THE CITY & SOUTH LONDON RAILWAY ELECTRIC TRAIN
PART 10 – THE LOOSE ENDS AND THE END

by Piers Connor
with Printz Holman

MORE ON MOTOR CARS

In Article 6 of this series we described the C&SLR's attempts, in 1894-95, to operate a motor car train and we suggested some possible design features. Now, with the addition of much detailed research carried out by Printz, together with a lucky find by me, we can include some more details and observations, including a drawing of the train, a photo showing what we believe to be the original motor bogies and sketches that I've prepared showing how the motor bogie could have been fitted under an Ashbury-built car.

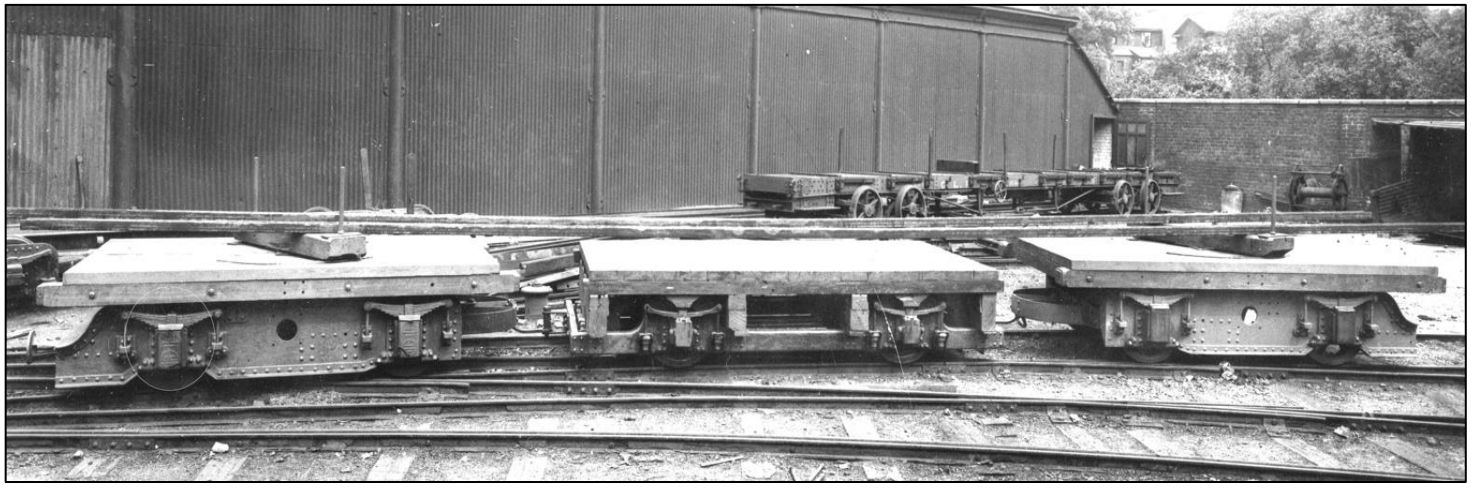

Figure 1:This is a set of three bogies seen at Stockwell depot coupled together to form a rail carrying wagon for the C&SLR. Our interest is in the two end bogies. These are the specially ordered motor bogies, designed for the C&SLR motor car train of 1894 being reused following the closing down of the motor car experiment. We don't know where the middle bogie came from but it looks like a tube railway design. Photo LT Museum.

The motor bogies appear in a photo (Figure 1) of a C&SLR rail-carrying set of three 4-wheeled flat wagons. Each wagon uses a bogie as its main structure and each has a boarded wooden frame added on top to carry the rails. The two end wagons use the bogies that were identified by Printz as those used in the experimental motor car train. This identification is confirmed by a German magazine article dating from just after the time that the experimental train was operating. More on this source later.

The bogies were originally ordered in April 1894[1]. They were each designed to accommodate a single electric motor, believed to be of the Mather and Platt (M&P) type, with its armature fitted round the axle and with the motor partially supported on the bogie frame. The intention appears to have been to try to mount the motor as it had been mounted inside a locomotive but suitably adapted for the bogie. The shape of the bogie is unusual, being similar to the standard design used on the early trailers at the in-board end but heavier in construction and extended at the outer end, apparently to provide room for a drawbar and coupler in case a tow by a locomotive was needed.

The idea of getting a Mather & Platt motor to fit under an Ashbury trailer car intrigued me, so I decided to have a look at how it might be done. The motors were very bulky by modern standards and they weighed two tons each. As installed on the M&P locomotives, they were mounted inside the locomotive frame but they protruded through the loco floor by as much as 14 inches, even though they were mounted at an angle of 60 degrees from the vertical (see Figure 3 in Article 2 in this series[2]).

Unlike the locomotives, where the motors were mounted in a static frame, the traction motor on the motor car had to be mounted on the bogie frame and the bogie had to move under the car by up to

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1 BTHR, CSL 1/3, p.427, 10 Apr. 1894.

2 *Underground News,* March 2019.

5 degrees to the left or right. This movement was required for the 100-foot radius crossover at Stockwell, the most severe on the system. In addition, it was necessary to provide the structural support for the car body connection to the bogie (the body bolster) and its counterpart on the bogie (the bogie bolster). To me, this looked like quite a challenge so, with only the existing carriage and locomotive drawings as guidance, I decided to see how the bogie might fit under the car and then how the motor would fit in the bogie. I used a simple drawing programme on my computer to test some ideas.

TRIAL AND ERROR

I began by assuming that, because of the very tight fit, the motor would have to be fitted vertically, rather than at the 60 degree angle of the locomotive mounting, but I soon discarded this because of the large mass that would be concentrated on one axle. This was likely to create an unacceptable level of vibration and might also have led to wheel unloading on the non-motored axle, so I started to look at ways of getting the motor to fit into the bogie frame at an angle.

I did a series of sketches to see how it would fit and at what angle. In doing this, I had to allow room for the motor to turn with the bogie but without hitting the body bolster. This proved quite difficult. There are no detailed dimensions for the M&P motor so I had to scale off the drawings that exist; not good practice but the only way available. I went for a 'trial and error' approach.

A big issue was the need to provide a support system for the motor, similar in principal to that provided on the locomotives but to allow clearance for bogie rotation. On the early locomotives, one end of the motor was hung from a frame arching across the width of the locomotive. A similar arrangement was needed in the bogie environment, additionally allowing for the 5 degrees turning off the straight on either side. At the same time, the motor had to protrude through the car body floor and had to turn without hitting anything.

Another issue was the connection between the car body and the bogie. The bogie had to be connected to the car body by a steel pin passing through the body bolster on the car and the bogie bolster on the bogie. This pin is the pivot point for the bogie. With the motor positioned at an angle towards the centre of the bogie frame, both bolsters had to be positioned low down to provide the necessary clearance (Figure 2). The arrangement was similar to that already on the passenger cars but the centre section had to be further lowered to provide the necessary clearance.

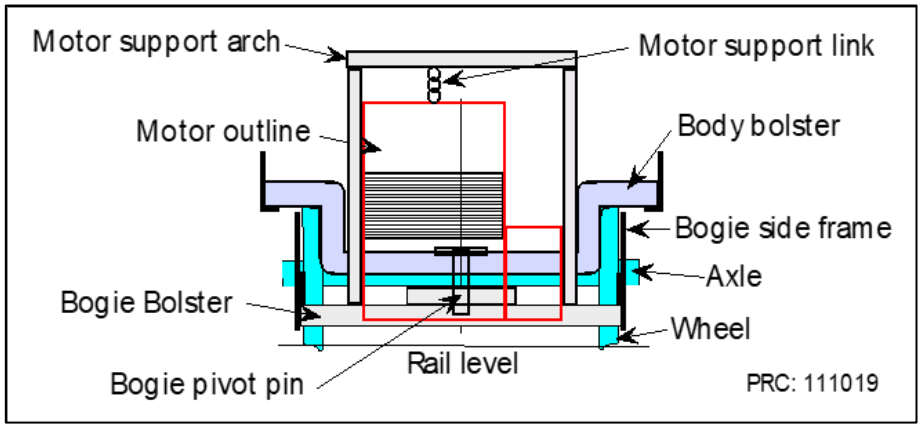

Figure 2: A schematic of the motor car end elevation demonstrating how the body bolster had to be built with its central portion lower than the ends in order to accommodate the motor, which tilts over it. This was already the standard arrangement on the C&SLR cars but was deepened for the motor car. I imagine the motor support was a built-up arch with the motor suspended by links as on the locos. Drawing: P. Connor.

The bogie bolster also had to carry the support structure for the motor whilst being able to rotate. It was difficult to find a way to connect the motor to the support structure because a large part of the available space was taken up by the field magnet windings and there was nowhere to fix anything. I decided to copy the locomotive method so I put in a steel support arch over the top of the motor. This had to be attached to the bogie bolster in such a way that it didn't interfere with the turning of the bogie. This is quite difficult, as Figures 2, 4 & 5 show.

An important factor in my exercise was the bogie wheelbase, which had to be long enough to accommodate the tilted motor but not so long that it caused wheel wear on the severe curves. I began with a 4ft 6in wheelbase but it proved impossible to get the motor to fit at a sensible angle without interfering with the body bolster. A better fit was achieved using a 5-foot wheelbase.

In the end, after testing with 11 variations of the drawing, I managed to get the motor to fit at an angle of 60 degrees, as was done on the locomotives. But, and this is a big but, it could only be done if the bogie pivot point was set towards the rear by 6 inches. The bogie thus becomes

asymmetrical, rather like the 1938 Tube Stock but with the motored axle set further out than the trailer axle. The only way out of this problem would be to reduce the angle of the motor but this would cause it to intrude further into the car body space and put more weight onto the driving axle.

I believe that there is some evidence for my choice of solution. A detailed examination of the photo of the motor bogie shows that it is possible that the design was asymmetrical. On the bogie side frame, there are no rivets where you would expect to see them if the bogie bolster was secured to the side frame at the mid-point between the axleboxes, but there are some closer to the non-motored axle, suggesting an asymmetrical layout (Figure 3). Getting the inside-hung brake shoes into the remaining space with this solution would be tight but it is do-able. I suspect that the hole seen in the side of the bogie frame was for access to a brake lever pivot.

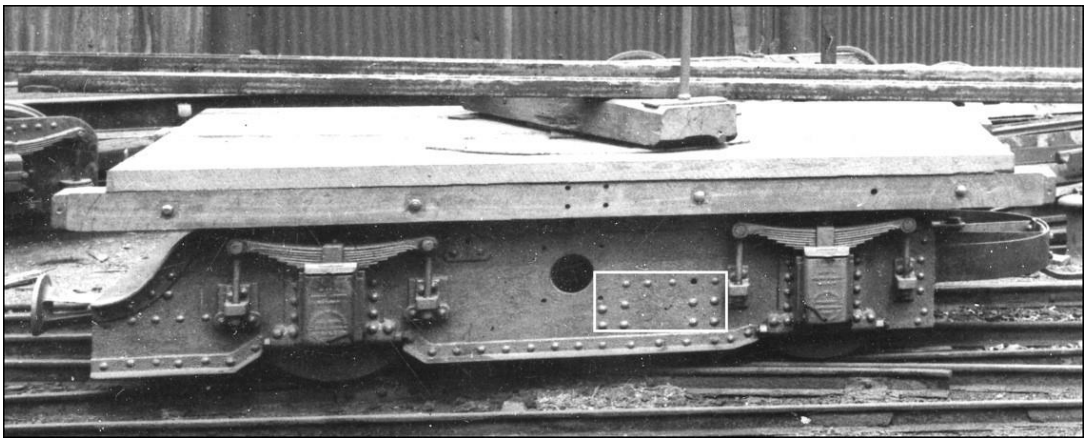

Figure 3: C&SLR motor bogie showing, inside the white rectangle, the location of rivets believed to be where the bogie cross members were attached to the side frame. Photo: LT Museum.

THE POSSIBLE SOLUTION

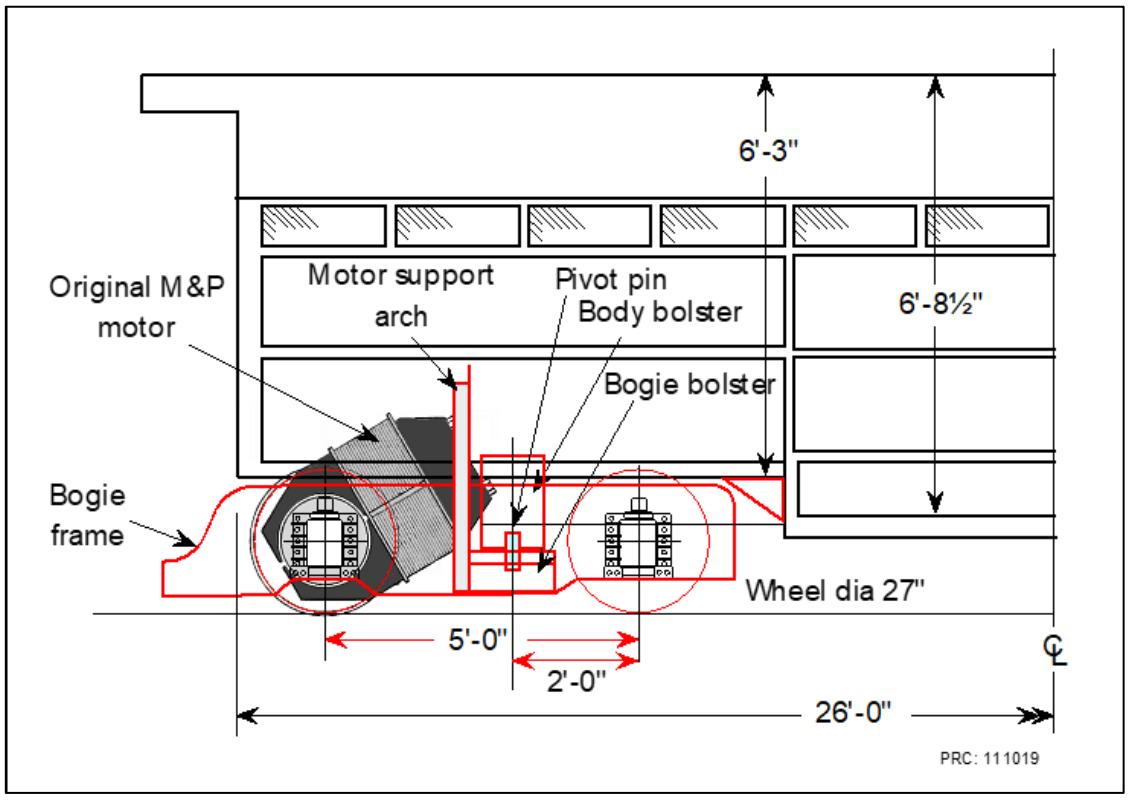

Figure 4: A schematic side view demonstrating how a M&P motor could have been fitted to a C&SLR Ashbury car with a motor bogie. The motor is held at an angle of 60 deg. by a hook attached to the motor support arch. The motor support arch is attached to the bogie bolster structure so that it clears the body bolster when the bogie rotates on a curve. Note that the bogie wheelbase is 5ft 0 ins and the pivot point is set at 2 feet from the rear axle, giving an asymmetrical layout. The wheel diameter is 27 ins., the same as the C&SLR's locomotives of the period. The drawing is not exactly to scale as the necessary data is not available. Drawing: P. Connor.

Having spent some time on the trial and error process to see how the M&P motor could be made to fit under an Ashbury car, I tidied up the drawings to show how it might have worked. The drawings provide a side elevation (Figure 4), an end elevation (Figure 2, discussed above) and a plan (Figure 5) of the motored end of the car.

The side elevation (Figure 4) shows how the motor bogie could have been positioned under the car. The motor is shown mounted on the leading axle, although my first instinct was that it should be on the trailing axle because the motor itself protruded through the cab floor and created a considerable obstruction, much as on the locomotives. Being on the front axle reduced the space available for the driver to stand to a few inches. However, there was no reason why the driver couldn't stand

behind the motor, as long as he had an unobstructed view forward. Other evidence, as we will describe later, supports the idea that the motor was on the front axle.

My schematic of the bogie plan under the car shows (Figure 5) how tight the clearances were for the 5 degree rotation needed. The two areas with particular difficulty were the motor support arch and the brake rigging (not shown), both of which were right on the limits of tolerance, if indeed there was any tolerance.

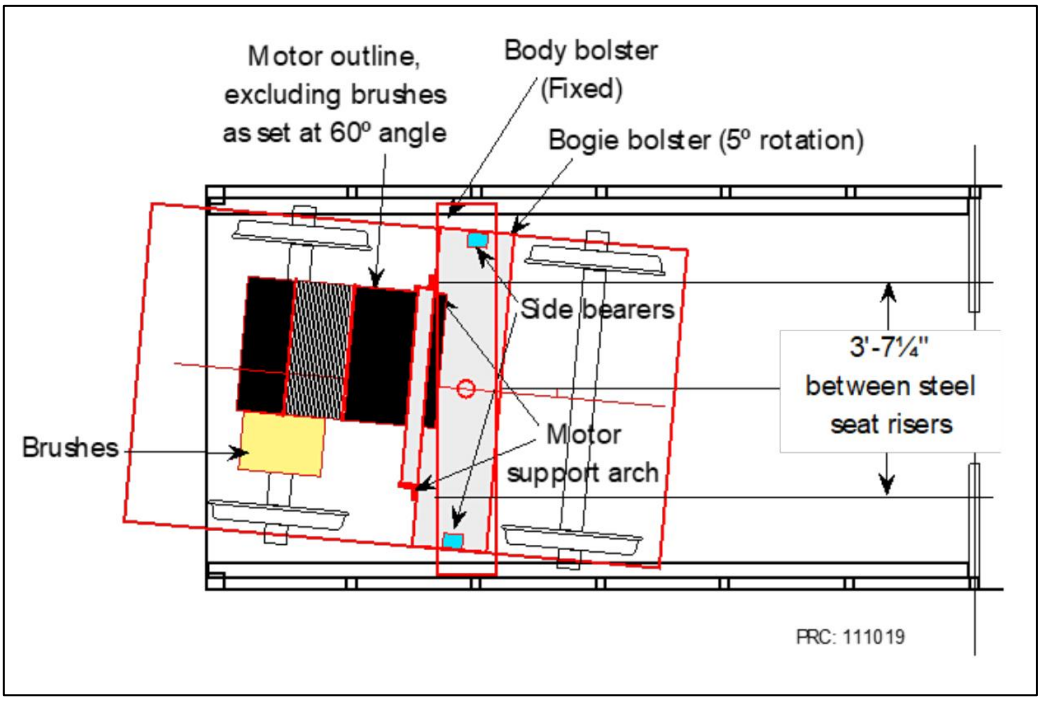

Figure 5: The schematic plan view of a possible arrangement of the M&P motor in the specially designed bogie fitted to an Ashbury car. The bogie is shown at an angle of 5 deg. from tangent as it would appear on a 100-foot curve. The fit is quite tight, particularly where the motor support arch is attached to the bogie bolster. It is likely that the steel seat risers that ran the full length of the original cars were cut back to allow the motor to fit. Not surprisingly, it's not exactly to scale. Drawing: P. Connor.

THE GERMAN FACTOR

Whilst going through the possible arrangements for fitting a motor under an Ashbury car, I also spent some time looking for any published hints as to how it might have been done. For many years I have used a US-based website called **archive.org** for research into railway engineering. It is packed with copies of out of copyright documents, magazines and books that can be read online or downloaded and there is much of interest on electric traction. Despite being mainly US sourced, some information on British systems is available and it was here that I found a sketch of the C&SLR motor car train.

The sketch was in a German magazine called 'Deutsche Bauzeitung'. I was searching "south London railway" to see what might be available on the C&SLR and it appeared amongst a range of other publications. The edition of 5 May 1900 contains an article on urban railway systems that includes a page of sketches of trains used on systems in London, Paris, Berlin, Budapest and Glasgow. It includes two trains from the C&SLR, showing them as a standard 3-car locomotive-hauled train and a 4-car motor car train, despite the latter having been abandoned as impractical by the C&SLR some four years earlier in 1896. I wondered about this and, trawling through other copies of this magazine, I discovered that the C&SLR drawing had appeared before, in 1896 (Figure 6), with a descriptive text, in German of course. I don't speak German but, thanks to Google Translate, I managed to get a good idea of what was written. I have tidied it up a bit to produce the following paragraph which relates to the rolling stock.

GERMAN TRANSLATION

The [C&SLR] trains consist of 3 cars and an electric locomotive. However, as the Liverpool elevated railway has shown how much more advantageous it is to operate with motored vehicles instead of electric locomotives with trailer cars, a test train of four cars has been made with the motors mounted under the two end carriages, and it is likely that this system will take over. A noteworthy innovation of the same is that a common bogie frame is used to carry the ends of a two-car body. One unit, arranged this way with a coupled pair of cars and with the motor at one end forms half of a train and can be moved and replaced independently.[3]

[3] Translation edited by P. Connor from '*Deutsche Bauzeitung*', 4th July 1896, p. 344.

INTERPRETATION

In interpreting this article, we have to be very careful. It suggests a number of ideas that are misleading and we know that both the text and the drawing are, in a number of areas, inaccurate. It demonstrates that the press is not always a reliable source of technical information, although *Deutsche Bauzeitung* is regarded as one of Germany's top architectural and civil construction journals and is still in publication after over 150 years.

The illustration accompanying the article is shown in Figure 6. It shows the same arrangement as the one reproduced in the 1900 edition of the magazine. The illustration provides an initial degree of credibility in the part that shows a 3-car C&SLR locomotive-hauled train, which is a pretty good representation of a train with a locomotive of the 1890-91 era. However, the locomotive is missing a traction motor and the cars have some errors in the details. This suggests that the draughtsman made some assumptions about things he wasn't too sure about or couldn't remember. As a result, it is wise to approach the drawing of the motor car train with a degree of caution.

To begin with, the design of the cars in the motor car train varies from any actual C&SLR types that we know of, apart from the general shape of the body and the inclusion of the small windows. The gates are of a different design and none of the bogies appear to match any of the standard C&SLR car bogies. The depiction of the two bogies in the middle of the train being connected in some way is not credible and neither is the idea of one bogie supporting two car ends. The wheelbase of such a bogie would have been too long for the very sharp curves on the line[4]. What is significant though, is that the two motor bogies are shown as very similar in shape to the two bogies identified by Printz as those used on the motor car train (Figure 1).

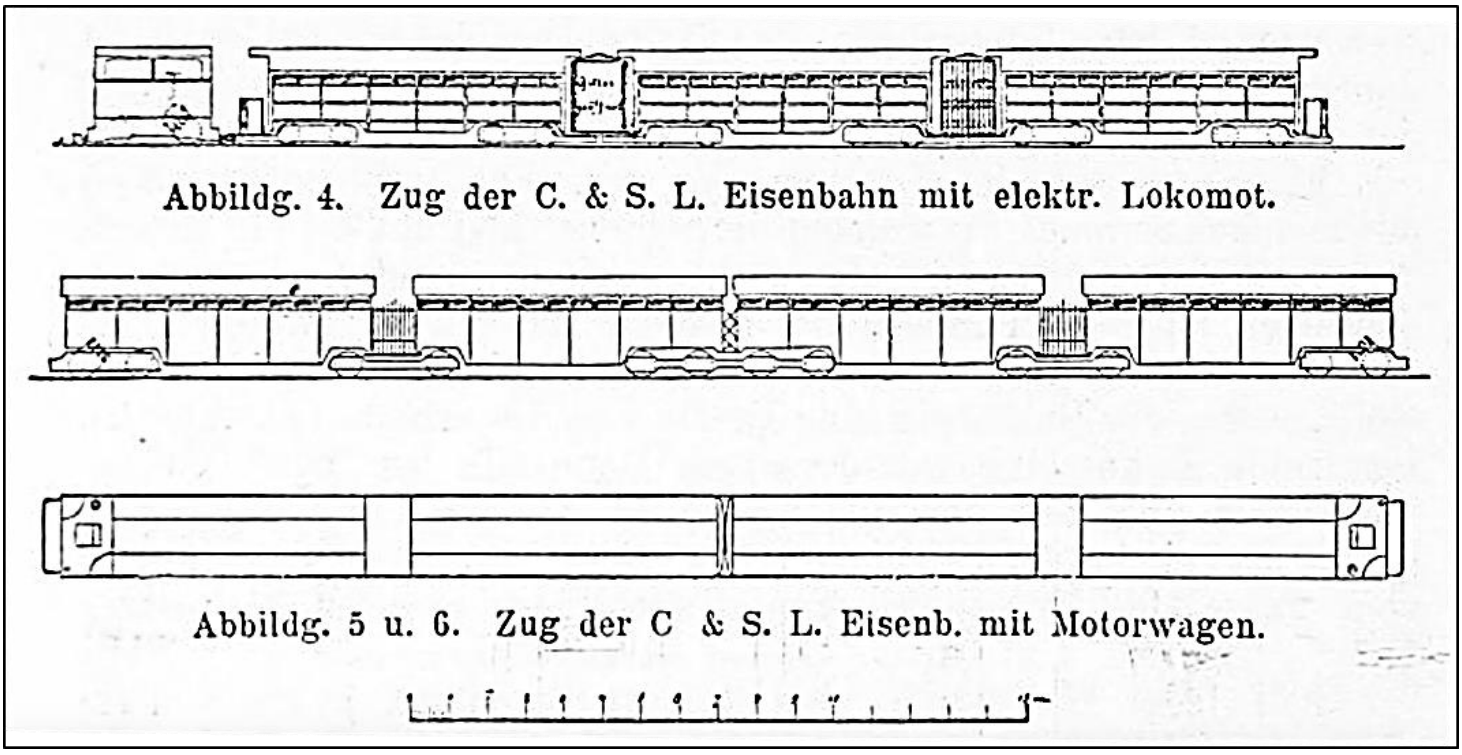

Figure 6: An enlarged copy of a drawing of C&SLR 3-car train and locomotive (above) and 4-car motor car train (below), that appeared in Deutsche Bauzeitung magazine in 1896. It shows the motor car train with an electric motor located on the leading and rear axles of the train and with single bogies between pairs of cars to give an articulated formation. It also shows the two articulated pairs of cars close coupled in the middle of the train with no passenger entrance platform at that point. Neither of these two depictions are really credible for the C&SLR. Source: 'Deutsche Bauzeitung', 4 July 1896, p.344.

Then there is the middle point of the 4-car unit, where the German article suggests there was a coupling point, allowing the train to be split into two halves. This might suggest that there was an intention to run 2-car motor car trains. The depiction of two bogies joined together would have made

[4] The author of the German article describing the idea of a 'shared bogie' on the C&SLR seems to have been well ahead of his time. I can find no references to the idea of a shared bogie or an articulated carriage before the early 1900s, when H.N. Gresley (of the Great Northern Railway) patented the idea. Perhaps there's a reader who knows different.

this impossible and is obviously an error and, as Printz reminded me in our discussions about this article, although the C&SLR did once consider using two car trains for off-peak services, it was found impracticable because of the design of the intermediate gated platforms, which had to rest on the extensions of the two adjacent bogies. If one was removed, the platform would only be available on one car and it wouldn't be secure. What is also strange is the very close coupling shown in the drawing. If it was arranged in this way, it would prevent the use of the position as an entrance platform. This would have increased dwell times and thus eliminated much of the benefit of the increased capacity of the train.

We know that no intermediate driving controls were provided. The Board of Trade inspecting officer's report on the train speaks only of driving positions at each end of the train. It also mentions a power cable that ran along the roof of the train and the importance of ensuring that it was isolated from the passenger accommodation. There is no mention of intermediate driving positions or of traction power being fed down into the carriages in the centre of the train. In any case, there would have to be facilities for easily disconnecting the cable at the mid-point of the train and somehow connecting or switching in the control equipment. There was a requirement that the electrical fittings and connections were isolated from the passengers to prevent danger of injury from electric shock or fire. As there was only direct control of the traction current, these requirements would also have to apply to any additional control areas.

We know that it was impossible to uncouple a car from a standard three-car train in service conditions because the main Bostwick gated platforms required the support provided by the coupled bogie extensions that spanned the gap between two carriages. When the motor car train was constructed, it is possible the engineers recognised the advantage of allowing for central uncoupling for a whole variety of practical reasons. There is no indication that they had any incentive to use this train for a two-car experiment or that they had ideas of creating multiple units.

It is worth remembering that the C&SLR's engineer, Peter McMahon, would have been given a simple brief in 1894; he had to get a four car motorised train to operate with the objective of increasing capacity and replacing the locomotives. Overcoming the problems of fitting and operating electric motors in a tight space and controlling one of those motors from the opposite end of the train was enough of a challenge without adding further complications.

Where the German translation says, *"One unit, arranged this way with a coupled pair of cars and with the motor at one end forms half of a train and can be moved and replaced independently".* We should note the words 'half a train' and 'moved and replaced independently'. There is no suggestion that this half a train could operate as if it were a complete train but it could apparently be moved and replaced independently of the other half. It is also worth noting that getting a 4-car train up the ramp to the depot at Stockwell would have been difficult, so the ability to divide the train into two halves would have made this operation a lot easier.

McMahon alluded to this in 1904[5] when he said, "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". This appears not only to confirm that the train could not operate as two units, but that it was never uncoupled in service. The facility to uncouple would probably only have been used when the train had to get into the depot.

OTHER EVIDENCE

Prior to the discovery of the German article, virtually the only information we had on the motor car train is a few references in the minute books, brief notes from the (now destroyed) inspecting officers reports and some comments by McMahon in his paper.

However, we can look to the research done by Printz, who notes that two cars were seriously damaged early in the life of the railway; it is highly likely that these were rebuilt as the motor cars. One of these cars had its front bogie ripped out, which would have affected the frame and the area around the bolster pin – the very area that would have required major rebuilding to allow the fitting of the motor bogie.

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[5] 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.

Looking at the period after the experiment, it seems pretty certain that the two central, unpowered cars, which had undergone minor modifications to allow the traction power cable to be carried along their roofs were, once the cable had been removed, fit to be returned to service. It is difficult to imagine that the two defunct motor cars would have been allowed to occupy valuable track space after a decision had been made to stop the trials but we should remember that the company did not like to get rid of anything. We don't know what happened to the bodies but, in all likelihood, they were removed from the bogies and put in spaces to the side of the track, as was done with other bodies seen in some later photos of the depot. This would have allowed the standard (non-motorised) bogies and the electric motors to be recovered for reuse. The driving bogies (less their motors) were specially designed and wouldn't have been suitable for use as car bogies, so they would also have been put to one side at this time. There is evidence to suggest that the conversion of these bogies to a rail carrying unit was carried out some time before 1914.

In assessing the veracity of the German article, it appears possible that the author visited Stockwell and saw the train, or at least what was left of it. We can note particularly the plan of the carriage that includes some detail that we would not expect to see if it had been drawn purely on a verbal description. For example: there are two quarter-circular arcs at adjacent corners of the driving compartment and two circles of different sizes placed asymmetrically within the compartment, but in a position that is repeated at both ends of the train. This is the something that a draughtsman might add if they had seen it, but would be unlikely to create just for the sake of it, as it adds nothing either aesthetically or as a way of explaining a key point. We don't know what they depict and we know for certain that some things have been guessed – or remembered inaccurately – by comparing the illustration of the three-car train to the real thing.

Taking all the above into consideration, we may use this German article to give us a basic impression of the motor car train, but we should not fall into the trap of using it as a definitive way of filling in the blanks in our knowledge. Regrettably there are a number of mistakes and some facts seem to have been made up, so we must treat it with caution.

DISPOSAL

As described in last month's article, the reconstruction of the C&SLR to allow standard tube-sized trains to operate over the line began in 1922 and, while the work was going on, varying levels of reduced train operations continued for a time but the line was closed throughout from 28 November 1923. By that time, as we saw last month, some locomotives and passenger cars had been converted for use as engineer's vehicles but the rest of the fleet became redundant. They were to be replaced by new 1923 Tube Stock.

The C&SLR had no use for the old cars and quickly started to get rid of them. Some of them were moved off the railway to be used as store rooms, tool rooms and even changing rooms around the Underground and many were sold off to private individuals for use as garden houses and tool sheds.

Many of them survived into the 1960s and a few to the present day. Some of the information about the different batches of cars described in our story has been made possible by the survival of various examples and by the detailed examination of them by Printz.

Figure 7: Two Hurst Nelson cars (minus bogies) being hauled by road into Acton Works in 1925. They were to become changing rooms for the new sports field being provided next to the works for District Railway employees. Source: Collection: B.R. Hardy,

One of the early cars was retained and rebuilt extensively to convert it into a close representation of the original design. The rebuilding was necessary because of the modifications that had been carried out on many of the original cars, in particular the enlargement of the windows. It was exhibited at the 1925 centenary celebrations at Darlington, along with locomotive No.36 and then at the District Railway 60th anniversary at South Kensington in 1928. Both vehicles were stored at Lillie Bridge until 1937 when the car was transferred to York Railway Museum. In 1975 it was passed to the LT Museum and is now on display at Covent Garden.

The locomotives, or the 40 of the original 52 that were left on the books at the end of 1924, were mostly broken up for scrap at Stockwell. Only two machines survived, an original Mather & Platt machine and the Crompton-built No.36, which was repainted for exhibition at Darlington as noted above and which was eventually mounted on a plinth at Moorgate Metropolitan Railway station. It was seriously damaged in an air raid in December 1940 and was subsequently broken up. The wheels, axles motors and number plate survived and were eventually sent to the Science Museum.

The surviving Mather & Platt locomotive was reconstructed at Stockwell from the body of locomotive No.13 and parts from

Figure 8: C&SLR locomotive No. 36 standing on its exhibition plinth amidst the rubble of Moorgate (Metropolitan) station following the air raid of 29th December 1940. The locomotive was later broken up for scrap although some parts were saved and were later donated to the Science Museum. Source: Unknown.

Nos 1 and 14. It was given the number plate from No.1 but this was changed back to 13 when it was transferred to the LT Museum where it remains to this day[6].

EPITAPH

The City & South London Railway was the world's first locomotive operated, passenger carrying electric railway to survive beyond the experimental stage to give regular service. It was also the first tube railway. One American book, published in 1893, described it as, "that pioneer of high-power and high-speed electric traction"[7]; a little over the top for us today perhaps but it is notable that the C&SLR was regarded around the world as the leader in railway electric traction in the 1890s and many cities are recorded as using the line as the example that would solve their own urban transport problems.

Another technical feature that the C&SLR pioneered was the use of gearless motors. Although some earlier experiments had demonstrated electric motors with the armatures fitted round the axles, none had actually been used for traction. The normal approach was to drive electric tramcars with gears so as to provide the necessary torque with a motor that would fit under a tramcar floor but, as we've described in this series, in those days, gears were crude, unreliable and very noisy. Some tramcar operators reported having to change gears every few weeks, an expensive and time-consuming operation, so the gearless motor seemed a good solution. Eventually, better materials for gears and installation in an oil bath were introduced to solve the problems and the gearless motor became obsolete.

One final feature of this railway that we should remember today is that it was largely designed by British engineers. This was contrary to the course of development in electric traction, which was generally more advanced in the US than in Britain. Starting with the civil construction of the C&SLR by James Greathead (who was actually South African) and system design by the Hopkinson brothers, Edward and John, and then installation under George Grindle and ending with operation under Peter McMahon and Thomas Jenkins, they were guided by the skilful chairmanship of Charles Grey Mott. They were pioneers in urban electric traction and their basic ideas and experience formed the foundations of what the Underground has to this day.

6 Holman, P. *The Amazing Electric Tube*, LT Museum, 1990, p. 68.
7 Crosby, O.T. and Bell, L., *The Electric Railway*, The W. Johnson Company Ltd., New York, 1893, p.254.