plate 73).—In this car again the leading pair of wheels of the motor bogie are the driving wheels, the cylinders being fixed outside the frame between them and the trailing pair. The slide-valves are placed above the cylinders and are actuated by means of the Walschaerts gear. The cars are lit by Stones' system of electric lighting, the current being generated by a dynamo suspended from the carriage underframe and driven from one of the axles. The water-tank is also suspended from the underframe and holds 660 gallons. Provision is made for driving the car from either end, and for this purpose the vestibule is fitted with a steam regulator, whistle-handles, and Westinghouse and hand-brakes. There is also fitted Chadburn's telegraph apparatus, which indicates the various notches backwards and forwards at which the driver wishes the gear to work.

Great Central Railway Car (Figs. 11 and 12, page 664).—Both vacuum automatic and hand-brakes are used, and, together with the

FIG. 12.

*Boiler for Steam-Car, Great Central Railway,
Fig. 11.*

Working Pressure, 150 lbs. per sq. inch.

Heating Surface:

Tubes . . . 558.00 sq. ft.

Fire-box . . . 52.86 " "

610.86 " "

Grate area, 13 sq. ft.

FIG. 11.—*Steam-Car No. 3, Great Central Railway.*

To seat 16 First- and 34 Third-Class Passengers.
Cylinders, 12"×16". Water, 550 gallons. (For Boiler Details, *see* Fig. 12.)

FIG. 17.—*Steam-Car, South Eastern and Chatham Railway.*

To seat 24 Smokers and 32 Non-Smokers.

Heating Surface: Tubes, 337.0 sq. ft.; Fire-box, 44.5 sq. ft.—Total, 381.5 sq. ft. 167 Tubes; 1½" outside diameter.
Grate area, 8.8 sq. ft. Water, 400 gallons. Coal, 15 cwt. Working Pressure, 160 lbs. per sq. inch. FIG. 18.—*Steam-Car, Canadian Pacific Railway.*

To seat 52 Passengers. Water, 740 gallons. Heating Surface, about 600 sq. ft. Working Pressure, 160 lbs. per sq. inch.

steam regulator and whistles, can be governed by the driver from either end, while there is electrical communication between driver and conductor. The passenger compartments are heated by steam from the engine, and the car is lit throughout by electricity, the dynamo and accumulator being suspended from the underframes, the former being driven by a belt from one of the axles. The water storage is also under the frame.

London and North Western Railway Car (Plates 74 and 75).—In this car the cylinders are carried inside the frame of the motor bogie, while the water-tank, which has a capacity of 455 gallons, is carried under the carriage body, but attached to the engine-bogie. The engine can be worked from either end of the car, which is fitted with automatic vacuum and hand-brakes, and is lighted throughout with electricity on Stones' system.

South Eastern and Chatham Railway Car (Fig. 17, page 665).—The cylinders of this car are carried outside the frame placed horizontally with the valves on the top, the latter being operated by means of the Walschaerts gear. Water to the amount of 400 gallons is carried in three tanks, one on each side of the boiler with a well tank between the frames. Vacuum automatic and hand-brakes are provided. The guard's compartment is fitted with levers for working the reversing gear, regulator, whistles, and hand-brake, while electrical communication is provided between each end of the car. The carriage is fitted with Stones' system of electric lighting, the dynamo accumulators being carried underneath the frame.

Great Southern and Western Railway of Ireland Car (Fig. 13, Plate 74).—In this design the leading pair of wheels of the motor bogie are the driving wheels, the cylinders, which are outside the frame, being slightly out of the horizontal. The valves are operated by means of the Walschaerts gear. Steam can be shut off from either end of the coach, while electrical communication is provided between front and rear portion. The average speed of this car is 20 to 21 miles per hour.

Canadian Pacific Railway Car (Fig. 18, page 665).—The car is to be operated by steam generated by fuel oil, while the boiler is a return-tube boiler with a superheater fitted in the back end of the boiler. The cars have single driving wheels and their valves, which are of the piston type, are operated by the Walschaerts valve-gear. Acetylene gas is used for the lighting purposes. The oil is consumed in a circular Morison furnace, 32 inches inside diameter by 5 feet 6 inches long.

Great Northern (Ireland) Railway Car (Fig. 19, page 668).—The cars built by this company have cylinders fixed horizontally outside the frame, between the wheels, driving to the trailing pair which are coupled to the leading pair. The valves, which are on the top, are operated by the Walschaerts type of gear.

The cars are fitted with an automatic vacuum-brake operated from either end of the car, while there is a hand-brake on the car itself. The cars are all heated by steam and lit electrically on Stones' system. Electrical communication and speaking tubes are provided between the driver's and guard's compartments.

North Eastern Railway Car (Fig. 20, Plate 76).—This company, while having no steam motor-cars, has a number of engine and coach combinations performing practically the same service, as the engine can be driven from the front end of the coach when running behind it. A driver's compartment is forward in the rear end of the coach and fitted with a wheel for the reversing gear, a lever for the steam regulator, an air-brake valve, a hand-brake and a whistle worked from the air-brake reservoir. The driver has therefore complete control of the locomotive, with the exception of the cylinder drain-cocks and sanding gear, which are worked as required by the fireman. The reversing gear is worked by the hand-wheel keyed to a shaft, which carries a sprocket wheel gearing with a longitudinal shaft by a chain. This shaft extends the whole length of the coach, and gears to the screw of the reversing gear by means of an intermediate shaft and chain. A three-jaw clutch is interposed

FIG. 19.—*Steam-Car, Great Northern Railway (Ireland).*

To seat 20 First-Class and 39 Third-Class Passengers.

Heating Surface, 653·1 sq. ft. Grate area, 11·5 sq. feet. Tank Capacity, 550 gallons. Working Pressure, 175 lbs. per sq. inch.

FIG. 21.—*Steam-Car, Port Talbot Railway.*

To seat 66 Passengers; 8 in Luggage when required.

Heating Surface: Tubes, 591 sq. ft.; Fire-box, 69 sq. ft.—Total, 660 sq. ft. Grate area, 13·1 sq. ft. Capacity of Water Tanks, 600 gallons.
Capacity of Coal-Bunk, 40 cu. ft. Working Pressure, 170 lbs. per sq. inch.

to disconnect the operating gear, when it is desired to work the locomotive from the footboard.

This railway company has also an electrical car running between Scarborough and Filey, which is operated in a somewhat novel way. A storage battery of 38 cells is suspended between the frames and supplies current to the generator, which is used as a motor to start up the petrol engine. After the engine has been started, the current is switched off, and the motor takes its proper place as a generator. A small exciter is used both to excite the main generator which drives it, and to supply the lighting current for 30-72-volt 16-c.p. lamps. The voltage of this machine can be increased to 95 volts for charging the battery when not required for lighting.

Missouri Pacific Railway Car.—This company is now building a car which is being manufactured by the St. Louis Car Co.; its special feature is the engine, which is being manufactured under the Wagenhals patents. The engine is of the double-cylinder type actuated by the Stephenson link-motion. The frame of the engine will be secured to the rear of the frame of the truck, and the forward end of the engine-frame will be secured in journal-bearings on the axle. The crank-disc will be located on a jack-shaft carrying a gear which will mesh into a gear on the axle of one pair of wheels. Steam is generated with oil fuel, of which the car will carry 1,000 gallons, and the engine will develop 275 H.P.

Port Talbot Railway Car.—The car being built to the order of the Port Talbot Docks and Railway Co. is well worthy of mention, and presents many novel features, Fig. 21 (page 668). The motor bogie, as will be noticed, is a 6-wheels-coupled type, with 3-foot wheels, the valves being operated by an adaptation of the Walschaerts gear. The car is lit by electricity generated by a steam turbine-driven dynamo. As will be seen from the diagram, Fig. 22 (page 670), the gradient this car has to work is extremely steep—3 miles of 1 in 40.

FIG. 22.

Port Talbot Railways. Llynvi and Garw Railway

Among many other lines using railway-motor-cars with advantage may be mentioned:—

N. W. of India Ry. Figs. 23 and 24, Plate 76; and Plate 77.

Great Northern Ry. Figs. 26 and 28, Plate 78; and Fig. 27 (page 672).

Vesterias Ry., Stockholm. Figs. 29 and 30, Plate 78.

C. S. African Ry. Fig. 31 (page 672).

L. and S. W. Ry. Fig. 32, Plate 78.

Glasgow and S. W. Ry. Fig. 33 (page 673).

L. B. and S. Coast Ry. Fig. 34 (page 673), and Figs. 35 and 36 (page 674).

L. and Y. Ry. Fig. 37, Plate 79.

North Staffordshire Ry. Fig. 38 (page 675).

The details and remarks, given in Table 3 (pages 676–677), on some of the best-known electric railway systems may be of some interest, and will not therefore be out of place in this Paper.

It is a fact worthy of remark that, while the Metropolitan, North Eastern, Fig. 39 (page 675), and Liverpool and Southport, are the only English electric railways to make use of high-tension transmission, all the foreign ones do so with the exception of the Boston Elevated and Grenoble-Chapriellan. To the above English

railways the Metropolitan District and Central London should be added. The Isle of Man electric tramways, while perhaps not coming under the description of an electric railway, may be mentioned here, owing to the fact that the power is transmitted at 6,000 volts.

Again, the foreign railways are the only ones up to the present, with the exception of the Metropolitan, who have made use of the turbine to provide the motive power to the dynamo. In the case of the Grenoble-Chapriellan, this motor power is supplied by a waterfall 1,476 feet high, and is distributed to the turbines from a collector placed outside the station.

The Valtellina Electric Railway also derives its motive power from water. In this case the water is taken from the River Adda, and has a flow of 550,000 cubic feet with a maximum head of 90 feet, and is sufficient to develop 7,500 H.P.

Advantages.—The advantages of the rail-motor system of carrying passengers may be placed as follows:—Owing to the small unit, a much more frequent service is given with a better percentage of freight to dead weight hauled, while the mileage cost of working is only about one-third the cost of an ordinary passenger train-mile. The facility of picking up and setting down passengers at line crossings, small villages, etc., makes the service more popular, and enables many passengers to travel who would not otherwise be able to. The rapid rate of acceleration makes the through speed higher. The experience of those railways which have given both an extensive trial is that the system is equally advantageous for heavy and sparse traffic. In the first case, the motors sandwiched in between the regular trains find a traffic without taking it away from the trains, while in the second the traffic has been developed by the more frequent service. The number of steam-cars at present running, and the ever-increasing number both at home and abroad, proves their utility, and it seems certain that in them railways have the best, and in fact only, effective answer to street-car competition.

In conclusion, the authors wish to thank the engineers and others who have supplied details and drawings of the cars on their

(Continued on page 678.)

FIG. 27.—*Steam-Car, Great Northern Railway.*

To seat 16 Smokers and 20 Non-Smokers in Third-Class, Saloon for 10 Firsts or 12 Thirds, and 5 in Luggage when required.—Total, 53.

Heating Surface: Tubes, 326 sq. ft.; Fire-box, 56 sq. ft.—Total, 382 sq. ft. 178 Tubes $1\frac{1}{2}$ " ext. diam. Grate area, 9.5 sq. ft.

Capacity of Tanks, 560 gallons. Working Pressure, 175 lbs. per sq. in. Capacity of Bunker, $12\frac{1}{2}$ cwt. Total Weight, 42 tons 10 cwt.

FIG. 31.—*Steam-Car, Central South African Railways.*

Details of Boiler, see Fig. 10, Plate 73.

FIG. 33.—*Steam-Car, Glasgow and South Western Railway.*142 Tubes $1\frac{1}{8}$ inches exterior diameter. FIG. 34.—*Steam-Car, London Brighton and South Coast Railway.*

To seat 48 Passengers.

Heating Surface: Tubes, 327.4 sq. ft.; Fire-box, 41.6 sq. ft.—Total, 369 sq. ft. 242 Tubes $1\frac{1}{8}$ " ext. diam. Grate area, 7 sq. ft.
 Total Weight, 34 tons 2 cwt. 3 qrs., empty. Tractive Power, 28 lbs. for each 1 lb. M.E.P. in Cyls. Hand-screw and Vacuum Brake.

FIG. 35.—Engine and Trailer-Car, London Brighton and South Coast Railway.

To seat 32 Non-Smokers and 28 Smokers. Luggage Capacity, 466 cu. ft.
Heating Surface, 518 sq. ft. Grate area, 10 sq. ft. Weight of Engine, 24 tons 7 cwt. Weight of Car, 23 tons 6 cwt.

FIG. 36.—Self-propelled Petrol Car, London Brighton and South Coast Railway.

To seat 48 Passengers.

FIG. 38.—*Steam-Car, North Staffordshire Railway.*

To seat 6 Smokers and 40 Third-Class Passengers.

Heating Surface : Tubes, 328 sq. ft. ; Fire-box, 40 sq. ft.—Total, 368 sq. ft. Grate area, 7 sq. ft. Working Pressure, 180 lbs. per sq. inch.
Total Weight, 32 tons 9 cwt. 1 qr.

FIG. 39.—*Electric Autocar, North Eastern Railway.*

With magnetic rail-brake, speed 36 miles per hour. Petrol motor, 4 cyls. 8½ ins. by 10 ins. 420 revolutions, driving generator.

TABLE 3.—*Details of Electric Traction on the various Railways shown below.*

Name of Railway.	Gross Power in Kilowatts.	Pressure Generated in Volts.	Pressure used in Motors, in Volts.	Gross Power Capacity of each Train.	Number of passenger seats per Train.	Ruling Gradient.	Remarks.
Liverpool & Southport	6,750	7,500 (3-phase)	600 (direct current)	H.P. 1,200	270	1 in 85 for a short distance	—
Great Northern & City	3,200	550 (direct current)	500 (direct current)	500	50	1 in 30	—
Mersey	4,650	650 (direct current)	600 (direct current)	400 (single) 800 (double)	Average per train = 60.	1 in 30 maximum 1 in 27	Secondary batteries are utilised in the generating station for taking peak loads.
Liverpool Overhead	5,400	500 (direct current)	500 (direct current)	400	160	1 in 200	ditto.
Metropolitan	14,000	11,000 (3-phase)	550 (direct current)	1,200	322	1 in 44 for about 14½ chains	—
North Eastern (Fig. 39, page 675.)	11,200	6,000 (3-phase)	600 (direct current)	600	186	1 in 27 (goods line) 1 in 50 (passenger line)	—

Liverpool & Manchester	6,000	10,000 (3-phase)	550 (direct current)	560	35	—	Proposed Mono-rail.
Central London	—	5,000 (3-phase)	500	—	336	—	—
Metropolitan District	4,000	11,000	550	1,600	312	1 in 43	—
Waterloo & City	1,200	525 (direct current)	500 (direct current)	160 (single) 320 (double)	50 204	1 in 30 for a distance of 900 feet	—
Boston Elevated	36,844	550	550	1,200	192	1 in 20	—
Paris Metropolitan	6,000	5,000 (3-phase)	600 (direct current)	200 300	60 per car.	1 in 3·6	—
Paris-Orleans	2,060	5,500 (3-phase)	550 (direct current)	668	525	1 in 100	—
Grenoble-Chapriellan	750	2 × 600 (direct current)	600 (direct current)	70	36 per car.	—	Water Turbines.
Lecco-Sondrio (Ganz)	4,476	20,000 (3-phase)	3,000 (3-phase)	600	56 per car.	—	Water Turbines.
Valtellina Electric	6,000	20,000 (3-phase)	3,000 (3-phase)	600	170	1 in 50	Water Turbines.
Burgdorf-Thun.	3,720	4,000 (3-phase)	750 (3-phase)	240	136	1 in 40	Water Turbines.

respective railways, and to remark that they have endeavoured to treat the subject on its merits as they have found them, and to put before the Members the conclusions arrived at, and in this they trust they have succeeded.

The Paper is illustrated by Plates 70 to 79 and 17 Figs. in the letterpress.

Discussion on Wednesday, 1st August 1906.

Mr. JOHN A. F. ASPINALL, Vice-President, in opening the discussion thought Mr. Riches had been rather a pioneer in the matter of railway-cars. As was stated in the Paper there were two cars on the Lancashire and Yorkshire Railway, the locomotives of which were made from Mr. Riches' design, and since then quite a number of other cars had been built which, though they differed somewhat in design, had been made in that way to suit the local conditions. With regard to the historical part of the Paper, he noticed that a little credit had not been given to a man who, he believed, was the first to produce a car of the kind described, namely, the late Mr. Alexander McDonnell, the locomotive engineer of the Great Southern and Western Railway of Ireland. It fell to his (Mr. Aspinall's) lot in 1876, as Mr. McDonnell's assistant, to construct the first car of that kind which was made for the Castle Island and Gortatlea Railway in Kerry, which ran for many years upon that line. It was a six-wheel coupled engine, with a first-class and third-class car behind, carried upon a bogie, and was intended for dealing with the shunting work at the two terminals as well as for carrying passenger traffic. The Great Southern and Western Railway built a certain number of cars of that kind in after years, and it was quite possible they were still running.

For starting a service upon a new branch line in the country, there was no doubt that a motor-car was of very great use. It was also of use for adding to the existing services between trains which

ran upon branch lines, where a company was not justified in going in for largely increased train service, but where a certain amount of additional accommodation could be given to the public by running rail-motor-cars, which might almost be called tram-cars. For that reason where his company had used them, running between existing train services, they had made them of one class, making an open vehicle from end to end, with only a third-class compartment, and even no smoking compartment, arguing that if anybody was willing to travel for a quarter of an hour or twenty minutes in a tram-car without a smoking compartment they could easily do so in a railway vehicle. The result was that it was not necessary to provide the percentage of extra space for a first-class carriage, a percentage of space for the second-class, and the percentage of space for the smoking compartment, which meant so much loss if it was not filled. The compartment was common to all, and a very much better commercial result was obtained by dealing with the question in that way. In one or two cases the cars had been used upon branch lines where the trains could not possibly have paid. The ordinary trains had been swept off the line, and an ordinary third-class rail-motor-car substituted, with the result that the receipts had been doubled upon a line that otherwise was not paying.

The authors referred to the fact that electrical trains were not equipped with electrical brakes. He did not think it was desirable that electrical trains should depend upon electrical brakes. If they did, the failure of the current at any one moment would render the stoppage of the train practically impossible; and however efficient an electrical brake might be, possibly it was far better that the train should be equipped with some form of power-brake, either vacuum or pressure as the case might be. That brought him to another point, in connection with the frequent stopping of trains worked electrically. He believed one of the most important things which electricians could supply would be some form of perfect regenerative control. He was quite aware there were in existence at the present time several forms of regenerative control, but they were not as yet adapted to railway purposes. There was a field for somebody to work on, which would mean the saving of a great deal of money

(Mr. John A. F. Aspinall.)

when an effective system was produced. Even when such a system was produced, it would not be desirable to do away with the form of power-brake of which he had spoken, but some of the energy of the train ought to be turned back into the mains in some form or other, in order to give what he might perhaps roughly and inaccurately describe as some form of fluid stoppage, not mainly for the purpose of saving current, but as a more scientific method of quickly reducing the higher speeds, leaving the final stop to the ordinary power-brakes. The difficulty at present was that, by means of power-brakes actuating brake-blocks, a very large amount of cast-iron was being worn away. The loss was tremendous, and he could not believe it was mechanically right to stop the trains with so much friction, and thereby create an immense amount of waste, consisting of cast-iron scrapings, in addition to the incessant wear and tear of the pins and other parts of the brake rigging. If things went on as at present, ultimately the limestone ballast underneath the track would become of more value to the iron smelter than to anybody else.

The authors gave (page 657) comparative figures of electrical working and working by rail-motor-car, but he noticed they had taken a very small mileage, namely 11,000 miles per annum, which only worked out at 37 miles per day. That Table must have been made out for their guidance in the earlier days when there were fewer motor-cars running than at the present time; and if it were read as representing the practice of today it might be somewhat misleading. Undoubtedly it would be impossible to work electrically with so small a service in anything like an economical manner. The price put down of 1d. per unit for current might be a reasonable sum for an engineer to be charged with on so small a service, but it would be more than twice as large as any railway company could produce the current, if it were running a considerable system of trains.

The authors referred (page 670) to high-tension currents being used on the Liverpool and Southport line. In the way in which the Paper was worded, he thought it might lead to a misconception. As a matter of fact, the current was produced at 7,500 volts at the generating-station, but when it reached the rail it was used

at 600 volts. Another point in connection with rail-motor-cars was that, if a railway company within whose district tramways had created a very serious and troublesome competition, started a motor-car service which ran parallel with the tramway, they would have the satisfaction of knowing that the public were sufficiently anxious to save their time as to prefer the rail-motor-car service to the slower moving tramway, and his company had been fortunate in having that experience, at any rate in one case. Although railway companies had the knowledge that, as ratepayers, they had unfortunately to pay for any loss which the tramway incurred, they were prepared to take the money themselves rather than allow it to go into the Corporation's pockets.

One detail connected with the cars which were made to stop at many places where there were no stations in order to pick up the people in country districts was, that in the case of the Lancashire and Yorkshire Railway, and he believed in the case of one or two other companies, an arrangement was made whereby the guard, as soon as the car stopped, pulled a lever and let down a series of steps, which made it easy for the passenger to ascend or descend to the rail level. When those steps were pulled down, the same movement opened a valve which put the brake on, and the car could not be started until the steps had been pulled up again and the brake released. The general result of the use of rail-motor-cars on the Lancashire and Yorkshire Railway, in its crowded working-class district, had been that they had attracted a great deal of additional traffic, but they must not be looked upon as being vehicles which were only useful for a place where there was a good deal of traffic. Motor cars had their uses in country districts where there was little or no traffic; they had their use where a company desired to put them on as an additional service between main-line trains, as the Great Western had done in their lines running into London. There a considerable power in the engine was required in order to obtain quick starting and getting the train away rapidly, so that it would not be overtaken by following trains; and in order to have a service, it was necessary to have platforms at the halts, so that the people could get out quickly and not be delayed by having to go up and

(Mr. John A. F. Aspinall.)

down steps such as he had described. Each case required considering on its own merits; it was impossible to lay down any particular rules as to the form of car which would suit any district, without carefully studying each individual case.

Mr. JOHN MACAULAY thought the Paper was a very valuable one indeed, and regretted that the chief railway officials of the country had not been present to hear the excellent remarks that had been made both by Mr. Riches and Mr. Aspinall. When Mr. Dugald Drummond of the London and South Western Railway Company brought the railway-motor-car described in the Paper to the notice of railway companies in general, he (Mr. Macaulay) as a traffic officer of some considerable years' service, went and saw it, and at once came to the conclusion that it was one of those conveniences which, if properly carried through, would be of immense value, not only to the travelling community, but to the companies themselves. The present was a time of fierce competition, and unfortunately railway companies had in a great measure to maintain the schemes which were established by municipalities, because, as Mr. Aspinall very properly said, if they did not pay, the railway companies had the satisfaction of knowing that they assisted in making them pay. However that might be, the railway company of which he was the General Manager immediately had one of the cars built, and a service was now maintained by two of these cars between Pontypridd and Caerphilly, a distance of a little over six miles. He thought it would be a good opportunity, having regard to the distance, to put down eight or nine stations and reduce the fares something like 35 per cent., with the result that it was one of the best investments the company had. He felt quite sure that the railway-motor-car, as Mr. Aspinall had just stated, was a great advantage, not only to the public but as a source of revenue to railway companies; and if the railway-motor-car was brought into existence more generally, he felt sure that a great deal of the traffic that railway companies had lost throughout the country would be recovered.

The PRESIDENT said that the Paper was such a very important one, that he proposed to adjourn the discussion and continue it at the next London Meeting.

Discussion on Friday, 19th October 1906.

Mr. HENRY LEA, Member of Council, thought the Paper was a most interesting one. He had travelled on several of the vehicles of the construction described in the Paper, and was struck with the obvious value they must have in railway work of the kind they were intended to fulfil. As a rule such coaches would run only short journeys, and when one reached the end of its journey, instead of the locomotive being shunted to the other end, as was the case in an ordinary train, the driver himself moved to the other end of the coach and the vehicle went back in the reverse direction. That undoubtedly saved a large amount of time and a considerable amount of fuel in shunting operations.

He noticed that the gradients were given in only two cases mentioned in the Paper. The Taff Vale gradient was given as 1 in 40, and the Port Talbot gradient was also the same figure. In the absence of knowledge of the gradients on the various lines on which the motor-car vehicles were used, it was rather difficult to compare their proportions for the work intended to be done; but with the information which was afforded by the Paper, he had, as he thought it would be of interest to the members, compared the eighteen examples given on the basis of the amount of heating surface per thousand cubic feet of piston-displacement in a run of 35 miles. The possible speed on the Taff Vale line was stated to be 35 miles an hour. In Table 4 (page 684) it would be seen that the eighteen examples were given in the same order in which they appeared in the Paper, and the heating surface per thousand cubic feet of piston-displacement in a run of 35 miles was given in the third column. It struck him, when he worked the figures out that they did not

(Mr. Henry Lea.)

TABLE 4.

	Railway.	Heating Surface in sq. ft. per 1,000 cub. ft. of Piston Displacement in a run of 35 miles.	Square Feet of Heating Surface per Passenger carried.
1	G. W. Ry.	10·7	10·8
2	T. V. Ry. (old type)	7·8	6·5
3	T. V. Ry. (new type)	9·8	8·2
4	G. N. Ry. of Scotland	10·4	10·9
5	G. C. Ry.	9·3	12·2
6	L. & N. W. Ry.	8·2	6·6
7	S. E. & C. Ry.	8·5	6·8
8	G. S. & W. Ry. of Ireland . .	10·3	6·8
9	Canadian Pacific Ry.	13·1 (oil fuel)	11·5
10	G. N. Ry. of Ireland	10·0	11·1
11	Missouri Pacific Ry.	—	—
12	Port Talbot Ry.	8·1	10·8
13	G. N. Ry.	8·1	7·2
14	L. & S. W. Ry. (last type) . .	7·0	8·7
15	Glasgow & S. W. Ry.	—	—
16	L. B. & S. C. Ry.	12·4	7·7
17	L. & Y. Ry. (new cars)	7·6	9·1
18	N. Staffs. Ry.	12·4	8·0

agree so closely as one would be inclined to expect them to do, and he thought it would be of interest if the authors could give an explanation as to why there should be such comparatively wide variations. It might be entirely due to the different gradients on the road, but if so the Paper did not afford the means of making allowances of that kind. He desired to point out that, in the third column, No. 14, which had 7 square feet of heating surface per 1,000 cubic feet of piston-displacement in 35 miles, had only 53 per cent. of the heating surface of No. 9, the Canadian Pacific example, but it would be noticed that the Canadian Pacific engine was run with oil fuel. Whether or not that had led the designers to provide more heating surface than they would have done if the fuel had been coal, he did not know. Whether that were so or not, No. 14, the London and South Western type, was only 56 per cent. of No. 16, the London, Brighton and South Coast type, and of No. 18, the North Staffordshire type; so that he thought there was some scope for an explanation as to why the proportions varied as much as from 100 to 53 and 100 to 56. In the fourth column the figures represented the heating surface per passenger, and again a great variety was shown. For instance, in No. 2 the Taff Vale Railway engine of the old type had only 53 per cent. of No. 5, the Great Central.

On page 662 the figure for the acceleration was given. That was a very interesting point, about which the contention had been that electricity had an enormous advantage over steam. The acceleration was given as 30 miles an hour in 32 seconds, which he estimated to be a mean acceleration of 1.44 feet per second per second. Of course the mean acceleration did not represent the rapidity of acceleration in starting from rest; there it would naturally be very much higher than 1.44, and the rate of acceleration would fall off as the speed increased. It would be interesting to know if the authors could state what the variations in acceleration were during the first quarter of a mile, or something of that kind.

It was stated (page 663) that, in the case of the Taff Vale Railway car, a distinct feature of the car was the ease with which the engine could be taken from the coach body, twenty minutes being ample

(Mr. Henry Lea.)

time for that work to be done, while it could be put under in the same time. That struck him as being a very remarkable state of things, and a feature of great value in vehicles of the kind described in the Paper, because no doubt the part of the vehicle containing the machinery would more often require attention in the repairing shops than the portion which consisted of the car only; and the ease with which a spare engine could be put under the end of the same car in place of the original engine, which had to be removed, was a very distinct advantage.

Mr. GEORGE HUGHES remarked that he was sorry he was not able to be present at the Cardiff Meeting, and no doubt he had suffered a considerable loss in consequence by not hearing the discussion which then took place. On the occasion of the Cardiff Meeting he sent a letter to the Secretary, which related to certain cars that had been designed by himself for the Lancashire and Yorkshire Railway. He was very pleased indeed to state that, in the first instance the company purchased two steam-cars manufactured by Kerr, Stewart and Co. to the designs of Mr. Hurry Riches, and on account of the excellent commercial results obtained from those cars they decided to build six designed by himself. A diagram of the boiler of the car was given in Plate 79, and some particulars of the bodies, giving the dimensions and particulars of the interior fittings and the heating and lighting arrangements were given in Table 5 (page 688). In Mr. Riches' cars the electric light was installed, but in those designed by himself incandescent gas light was adopted. The collapsible steps were a feature of Mr. Riches' car. He somewhat modified that arrangement in his own design, taking the precaution to place the handle which operated the steps in series with the electric bell which was used by the conductor to give the signal to the driver for starting. The point which had to be borne in mind was that when the lever was over and the steps were down the circuit was broken. In addition to that, he also adopted a scheme by means of which a bell-crank lever operated the valve which was known as the passenger communication-valve, causing the brake to leak on, and consequently they had, as it were, two bows to their fiddle on the

score of safety. An engine-driver and conductor were liable to forget that the steps were down, with the result that trouble was experienced, and the car naturally had to be taken out of service.

One of the features of the engine and boiler connected with his own design was the fact that the flange-plates of the boiler were standard flange-plates belonging to a class of engine of which his company had 270, and all the boiler mountings and so on were standard fittings. The members would readily conceive, therefore, the advantage in manufacture of making the engine cheaper. The car underframe was constructed on what one might term a cantilever principle, the main members were practically in the centre, protruding from the end of the car, and rested on the transom, or cross beam underneath the engine; in fact, the whole engine practically formed the bogie. As he had previously stated, the commercial results obtained from Mr. Riches' cars induced his company to build six more to their own design, and these had been working so satisfactorily that six more were now being built. The Walschaerts valve-gear had been adopted.

In examining the details of construction given in the Paper, the members would probably be struck with the large cylinder proportions, probably one of the largest adopted by designers in rail-motor-cars, namely, 12 inches diameter and 16 inches stroke. That, comparatively speaking, was a very large cylinder, and they had taken the precaution to adopt a maximum cut-off of 60 per cent. so that it was not hardly possible for the cylinders to run the boiler out of breath, as Mr. Pendred was so fond of calling it.

Mr. Lea had referred to the behaviour of the cars on gradients. The cars on the Lancashire and Yorkshire Railway were running on gradients of 1 in 40 and 1 in 50. They had started from a dead stand, with two trailers behind, on a gradient of 1 in 60, and before they reached the summit had attained a speed of thirty miles an hour. He had not worked the acceleration out as Mr. Lea had done in feet per second per second, but it was equal to about 40 miles per hour in thirty seconds. From the photographs exhibited, Figs. 40, 41, and 42, Plate 80, and the drawings given in the Paper, Plate 79, the members would be able to get a fair notion of the Lancashire and Yorkshire Railway car.

(Mr. George Hughes.)

TABLE 5.

*Principal Dimensions of Lancashire and Yorkshire Railway
Steam Rail-Motor-Car.*

Length over buffers	Feet.	Inches.
" of Car body	69	5
" of Passenger Compartment	47	6
Width of Car body outside	37	4½
" over handles and commodes	8	6½
Height from floor to roof	9	0
" " rail to roof	8	0
" " " to top of roof lamps	12	4¾
Distance from centre to centre of bogies	13	4¾
Wheel Base of engine bogie	45	2
" " " car "	8	0
Total Wheel Base	8	0
Diameter of engine bogie wheels	54	8
" " car " "	3	7½
Width between engine tyres	3	6
" " " frames	4	5½
	4	2
Cylinders	{ Diam.	Stroke.
	{ 12 ins.	× 16 ins.
Centre to centre of cylinders	Feet.	Inches.
Diameter of Boiler	6	7
Length of Firebox	4	3
Width of Firebox	2	8½
Height of Firebox	3	5½
	4	3½
Number of tubes	199, 1½ ins. diam.	
Working pressure	180 lbs. per sq. in.	
Heating surface of tubes	455 square feet.	
" " " firebox	54	" "
Total heating surface	509	" "
Grate Area	9'4	" "
Capacity of water tank	550 gallons.	
" " coal bunker	1 ton.	
Weight in working order, exclusive of passengers:—		
Leading motor bogie wheels	Tons.	Cwts. Qrs.
Trailing " " "	16	2 0
	16	12 0
Total weight on Motor Bogie	32	14 0
" " " Car Bogie	14	16 0
" " complete	47	10 0

He did not desire to allude further to the technical part of the Paper, but he felt rather tempted to touch upon what he might term the ethics of the subject—the reasons why the cars had been so successful, as he had no doubt all the members knew they had been. The authors had touched on certain points in that connection, which might be briefly enumerated in the following way. In the first place, they had stated that rail-motor-cars were extremely suitable for opening out a sparse country, and in addition to that it had been found that they worked very well between the ordinary trains. His own company had also found them exceedingly successful in densely populated districts. If he might just sum up the point, he thought it really turned on the question of giving people plenty of opportunities to travel by means of a good and frequent service. It was a well-known fact that, if a good and rapid service existed, people did travel more frequently than they otherwise would do. In order to illustrate the point, he desired to mention the fact that ordinary commercial men could probably allow themselves half-an-hour to get from their homes to their place of business. In the days of the old horse-car a man could live a certain distance from his place of business, whereas in the days of electric traction he could live probably twice or even three times as far from his place of business, and get to it in the same time as it previously took with the old horse-car. The result of that had been that the community had already experienced, and would continue to experience in the future, very considerable benefit from the fact that it was possible for them to live three times the distance from their place of business. Consequently electric traction and steam rail-motor-cars were some of the means, to some extent, of solving the housing problem.

Mr. WILLIAM H. MAW, Past-President, said he desired to make a few remarks before the discussion closed, in justice to the memory of his old friend, William Bridges Adams. He thought, in any discussion on the use of railway-motor-cars, engineers ought to acknowledge what they owed to the late Mr. William Bridges Adams. Probably very few of the members present had the pleasure of knowing Mr. Adams personally, but to some of the older railway men he would always

(Mr. William H. Maw.)

be remembered as a very interesting personality, who was most enthusiastic in advocating light and frequent railway traffic. More than sixty years ago Mr. Adams was engaged in endeavouring to get railway companies to take up the question of using combined locomotives and carriages in the form of light steam-trains. Mr. James Samuel, who was at the time the engineer of the then Eastern Counties (now Great Eastern) Railway, was good enough to give Mr. Adams facilities for trying his plans;* and he (Mr. Maw) remembered very well that when he went to the Stratford Works in 1855 to serve his time, some of the later examples of Mr. Adams' work had just been removed from the line. The time did not then seem to be ripe for the use of such cars, but they embodied very many features which he thought deserved to be remembered.

One of Mr. Adams' most successful cars, the "Enfield,"† was put on the Eastern Counties line in January, 1849. It weighed about 15½ tons empty, and about 21 tons loaded; it had a passenger compartment which accommodated eighty-four passengers, and it hauled a trailer 40 feet long and 9 feet wide which carried 116 passengers. That engine and car ran for several years. He happened to have a very lively recollection of the "Enfield," because when he went to the Eastern Counties Railway it had just been placed on the scrap-heap. Two years afterwards it was removed from the scrap-heap, it being decided that it should be done up and used for hauling a directors' carriage. The stripping and overhauling of the engine was put chiefly into the hands of a fellow apprentice and himself; they did half each, one doing one side and one the other. The old "Enfield" had a very low platform, only about 18 or 20 inches above the rail-level, and the whole of the motion was above the foot-plate, and it could be seen by the driver and by any one on the platforms of the stations. His fellow apprentice, Crane, and himself were not very busy at the time, and they took a pride in getting up bright everything that could be polished, and made what they thought was a very good job. They were very proud of the engine when it went out for trial, but their pride had a fall very

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* See Paper by J. Samuel; Proceedings, June 1848, page 8.

† See Paper by J. Samuel; Proceedings, October 1849, page 4.

shortly afterwards, because when running through the first station—Lea Bridge, where a new platform had been erected—they heard a very loud scraping noise, and the engine was brought up standing. It was then found that the edge of the foot-plate had cut into the brick front of the platform, and that the engine was fixed. They had ignominiously to get another engine to haul them back to a cross-over road, and subsequently, when they got back to Stratford, a good piece had to be chipped off the foot-plate of the engine on each side. After that the "Enfield," which was really a very interesting engine, did good work for many years. When it was placed on the road after the overhaul, the carriage part was taken off; a buffer-plate was fitted at the trailing end, and it was used as a hauling engine. The engine had cylinders 8 inches in diameter and 12 inches stroke. He thought it might be of interest to the members to mention these early steam-carriages.

After Mr. Bridges Adams' efforts there seemed to be a gap of about thirty years before anything more was done, and then, as was mentioned in the Paper, Mr. Rowan brought out some combined steam-coaches. About the same time the late Mr. Robert F. Fairlie did a good deal in the same direction; the Belgian engineers also took the matter up, and a number of combined locomotives and carriages were exhibited in 1873 at the Vienna Exhibition. They were introduced then, not so much for intermediate traffic on standard railways as for use on light railways, and he believed many of the engines were still running. These steam-carriages, however, did not take on as they might have been expected to do, and he thought perhaps the real reason of Mr. Adams' and later engineers' want of success was that the combined engines and carriages were used as trains that had to be turned. Mr. Lea had referred (page 688) to the fact that the present engines were run both ways, and that was a very great advantage indeed. All the earlier engines had to be turned on a triangle or a turntable, and that made all the difference with many conditions of traffic. The Paper was one of great value, and he hoped that some of the other locomotive superintendents who were using rail-motor-cars would give the Institution the benefit of their opinions, which he was sure the members would be very glad to hear.

Mr. L. PENDRED inquired whether either the authors or some locomotive engineers, who might speak subsequently in the discussion, could give figures of the cost of running rail-motor-cars, either per ton-mile or per passenger-mile. So far as he had been able to ascertain, he believed the cost was extremely low. The figures given in Table 1 (page 657) referred only to a single railway. He thought the results obtained on other railways would be found valuable and interesting.

Mr. ROBERT H. BURNETT remarked that he had attended the meeting rather to learn something from railway men who had had experience of the working of railway-motor-cars than with the intention of speaking, but having given some time to the study of the question, he would, in response to the Chairman's request, gladly make a few remarks. In looking at the different designs illustrated in the Paper, one feature had struck him, namely, the difference between "single" and coupled engines. This marked difference was apparently due to there being no common ground upon which the designs were based. For instance, one speaker had commented on the advantage of the system because the engine and car were self-contained, and that it was a simple matter, therefore, for the driver to go to the other end of the car and work the vehicle backwards instead of running the engine round the car. That was excellent, but the moment a trailer was added that simplicity was gone, because the engine and car had to run round the trailer, as he did not believe the Board of Trade rules permitted of a train being pushed backwards. That was the first point to be settled; was the design of the locomotive to be suitable for an engine and car in one, or was it to be an engine, with a car attached to it, capable of hauling not only its own car but a train of one or more vehicles in addition? He had known of specifications requiring that the engine should be capable of hauling not only its own car but several other carriages, and on special days a few horse-boxes also. The moment a number of carriages were put behind the car, an ordinary train of more or less weight was at once introduced.

Further, it had been stated that another advantage of the rail-motor-car system was that the motor-cars were suitable for running between the ordinary trains upon suburban lines, and picking up passengers at those stations where it was not worth while for the ordinary trains to stop—that is, in districts where the permanent way was of the usual strong character. But it had also been stated that the system had a great advantage in creating a traffic in outlying districts, which rather implied light railways. If an engine had to be designed for a light railway, the weight upon the driving-wheel must of course be kept down, and in that case it might be necessary to couple the second pair of wheels to get the required adhesion for the rapid starting and acceleration which was so essential in the motor-car system of working. On the other hand, if it was intended to run upon thickly populated suburban lines with strong rails, then the weight upon the driving wheels was of secondary importance, and they could be loaded up to the axle-weight of the ordinary engines running over those parts of the line, and all the adhesion required for rapid starting could be got on a single pair of wheels. Coupling-rods could therefore be very well dispensed with and the utmost simplicity of design attained, thereby ensuring a free and steady-running engine with a minimum of tear and wear. He could not therefore understand why coupling-rods were used in a number of the engines described in the Paper, which would appear to have been designed for lines with amply strong rails.

He desired, in the next place, to make a few remarks with regard to the types of boilers used in the various designs, although he was aware of the danger of criticising designs without full knowledge of the conditions that had determined their adoption. He was therefore not criticising what had been done but only pointing out the differences. He did not quite understand why the boilers of some of the steam rail-motor-cars illustrated were of a different design from the ordinary locomotive type. It seemed to him that, if the ordinary type of boiler was suitable for a big engine, it was quite suitable for a small one, and moreover, it lent itself perfectly well to the conditions. If the boiler was placed forward, it could readily be got at for firing at the back of the box. The boiler shown in

(Mr. Robert H. Burnett.)

Fig. 34 (page 678) was a good example, because the bulk of the weight came upon the front axle; and thus the required adhesion was obtained on a single pair of wheels, which, on account of the simplicity of parts it admitted of, was good engineering practice. But if it were found that, with a boiler of the required size, too great a weight would thereby come upon the front axle, there was no reason why the pivot upon which the front end of the car rested should not be placed backwards towards the second axle, as far as need be to obtain the axle-weights required. The vehicle would go round corners just as well whether the pivot was halfway between the two axles of the engine or nearer the one or the other. That was done in an engine in the design of which he had taken part for the North Staffordshire Railway, and which was repeated in the case of Fig. 34 to which he had already referred. The engine was a "single" engine, with the leading axle as driver, the cylinders being placed backwards towards the trailing axle, and the pivot put nearer that axle than the leading axle. In that way it was enabled to proportion the load upon the axles exactly as was required, and although the engine had no coupling-rods the adhesion was ample. If the figures were worked out for the weight of the engine and car, and with a trailer in addition, accommodating as many passengers as the car itself, it would be found that, with a load not exceeding, say, 12 tons upon the driving axle, the proportion of adhesion weight to the total load the engine had to pull was equal to that of a tank engine of 100 tons, with all its axles coupled, drawing a train of 400 tons inclusive of the weight of the engine. It was therefore, as he had already said, a matter of surprise to him to see coupling-rods used in some of these steam motor-car engines. The engines on the North Staffordshire Railway with their car and a trailer would start from rest and gain a speed of 30 miles an hour in about twenty-five seconds, and at a speed of 40 miles an hour, which they frequently attained between stations, they ran with remarkable freedom and perfect steadiness. He invited engineers who had obtained experience opposite to the views he had expressed to make it clear why coupling-rods were used, because their reciprocating action was harmful in tending to give unsteadiness to the engine at the higher

speeds, and this was communicated to the car. He would not go into the commercial question, because that was a matter for traffic managers to settle, the business of mechanical engineers being to produce the most suitable engine for the purpose required.

Mr. G. H. BURROWS stated that he possessed some data with regard to the Great Western Railway cars which might be of interest to the members. The first two cars were built at Swindon just three years ago, October 1903, to Mr. Churchward's design, and were put to work in the Stroud Valley. The results obtained speedily justified further expenditure, and the Great Western Company had gone on building from that time until the middle of the present year, and now had eighty motor-cars running. Thirty-four of them were 70 feet long, and the majority of the rest were 59 feet 6 inches long. In addition to the motor-cars, thirty-four trailer cars were running, most of which were also 70 feet in length. The original cars were open from end to end, of course excepting the engine room, but the later cars were made a little more elaborate. They had a motor room, smoking and non-smoking compartments, a driver's compartment at the other end, a central vestibule, and a luggage compartment, so that they were fairly elaborate as compared with the first cars. The cars were running on different parts of the system, and on gradients ranging from 1 in 42 (on the Hemerdon Bank just out of Plymouth) to 1 in 100 at other places. The motor-cars and trailer cars were fitted with regulator gear, brake gear and whistle gear at each end, so that they could be run in a shuttle service without turning or running round on a triangle. The cars carried 450 gallons of water, and, without a trailer attached, they ran about 30 miles without taking a fresh supply of water.

A typical service for the cars was that between Chalford and Stonehouse on the main line between Swindon and Gloucester, which was a half-hour service. The actual run was twenty-five minutes, and in that length there were nine stops, which worked out at an average of about three quarters of a mile per stop. The Stroud Valley had an estimated population of 40,000, and, with the exception of Stroud and Stonehouse, the population was fairly well

(Mr. G. H. Burrows.)

distributed. The average run of a motor-car was about 200 miles per day. With nine stops in twenty-five minutes it would be obvious that a fairly high acceleration was necessary, and from an actual test an acceleration of 1.47 feet per second per second, or 30 miles an hour in 30 seconds, was obtained at 60 per cent. cut-off.

Mr. Hughes had referred to the question of the cut-off. The motors on the Great Western were running with 75 per cent. maximum cut-off, and no difficulty was experienced in keeping up the boiler pressure. With regard to maintenance, one of the greatest troubles experienced was due to the bad water used in the boilers; but as the different water-softening plants now being installed came into operation, it was hoped that those troubles would be speedily overcome. Another trouble experienced was due to the frames. The cross-stays on the earlier cars were not stiff enough between the frames. He noticed that a diagram of the car was not given in the Paper, but the engine was similar to Fig. 11 (page 664), having outside cylinders driving on to the trailing coupled-wheel. That arrangement produced a certain racking action between the two frames, and if the cross-stays were not fairly substantial they began to work loose, especially at the cylinder end. To remedy that trouble, stiffer angle-irons and plates were put in, and the trouble was being gradually overcome. The original cars had 3-foot 6-inch driving wheels, and were designed to run about 30 miles an hour. They were, however, speeded up considerably above this, and it was found the engines correspondingly suffered. Later engines have had 4-foot driving wheels. These made a less number of revolutions for the same speed, and the engine was not stressed so much.

With regard to repairs, the boiler was first of all detached from the carrying brackets on the engine frames, and lifted through the roof by an overhead crane; and after that it was an easy matter to run the engine out from underneath the car. That, of course, only happened in the case of heavy repairs, the cars being sent to one of the main depôts, such as Swindon or Wolverhampton, or a dépôt where the necessary facilities were available. Recent developments had been more in the direction of using a separate engine entirely, and running it with a trailer car, or two or three trailer cars as might be necessary.

The trailer cars and the engine were fitted with double regulator gear, so that the engine itself could be driven from the end of the train, as it were, and a shuttle service still be maintained. The motor-car traffic at Plymouth had become very heavy indeed, and one of the latest ideas was to run an ordinary engine with two trailer cars at each end, so that the motor-train was composed of five vehicles. The driver would be at either end of the train, and the fireman would be on the foot-plate to maintain steam.

Mr. Pendred had asked for some figures with regard to the cost of running (page 692). He had no figures of the actual cost of running, but it might be interesting to give the coal-consumption. The coal-consumption in motor-cars on the Great Western Railway for the last six months varied from 13 to 25 lbs. per mile, according to the gradient or load.

Mr. A. DOUGLAS MACKENZIE wished to join issue with Mr. Burnett in the remarks he had made (page 695). The Chairman had asked those members of the Institution who were actually engaged in working rail-motor-cars to endeavour to bring forward as an addition to the Paper reliable figures as to the costs. He was glad to say that the authors themselves had given some valuable figures on page 657, to which he asked the members to turn for a moment. On that page the authors gave the cost per mile of the original system with a small engine and train, and in the last column the cost per mile of steam-cars. The remark had been made in the course of the discussion by Mr. Burnett that mechanical engineers were not concerned with the working costs, but were only asked to produce the best vehicle for the purpose. He ventured to join issue with that statement, and to say that the best vehicle for the purpose was the one which did the work most satisfactorily at the lowest cost. It was, therefore, necessary to know the cost factor before it could be said which was the most satisfactory vehicle. Again, as mechanical engineers, it was no good producing a vehicle which was a curiosity, valuable and ingenious perhaps, but too costly to work. He was aware of a most ingenious road-motor that had been constructed which would ultimately find its way, he hoped, to the South

(Mr. A. Douglas Mackenzie.)

Kensington Museum, but it could never be used in practice because its cost was twenty-five times that of any ordinary vehicle.

He hoped the gentlemen who were concerned with the making of rail-motor-cars on the various railways would collaborate together and give reliable figures of the actual cost per mile of the various systems employed. These should include the self-contained steam-cars of the type illustrated in the Paper, and the independent systems which seemed to be experimented with a great deal, namely, a separate engine and a trailer, or an engine placed between two trailers; and these figures should be compared with the cost of petrol rail-motor-cars and electric autocars. The Great Northern Railway Co. were using a petrol motor-car (which he did not think was illustrated in the Paper), and the London, Brighton and South Coast Railway Co. were also using a similar car. The electric autocar of the North Eastern Railway, Fig. 39 (page 675), had a petrol motor for generating its power, but the transmission was electrical, and it also had accumulators or secondary batteries as part of the transmission system. He thought it would be extremely valuable to place on record in the Proceedings of the Institution the cost per mile of those various systems.

Referring again to Table 1 (page 657), it would be found that the cost for steam-cars came out at 7·74*d.* per mile, and the cost of the original system of a small engine and train at 23·45*d.* What was the difference between the small train and the train which it was stated was being experimented with on the Great Western Railway, consisting of two trailers, an engine, and two other trailers? Probably the only difference was the fact that it did not have to be shunted; but surely the running costs, the costs per mile, could not be very different from those of the original small train. In any case it would be an extremely interesting addition to the Paper if those figures could be furnished.

Mr. MAX. R. LAWRENCE desired to ask the authors for a few more particulars of the motor-cars referred to in the Paper. He was exceedingly interested in the train with the engine in the middle which was worked from each end. It struck him that that system

struck the nail on the head, and that the chief success of rail-motor-cars was due to there being no shunting at the terminal stations. He had been in charge of running sheds on the Midland Railway at Manchester, where that difficulty was very accentuated indeed. For instance, a suburban train ran in, and another engine had to be attached at the other end in order to draw the train in the reverse direction, and that must of necessity increase the cost of locomotive power for such short distances as between Manchester and Stockport and Manchester and Liverpool, 20 and 40-minute runs. Owing to that fact it was necessary to have 20 per cent. more engine power for the same haulage, simply because an engine had to be used at each end of the train. In his opinion the question of economy of fuel did not enter into consideration at all. When such figures were obtained as had just been given of 13 lbs. to the mile, with coal at its present price he did not think it mattered whether it was 13 lbs. or 20 lbs. The wages, capital outlay, and other considerations made the coal cost sink into insignificance.

Mr. E. J. C. MANICO said he had been particularly struck with the ingenuity shown in the various designs of rail-motor-cars. Through the courtesy of Mr. Churchward he had a run on the early cars in the Stroud Valley, and found that they ran very steadily, notwithstanding the rather top-heavy type of boiler used. With a boiler so large in diameter and so high, it was natural to expect some rolling would have taken place on the road at both ends, but he found the car ran most steadily. One point which had struck him was that, when there was a trailer on, and the train was run in the reverse direction, the trailer would be pushed along; and it was a question as to how far that was safe. A speed of 40 miles an hour was attained on the run he made on the Great Western Railway, and the vehicle was if anything steadier at a high speed than at a moderate speed.

Another point of importance was, how did these systems of steam carriages compare with an ordinary train and engine for "dead weight per passenger carried," assuming each to have its full complement of passengers? He would have liked to see a column

(Mr. E. J. C. Manico.)

inserted in page 658 giving the comparison between the different cars on this head. He had for his own satisfaction worked it out on the weights given, and found that it varied from 18 cwt. in the case of the London and North-Western car to 11.4 cwt. in the new Taff Vale car, dead weight per passenger. Now with an ordinary North London train of 18 coaches, carrying 532 passengers, and weighing 114 tons 12 cwt. without the engine, or 164 tons with the engine, it gave only 4.3 cwt. and 6.16 cwt. respectively.

Mr. SIDNEY STONE remarked that one point had occurred to him while listening to Mr. Manico's remarks, namely, that it would be interesting to know whether, when the motor-car was in the middle and one or two trailers were being pushed along, there was any difference in the wear of the tyres at the other end. The action became somewhat different, especially round curves, and he knew that on some railways, where electric traction was used, there was a considerable amount of rail and tyre wear taking place. It would be interesting to know whether it had been found that the pushing of one or more trailers had any effect in that direction.

He noticed in the Paper that there were three different types of boiler mentioned, and it would be very interesting to know their consumption of fuel. He also noticed that Mr. Hughes had done what one of the speakers had advocated, namely, he had put his pivot or his bogie-centre very near the trailing-wheel. The weights were not given, and it had occurred to him that that probably would be taking too much weight off the leading wheel. The question of coupled or single engines had also been raised. A single engine gave certain results, but in the event of very dirty weather he thought it would be found that the coupled engine was very much better. With regard to acceleration, he hoped that Mr. Hughes would give in the Proceedings some results of acceleration on his electric trains compared with motor trains.

Mr. S. B. HASLAM, in reply, thought the members would feel rather disappointed at the absence of electrical engineers from the discussion. Mechanical engineers had been rather looking forward

to hearing some remarks from electrical engineers on the subject, especially as subsequent to the Cardiff Meeting a letter was written to the "Electrical Review," in which somebody, who did not sign his name, discussed "the very narrow-minded way" in which matters electrical were looked at at that Meeting, and who even went so far as to say that locomotive engineers were twenty years too late in bringing the motor-car forward. In view of that fact he had hoped that several electrical engineers would have joined in the discussion.

Mr. Aspinall at the Cardiff Meeting made several remarks on the subject of regenerative control (page 679), but he (Mr. Haslam) did not think that the gradients met with in railway work were sufficient to overcome the braking effect of the regenerative control, and he did not think it was applicable to railway work. With reference to the costs, Mr. Aspinall also called attention to the small mileage given in the comparative costs, Table 1 (page 657). The costs in the Table were got out when the Taff Vale Railway were first considering the matter, and that only in its application to a very small branch of about five miles long with extremely sparse traffic. The question of motor-car traffic was really started with the idea of tackling sparse traffic more than congested traffic. The reason also that more costs had not been given in the Paper was because they had not been supplied by the railway engineers, and the authors thought it was better to leave them out altogether unless they could be given fully. He believed the average cost of actual running would work out at 5*d.* or 6*d.* per train-mile, not of course allowing for the interest on the first cost, which brought the figure up considerably.

With reference to Mr. Lea's remarks about the various differences in construction (page 685), he thought the superintendents themselves, and their various ideas on the matter and the conditions which had to be contended with, were chiefly responsible for that state of affairs. Mr. Lea also called attention to the easy detachment of the engine from the carriage, and stated that that would simplify matters in first cost, as a greater number of engines could be ordered compared with the car-bodies. In the latest order placed by the Taff Vale Railway Company, 100 per cent. more engines were

(Mr. S. B. Haslam.)

ordered than car-bodies, because of the extra wear they had to bear.

The question of separate small engines and coaches was very interesting, but it was not motor-car traffic, because if separate engines were used, trailers run behind, and the various means of shunting were discussed, they might just as well have a train and not call it a motor-car, because in fact it was only a small train. Trailers had to be used and had to be kept in stock because sudden rushes might be obtained at certain times, and then it was not a difficult matter for trailers to run on the one journey. For instance, coming in from the suburbs into the town in the early morning, a trailer could be put on to the train, could be left at the town when it arrived there, and go back again in the evening when the rush came on again, so that the shunting difficulties would only apply on one or two occasions, as a trailer would not always be used.

The CHAIRMAN thought, from the enquiries that had been made by various speakers, there were very many points on which the members would like to have further information. This was a progressive world, and he was glad to say that even since the Cardiff Meeting the authors had learned something, and they would be very pleased to embody all the up-to-date information they had obtained in the amplified reply.

Mr. WILLIAM H. MAW, Past-President, said he would be very pleased to perform the duty which the Chairman felt he could not do, namely, propose a very hearty vote of thanks to the authors for their Paper.

The resolution of thanks was carried by acclamation.

The CHAIRMAN, on behalf of Mr. Haslam and himself, thanked the members for their hearty vote of thanks.

Communications.

Mr. ROBERT GUEST wrote that the Isle of Wight Central Railway had introduced a steam railway-motor-car to work on a branch line $6\frac{3}{4}$ miles in length, on an average gradient of 1 in 90 up for the first $4\frac{1}{2}$ miles, and a slightly easier average down for the last $2\frac{1}{4}$ miles. The weight in working order of the combined vehicle was 32 tons, and the length over all 61 feet. On the little running already done he had found the consumption of coal to work out a trifle over 16 lbs. per mile, using Nixon's Navigation coal. One noticeable feature in the running had been the absolute immunity from vibration of the engine being felt in the coach portion. This, no doubt, was due to the engine and coach frames being separate, and to the large indiarubber washer which encircled the engine bogie-pin. Another feature he noticed was that, when sitting in the second-class compartment, and close up to the engine, any loose rail joints or rail subsidences were very apparent but became less as seats were taken further back, until at the far end of this compartment from the engine, and also in the first-class portion at the hind end of the car, this motion was not noticeable. It was no doubt carried through on the channels of the coach underframe which were carried forward and held the engine bogie-pin, as the rocking on the engine foot-plate through the short wheel-base was rather pronounced.

Mr. E. A. HEATH wrote that he considered it was not a question of railway-motor-cars or electric traction, but railway-motor-cars or continuance of the existing service on railways in many instances where branch lines and sparsely populated districts were concerned, because, as the author said, the initial cost in many cases would be too great and the traffic would not warrant such expenditure. He was not questioning electric traction for suburban lines, where there was large passenger traffic during some hours of the day that required a quick and frequent service; in that case he considered that railway directors would be justified in electrifying their line, if capital could be found. The Lancashire and Yorkshire Railway had electrified

(Mr. E. A. Heath.)

their line from Liverpool to Southport, and it had benefited both shareholders and passengers. Railway-motor-cars had supplied a long-felt want, and the companies could have had the traffic long ago, had they considered it worth catering for; but they had to feel the severe competition from tramway companies before they would try something different than a locomotive with four or five carriages to supply the wants of the public situated 5 or 6 miles from a town. Now it was being proved that a good return could be made on small amounts invested in railway motor-cars, by catering for the sparsely populated districts and giving them a frequent and fairly fast service, and short distance stages. Moreover this had been the means of creating traffic at line crossings, which would otherwise be lost and probably go to swell the returns of some tramway company.

Mr. LACEY R. JOHNSON wrote, giving particulars of the recent experience with the Canadian Pacific Railway motor-car illustrated on Fig. 18 (page 665). The capacity of the car was now 56 passengers instead of 52; and, although the motor was built originally with 10-inch by 15-inch cylinders which were bushed, they had since taken the bushes out, leaving the cylinders 11 inches by 15 inches. In regard to the weight on the bogies, 36.6 tons were carried on the motor journals, and 24.1 tons on the rear truck of the car, making a total of 60.7 tons. With regard to the total heating surface of boiler, it was only 530 square feet instead of 600 square feet. The water-carrying capacity of tanks under the car was 900 Imperial gallons instead of 750, and the tractive force, instead of being 2,500 lbs., should be 6,000 lbs. The working pressure of the boiler, which was easily maintained in service was 180 lbs. instead of 160 lbs.

The car had now been in service during the whole of this summer, running between Montreal and St. Annes, a distance of about 20 miles, and giving three round trips per day with fairly good satisfaction to the railway company, and great satisfaction to the passengers carried. From a passenger standpoint, the absence of smoke and cinders, which usually accompanied the steam locomotive,

FIG. 43. *Canadian Pacific Railway. Steam-Motor-Car, No. 88. Profile and Speed Chart. 3 Nov. 1906.*

Average Speed:—Westmount to St. Annes 30.3 m.p.h. (Figures denote Gradients in 100.)

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(Mr. Lacey R. Johnson.)

were eliminated, consequently the passengers could make continuous trips without soiling their hands or their clothes, and in hot weather it was possible to have the windows of the car open without it being filled with cinders and smoke.

The general design, both of the motor and the car, has been found very satisfactory, and in order to save the trouble of turning the car at each end of the trip, a conductor's compartment was fitted at the opposite end of the car to the motor, in which was fitted one of Chadburn's marine telegraphs for communicating to the engineer instructions whether to "go ahead," "back up," "full speed," "half speed," or "stop." There was also in this compartment an operating valve for applying the air-brake of the "Westinghouse" automatic type. The conductor also had connection with the whistle, so that, outside of the mere manipulation of the motor itself, he could control its running when backing up. There was also a bell fitted on the rear platform of the car operated by an air-motor, so that warning could be given on approaching level crossings, or when starting the car from a platform.

The writer noticed that the Paper was confined almost entirely to a description of the various cars used on different railways in different parts of the world, and the question of performance had not been gone into, except in a very general way. He thought, therefore, that some of the figures connected with the performance of the Canadian Pacific Railway car might be interesting to the members. For instance, crude oil was used as fuel, burnt, as shown in the Paper, in a brick-lined "Morrison" furnace by the use of a burner, designed in their own office, of the "Booth" type, having about a 1-inch slot. When they first commenced to operate the car, 1.8 Imperial gallons of oil were consumed per mile, but, since the men had gained experience in the handling of the machinery, the consumption had been reduced to 1.6 Imperial gallons per mile, and it was found that 5,000 lbs. of water were evaporated per hour, giving a factor of 1 lb. of oil to 10 lbs. of water. The oil was carried in a tank formed in the main framing of the motor, which had a capacity of 200 Imperial gallons. This oil was carried under a pressure of 15 lbs. per square inch, and was heated on its

passage to the burner, which increased the rate of combustion considerably over using it at its normal temperature straight from the tank.

As already stated, the boiler was worked at 180 lbs. per square inch, and this steam was superheated by passing through coils of pipe, having a heating surface of 62 square feet, in the combustion chamber of the boiler, to an actual temperature of 600° F. Of course, there had been troubles and difficulties in the operating of this car, before they got it to its present state of efficiency, but they were all minor mechanical defects in the least looked-for places. The first trouble was caused by the heating of the journals which were originally 8 inches by 8½ inches, but they had since been increased to 8 inches by 12 inches, which cured that trouble. The next difficulty encountered was, the keeping of the fire-brick structure in the furnace to its proper shape, owing to the jar while running over the road, and that had been got over by having bricks made the proper shape, instead of using the ordinary fire-brick. Then again, they had a great deal of trouble in keeping the joints of the superheater headers tight, under the high temperatures encountered in the combustion chamber, which ran up to 1,100° F. This had been entirely removed by building up asbestos cement round the headers and joints, and now he thought they had a car of which they could be proud. Fig. 43 (page 705) showed the profile of the road between Montreal and St. Annes, and also a speed chart taken during actual running on schedule time.

Mr. W. F. PETTIGREW wrote sending a photograph of the railway-motor-car, with trailer, Fig. 44, Plate 80, recently designed by himself and built for the Furness Railway at the Company's Works at Barrow-in-Furness, with a view to the economical working of the passenger service on the Windermere and Coniston Branches on the Furness Railway. On the Coniston Branch, Broughton Station is on a gradient of 1 in 49, and the car was required to start from rest on this gradient; as it was intended to run a trailer repeatedly, in addition to another carriage or horse-box when required, it was necessary to have a car of some power. The seating capacity is for

(Mr. W. F. Pettigrew.)

12 first-class and 36 third-class passengers, a luggage compartment also being provided. Transverse seats have been arranged in both compartments, the first-class being upholstered in moquette and the third-class in rattan, the whole being electrically lighted and heated with steam throughout. The car-body is framed in teak with clerestory roof, whilst the engine compartment is built entirely of mild steel sheets and angles, panelled to correspond with the other portion of the carriage-body. The underframe is also built of steel channels throughout, carried on one end by a standard carriage bogie, the other end being pivoted at the centre of the engine bogie. The total length of the car over buffers is 60 feet 11 inches, distance between centres of bogies 40 feet, and the total wheel-base 48 feet.

The cylinders of the engine are 11 inches diameter, with a stroke of 14 inches, operated by means of the Walschaerts valve-gear, with wheels 2 feet 10 inches diameter.

Steam is generated by means of a locomotive type of boiler, having a working pressure of 160 lbs. per square inch, which is placed with the fire-box to the front end, giving a clear look-out for the driver. The tank has a capacity of 500 gallons and is placed on the engine bogie over the driving wheels, whilst the coal is carried in the motor compartment. Provision has been made for controlling the steam throttle-valve, vacuum, steam and hand-brakes, and whistle from either end of the coach. The cost of running works out at less than 50 per cent. of running the ordinary engine and train of three or four carriages. The heating surface per 1,000 cubic feet of piston displacement in 35 miles is 15.5, and the heating surface per passenger is 10.6.

Mr. E. E. TASKER wrote that there were a few points to which he would like to refer more particularly when regarded from the electrical engineer's standpoint, and in this connection he felt it would add materially to the value of the Paper if additional figures and information—embodying quite up-to-date practice of a typical electrical equipment—could be furnished as a supplementary note to the particulars already given. He would refer to page 651, wherein it

was stated that generally the electrical equipment and operation of branch and main lines would result in a loss to the railway company, and he agreed with this in so far as main lines *in this country* were concerned, since the initial expenditure to equip the lines electrically would be a heavy item, and the saving in fuel consumption to be attained by this method of propulsion would not compensate for such a heavy outlay. This was brought about by the good and comparatively cheap supply of coal that could be obtained, and also to the fact that water-power was not available in sufficiently large quantities to be utilised effectively; on the other hand, in other countries where coal, oil, or equivalent fuels were expensive or of poor quality and water-power was available, the aspect of the case was entirely different.

As bearing on the question of main-line conversion to electric working, he would like to point out that the Valtellina line, 67 miles in length, was more or less an experiment to ascertain whether it was desirable to convert to electric working the railway system of Northern Italy; moreover, on the particular part covered by this scheme the chief problems and difficulties to be dealt with in main-line working were in evidence. Further, he believed this portion of the line was less remunerative than many others in that part of the country, and if he remembered rightly, the total receipts per train-mile (about half from goods and half from passengers) were about 3s. 4d.* He would be glad if the authors could give some results as to the cost of working, together with the profits—if any—that had been made by this line during recent periods. It appeared to the writer

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* Since writing the above, he (Mr. Tasker) had received from Messrs. Ganz and Co. the following particulars in relation to the cost of equipment and upkeep of the Valtellina line:—

(1) For the overhead conductors, including material and labour, the initial cost per mile of single track varied between £530 and £800, depending upon the precise local conditions met with during erection, and also as to whether wooden or iron poles were used.

(2) The working costs of the electrical portion of the rolling stock and line were (a) upkeep of line per mile per annum, £22, and (b) upkeep and renewals of rolling stock 0·690d. per locomotive-mile per annum.

(Mr. E. E. Tasker.)

that with the average receipts per train-mile in this country so very much greater than the figure already mentioned, the question of branch lines working by electrical methods was one of the problems that had to be faced in the near future, these branches acting more as feeders for the main lines and partaking of the nature of a light railway or tramway service. Owing to the number of electrical power companies that were springing up in various parts of the country (and with modern transmission methods and the high efficiency obtained), there would in a great many instances be available for the railway company a cheap and effective supply of energy for the working of their branch and local lines. He recognised that there were many instances where the steam-car was the best and proper solution of the problem of branch-line working, and the most economical, taking into account the nature of the service requirements and local conditions.

He gathered that the figures given in the Paper were collected during 1903, but since that time the price of electrical machinery had been lowered considerably, and the single-phase motor for traction work had been satisfactorily developed. It would be exceedingly interesting therefore if the authors could give the initial cost and also the working costs per mile on a modern basis, as such up-to-date figures would form a most excellent comparison and valuable addition to the Paper. If the branch lines were going to be equipped electrically, it was undoubtedly to the single-phase motor that one must look for assistance in carrying this through.

In the various electrical systems mentioned in the Paper, there was no reference to the cost of working by alternating currents, and he would like to ask the authors whether they went carefully into such a scheme, and if they could give some figures indicating the initial costs and upkeep of an installation of this nature. At the present time there were several lines either completed or in course of construction both on the Continent and in America.

Reference was made (page 656) to the necessity of furnishing electrically-propelled cars with mechanical brakes; he thought all engineers were agreed that such brakes formed a necessary part of the equipment. In the first place, with modern designs of motors

their output was fixed by the heating limit (and not by sparking due to heavy overloads), and for this reason, if the motors were to be used as generators for the purpose of braking the train, they would obviously have to be larger in their proportions, and consequently heavier. On the other hand, the motors could always be arranged to be used in cases of emergency for braking purposes, and in this respect had advantages over the steam equipment, since their retarding effort was uniform through a complete revolution. With an electrically-equipped car, usually the whole car weight was utilised effectively for retardation—assuming the motors were used as brakes—whereas with a steam equipment, as those illustrated in the Paper, the weight on one end of the car only was available for this purpose. Another element which had made necessary the adoption of mechanical brakes on electrically-propelled cars was the desirability of sometimes adding trailer cars to them, and the mechanical brakes were consequently a necessity for controlling the trailer as well as the motor-car.

With regard to Table 1 (page 657), he would ask if the authors would furnish an analysis of the amounts under heading "maintenance, wages, &c.," as it appeared to him that with this information the merits or otherwise of the various systems enumerated could be more easily ascertained. In this connection he would like to know if the figures under heading "third-rail system" were based on a 500-volt continuous current supply, and how much of the £680 referred to as maintenance, &c., was apportioned to (a) wages; (b) maintenance of car; (c) maintenance of track. Again, in regard to the items of £7,136 for preparing track, did this include copper bonding of the return rails? He referred to this more particularly, as with an alternating system, with moderately high pressure *on an overhead line*, the rails might be used as return with a very small expenditure for copper bonds, since, by grinding the surface of the rails at the fish-plate and the contact surface of the fish-plates themselves, a good electrical conducting joint could be made by the use of a special form of plastic material covering the two ground faces.

Referring to Table 3 (pages 676-677), he was sorry to see that the City and South London (the pioneer "tube" line) had been

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omitted. Besides being of historical interest, it possessed an unusual feature in connection with the transmission of energy by high-tension continuous-current, and the over-all efficiency of the system was very high. In respect to the Burgdorf-Thun Railway (the last on the list), while it was true the generating pressure was 4,000 volts, he would point out that this was stepped up to 16,000 volts for transmission purposes. The energy for working the line was derived from the Kanderwerk power-house situated about 10 miles from Thun, where the Kander falls into the Lake of Thun. This line was of interest, as it was constructed more for every-day traffic and did not depend upon a busy holiday season like the Gornergratt, Jungfrau, and other mountain railways.

On page 662 the authors indicated the acceleration of the Taff Vale Railway cars, and he would ask whether such a rate caused discomfort to the passengers due to the uneven turning moment of the propelling engine—that is to say, was not the speed obtained by a series of impulses, each causing a lurch, to the discomfort of the passengers? This feature was very noticeable on some of the carriages near the engine on certain lines with a train composed of several coaches, and it seemed to the writer that the effect would be more pronounced and intense in the motor-cars where the engine formed an integral part of the coach. The authors pointed out that, by adopting motor-cars such as those referred to in the Paper, frequent stops could be made to pick up passengers and merchandise; the more frequent the stops became the nearer the conditions approached those of a tramway or suburban railway service, and the question of quick acceleration became one of paramount importance. It was well known that, provided the acceleration was uniform, a much higher rate than the mean of that given (*i.e.* 30 miles per hour in 32 seconds) could be withstood by the passengers without discomfort, and in this respect an electrical equipment gave ideal results. Would the authors state what *maximum* acceleration was given by the Taff Vale or any other cars referred to in the Paper, and whether the acceleration was imparted to the car by impulses as suggested above,

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Messrs. RICHES and HASLAM wrote, in further reply to the Discussion, that in dealing with the remarks made by Mr. Aspinall at the Cardiff Meeting, the first point not answered, but requiring an answer, was with regard to the mileage (page 680). This small total, namely, 11,000 miles per annum, was that required to be covered on the small section of line, sparsely populated, in connection with which the Taff Vale Railway made their first experiments. With regard to this, it might be stated that the mileage now run by the Taff Vale Railway cars was about 360,000 miles per annum. The same reason might be given for the figure of 1*d.* per unit quoted as the price for electric current taken from a supply company. Mr. Aspinall also referred to the remarks with reference to the voltage of the Liverpool and Southport Railway (page 670), and seemed to think that the wording might lead to a misconception, but on reference to the paragraph it would be found that the words "high-tension *transmission*" were used, and in the data on page 676 it would be seen that the pressure used in the motors was given at 600 volts. Mr. Aspinall also called attention to the practice of the Lancashire and Yorkshire Railway of having steps which could be let down and pulled up at level crossings, etc., and which, when down, by a valve operation applied the brake. This was of course a good idea, but in the opinion of the authors it was better to build small platforms at the various stopping places, both for saving time and as a safety precaution. Level crossings should be avoided when possible.

With reference to Mr. Henry Lea's remarks on the discrepancies in the various types of motor-cars (page 683), and the extremely interesting Table he had compiled on heating surfaces per piston-displacement and per passenger, these, as was pointed out, were due to the different conditions pertaining to the traffic, and to the locomotive engineers' different ideas as to dealing with this traffic under these conditions. In the process of time practice would undoubtedly

(Messrs. Riches and Haslam.)

become more uniform, but at present these motor-cars were barely out of the experimental stage, and alterations and improvements were bound to follow each other, especially with regard to boilers. With reference to the acceleration, since the Paper was written the Taff Vale Railway had endeavoured to carry out some minute experiments with regard to this question, and the results would be given later.

In the remarks of Mr. George Hughes (page 686) a misconception might be arrived at. Mr. Hughes remarked that "In Mr. Riches' cars the electric light was installed, but in those designed by himself incandescent gas-light was adopted." This presumably meant that in the two cars Mr. Hughes had built to Mr. Riches' design, the electric light was installed, as in all Mr. Riches' cars Pintsch's system of oil-gas was used.

The authors wished to thank Mr. Maw for his interesting information with regard to the late Mr. W. Bridges Adams, and also Mr. Aspinall with regard to Mr. Alexander McDonnell. It was only fair to these pioneers that their connection with the subject should be mentioned in a Paper which was more or less a historical résumé of that subject. That the facts were not fully known to the authors on this matter was the only reason they were not mentioned.

With reference to the remarks of Mr. Robert H. Burnett (page 692), the Board of Trade rules did not object to a train, as he mentioned, being pushed backwards, but the engine must be actuated and controlled from the extreme front. Mr. Burnett mentioned that he had information of specifications requiring that the engine should be capable of hauling not only its own car, but several other carriages, and on special days a few horse-boxes. To the authors this did not appear to come under the subject of Railway-Motor-Car Traffic. His remarks on the subject of coupled or single-driving wheels were of course in accordance with established practice.

Dealing with Mr. Mackenzie's request (page 698) for reliable figures as to the actual cost per mile of various systems employed, owing to several railways not furnishing these particulars they were not given in the Paper, but an average had been taken from four or five railway companies who did submit these costs, and they were here given:—

COSTS PER MILE.					Pence per mile.
Running :					
Engine, coal and water	.	.	.	.	1·86
Oil and stores	.	.	.	.	0·24
Repairs and Renewals :					
Engine	.	.	.	.	1·026
Carriage	.	.	.	.	0·6
Cleaning	.	.	.	.	0·266
Wages :					
Engineman	.	.	.	.	1·486
Conductor	.	.	.	.	0·586
Total					<u>6·064</u>

It was obviously impossible, in a Paper or reply like this, to give the enormous amount of information Mr. Mackenzie asked for, as to the various systems; and while the authors agreed that it would be valuable to place on record in the Proceedings of the Institution the cost per mile of all these systems, they did not think that this communication was the place for it. Mr. Lawrence was chiefly interested in the train with the engine in the middle, worked from each end, but this, the authors thought, appeared out of place in a Paper on Railway-Motor-Car Traffic.

Mr. E. J. Manico wished to know how the systems of self-contained cars compared with a short train and engine, as previously used, for dead weight per passenger carried. Taking the train as consisting of locomotive and three coaches, weighing 82 tons 10 cwt. and having accommodation for 136 passengers, and the motor-car as averaging 54 passengers with a weight of 40 tons, the following figures would be obtained:—

Dead Weight per Passenger.		
	Full.	Empty, i.e. one passenger.
	cwt.	cwt.
Motor	14·82	800
Train	12·15	1650

(Messrs. Riches and Haslam.)

The full comparison was shown graphically by means of the accompanying curves, Fig. 45. The first showed the dead weights from 1 to 136 passengers in the case of the train, and from 1 to 54 passengers in the case of the car. The second was an enlargement of the curves taking 10 passengers as a minimum.

Mr. Sidney Stone wished to have figures as to fuel-consumption of the different types of boilers, but there would be little variation

FIG. 45.—Comparison of Dead Weight per Passenger in a Short Train and a Motor-Car.

in this, the difference in types being accounted for by the different requirements of the lines, while the fuel-consumption depended chiefly on the work done. The question of coupling, with regard to the position of the pivot or bogie-centre, depended also on the nature of the work. If the necessary adhesion could be got from one pair of wheels it was, of course, preferable, but if not, it was necessary to couple, and the pivot must be arranged to adjust weights for the various considerations.

The authors welcomed the contribution of Mr. Tasker (page 708), but regretted that they were not in a position to open up the whole matter again, and supply as full information in regard to present-day installation expenses, as they would like. This information would not be quite compatible with the ideas of the Paper, as the Paper had a statement of the facts as to why steam-cars were adopted in preference to electric-cars on the Taff Vale Railway, and immediate experience of the authors with reference to this. The authors would, however, state that every scheme which electrical manufacturers could suggest or lay before them was considered, and the questions of single-phase alternating high-tension and low-tension transmission were all given due consideration.

With reference to Mr. Tasker's request for costs of working and profits—if any—of the Valtellina Electric Railway, he would find all the information he might require in the "Engineering Review" of 9th December 1905, page 463. An analysis was furnished of the various amounts under maintenance, wages, etc., as desired, though it must be understood that these costs were averaged out, and must not be taken as being definite costs appertaining to any one railway. These costs were previously given in replying to Mr. Mackenzie (page 715).

With reference to Mr. Tasker's remarks as to making a good electrical conducting joint as against copper bonding, in the opinion of the authors this was not an ideal system for railway work where a certain number of heavy goods trains were also to pass over the system; and the cost of relaying rails when necessary would of course be proportionately greater than if it were merely a question of transferring the copper bond from one rail to another. The figures given with reference to the expenses of electrical installation were the best quoted by leading manufacturers and contractors.

Regarding the question as to discomfort, up to an acceleration of 40 miles an hour in 30 seconds, none whatever had been felt by the passengers owing to the uneven turning moment, and if the engine were properly balanced there should be no discomfort at even higher speeds. In the opinion of the authors the discomfort noticed by Mr. Tasker on certain lines was probably due to an unsatisfactory draw-gear.

(Messrs. Riches and Haslam.)

Mr. Lacey Johnson had communicated two separate lots of information, showing that he has made some alteration since his first communication, and the authors had pleasure in seeing his latest results.

In reference to further points raised in the discussion, the authors were now able to include two diagrams, Plates 80*a* and 80*b*, showing the speeds at which the railway-motor-cars ran over the two sections of the Taff Vale Railway. These would enable the Members to compare the speed and acceleration at every part of the two journeys.

Fig. 3. *Taff Vale Railway. Old Car, 1904.* Fig. 4. *Taff Vale Railway. New Car, 1906.* *Mechanical Engineers 1906.*

Fig. 5. Front End and Boiler of Taff Vale Railway Car.

Cylinders, 10 $\frac{1}{2}$ in. by 14 in.
Wheels, 3 ft. 6 in. and 2 ft. 10 in. diam.

464 Tubes.
1 $\frac{1}{2}$ in. outside diam.

Fig. 6. Boiler for Taff Vale Railway Car.

Heating Surface:—	Tubes, 414.21 square feet.
	Fire-box, 50.63 " "
	Total 464.84 " "

Fig. 7. Great North of Scotland Ry. Details of Boiler (see Plate 73).

Great North of Scotland Railway.

Fig. 8. Boiler (Cochran) for Steam Car.

Fig. 9. Well Grate of above Boiler.

Cross Section.

Diam. 6ft. 0in. Height, 9ft. 3in.
Heating Surface, 500 square feet.
Grate Area, 9 square feet.
Working Pressure, 150lbs. per sq. in.
Tubes, 294. 1½ in. diam.

Central South African Railway.

Fig. 10. Vertical Multitubular Boiler (Cochran) for Steam Car.
Long. Section.

Cross Section.

Fig. 13. Great S. and W. Railway of Ireland.

Cylinders, 8 $\frac{1}{2}$ in. by 12 in. 333 Tubes, 1 $\frac{1}{2}$ in. outside diam.

Heating Surface:—Tubes, 551.6 sq. ft. Fire-box, 41.4 sq. ft. Total, 393 sq. ft.

Bogie Centres, 35 ft. 0 in. Over Buffers, 54 ft. 0 in.

Figs. 14, 15 and 16. L. & N. W. Railway.
Steam Car, driven from either end. (See Plate 75.)

Boiler in position
on Engine Truck.

View of Hind End of Car, showing wheel
for working regulator when this end leads.

Fig. 15.

Mechanical Engineers 1906.

Particulars of Valve Gear.
Travel of Valves, 2½ ins. Lap, ½ in. Lead, ½ in. Inside Clearance, Nil.

Throw of Eccentric, 1½ in.
Angle of Advance, 13°.

Water Capacity:—Engine, 268 galls. Car, 187 galls. Total, 455 galls.
Coal " :—16 cwts.

Fig. 16. Boiler and Pivot for L. & N.W. Ry. Car.

Heating Surface:—Fire-box, 41.77 sq. ft. Tubes, 275.50 sq. ft. Total, 317.27 sq. ft. Grate area, 6.38 sq. ft.

Fig. 20. N. E. Ry.

Figs. 23, 24 and 25. N.W. of India.

Fig. 24.

Details of Boiler

(see Plate 77).

Fig. 25. *Boiler for N.W. of India Car.*

Fig. 26. G. N. Ry. (See Fig. 27 in letterpress).

Fig. 28. Later Car. G. N. Ry.

Figs. 29 & 30.

Vesterias Ry., Stockholm.

Fig. 32. L. & S. W. Ry. To seat 40 Passengers.

Fig. 37. Boiler for L. & Y. Railway Car.

(Photos, see Plate 80.)

Plate 79.

Heating Surface :—Tubes, 455 sq. ft. Fire-box, 54 sq. ft. Total, 509 sq. ft.
Grate area, 9.4 sq. ft. Water capacity, 550 gallons. Coal, 1 ton.

(Mr. George Hughes' remarks.)

Figs. 40, 41 and 42. *L. & Y. Ry.* (For Details, see Plate 79.)

Fig. 41.

Fig. 42.

(Mr. W. F. Pettigrew's communication.)

Fig. 44. *Furness Railway.*

To seat 12 First and 36 Third-Class Passengers.

Cyls., 11 in. by 14 in. Wheels, 2 ft. 10 in. diameter.

Heating Surface:—Tubes, 438.4 sq. ft. Fire-box, 71.0 sq. ft. Total, 509.4 sq. ft.
 226 Steel Tubes. $1\frac{3}{4}$ in. ext. diam. $2\frac{1}{2}$ in. pitch. Grate area, 12 sq. ft.

Water, 300 galls. Coal, 15 cwt. Working Pressure, 160 lbs. per sq. inch.

(Authors' reply.)

Fig. 46. Taff Vale Ry. Steam-Car (Fig. 2, p. 654). To seat 73 persons.
Speed Chart, Pontypridd to Cardiff.

Speed Chart, Cardiff (Queen Street) to Cadoxton.

Continued from above