ON BROWN'S TRAMWAY LOCOMOTIVE.

BY MR. B. C. BROWNE, OF NEWCASTLE-ON-TYNE.

The conditions that are required to be fulfilled in a Tramway Locomotive over and above those of an ordinary locomotive are tolerably well recognised, and may be enumerated as follows :—

(a) There must be no visible smoke or steam, no visible fire, no noise of either blast or machinery, and no visible working parts. The object of all these restrictions is to avoid frightening horses or annoying the public.

(b) The engine must work both ways, the driver being always in a commanding position ; it must be able to exert great power for starting and stopping on steep inclines, and must both start and stop very easily ; it must run round sharp curves, and adapt itself to any inequalities in the road ; its working parts must be readily accessible and easily repaired ; its firing and feeding must need no attention while it is running ; lastly, it must be worked of course by one man. These are matters of practice and economy.

(c) The Board of Trade requires beyond these a speed indicator always visible to the driver, a governor, and a bell or whistle for signalling.

The writer, having carefully considered these conditions, came to the conclusion that among existing engines they were best and most economically met by the engine of Mr. Charles Brown of Winterthur, mention of which has already been made in M. Mallet's paper read before the Institution in Paris, in June 1878. This engine has worked regularly in Geneva since the summer of 1877 ; in Milan since the beginning of 1878 ; in Hamburg and Strasburg since the summer of 1878 ; in Paris since the autumn of 1878 ; in Rome and Tivoli since June 1879 ; in Ribeauville since August 1879 ; in Florence and Cuneo

Dronero since November 1879. In addition to the above places where the engines are in regular work, they have been, or are, running on probation at Lisbon, Oporto, Turin, Brussels, Berlin, Cologne, Madrid, Milan, Monza, Villa Regoa, and Villa Reale (Portugal). In most of the above places the consequence of these experiments has been that the question of steam traction versus animal traction has been decided in favour of the former; but the carrying of this decision into execution has been frequently impeded by the conditions imposed by the local authorities, or by financial difficulties.

I. *Description of the Engine* (Plates 1, 2, and 3).—The leading principle of this engine is that of working with very high pressure (220 lbs. per sq. in.). The boiler (Figs. 2 and 3) consists of a vertical cylinder A, containing the fire-box in its lower part. To this is riveted, opposite the fire-door, a horizontal barrel B with tubes, like that of an ordinary locomotive; this barrel is entirely below the water-level. The whole is made of steel, carefully selected and tested. The grate C is steeply inclined downwards from the fire-door, so as to increase its area and efficiency; and there is a drop-bar D at the bottom for letting down the fire. The ash-pan is provided with an ordinary door for regulating the draught. Owing to the height of the outer fire-box, there is a very great range of water-level (about 20 inches). Hence the driver need never attend to his fire or feed his boiler during the longest run usual on tramways.

The cylinders E are horizontal and above the foot-plate, the steam chest being below the cylinders, by which arrangement they are always kept clear of water. There is a great range of expansion. With valve-gear of the proportions indicated in Figs. 4 and 5, the distribution of steam is as shown in the Table annexed, the distances being expressed in percentage of the stroke of piston. The lead is constant at $\frac{3}{32}$ in.

	Admission.		Release before end of stroke.		Compression.	
	Fore. Per cent.	Back. Per cent.	Fore. Per cent.	Back. Per cent.	Fore. Per cent.	Back. Per cent.
Forwards	76	80	7	4	6	9
	67	67	10	7	10	14
	49	47	16	14	20	21
	26	24	27	26½	34½	34
Stop	7	7½	44	42½	53	53
Backwards	21	22	29	27	35	36
	47	50	16	14	19	22
	66	70	9	8½	12	13
	78	80	5	5	7	7

In the engine shown the cylinders are $5\frac{1}{2}$ in. diameter and $11\frac{3}{4}$ in. stroke. Each piston-rod works a rocking beam F, Fig. 1, which, by means of a connecting-rod G at the other end, transmits the movement to the driving wheels, and thence by ordinary coupling-rods to the leading wheels. All the pin-ends, lubricating holes &c., are carefully covered to keep out the dust. The valve-gear (described more fully below) is of a very simple description, entirely avoiding eccentrics, links, or other sliding motions, so objectionable on account of dust, mud &c. The rocking beams on each side, and the other working parts, balance each other without the need of balance-weights on the wheels. The motion of the engine is thus made very smooth, and free from oscillation or "galloping"—a very essential point with a short wheel-base.

The whole of the working parts, as well as the boiler, are so arranged as to be readily accessible for both cleaning and repairs. Everything is made as light and strong as possible, and both steel and phosphor-bronze are largely used. The position of the cylinders is very convenient, and very well sheltered from dust and dirt.

The hind axles support the weight of the engine by springs in the ordinary way; but the front axle has two sets of volute springs H, Figs. 2 and 3, placed together in the centre, so that the engine is practically supported on three points. On these springs the front axle has free play; and as side-play is also given to the axle-boxes, which are united by a frame, the engine runs very smoothly, while the four wheels all take a bearing on the roughest roads. The wheels are from 24 in. up to 28 in. diameter, according to the character of the line.

The water-tanks are placed between the frames. There is one I, Fig. 2, for the feed-water, which holds about 110 gallons; and a small one J for the condensed steam, holding about 30 gallons. The mode of disposing of the exhaust steam is as follows. The cylinders are fixed on the two ends of a cast-iron box K, which forms a support for the bottom of the smoke-box; into this the steam is exhausted, and in many cases is passed from thence direct into the chimney, into which it flows in an almost continuous noiseless stream. The chimney is very large, and has interior smaller chimneys of gradually increasing diameter. But if a condenser is required, which probably will almost always be the case in towns, the steam ascends to a layer of copper pipes L, which are arranged over the roof and kept cool by the air passing between them. The condensed steam flows down to the small tank J, which can be emptied at any convenient place at the end of the run or elsewhere. It is not allowed to mix with the feed-water, on account of the dirt and oil that would then get into and injure the boiler.

In Paris these engines have no condenser, and in Germany they sometimes have and sometimes have not; but in England the condenser will probably be always an absolute necessity.

The brakes are worked by hand, and are very strong; but in future all engines will be fitted with steam brakes. There is a pump and an injector for feeding, and the ordinary arrangement of sand-boxes. All the handles are arranged in duplicate, so that the engine can be worked equally well from either end. The driver always stands full in front. The engine is handled easily by one man, wherever the local authorities allow it; and practice has

proved that one man is sufficient. The couplings are central, and arranged to push and pull. When the engine runs against the car, the couplings come together, the driver drops in the coupling-pin from where he stands, and the connection is made. The fuel is coke. The weight of the engine loaded is about $6\frac{3}{4}$ tons.

II. *Description of the Valve-Gear.*—The valve-gear, as already mentioned, is very simple, and contains no parts liable to suffer from dust, mud &c. The distribution of steam is very correct both in fore and back gears, much better in fact than can be obtained by the common link motion, as a very slight inspection of the foregoing Table will show. Figs. 4 and 5, Plate 3, are diagrams of the valve-gear &c., which will serve to make the mode of action intelligible: Fig. 4, mid gear; Fig. 5, full lines, fore gear full; dotted lines, back gear full. It will be seen to have some similarity with Hackworth's or with Waelschaert's, but to differ from these in being worked off a pin situated at some point on the connecting-rod, and in requiring neither eccentrics nor cranks; further the new gear is furnished with several combinations which render it easy to eliminate any errors caused by the curved paths of the various parts composing the mechanism; indeed, by very carefully choosing the proportions, the distribution may be made nearly mathematically correct for each notch of the sector, as well in backward as in forward gear. The gear, as shown in the diagrams, is adapted to an engine fitted with a working beam; the motion is taken entirely from one point A in the connecting-rod, situated at about one-third of the length from the crank-pin end. The path described by this point is an ellipse with a curved major axis, the curvature being produced by the small end of the connecting-rod being constrained to move in the arc of a circle by the working beam; this curved ellipse serves to neutralise the error which would otherwise be present, arising from the curve described by the end of the pendulum lever B. The upper end C of this lever B is articulated to a system of radius rods D and E, forming a sort of parallel motion; E turning on a pivot at F, and D sliding in and out of an oscillating socket at G. Both E and D are attached

to the double-armed lever, or reversing shaft, H: this lever turns about the fixed point J, and can be set at any angle between full gear fore and full gear back, Fig. 5. The mechanism is connected to the slide-valve by the connecting-rod L from the point K, situated on the pendulum lever B at about one-eighth of its length from the upper end. The motion of D and E causes the ellipses described by the point K to have a curved major axis, and thus eliminates the error which would be caused by the angular motion of the rod L.

It will be seen in Fig. 4 that in mid gear the major axis of the ellipse described by the point K is nearly vertical, as shown to a larger scale at P; and that the motion imparted to the valve when the gear is in mid position scarcely exceeds the sum of the lap and lead at both ends, which is the amount of the space between the two dotted lines MM and NN. This amount of motion is consequently not sufficient to admit so much steam as that the engine will move.

Fig. 5 shows, in full lines, the reversing lever in full forward gear; the elliptical path of the point K, as shown enlarged at R, is now seen to be inclined, and to extend much beyond the limits of its horizontal travel in mid gear, Fig. 4. The areas of the parts of the ellipse R beyond the dotted lines MM and NN represent the amount and duration of the openings for entrance of steam, in this case amounting to about 76 to 80 per cent. of the stroke. By placing the reversing shaft in any position intermediate between full gear and mid gear, any desired amount of expansion may be obtained.

Fig. 5 shows also, in dotted lines, the position of the mechanism in full back gear; the operation of the gear in this position is the same as described for fore gear, only reversed.

The lead is constant for all positions of the reversing lever. For it will be seen on trial that the points C and J always coincide when the engine is on the dead points, in whatever position the reversing lever may be. A further advantage of this gear is that it is not much affected by the vertical play of the axles.

III. *Dimensions and particulars.*—The engine shown in the drawings is of the Type No. II., which is considered to be a useful

average size. It is the size most in use, and will haul with ease 15 tons up a gradient of 3 per cent., or 1 in 33. No doubt in time many modifications will have to be made, to suit the varying requirements of different towns and districts.

The principal dimensions and particulars of the three types of engines at present made are given in the following Table :—

Particulars of Engine.	Type No. I.	Type No. II.	Type No. III.
Weight in working order without condenser	17,000 lb.	14,500 lb.	11,600 lb.
Weight in working order with condenser ...	18,300 lb.	15,500 lb.	12,300 lb.
Water in Tank	160 gals.	110 gals.	108 gals.
Weight of Fuel	270 lb.	224 lb.	180 lb.
Wheel base	5 ft.	5 ft.	4 ft. 10 in.
Diameter of wheels	24 to 28 in.	24 to 28 in.	24 to 28 in.
Diameter of cylinder	6 $\frac{7}{16}$ in.	5 $\frac{1}{2}$ in.	4 $\frac{3}{4}$ in.
Stroke	11 $\frac{1}{4}$ in.	11 $\frac{3}{4}$ in.	11 $\frac{3}{4}$ in.
Heating surface	130 sq. ft.	102 sq. ft.	81 sq. ft.
Maximum pressure	220 lb.	220 lb.	220 lb.
Extreme length	12 ft. 3 in.	12 ft.	11 ft.
„ breadth	6 ft. 6 in.	6 ft. 4 in.	6 ft. 4 in.
„ height	12 ft.	12 ft.	12 ft.
Tractive force with 24 in. wheels	3000 lb.	2300 lb.	1700 lb.
„ „ „ 28 in. „	2570 lb.	1970 lb.	1450 lb.

IV. *Working Cost.*—As regards cost of working there is not yet any actual experience in England. In Strasburg, where each engine draws at different times two, three, and frequently four cars, it is considered that, since a sufficient number of horses would have to be kept to work the maximum traffic, the comparison between the cost of engine-power and of horse-power is very greatly in favour of

the former ; and that, even where a fixed and regular traffic exists, the cost of engine-power is much less than that of horses.

It will require the experience of many years to arrive at anything like exact figures as to working cost. During a great part of the time for which these engines have been running they have been only feeling the way. The advantage of mechanical traction varies greatly with the nature of the traffic. When this is subject to great fluctuations, as in the case of Strasburg just mentioned, mechanical traction is enormously cheaper than animal traction ; but on lines where the traffic is less fluctuating, and the service can be carried on by one-horse cars in rapid succession, the advantage of mechanical traction in the shape of a locomotive is less apparent. In such cases the combined car and engine would probably be more advantageous. On the other hand in cases of heavy gradients the advantage of mechanical traction is very great, as long heavy gradients are very ruinous to horses.

In Strasburg the Company has twelve engines of No. II. type. During the week six to eight engines are at work ; but on Sundays often the whole twelve are running, as the traffic on the week-days does not average more than 40 per cent. of the Sunday traffic. The consumption of fuel and oil per engine, as well as the distance run, during four months in 1878, is shown in the annexed Table taken from the books of the Company :—

1878.	Fuel, including getting up steam.		Lubricating material.		Distance run per day and per engine.	Number of passengers per engine.
	Coke per hour.	Coal per day.	Oil per day.	Tallow per day.		
	Lbs.	Lbs.	Lbs.	Lbs.	Miles.	
August	20·00	16·00	2·80	0·00	51·00	771
September	23·00	67·20	2·25	1·06	49·20	680
October	25·25	70·25	2·96	1·13	48·50	604
November	30·50	83·00	3·30	0·81	44·80	560
Mean	24·68	59·11	2·82	0·75	48·37	654

The cost of working per day and per engine is as under, according to the books of the Strasburg Company :—

	Marks or Shillings.
Redemption and Interest	4·80
Repairs and Cleaning	3·81
Coke and Coal	5·00
Oil, Tallow, and Packing	1·50
Wages of Driver	4·80
Total	<u>19·91</u>

This is equivalent to about £1 for 50 miles, or about 5*d.* per mile.

The arrangements at Strasburg for repairing and for conducting the traffic are very complete and under good control. The engines are regularly washed out at short intervals, and the smallest defects are made good immediately. The want of the above arrangements, together with a bad line, has been the cause of the abandonment of more than one attempt at introducing steam traction.

It is necessary to have from one-fourth to one-third more engines than are daily at work, so that repairs, washing out, cleaning &c., may be done thoroughly, and also as a reserve for contingencies; and on this assumption, the cost of working six engines daily with two in reserve would be as under, taking the Strasburg prices as correct :—

	Marks or Shillings.
Redemption and Interest on 8 engines, at 4·80 .	38·40
Eight Drivers, „ 4·80 .	38·40
Repairs, Cleaning, &c., for 8 engines, „ 3·81 .	30·48
Coke and Coal, „ 6 „ „ 5·00 .	30·00
Oil and Tallow, „ 6 „ „ 1·50 .	9·00
	<u>146·28</u>

Hence the daily cost for six engines in service and two in reserve is $\frac{146\cdot28}{6} = 24\cdot38$ shillings per engine working, or say 6*d.* per mile.

In case of the reserve engines being occasionally in service, the daily cost per engine would be somewhat less.

The above refers to Strasburg, where the number of miles run is small. We will now take another case, that of the Hamburg and

Wandsbeck Tramway, where the service is more severe, the line in bad order, and the means of repairing very scanty ; here each engine has to run 81 miles per day with 2 cars, or has 10 double trips per day. The consumption is 670 lb. of gas-coke per day, costing 6s. The daily outlay is as under :—

	Marks or Shillings.
Redemption and Interest	5·35
Repairs and Cleaning	4·50
Driver	4·50
Boy to help	2·00
Fuel	6·00
Oil and Tallow	1·70
Total, without reserve engines	24·05
For the reserve engines must be added one-third of the first four items, or	5·45
Total Daily Outlay, including reserve engines	29·50

This is equivalent to $4\frac{1}{2}d.$ per mile only.

We may compare the above with the cost of working the line with animal traction, which for 1877, according to the report of the Company, was as under :—

	Marks or Shillings.
Stable staff	58585·25
Stable working expenses, cleaning, &c.	7911·35
Oats	77205·87
Maize	96063·39
Hay	54629·86
Sundry forage	29066·95
Straw	21264·41
Sawdust	12269·00
Shoeing	24477·15
Harness	4892·30
Depreciation of horses	37624·73
„ stable inventory	3478·24
Interest on the value of horses, 5 per cent. on 244900	12245·00
Gross total without drivers	439713·50
Deduct the value of the manure	10583·76
Net total without drivers	429129·74

For the year 1877 the total number of double trips made amounted to 118,911 ; so that we have :—

	Marks or Shillings.
Cost per double trip without driver	3·695
Add cost of driver per double trip	0·375
Total per double trip	<u>4·070</u>

Hence 10 double trips (following the mode of calculating for steam traction) would cost per day with animal traction 40·70 shillings, or 38 per cent. more than the cost with steam (29·50s.). There is the further advantage with steam traction of being able to haul more than one car at a time, which is not taken into consideration in the above calculations. To make the difference clear, the greatest number of persons carried at one time with horse traction would not exceed 50 to 60, whilst with steam traction 100 to 120 persons in two cars is not at all an uncommon number. In Strasburg 200 to 250 passengers have often been carried in one train of four cars. Taking into consideration the ease with which two double-storied cars, fully loaded, can be hauled by engine power, even on steep inclines, the economical advantage of mechanical traction is very apparent. Thus :

	Marks or Shillings.
2 Cars with animal traction cost per day $40\cdot70 \times 2 =$	81·40
2 Cars with engine traction cost per day	29·50
Difference in favour of engine per day	<u>51·90</u>

In the above sum the outlay for conductors, car capital, and repairs of cars &c., is not included, being the same in both cases.

According to later data obtained at Strasburg for a period extending over a year's working, the result is as under :—

- Repairs* per day and per engine, 4·60 marks or shillings.
- Average work per engine per month, 1800 kilos or 1100 miles.
- Average number of days' service per month, 19 to 20.
- Average consumption of coke, 1·60 kg. per kilo. or 5·68 lb. per mile.
- Lowest consumption of coke, 1·35 kg. per kilo. or 4·79 lb. per mile.
- Lubricating material per day and per engine, 2·24 lb.
- Load hauled, from $7\frac{1}{2}$ to 16 tons over gradients up to 1 in 30.
- Average speed, 12 kilos (or $7\frac{1}{2}$ miles) per hour including stoppages.

* These include renewal of a number of tyres, some new springs, and some small alterations, especially in the construction of the connecting and coupling rod ends. These items, which will not recur, make the cost of repairs higher than in the first calculations.

In Hamburg the average load hauled is 15 tons over very undulating ground with few level stretches, and with gradients varying from 1 in 100 to 1 in 33. In Brussels, Turin, Florence, and Madrid, engines of No. II. size work inclines up to 1 in 15; and in Geneva a No. I. engine works regularly on a long gradient of 1 in 18, on which the rolling resistance is so great, in consequence of the sharp curves and the excessively dirty state of the rails, that it is often necessary to use steam even when descending. The load hauled is about 7 tons.

The number of engines actually built and at work up to the end of 1879 was 65, and about 20 more were then in course of construction. The oldest engine has been running at Geneva for about $2\frac{1}{2}$ years. The average running consumption of coke with these engines, exclusive of getting up steam, is on level roads 1 kg. per kilometre, or 3.6 lb. per mile, with an average load of 10 tons, and a speed of 12 kilometres, or $7\frac{1}{2}$ miles, per hour, including stoppages.

V. *Comparison with other systems.*—The established types of tramway engines naturally divide themselves into three classes: (1) The independent locomotive class; (2) The fireless locomotive, using steam; (3) The compressed-air engine. There are also gas engines &c., but none of these are before the public. The two last classes have in common the fact that they require to work from a fixed base or station; and the whole history of the railway system goes to show that in the long run, wherever they compete on equal terms, the self-contained locomotive is more economical and more efficient than any arrangement which involves stationary plant. As regards the fireless locomotive, many of the advantages claimed for it are also possessed by the Brown locomotive, since this also carries steam at a high pressure, and only needs attention to fire and water at long intervals. No doubt in places such as docks and warehouses, where fire is absolutely forbidden, the fireless locomotive would be valuable; and, to carry out the same principle, among bales of cotton, in grain warehouses, or other places where steam or damp of any kind is objectionable, compressed air will be the obvious motive power. Compressed air will also probably be the motive power underground.

As regards the advantages of a combined car and engine, when all is considered, the single real advantage in favour of the combination seems to be that of additional adhesion; and this is only obtained either by coupling many wheels together, which is inconvenient in tramway work, or by putting more weight on each wheel, which is looked on with ill favour by the owners of tramways, whose roads are generally unfit for any additional load. Still there are cases where this construction seems advisable; or rather perhaps the adoption of some of the arrangements by which the weight of one end of the car is borne by the engine. Mr. Charles Brown has built cars on this principle, where the car is carried by the engine at one end and by a bogey at the other. There are several admitted drawbacks to a combined car and engine, *e.g.*, that any repairs to the engine lay the car also off work, that the car has to go into the workshops where it is liable to get dirty, that different descriptions of cars cannot be used for different occasions without great extra outlay in plant, that each engine can take only one car, and that the combined engine and car is very troublesome and heavy if it gets off the line. Nor is there any obvious saving in first cost.

Lastly, we have to consider simple tramway locomotives. Both theory and practice show that in many points we must not be too closely confined by the recognised traditions of locomotive work. Possibly even in ordinary tank locomotives, for slow speeds and bad roads, there is too much resemblance in detail to the strong and comparatively rigid main-line engine, designed for good roads and high speeds. A light tramway engine cannot afford to depart from the most favourable conditions for traction and self-preservation; thus in the Brown engine the arrangements of the springs and axle-boxes are designed with the view of keeping the four wheels constantly on the road, and of making the engine run smoothly. Similarly the other parts, as described above, are all considered with a view to the special requirements of the work to be done. In fact daily experience seems to suggest, not that tramway engines will return to the type of the common locomotive, but rather that in many cases several of the special features of the Brown tramway engine may not impossibly be adopted with advantage in some of the classes of engines designed for railway work.

Discussion.

Mr. B. C. BROWNE wished to observe that the statement on p. 47 of the paper—"In future all engines will be fitted with steam brakes"—applied only to those made for English use, the Board of Trade having expressed a strong opinion in favour of steam brakes. For that reason, and perhaps for that reason only, it was desired to use them. With regard to some of the Tables printed in the paper, he had been asked why they were not always put in the form in which it was easiest to compare them with each other. The reason was that they were all taken as exactly as possible from books or reports of various tramway companies. Of course, in running these engines in England, he had had to make some small additions, simply to meet the Board of Trade requirements; *e.g.*, to put on a speed indicator and a governor, and also to close in the sides. He had preferred however to submit the engine to the Institution simply as Mr. Brown himself had made it, without putting in those small matters which he had added, but which might be taken away at any time and had no special interest in them. He would add that if any gentleman wished to see the engine at work, he could do so, since by the kindness of Mr. Webb it would be exhibited on the following morning at 11 o'clock near the Willesden station.

Mr. HENRY HUGHES said he had been running an engine in the public streets twelve months before the Brown engine was brought out; and he could not adopt the author's conclusion, that Mr. Brown's engine was the best that had been brought out for tramway purposes. In many respects he considered it to be the worst. For instance, he considered it a mistake to work in the public streets with 220 lbs. of steam. It was well known that with very high pressures it was very difficult work to run along the public streets. The jar of running over stones injured the pipes, and there was great difficulty in keeping the pipes and joints sound. Any gentleman who had had experience

in the bursting of tubes would know that it was a very awkward thing for the driver and passengers if a tube should burst under 220 lbs. pressure. Again, he considered the fire-box was not well designed to stand so great a pressure, and especially that the bend just under the tube-plate, at the junction between the vertical and horizontal parts, was a very weak point in the construction. He also thought that more stays ought to be put in above the fire-box; but perhaps that was only an omission in the drawing. That was, he believed, a design of boiler very commonly used, and very convenient, for portable steam engines; and a very good one for giving a great range of water-level above the fire-box. He did not think it was economical (although the amount of fuel consumed was said in the paper to be very small), because of the shortness of the tubes. He supposed that the tubes were made short and the pressure high in order to produce a great heat in the chimney, and thus to superheat the exhaust steam, so that it might not be seen in the streets. But an ordinary locomotive boiler could be made to do exactly the same by simply lengthening the barrel and putting a large dome in the middle; and he believed it would then be a better boiler and more useful for tramway work.

The position of the cylinders he did not consider an improvement. He did not think it very important to keep the cylinders so much out of dust and dirt: he believed that the blame had often been thrown on dust and dirt, when it ought to have been attributed to bad workmanship in the engines. An express locomotive was often covered with sand in its journey, by passing at high speed through an atmosphere containing a great quantity of sand; and yet very little damage was done to it.

Some merit had been claimed because the axle-boxes were made to move laterally within the horn blocks. It was no doubt necessary for tramway work to give the axle-boxes some lateral movement; but he thought that could be done without any complication of machinery, or anything peculiar in the springs. He understood that the springs used were spiral springs, which he thought were the worst sort that could be used upon tramways, because the section was so small, only $\frac{1}{2}$ in. or $\frac{5}{8}$ in. diameter.

Mr. B. C. BROWNE said that there were spiral springs on the front axle, but ordinary leaf springs on the hind axle.

Mr. HUGHES believed that Mr. Brown used to have them all spiral, but he supposed he had found out the difficulty just alluded to. Spiral springs would not do for tramway work. The ordinary leaf spring had a very great section, and offered great resistance, whereas spiral springs broke through rapidly; and if one went, the rest would very soon follow.

There was a great objection also to the form of condenser shown. There were evidently two opposing tendencies at work, one to make the steam in the chimney as hot as possible, so as to become invisible, and the other to take the steam into a condenser, in order to condense it. The tubes, as shown, were not at all sufficient for condensing the steam that would be used; he did not believe that a twentieth part of it would be so condensed. The weight of brass which was carried in those tubes would be far better carried as cold water, in that it would condense much more steam. He had himself tried all sorts of condensers, and had calculated the time which tubes took to condense, and the amount of water required to condense steam from certain classes of engines. He had tried mixing the air directly with the steam, but by that means he only produced a cold London fog. He had come at last to the conclusion that there was no better way of getting rid of steam in a tramway engine, than by sending it into a closed cold-water tank and confining it there. If there was any exit into the air, the steam would be sure to show. It might be possible for a certain distance on a level to condense the steam in the tubes shown; but when going up a gradient of 1 in 20, perhaps ten times the previous amount of steam would be required, and then the engine would puff out steam enough to fill the street, which in a place like Glasgow or London would certainly not be allowed.

Another small point was that, for the sake of the drivers, the engine should always be cased in at the ends, as well as at the sides, which was not done with the engine described.

The statements in the paper concerning fuel certainly required further explanation. In the Table in p. 51 the coke was taken per hour and the coal per day; the engine miles were also given per day, but the number of hours in the day was not stated, and therefore it could not be seen what was the real amount of fuel consumed. Further on at p. 55 the consumption of coke was stated to be 3·6 lbs. per mile. Was it possible to run for ten minutes over a mile of tramway, where the resistances were more than double what they were on a railway, using only $3\frac{1}{2}$ lbs. of coke?

The paper stated that in this country no experience had been obtained of the cost of working; but his firm had kept accurate accounts for three years on the Vale of Clyde Tramway, which they were working in Glasgow; and from the experience there acquired it might be taken for granted that on an average the cost would be five pence per mile.

Turning now to the difficulties that had to be overcome in working tramways by steam, he would first mention the bad state of the tramways which had been laid in early times. To work an engine successfully on a bad tramway was hopeless. Next, the points and crossings should be particularly attended to, and kept in first-class order; because the wheels were apt to drop into the opening of the crossings, and so make the engine take both roads. Impediments caused by stones, bits of wood &c., that got on the line had also to be contended with: such things produced a very great jar on the engine, and he thought some simple means might be adopted to throw them out of the way. The chief point however was to have good drivers and good management. If engines were built strongly, and good managers and drivers were employed, success would be secured. From the experience he had had he was perfectly certain that in a few years steam would be universally used; but that could only be attained by having the proper men.

Another point which he thought very essential in tramway engines was the size of the wheels. In the drawings it would be noticed how very small the wheels were in proportion to the size of the engine. But a small wheel was required, only when a large excess of power was needed occasionally for the purpose of going up hill easily: in the present case there was plenty of space to put

large wheels and large cylinders, and by doing so a very great reduction in the piston speed would be obtained. The last fifteen engines that he had himself designed, were running at half the speed of the previous ones. The power might be increased at any time by reducing the size of the wheels, but the ordinary traffic could be worked even with a 4-foot wheel, without any inconvenience to the engines, and with a very greatly reduced amount of wear and tear: and wear and tear after all was the great element of cost in a tramway engine. There should also be very few parts in such an engine. In the engine before them the rocking beam was an addition that might be dispensed with. He had himself seen, on this engine in Paris, $\frac{3}{4}$ in. of play between the end of the lower connecting rod and the pin of the rocking beam; and he was then informed by the government inspector that the engine worked very well, but that he was going to couple the cylinder direct on to the crank-pin, and then it would be a very good engine indeed.

He should like to add a few remarks upon a very extraordinary accident that had occurred to his own engines. Twelve of those engines were taken to Paris, and in about a fortnight eleven of them were *hors de combat*. Previously to this one of the same engines had been worked constantly for a month, and had worked remarkably well. The water then used was that from the Seine at the Bastille; the cylinders were oiled with suet, and the engine was worked by the company's own men. It worked so satisfactorily during the month, that twelve engines were ordered. Some of these were run by his own drivers, and some by French drivers, and the water was taken from the Seine and the Marne. Not one of those engines would stand five days. He was assured that no oil had been used for the cylinders from the first; and certainly nothing but suet had been used on the experimental engine, which yet was one of those that gave way. In some cases the tubes completely broke off, and the whole contents of the boiler came out in the street. In some the tube-plate would bulge in, in the centre below the tubes, and in some the fire-box itself was bent. The failure was not gradual, but instantaneous. The engine would be going one way perfectly sound, and would come back almost directly

all wrong; and would then go back again quite right. He called in the assistance of M. Tresca, who said that the cause was undue expansion of the tubes and fire-box; that the boiler was made too stiff in the outside shell, and that the expansion of the tubes and the fire-box prevented the tubes from having their proper hold on the tube-plate; therefore the tube-plate, from the pressure of the steam within, pressed outwards and bulged out below the tubes, causing them to bend and break off. M. Banderali of the Northern Railway was also kind enough to take great interest in the matter, sending his men to repair the engine at cost price; and he could not believe in its being anything but that the workmanship of the boiler was not good. Of course he himself knew that it could not be bad workmanship, because he had had boilers which had worked three years without the slightest leakage. Most of the French boiler-makers refused to believe that, and wished to put in new fire-boxes; but he knew that those fire-boxes had stood the pressure of 17 atmospheres under the Government inspection at Paris. However M. Banderali repaired the engine perfectly; but although the work was done by excellent men, some of whom had been engaged in similar work for the last fifteen years, it did not last three hours. It was again repaired, and it again gave way. At last he was obliged to come to the conclusion that oil had been put into the boilers. For the axles, an oil containing animal fat had been found to answer remarkably well, because it had great consistency and did not run through the bearings readily. Outside the suet cups was inscribed "suet" in English, in order to prevent any of this oil being put into the cylinders; but probably the French drivers had mistaken the meaning of this; at all events they had taken care to pour plenty of oil into the boiler through the suet cups, and no doubt that formed a calcareous soap, and caused all the mischief. When the tubes were taken out however the calcareous matter was perfectly dry, and could not be seen to contain any fat at all; but when it was put into a crucible and burned, the fat could be smelt. The boilers had since been washed out with muriatic acid; and a separate tank had been put on for the condensing water, as Mr. Brown had done. The boilers were now fed with pure water, and he believed that they would have no more difficulty in the matter.

Mr. F. C. WINBY said that tramways had generally been made too light to carry locomotives. Some time ago he had observed the tramway engines running in Paris, and noticed that the road was knocking the engines to pieces, and the engines were knocking the road to pieces; but there was now no difficulty in laying down a line, with an improved section of rail, that would carry the heaviest locomotives. The features that had to be looked to in designing a tramway locomotive were—to bring the weight well upon four wheels, with not more than 5 ft. wheel base, which was the utmost limit that would pass round curves of 35 ft. radius; to condense the steam; to make as little noise as possible; and to keep the machinery well above the ground. It occurred to him that in Brown's locomotive a better arrangement might have been an intermediate crank-shaft close to the fire-box, acting by a connecting rod on the leading wheel. With regard to the valve arrangement, he saw no advantage over the ordinary valve-gear; for the number of joints and levers used would, in wearing, produce collectively a very considerable play in the connection between the pistons and the valves. It had occurred to him also that a good condensing arrangement might be made by using a water tank having a number of tubes passing through it, like an ordinary surface condenser, and by forcing a quantity of air through those tubes, to absorb the heat. On a line he had recently constructed, which ran $\frac{3}{4}$ mile up an average gradient of 1 in 20, and then $2\frac{1}{2}$ miles down hill, some mode of storing up power was much wanted, so that what was gained in the descent might be utilised in the ascent, when returning.

Mr. W. SCHÖNHEYDER had observed from the drawings that in communicating the motion from the cylinder to the rocking beam F' (Fig. 1) a dog-link was used. He thought that was very objectionable, because it was impossible to get sufficient wearing surface for the block in the link. He did not know what the size of the block was in that case, but with $5\frac{1}{2}$ -inch cylinders, giving a piston surface of about 24 sq. ins., and with 220 lbs. pressure per sq. in., there would be a total pressure of about 5300 lbs. on the piston. Probably the block would only have about 10 sq. in. of surface; so that there would be

over 500 lbs. per sq. in. upon it. No surface of that description would stand such a pressure. The same action went on there as in the guide bars for cross-heads, where it was known that the pressure should not be much higher than 40 lbs. per sq. in.; so that a block of that description must necessarily wear very fast; and from the remarks of Mr. Hughes it appeared that these blocks had actually worn very badly in Paris. In Figs. 4 and 5, Plate 3, he saw that a better construction had been substituted.

Another point to which he would refer was the boiler. If a boiler of that construction was to stand 220 lbs. per sq. in., it must be constructed of enormously strong plates, because the angle connecting the horizontal with the upright part formed a very weak point. It was the old story over again of the dome placed upon a Cornish boiler, and the whole of the metal cut away to make room for it. How such a boiler could stand 220 lbs., without very strong stays or some enormous thickness of plates, he could not understand.

Mr. W. Lyster Holt observed that on page 51 a statement was given of the consumption of coke and coal for four months at Strasburg; and it was very remarkable that in each successive month the consumption of both coke and coal increased, while the mileage of the engines and the number of passengers decreased. That, as it seemed to him, could only be accounted for in two ways. Either the engines rapidly deteriorated, or else there was something radically wrong in the distribution of the steam. Perhaps the wear and tear was greater than it would be with ordinary eccentrics and link motion. Then he noticed that on page 52 the cost per mile was given as 5*d.* He could only say that the tramway companies in Paris would be only too glad to let the whole of their tramways at 7*d.* per mile, to be worked by any contractor who would supply the engines.

With these engines the same difficulty occurred as with all other tramway engines, namely, the enormous expense of repairs. He included in this the redemption and interest, which, as he understood it, would mean renewals. According to the paper the repairs and renewals would cost over 2*d.* per mile out of 5*d.*, or over 40 per cent.

He noticed also that on the Hamburg and Wandsbeck tramway, where the service was more severe, and the engine ran 81 miles per day, the consumption averaged 670 lbs. of gas coke per day, or considerably over 8 lbs. per mile. His experience in Paris was that this was about the average consumption there. Therefore there was nothing economical in the engine which they were considering. He could not see how that consumption, in actual work, of very nearly $8\frac{1}{2}$ lbs. per mile could be reconciled with the statement on page 55, that the average running consumption of coke with these engines was only 3.6 lbs. per mile. If such a result could be arrived at, he need hardly say that steam would very soon replace horses, as no doubt it would eventually.

It was observed on page 44, regarding the qualifications of a tramway engine, "Lastly, it must be worked of course by one man." His own experience in Paris had been that it would be absolutely dangerous to work with one man in crowded thoroughfares. A tramway driver, the moment he had started his engine, could not pay any attention to the engine itself; he had to look to the street crossings, and matters of that kind: and he questioned whether even on a railway, where the driver had less to do, any locomotive superintendent would advocate running an engine with one man. In running one way, with Brown's engine, the man was at the smoke-box end, and consequently he was right away from his fire door. That would not so much matter when the engines were new; but after running a certain time locomotives were apt to leak, and tubes to burst, and the man would not be near to plug them up. It was well known too that tramway locomotives had a disagreeable habit of priming; but the driver, being sheltered by the cover, did not feel the effects of that priming, and often knew nothing about it. His belief was that half the accidents which had occurred to tramway locomotives through shortness of water, had been caused by the simple fact that the driver thought he had got a boilerful of water, when it had primed away. He did not take the trouble to look at his gauge glass: in fact he had not time to do so, having to look out to prevent accidents; and so he was suddenly astonished by the safety plug burning out. He was speaking of things that had happened

perhaps once a week. In his opinion therefore it was a mistake to leave the engine with only one man. There might be a small boy, as in Paris, to blow the horn and look after the fire; but there must be a thoroughly competent man whose sole attention, or at least the greater part of it, must be given to the engine, as in the case of an ordinary locomotive.

The Brown engine certainly possessed one good feature in the machinery being raised from the ground; for his own experience had been that, apart from the defects of the road, dust had been the great enemy of tramway engines. It must be remembered that with an ordinary tramway locomotive the crank and the big end of the connecting-rod and the eccentric straps sometimes came within 2 in. of the ground: as for instance with the engines working at Rouen and Paris, having inside cylinders of 7 in. diameter and 11 in. stroke, and wheels 2 ft. diameter on tread when new. Moreover a tramway rail was not like the raised rail of an ordinary railway, but was on a level with the ground, and had a groove in which the dust and dirt accumulated, to be churned up by the wheels. This was no new point, because the same evil occurred in India, with a very different sort of service, as Mr. Crompton had informed them (*Proceedings*, 1879, p. 503). Further he believed it to be a well-known fact that in very small narrow-gauge locomotives, where the machinery was very near the ground, it had been observed that after even only ten days' service the brasses &c. had been completely worn and cut through. Unfortunately the paper gave no statistics as to the cost of working Mr. Brown's engines in Paris. Had it done so, they would probably have been able to compare it with the cost of working three or four ordinary types of engines, such as Merryweather's, Fox Walker & Co.'s, and the *Compagnie de Fives-Lille's* engines. He did not know whether Mr. Brown's engines were running now in Paris, but if they were it would be interesting to learn what they were now doing, because other engines with six wheels, constructed in Belgium, had been lately running on the same line; and that line was constructed better than the generality of tramways in Paris. Underneath the longitudinal timbers were cross sleepers, similar to those in the tramways at Rouen.

They had heard from Mr. Hughes that he had suffered very much from the fire-boxes of his engines in Paris giving out. For two years he (Mr. Holt) had used for his engines the same water as Mr. Hughes had employed, and did not experience the same effects; but he did not condense. This point was certainly one that required some investigation, because the experience was so contrary to that of the Metropolitan and District Railways. So far as he was aware, it was not found there that the introduction of oil and tallow had any hurtful effect on the engines. In fact he had heard one locomotive superintendent say that it was an advantage, as he did not use so much oil and tallow as he otherwise should.

Mr. R. E. B. CROMPTON, referring to Mr. Hughes' observations about large wheels, said that all engineers would put large wheels on tramway engines if they could; but large wheels, without corresponding increase in length of stroke and consequent increase in general dimensions, meant slow piston-speed, and the piston-speed was very small in tramway engines already; it was not desirable therefore to decrease it, if it could be helped. He wished to protest against Mr. Hughes' objection to high pressures. Mr. Brown had apparently succeeded in carrying his pressure of 220 lbs. without any extraordinary trouble. No doubt with that construction of boiler it might be supposed that under 220 lbs. pressure there would be considerable distortion at the junction of the vertical and horizontal parts; but he had no doubt that by using strong flanges or angle-iron rings Mr. Brown had prevented that.

The arrangement for condensing the steam did not seem sufficient. Mr. Tomlinson, in speaking on M. Francq's paper at Manchester (Proceedings 1879, p. 630), said that with a condensing surface of 1600 sq. ft., or considerably more than the heating surface in the boiler, he did not condense one-tenth of the steam. He was himself present at several trials made some years ago with Mr. Perkins' small road locomotives, working at about 500 lbs. pressure; and there an air condenser was required that weighed nearly as much as the whole engine besides, in order to condense the whole of the steam. The condenser shown to the meeting would, he thought, do

more harm than good. The steam that escaped would come out in a very visible form. As far as his experience of engines on roads went, the best way of getting rid of the steam was not to attempt to condense it at all, but to keep it as long a time as possible in contact with the heated gases, and so superheat it. That answered in every way, except in very moist atmospheres, and there, do what they might, they could not get rid of the steam. He had been present at several trials of tramway locomotives in Leeds; and he found that the steam was not visible in the high parts of the town, but directly the engine got to the lower parts, the steam showed itself in dense clouds.

He noticed that Mr. Brown had made his boiler as nearly a vertical boiler as possible. He did not see why it should not be a vertical boiler altogether; that would get rid of any trouble there might be at the connection with the horizontal part, and would make it a great deal cheaper. He was convinced that for tramway purposes, where height was not so important a matter, and the boiler might stand as high as the tramcar itself, the cheapest thing that could be put in was a vertical boiler. The question of steam on tramways would not be solved until somebody produced a cheap engine; and none of the engines as yet produced had at all approached the point required. Probably the Brown engine cost the maker £700 or £800; while, as he had tried to show at the Paris meeting (*Proceedings* 1878, page 431), it would be impossible to compete with horses in England, where cars had to be run at short intervals, until the cost was brought down to about £300.

Mr. HOLMES HIRD said the author stated in page 49 of the paper that the valve-gear was not much affected by the vertical play of the axles. He happened to have had some experience of valve-gears, and it appeared to him that the vertical play of the axles in this case would affect the working of the valve-gear. In reference to the question of larger wheels, there was this disadvantage in them, that they would involve the necessity of larger cylinders, and much stronger and heavier working gear: the framing and wheels would also have to be considerably heavier. This addition to the weight was a very important matter in a tramway engine.

Mr. J. D. LARSEN had closely observed these engines from the time when they began to run in Paris, and so far they had given every satisfaction. Where they had failed, so far as he had observed, the fault lay in the road. If that was in fair condition the engines were all right; but they went at rather a high speed, and whenever they came to an inequality in the rails they sustained a shock that tended to knock them to pieces. He was in Hamburg last June, and the engines there were working very well; but they also, as Mr. Browne would admit, met with some difficulties, because they were too slight for a bad road. For new tramways such engines would no doubt answer admirably. He wished to know if Mr. Browne could state the working expenses in Paris. He had taken great interest in the Brown engine, and, so far as he knew, it had done better than any other engine for tramways.

Mr. D. HALPIN, referring to Mr. Hird's observations about the valve-gear, thought, if the motion were analysed, it would become evident that the vertical motion of the axle could not have much effect on the valve motion. The point where the attachment to the connecting-rod was made, for imparting motion to the valve-gear, was stated to be at about one-third of the length of the connecting-rod: consequently at that point the motion would only be one-third of the whole of the vertical motion due to the springs; and taking into consideration the further reductions due to the link-work, the versed-sine of the arc produced would be almost nil.

Mr. T. R. CRAMPTON thought that the vertical movement of the axles had practically no effect. With regard to the bearing surface on the end of the piston rod, that might be increased by making the loop longer. It was very important to have a large surface there, to prevent undue wear; but there was no doubt in his mind that the valve-gear shown, if properly made, would answer all practical purposes. It had also the advantage of giving the rocking lever, when going quickly, a proper balance. He did not however attach any importance to such points: the production of a good engine was not a serious difficulty. Attention should chiefly be directed to the road. In his

opinion a tramway road should be very much stronger, not lighter, than the ordinary railroad. Heavy cars were running over it at all times; there were serious shocks from vehicles passing along the common road over the rails; and he thought therefore considerably more would have to be expended on tramways than had been usually regarded as necessary.

With respect to the engine itself, a tramway could never be kept in the same order as an ordinary road; and it was very essential therefore to have proper arrangements of springs, so that, under any conditions of the road, there might always be the same weight on the wheels. That was best attained by the three-point system used by Mr. Brown; and it could be carried out with six wheels as well as with four.

It was his impression that there was also a future for the Fireless engine described at the last meeting, because it was exceedingly simple in construction; and whether it burned a little more fuel or not was of no very great importance. According to the paper only 3 or 4 lbs. of fuel were used per mile in the Brown engine, yet the total expenses were 5*d.* per mile, so that the fuel was only about 10 per cent. of the whole cost. If 2 or 3 per cent. of that was saved, and 20 per cent. more was expended on repairs, through extra wear and tear, was the saving worth having at the price?

He agreed with Mr. Hughes in regard to the size of the wheels. In a tramway it was desirable to reduce the wear and tear, and to keep out of the dust as much as possible; and he preferred to work direct by increasing the size of wheel, rather than have complications or additional parts. As the members no doubt knew, he had paid some attention years ago to the use of a separate crank-axle, and in certain conditions it was an admirable thing; but if the parts could be well balanced, and radiating axles employed, the arrangement he thought would work well as it stood. With very small wheels some parts must be close to the ground, and the pistons must be run faster. In a tram engine, going only 8 or 10 miles an hour, the increased piston-speed was not perhaps injurious; but the increased expense due to wear and tear was very great. Large wheels involved a little extra weight; but the extra cost of labour in their construction, compared with the total cost of the engine, would be trifling.

A remark had been made with regard to short tubes. Mistakes were often made as to what was short and what was long in a tube. The question simply was, how large was the area as compared with the length. A tube 3 ft. or 4 ft. long might be a very long tube if it were only $\frac{1}{2}$ in. diameter ; at least there would not be much heat at the smoke-box end with those proportions.

There was one other point to be mentioned, that of the coning of the wheels. Of course in passing round sharp curves, with a small wheel-base, it was only the flange of the fore wheel that was in contact with the outer rail. The flange of the hind wheel was in contact with the inner rail ; therefore in that wheel the large end of the cone was grinding round upon the inner rail. If that matter were looked at a little, it would be found that it would be much better if the wheels were made parallel. There would be less friction, the curves would be more easily passed, and there would be less wear and tear. Some twenty years ago he had induced Mr. Haswell of Vienna to alter his whole system, and to use parallel rails and parallel wheels. Mr. Haswell afterwards wrote to him to say that his wear and tear of tyres was 30 per cent. less than with the coned wheels.

Mr. S. ALLEY had closely watched the working of steam on tramways for about three years, on the Vale of Clyde Tramways at Glasgow ; and agreed with many of the gentlemen who had spoken, that the matter of greatest importance was the construction of the road. The roads in general use were much too light. He thought Mr. Brown had made a mistake in making an engine that would adapt itself to a bad road. It was the roads that ought to be put right, and the making of such engines only encouraged companies to make bad roads. With reference to the condenser, he should like to ask Mr. Brown what was the weight of his condenser, working with an atmospheric temperature of 45° or 50° Fahr., *i.e.* what weight of tubes would be required to condense the steam thoroughly.

It had been remarked by Mr. Holt that it was not desirable to work an engine with one man. He could testify that for three years the engines on the Vale of Clyde Tramways had been worked by one man, and he did not know that a single accident had occurred, either through priming or anything else.

The matter that Mr. Hughes had mentioned with regard to his locomotives in Paris was curious and interesting. Mr. Hughes had consulted him about it, and at first, when he heard that the gradients were 1 in 10, he said that one end of the fire-box must be out of the water owing to the inclination. But having learned that the gradient of 1 in 10 was very short, and that the explosions did not often take place on this incline, he saw that that cause could have little effect. Eight boilers exactly the same as those in Paris had been at work on the Vale of Clyde tramways for three years, apparently under the same conditions; and in no case had they given any trouble, further than a few ordinary leakages, which were easily cured. These explosions in Paris appeared to have been almost instantaneous, as if by minute charges of dynamite; and it therefore would seem to be more a chemical than a mechanical question, and one which ought, if possible, to be probed to the bottom.

Mr. DANIEL ADAMSON thought the matter could be simply explained by the action of the Paris water, which would be drawn from the coralline oolites. All water highly impregnated with lime, whether carbonate of lime or sulphate of lime, had in its pasty character an enormous affinity for grease; and if there was any grease in the boiler when it was heated, the lime deposit would lay hold of it. The grease could then only be detected in the way Mr. Hughes had described, by putting the dust into an iron ladle heating it on the fire. The grease thus mixed with the lime dust could not be vaporised off the surface of the boiler plates until a temperature was attained of about 600°: and this temperature, which was that of a low red heat in the dark, would destroy the whole tenacity of the brass tubes, and, as had just been said, they would break off and explode almost as if by dynamite. But besides that, the greasy dust would adhere even to the under side of the tubes, which would get so overheated as to destroy the bearing power not only of brass, which was most treacherous at a high temperature, but of wrought iron or the finest mild steel. Boilers working on the Wear at Sunderland and at Hartlepool, supplied from the magnesian limestone, and, in some few cases, boilers working with

well water at Birmingham, and getting sulphate of lime from the triassic rocks, had experienced the same evil. This subject was well understood by a few engineers of large experience in stationary engines, and no doubt remained upon it. Similarly when surface condensation was adopted for marine boilers, the grease played a most active part in destroying the tubes; a greasy sedimentary deposit settled down, sometimes on one portion and sometimes on another, in the most erratic manner, and corroded a hole through in a few days.

He must add his testimony as to the weakness of the Brown boiler. The horizontal casing attached to a vertical boiler necessarily made a weak part at the joining of the two. The great experience on railways had shown that there were only two forms of surface that could be constructed with certainty. One was that of a cylinder, and the other that of a perfectly flat surface, where the bursting action was neutralised by means of stays. He had had great opportunities of watching this T construction of boiler under test, and also in actual working on the Stockton and Darlington Railway; and nothing could keep such boilers tight in the angle between the two parts for any long period of time. The simple explanation was, that if there was a curved surface, which yet was not a true circle, it would always tend to get into a circle under pressure, and leakage would follow, unless the structure was heavily stayed.

He could not agree that the working beam was any advantage to the engine. He did not see how it was possible to transmit the force from the piston through that lever without excessive weight, owing to the necessity for strength. If it was practically possible to have a rather larger and heavier wheel, and make the crank sufficiently large to get proper piston-speed, it must be evident that the engine would then be worked with the fewest possible parts, and the least chances of wear and tear. He did not quite acquiesce in the statement in the paper that the vertical action of the springs would not affect the valve-gear. Those who were familiar with Hackworth's single-eccentric reversing motion, knew that it could not be applied to a locomotive from the dancing of the springs; and the principles of the two were identical.

Mr. R. PEACOCK, referring to the question of grease getting into boilers, observed that the Metropolitan Railway engines, which had been working for fifteen or sixteen years, were still working without a change of either fire-box or boiler; and it was well known that those engines practically condensed all their steam, and that their boilers were fed from the condensed water. As a matter of course that water was greatly impregnated with the oil and grease that was put into the cylinders in the first instance, passed from thence into the condensed water, was taken up again by the pumps, forced into the boiler, and used over and over again. But with all that, it was the fact, he believed, that there were no other boilers so free from scale and dirt as those of the Metropolitan Railway. He was told that the fire-box tops and sides, though some had been at work sixteen years, were as clean now as when they were put in.

Mr. JOSEPH TOMLINSON, JUN., said Mr. Peacock was under a little misapprehension on the point he had raised, for this reason, that on the Metropolitan Railway only $\frac{1}{2}$ lb. of tallow was used for each pair of cylinders in a run of 100 miles, or $4\frac{1}{2}$ trips; and during that time the water was changed nine times, so that $\frac{1}{2}$ lb. of tallow was put into 8000 gallons of water. Moreover, as the steam was exhausted into the top of the tank, the grease being lighter remained on the top of the water, while the boiler was fed from the bottom of the tank; so that little or no grease ever got into the boilers. It was quite true that they had not put a new fire-box into any of their engines, though some of them had run over 600,000 miles; and they were almost as clean now as when new. He did not think however that this arose from the cause suggested, but from the construction of the fire-boxes, and the manner in which they were stayed. The steam was more easily liberated longitudinally than vertically. The roof bars were set very close together, with a $1\frac{1}{4}$ in. stay between them; and the steam ran along the top of the fire-box, under these stays and between the roof bars, and so kept the top of the fire-box clean.

Mr. CHARLES COCHRANE said that, with regard to the question of acid arising from the oil getting into the condensed water, he should like to give the result of twenty years' experience with boilers in the North, which were found to be pitted inside by the action of acid just along the surface line of the water. This action was removed entirely by the addition of a little caustic soda to the condensed water; and that water was constantly used as being the purest that could be had for their boilers, in the sense that it contained no solid matter, but simply a little acid, which would be deleterious to the water unless it was corrected by the soda. When he heard of boilers suffering by reason of the action of the oil used in the engine, he felt it ought to be known that there was such a simple mode of correcting this deleterious influence.

The PRESIDENT wished to mention one fact in reference to the boiling of grease in water. He knew a case of a boiler with a surface-evaporator condenser, where the water was used over and over again for a fortnight with very little loss. The boiler then began to leak at the seams, in consequence of the acid grease which formed on the plates. This was entirely cured by pumping in hard water; the lime in that water entirely neutralised the grease, turning it into a non-acid grease, and only produced occasional lumps of insoluble soap, which were perfectly innocuous. On the same principle Price's Candle Company converted ordinary neutral grease into acid grease, by extracting the glycerine from it by means of continued boiling at *very high pressure*, according to Tilghman's process. He had no doubt that the special trouble which had been experienced with the boilers under discussion was partly due to a higher pressure than usual being employed, as the neutral grease was much more quickly and thoroughly decomposed at such pressure, than at ordinary pressures. With regard to the case of Mr. Hughes in Paris, he believed Mr. Browne would give some confirmatory evidence in reference to it. In certain cases the water used in Paris, and elsewhere on the continent, was of such a nature, that the scale it formed upon the tubes took up the grease very greedily, and then it would become a sort of greasy stone.

Then the water would not touch the tubes, and the high temperature of 600° which Mr. Adamson had spoken of was necessary to decompose or drive off the greasy deposit. As soon as this had happened, the tubes, being at almost the highest evaporating temperature, flashed a great quantity of water into steam, which no doubt tended to strain the tubes and the boiler. It therefore seemed a mass of evidence was being obtained, which all tended to a clear explanation of the action going on in the boiler. In reference to what Mr. Peacock had said about tallow, he thought if much tallow got into a boiler, there would then be a quantity of grease which would boil to an acid grease; but if only $\frac{1}{2}$ lb. of tallow was used to 100 miles, and the water was changed nine times, it could scarcely affect the boiler.

Mr. B. C. BROWNE said in reply that the first point to which Mr. Hughes had called attention was the working at such high pressures. Of course he quite admitted that to have an explosion, or even a bursting of a tube in the street, with a pressure of 220 lbs., would be a very unfortunate thing; but at the same time in an ordinary locomotive, working at 150 lbs., if a tube were to burst or anything of the sort happened, it would be a very serious affair; and the additional pressure from that to 200 or 220 lbs. he did not think would make the matter very much worse. It must also be considered that a very much smaller boiler could be used with the higher pressure. The greatest possible amount of care and supervision could be exercised over the manufacture, and it could be made of the very best material. So far the boilers of Brown's engines had been made of steel carefully selected. The tubes were also of steel, or of homogeneous iron; and no more difficulty had been found in keeping them tight, either from the shape or the amount of pressure, than in other locomotive boilers. With regard to the question of joining the horizontal cylinder to the vertical, the way in which it was done was this. The hole was first cut in the larger or vertical cylinder, and the plate was flanged outwards on an easy curve: the horizontal cylinder was also flanged outwards, and the two were then laid on each other. Care was taken to see that they actually took a good

bearing of metal to metal all over, and then he believed they made an excellent joint. In the drawing all the stays were not shown. The rule for the staying of a boiler of that sort was much the same as the rules that would be used for the staying of any other boiler to be worked at high pressure.

With regard to the question of dust and dirt injuring the engine, Mr. Hughes had quoted the case of an express engine; but an express engine was raised a great deal higher than a tramway engine. It was true it went faster, but it ran on raised rails, which were always practically clean and dry. On the other hand, the tramway-road was almost like a ditch, into which everything flowed, not only water but mud; and with the small wheels there was far more opportunity for the dirt to get into the mechanism. He wished they had had some further expression of opinion on that point; but certainly, wherever he had seen a design for a tramway engine, great provision was made for keeping the dust and dirt off the machinery.

With regard to the condenser, Mr. Hughes thought it was insufficient for the work it had to do. In fact however they succeeded in showing very little steam, usually none at all. He believed that the condenser would practically condense all the steam when the engine was running; which was quite a different thing from the amount it would condense if the engine was at rest, because of the cold air constantly passing over it when running. The weight of the condenser was about 400 lbs.; it was all made of exceedingly light copper tubes, and it had 230 sq. ft. of surface. Theoretically he believed there was sufficient surface to condense two-thirds of all the steam that was used under ordinary circumstances. But of course when there were no horses in sight, or other objection, the drivers would perhaps throw off a little steam. On the whole Mr. Brown had certainly succeeded in preventing all complaints as to steam showing; and, after all, he believed that all engineers, in their heart of hearts, looked on the condenser as a mistake, and as entirely useless. They used it because people had the feeling that steam would frighten horses and perhaps be objectionable by going into the windows of houses; but they all looked forward to the time when tramway engines would be more used, and when they would be able to work

without condensers in England, as was done in other countries. In the meantime, whatever satisfied the Board of Trade and the public ought to be sufficiently good to satisfy engineers.

The shape of the boiler had been objected to by Mr. Adamson. He himself thought that after all the practical reply was that the boilers did not give any trouble. At Hamburg, after trying the engines for a year and a half, the police had just brought out regulations sanctioning the use of Brown's engine, and of no other, at least without special experiments. The engines there and elsewhere were quite out of Mr. Brown's hands, and belonged to the different Tramway Companies, just as locomotives were the property of Railway Companies.

With regard to fuel consumption, he quite expected that some observation would be made upon the Table at page 51 with reference to Strasburg. It certainly looked at first sight rather startling to see the consumption rise from 20 lbs. in August to 30·50 lbs. in November, while at the same time the number of miles was less. He thought that was chiefly owing to two causes. In the first place tramway engines would always use more fuel, and obviously more oil, in cold weather, when the oil was always clogging, than they would in hot weather, when the oil was liquid. Secondly, with engines making less mileage, there was more standing time and more cooling down than before, and the consumption per mile would be higher. It would be remembered also that 1878-9 was an unusually severe season. The winter came on early, and the engines then had to fight their way through the snow that was constantly falling; that, he believed, entirely accounted for the extra consumption. At page 54 the average consumption of coke was given as 5½ lbs. per mile. At page 55 it was stated that on level roads (Strasburg of course was not a case of level roads), and with a certain weight and speed, they could work with a consumption of 3·6 lbs. per mile. A letter received by his firm on 5th November, from the manager of the Strasburg Tramways, stated, "We use now on an average 3 lbs. of coal per kilometre;" which was 4·8 lbs. per mile, or roughly speaking about half-way between what was used in 1878, and what was spoken of as the consumption under practically perfect

circumstances: and, taking into account the difference between the Strasburg road and a dead level, that proportion was about what it should be. At Hamburg the consumption was much higher, but that was gas coke.

Mr. Schönheyder had found fault with the square link at the end of the piston rod. He admitted that it was not a perfect construction, and where the conditions were suitable they introduced a small connecting-rod. But it had one great advantage, namely that if it wore loose it could be so easily lined up, and adjusted to the greatest nicety.

With regard to the fact of one man working this engine, while there were necessarily two men on a railway engine, members should bear in mind the great ease with which a man could stop a tramway engine. Not only this engine, but almost all tramway engines could be stopped in something like their own length under ordinary circumstances. If a man suspected anything therefore, he could stop the engine at once. The engine was stopped, as it was, at all sorts of places and under all sorts of circumstances; it was a very small affair to halt at once if the driver suspected that anything was wrong. At the same time he did not remember ever hearing of a man having to stop his engine on account of want of steam, or for anything of that sort.

With regard to what happened with the Brown engines in Paris, he was sorry to say that he could only give exceedingly imperfect information. The engines in Paris were not made at Mr. Brown's works, though they were made on his principle. They were in the hands of other people, and therefore he could not speak with such accuracy on the point as he could wish.* But he could show that elsewhere the engines had been so successfully worked that people bought them in large numbers and came back again and again, and ordered more, which after all proved that they were a commercial success. Even if all the stories related with regard to the engines

* Mr. Browne has since informed the Secretary that these engines have worked on the 'Etoile' line, regularly and without cessation, for nearly two years. Their number has been increased to 17, and they are now the property of the Tramway Company.

in Paris were true, he did not think they would affect the question, because of course the best engine might be spoiled, if it were not used properly, or if it were put upon a sufficiently bad road.

With regard to Mr. Crompton's remarks, he knew that that gentleman was not fond of using a condenser at all, and he himself quite agreed with him. Mr. Crompton said that a tramway engine ought to be produced for something like £300, and that this engine had probably cost £700 or £800. As a matter of fact however they cost nothing like such a sum. But what he supposed Mr. Crompton really meant was that tramway engines would not succeed until they could be made for something like half their present cost; in other words, that half the amount of work and complications in existing engines must be swept away. Looking at the engine described, or at Mr. Hughes's engine, or any other, he thought they might pretty nearly see their way to that. First of all, they were now sacrificing a great deal to make the engines as light as possible. In many cases, if they did not regard weight, they could use more cast iron &c., and so make the engine a great deal cheaper. The condenser, the closing in of the sides, and several other parts, were really put to satisfy people outside, more than for any real work the engine had to do. At present they never knew what road they would have to go upon, or what load they would have to draw; but if they simply had to deal with one or two tram-cars, loaded full of people, on a fairly good road, and if they had got rid of all those outside considerations, as was the case on railways, there was no doubt that tram engines could be made enormously cheaper than they were now.

Some observations had been made on the tramway itself. He believed very few, even of those tramways that had never had an engine on them, were fit for anything. He had had to look at this tramway question, not only as an engineer, but also as a town councillor; and it appeared to him that, whatever system had been adopted, almost all roads were made far too light, not so much for the tramway work, as for the other work that came upon them. In almost all manufacturing towns, weights went through the streets amounting to as much as 10 tons on one wheel; he himself frequently sent out loads of machinery on wagons in excess even of

that. But those heavily loaded vehicles, once crossing over a tramway, might so injure it as to make it very awkward for either cars or engines passing over it afterwards.

With regard to the coning of the wheels, Mr. Brown had started by having an exceedingly small amount of coning, and now he had all his wheels absolutely parallel.

With regard to the question of oil getting into the boiler, he believed it was a matter of circumstances. It might be found that in certain places it was possible to mix up the condensed steam and the feed water without injury; but certainly it was safer, where it was practicable, to keep them separate from each other. In Paris and elsewhere a calcareous soap was certainly formed from the water and grease combined, exactly as had been stated by the President.

The PRESIDENT proposed a vote of thanks to Mr. Browne for his paper, which was unanimously passed.

The Meeting was then adjourned till the following day.

The Adjourned Meeting of the Institution was held at the Institution of Civil Engineers, London, on Friday, 23rd January, 1880, at Three o'clock, p.m.; EDWARD A. COWPER, Esq., President, in the chair.

The following paper was read :—

BROWN'S TRAMWAY LOCOMOTIVE.

Plate 1.

Fig. 1.
Side
Elevation.

Scale $\frac{1}{30}^{th}$

Plate 1.

BROWN'S TRAMWAY LOCOMOTIVE.

Plate 2.

Fig. 2.
*Longitudinal
Section.*

(Proceedings Inst. M.E. 1880)

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Scale $\frac{1}{30}^{th}$.
Plate 2.

BROWN'S TRAMWAY LOCOMOTIVE.

Plate 3.

Fig. 3. *Transverse Sections.*

M N

Fore

Back

M N

Fig. 4. *Valve Motion in Mid Gear.*

Fig. 5. *Valve Motion in Full Gear.*

Plate 3.