THE CITY & SOUTH LONDON RAILWAY ELECTRIC TRAIN
6 – MOTOR CARS

by Piers Connor
with Printz Holman

THREE STRIKES AND OUT

Our story of the City & South London Railway's (C&SLR) rolling stock has so far concentrated on the motive power adopted for the railway in the form of the electric locomotives that were used to haul the passenger cars. This method of operation survived for the whole of the life of the original railway from 1890 to 1923 but, during this 33-year period, there were three separate attempts to get away from this concept. Each of these attempts proposed trains made up of two motor cars with trailer cars between them and rather surprisingly, all three of them failed, but, before looking at them in detail, or at least as much detail as we have been able to get from the available resources, we should define what sort of trains they were actually considering and how they differed from today's multiple unit trains.

THE MOTOR CAR CONCEPT

In 1888, when electric traction was being considered for the C&SLR, no one had progressed much beyond the idea that it would work with a traction unit at the front pulling a train trailing behind it. At the time, most of the very limited experience of electric traction was confined to tramcars, usually single vehicles equipped with a couple of small electric motors driving the axles through gears, all packed in under the car floor. However, it was being recognised that some modified version of the concept was possible and that it might be applied to a fully segregated railway, providing a lot more capacity than a street railway.

The idea took the form of a traction unit provided at each end of a train and that, because it was electric, it would be compact enough to fit at or under one end of a passenger vehicle. Two such vehicles, if provided with one at each end of a train, would provide enough power for a 3- or 4-car train and remove the necessity for a separate locomotive to be attached at the rear of a train when it arrived at a terminus, to work the train on the return trip. All that had to happen was for the driver to change ends. Although this is normal practice today, it was a new idea then and it had the possibility to be a big step forward.

POWER AND CONTROL

However, there were two questions. One was the ability of the motors to provide enough power and the other was the question of control. Looking at power first, the little motors used for tramcars were, at that time, limited to around 10-15 h.p. To get enough power to pull a 3- or 4-car train, you would need at least 100 h.p., especially on a line like the C&SLR, which had some steep gradients. With big power came big motors, too big to fit under a car floor, which led to the need to provide a large space at the driving position to accommodate the motor and its control apparatus. If you were to get the required performance, you needed two motors and, as we've seen (Article 1 in this series), it was proposed for the C&SLR that they would put one at each end of the train.

Then there was the question of control. On a tramcar or locomotive, whether steam or electric, control of the traction system was carried out on the vehicle, with commands transmitted directly to the traction unit by the driver on that vehicle. On an electric vehicle, the controller, with its resistances, was inserted directly between the traction supply and the traction motors. But, when the traction is split between the driver's position at the front and the rear car, several vehicles behind, control becomes a real issue. How does the driver transmit commands to the rear traction unit? How can control be passed along the train? Today, we do it with low voltage control wiring and remotely controlled traction units and we call it 'multiple unit control' but this didn't exist at the time and it was a difficult question to answer.

In 1888, the thinking was based on the then limited experience with tramcars. One suggestion was that trains would use the front car only, with the rear car being towed. At the terminus, the driver would switch off the leading car, change ends and switch in (or 'open up' as we say on the

Underground) so that the rear car became the leading car and the former leading car would be dragged along at the rear of the train. Of course, this meant that the rear car traction kit was dead weight and much energy would be expended towing unused equipment around all day, much like the bi-mode trains that have been foisted on Great Western and LNER in recent years.

Some elevated railway operators in the US, who were converting their lines from steam to electric traction in the early 1890s, realised this was a problem and actually uncoupled the leading car at the terminus and coupled another at the other end for the next trip. This was OK but it retained the complexity of terminal working since the motor cars were simply passenger carrying locomotives. This was accepted since electric traction was expected to be cheaper and cleaner than steam anyway. In a logical translation of the language of steam technology, the electric motor cars on these lines were described as 'locomotive cars'. The concept relied on the electrical equipment being compact enough to fit under the vehicle so that the car body could be used to carry passengers.

THE FIRST PROPOSAL

As we saw in Article 1, after the C&SLR lost its cable car system contractor and started considering electric traction, James Greathead, the line's tunnelling engineer, apparently got behind the proposal that the trains should be made up of 3-car sets with electric motors driving the leading and trailing bogie wheels. His idea was probably founded in the design adopted for the Bessbrook and Newry Tramway, which had been opened in Ireland in 1885, and the suggestion went into the invitations to tender sent out to prospective suppliers for the C&SLR. However, in response, Mather and Platt (M&P) raised a number of technical objections to the idea in their proposal in May 1888 and offered locomotive-hauled trains instead. As we saw, they were told to stick to the motor car train remit and consequently, they offered a revised proposal in September 1888.

Another motor car option being cast about at the time was to control both traction units from the front. Mather & Platt mentioned this in both their proposals of 1888 but they considered it "open to objections"[1] and spoke of the difficulties of providing "connections" between front and rear units. This was because, at the time, proposals envisaged the connections between cars carrying the full traction current. To do this, the cables would have to be substantial and would have to pass along passenger carrying vehicles. This was recognised as risky but no one had yet come up with a better idea and it was later adopted on the Waterloo & City (W&C) trains built in 1898. The complexity in providing this capability meant that the W&C trains had 11 cables running along the roofs of the cars. When Bernard Jenkin, the line's engineer, described this arrangement he wrote, "When a carriage is taken out or put into a train these leads must be disconnected and reconnected in the right way, as any cross-connection would be disastrous as soon as the current was turned on. A box is used for connecting these cables between the carriages. It required considerable care in its design in order that it might fulfil all the requirements…"[2].

Jenkin[3] had to use the arrangement in order to meet the performance specification but he was obviously a bit nervous about it and rightly so. Any fault on the cable could cause overheating if the protecting fuse didn't rupture quickly and this would likely lead to a fire and a lot of nasty smoke coming off the insulation. In a deep level tube tunnel, this could have serious consequences. It didn't happen on the W&C but the lesson was disastrously learned on Métro Line 2 in Paris on 10 August 1903, when an electrical fire on a train caused the deaths of 84 people. Many of them died of smoke inhalation. The incident galvanised the Board of Trade, as the responsible government agency in Britain, to issue revised engineering regulations for tube railways in May 1904, including, amongst many other instructions, forbidding the use of cables between cars carrying traction power and the running of trains with motor cars in the middle of the formation. The first of these two regulations in particular was to define traction equipment design on the London Underground for over a century and even up to the present day.

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1 Mather & Platt (1888), Proposed Scheme for Working by Electricity, May 1888, page 5.

2 Jenkin, B.M., 1900. The Electrical Equipment of the Waterloo and City Railway. Proceedings of the Institution of Civil Engineers (Vol. 139, No.1900, pp.56-96), p.76.

3 Mr. B.M. Jenkin does not appear to be related to the C&SLR's own, much respected general manager T.C. Jenkin.

ANOTHER GO

Ultimately, as we know, the C&SLR abandoned their original concept for motor car trains and adopted locomotive haulage. This was, in my analogy of three strikes and out, 'Strike 1'[4]. However, there were many on the C&SLR who knew that locomotive haulage was not ideal in many respects and they seemed to have clung onto the idea that the motor car could be a way to improve things, so they had another go in 1894. This time, they got as far as buying some hardware and testing it.

The first inkling we have that something was going on was in a board minute of February 1894 when it was recorded that the engineer submitted drawings of a new motor car and train[5]. We don't know what it looked like nor who was selected to build it but, in April 1894, the board agreed that the Chairman (Mott), should be given the discretion to choose a supplier for an "experimental" bogie[6], so it was obviously happening, if slowly. The bogies were eventually supplied by J.H. Tozer & Son of Birkenhead. Tozer's were rolling stock agents who purchased equipment on behalf of railway companies and they did several orders for the C&SLR. We don't know who actually built the bogies. We don't know for definite where the motors came from either. There is no surviving record of the purchase of motors for the train and it seems possible that they used the motors from Locomotive No.1, since it was not being used in service.

On 14 December 1894, it was reported that a trial of the motor car train was "satisfactory", so it obviously was built and ran, although a Chairman's report to shareholders of August 1894 had spoken of "difficulties".

Printz Holman records[7] that two motor cars were converted from a couple of existing Ashbury cars and were operated in a 4-car formation with two trailer cars. He also notes that the traction units on the two motor cars were connected by power cables running along the car roofs.

The Board of Trade inspected this lash up and the C&SLR board were informed in January 1895 that it was considered satisfactory[8]. The train must have been considered successful because, in April 1895, Peter McMahon, the line's engineer, was instructed to get prices from potential suppliers for 4 x 4-car motor car trains[9].

It was now a year since the project was first proposed and a plan seems to have evolved that they would buy motor car trains when additional stock was required but continue using locomotives until they became life expired. McMahon was also asked to price up the conversion of the whole fleet. It was after this that things began to change. At some time before July 1895, it was decided not to proceed with motor cars because on 30 July, the board decided to buy additional cars of the conventional C&SLR design[10]. The motor car idea had been dropped.

REVERSE ENGINEERING

There are a few features of this train that we can deduce with a bit of reverse engineering. We know that the motor cars were converted from two Ashbury-built trailers, in their original condition with the bogies set at 18 feet and bogie wheelbases of 4 ft. 6 ins[11]. The train had a driving position at each end, together with a single motor mounted on one of the two axles of the leading bogie.

Printz describes the motor bogies as being a hybrid that combined features from the locomotive chassis and the carriage bogies. With no need to support an end platform, the bogie frame was extended forward just enough to allow it to carry a coupler clear of the body. With a length of 29 feet, each of the motor cars was around 3 feet shorter than a standard car when measured over the bogie ends.

Fitting a motor under the floor would have needed considerable alterations to the car underframe. If they used motors similar to those fitted to the most recent locomotives built by Siemens they would

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4 As you might have guessed, when I lived in the US, I enjoyed watching baseball.
5 BTHR, CSL 1/3. m. 374, 13 February 1894.
6 BTHR, CSL 1/3. m. 427, 10 April 1894.
7 Holman, P (1990), '*The Amazing Electric Tube'* LT Museum, page 69.
8 BTHR, CSL 1/3. m. 739, 29 January 1895.
9 BTHR, CSL 1/3. m. 818, 9 April 1895.
10 BTHR, CSL 1/3. m. 933, 30 July 1895.
11 Later cars had 16ft 9 in bogie centres and 5ft bogie wheelbases. More on this in future articles.

have needed the floor to be raised or cut open to allow room for them. This meant that the motor had to occupy some of the passenger area. The arrangement had to allow for bogie rotation on curves too. It is likely that the driver's position was over the leading axle while the motor was mounted on the rear axle. The driver was probably provided with controls similar to those on the locomotives and it is also probable that the front and rear motors were connected in series, like the locomotives.

We also should not forget that the motor had to be positioned to allow room for the body bolster, centre pin and bogie bolster. Again, this would have involved considerable structural work and it would have required the motor to be positioned to allow the bogie to rotate. Either it was mounted with the field coils at an angle like the locomotives or vertically as was done on the Bessbrook & Newry vehicles.

Then there was the question of what would be done if the train stalled, requiring passengers to be evacuated into the tunnel. The raised floors in the original locomotives meant that evacuation had to be via the rear of the train. With equipment squeezed into both ends of a motor car train, both exits were obstructed. Surprisingly, the potential hazards posed by ladies in long Victorian skirts, clambering over greasy motors to get out of a train, went unnoticed by the Board of Trade officer, who approved the carriages for passenger service.

From a business point of view, the design meant that the space for the motor and the driver would have resulted in the loss of 12 passenger seats in each motor car. A quick calculation shows that the 4-car train would have offered 104 seats compared with 96 seats on a 3-car loco-hauled train, so all this very expensive conversion work only increased capacity by a mere 7.7%.

LOCOMOTIVES HOLD THEIR OWN

More information about the experiment came to light in 1904[12] in the discussion on Peter McMahon's paper about the 3-wire traction supply system used on the C&SLR. He said, in reply to a comment that electric locomotives were out of date, "I think the electric locomotive for tunnel work will hold its own. We thought we had extinguished it some six or seven years ago, and with that object in view we built a motor-car train, which had nearly 25 per cent greater seating capacity for the same weight as with locomotives, but we found in tunnel work it was not nearly so successful as the locomotive for the following reasons: any slight repairs to the motors or switch-gear in the case of a motor-train means shunting the whole train of four coaches into a siding about 130 feet long, while the same work on a separate locomotive could be executed in a siding about 15 feet long, so that the siding accommodation required for motor-trains is a very serious item".

What McMahon was saying was that they needed long sidings to accommodate a failed train but that they only had a few short sidings along the route for locos. They could also call on spare locomotives stationed around the line to deal with failures. McMahon continued in his comments, "Again, while under repair the whole motor-train is thrown out of service, and with separate locomotives the train continues in service, and a smaller number of carriages are required. The advocates of the multiple unit system say that the train can be broken up into independent units, but this involves an enormous amount of shunting, unless fan-tail sidings are available, which is almost impossible in a tube railway system."

McMahon's views appear rather narrow and, looking back, few of his excuses seem to us to have much weight today. In fact, at the time of this discussion (1904), the Central London Railway had, in 1903, abandoned locomotives after only three years of operation and was running multiple unit trains equipped with the Sprague control system, supplied by BTH.

They ran with motor cars at each end of their trains for 35 years. However, McMahon's comments about getting a motor car train off the main line were well founded for the C&SLR, particularly where the only way to get trains into the depot was to haul them up the 1 in 3.5 ramp at Stockwell.

Perhaps, as Printz Holman relates[13], there was also a major breakdown incident involving the train that coloured people's views or, more likely, they didn't know how to handle the breakdown and it

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[12] McMahon P. V. Adjourned discussion on *'City and South London railway: working results of the three-wire system applied to traction, etc.*'. Journal of the Institution of Electrical Engineers. 1904 Apr; 33 (165):170-99.

[13] Holman, P (1990), '*The Amazing Electric Tube'* LT Museum, p. 43.

took too long to sort out. We should remember too, that the loco crews could look after the motors on route.

The motors were rather fragile and checking and adjusting brushes was a common issue but they couldn't do this on the rear car of the motor car train and it is likely that this caused some of the problems. In reality, the railway and its equipment was just not designed to handle motor car trains. Whatever the reason, this was the C&SLR's second 'strike' in their three attempts to introduce motor car trains and they forthwith resumed locomotive development with the completion of Locomotive No.17 in 1896.

TAKE OVER

In 1913, the City & South London Railway was taken over by the Underground Electric Railways of London Ltd (UERL). This was the company that owned the District and the three London Electric tube lines. They also absorbed the Central London Railway at the same time. All the companies were now under the same overall ownership and, in the case of the Central London and the C&SLR, they gradually began to adopt some of the parent company's operating practices. For the C&SLR, this was more difficult, since they were the only line relying on locomotive operation and they had the smallest tunnels of any of the Underground lines.

There was an immediate appraisal of the C&SLR. There was concern about the efficiency of the train operations and of the line's capacity and, sometime during late 1913, a proposal for new rolling stock was drawn up.

The result of this proposal that has survived is a drawing for a new train based on the latest stock, which happened to be that being built for the LER's Bakerloo Line extension to Queen's Park. The train was a straight copy of the Bakerloo design but squeezed into a 10 ft 6 in tunnel instead of the 11 ft 8¼ of the LER lines. The drawing survives in the LT Museum collection but it is actually marked in pencil "Bakerloo 1914", even though the tunnel diameter on the drawing shows 10 ft 6 ins. I offer a modern version of this drawing in Figure 1.

There appears to be a couple of errors in the drawing. The trailing end bogie is shown with a 6-foot wheelbase. This is obviously incorrect, as it leaves insufficient space for the bogie frame at the end of the car where the entrance platform was located.

I have set the bogie wheelbase at the usual C&SLR stock dimension of 5 feet. In addition, the side elevation of the car shows plain windows, with no means of ventilation. This was hardly the intention, especially since the car roof had no signs of ventilation either. The passengers would have been in danger of suffocation.

According to the drawing, the new trains would have been made up with motor cars, trailers and control trailers and they would have had multiple unit (MU) control. The leading and rear cars were to have had driving cabs and a motor bogie. Control of the rear bogie was to be achieved by connecting the traction system to a low voltage controller in the leading cab through a multi-core cable, as was standard on other UERL lines[14].

NEW TUNNELS

The tunnel diameter of 10 ft 6 ins shown on the original drawing is interesting, since there were sections of the original C&SLR route that were restricted to an internal diameter of 10 ft 2 ins. The proposed design would not have fitted in these sections. It transpires that they were looking at enlarging the tunnels as early as 1912.

The original UERL takeover offer required the C&SLR to promote a parliamentary bill to enlarge its tunnels to allow the use of the standard tube gate stock operating over the Hampstead tube line. They were planning on joining the two lines near Euston. By April 1914 the wording had changed to "the enlargement of certain portions of the tunnels to admit the use of larger rolling stock". Of course, money was an issue. There was some back tracking from the original proposal and the enlargement was now going to be confined to the sections of tunnel built to the 10 ft 2 in diameter.

Between 1912 and 1914, there had been various proposals to fund the enlargement. The new solution was clearly a cost-cutting exercise, which would require the enlargement of only the short

[14] For the story of the development of MU control, see "The Underground Electric Train", by Piers Connor, Crowood Press, 2015, p. 17 et seq.

section of 10 ft 2 in tunnels (Elephant & Castle to Borough Junction). Early in 1914, the C&SLR started looking for ways to pay for new stock and were, at one point, in discussions with the Metropolitan Carriage & Wagon Company over a scheme to buy “new, larger” rolling stock with payments deferred over a number of years[15]. The proposed Metropolitan Carriage & Wagon Co rolling stock (in the drawing) and the partial enlargement of the tunnels were actually part of the same project.

The tunnel enlargement work was actually started but it was suspended shortly after the outbreak of war in August 1914 and the new stock plans were shelved. No further rolling stock development took place until 1919 but it is interesting to speculate that we would have had a completely different railway and different rolling stock had not the Great War intervened.

[15] BTHR, CSL 1/9. m. 174, 13 May 1914.