THE METROPOLITAN RAILWAY ELECTRIC TRAIN

by Piers Connor

with Charles Horsey

7. BOGIES, CRADLES AND BLOWERS

EARLY BOGIES

In 1898, the Metropolitan introduced a new fleet of coaches that they referred to as 'Bogie Stock'. The coaches were the first on the railway to be provided with bogies instead of the usual 4-wheeled and 8-wheeled 'rigid' stock acquired previously. The new stock was part of a late 19th Century effort to modernise the railway. The new stock saw the introduction of bogies but also of a new type of bogie construction, using a technique known as pressed steel. The bogie design was referred to as Fox's patent. The design was a standard British arrangement but the use of pressed steel, as opposed to the more common steel plate, made it quite innovative for the period. Fox had first patented the pressed steel form for rolling stock frames in 1887 and introduced it as a bogie design soon afterwards. Samson Fox (1838-1903) was a steel manufacturer. He set up the Leeds Forge company and he developed the pressed steel process, originally for certain types of boilers, and then applied it to railway bogies. The Metropolitan used the design in various versions for much of its electric and coaching stock.

Following his success in England Fox later set up the Pressed Steel company in America. He became very wealthy and was a well-known philanthropist in the Leeds and Harrogate areas. He also paid for the building of the Royal College of Music in London. Down the generations, the Fox family became famous actors. His great, great granddaughter is Emilia Fox, (from the TV series 'Silent Witness'). She is the daughter of actor Edward Fox and niece of actor James Fox. Laurence Fox, from the TV series 'Lewis' and more recently, political sensationalist, is Emilia's cousin.

Fox's bogies were provided on both the motor and trailer cars of the Metropolitan's 1904-06 Saloon Stock (Figure 1). The Metropolitan's bogies came in two varieties – one to carry traction motors, the other as a trailer bogie. Both varieties had a 7-foot wheelbase. The main differences were in the bolster suspension and in the braking provision, where the trailer bogies had two brake blocks per wheel, while the motor bogies had only one per wheel. It is probable that they thought there wasn't enough room for the brake rigging around the traction motors for two brake blocks per wheel.

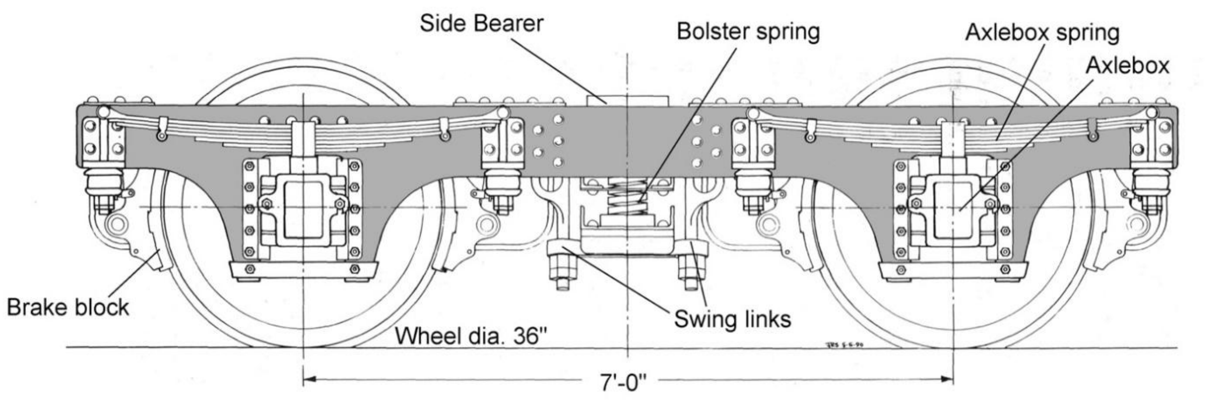

Figure 1: Standard Metropolitan Railway pressed steel trailer bogie (later referred to as Type MR by London Transport) with laminated (leaf) primary springs and coil bolster springs. This was the type provided for the 1905 Stock. Similar versions appeared on later stocks. The leaf springs rest on top of the axleboxes and are fixed to the side frame with brackets attached to 'spring hangers'. These spring hangers have to allow for spring movement at the connections so they are usually hooked onto the spring ends. At the bracket end, it is usual to have an additional small 'hanger bracket' spring, which can be a steel coil or rubber. The usual sprung bolster is provided but with coil springs. A similar but heavier design was used for motor bogies. The brake rigging is not included on this drawing, originally by J. Snowdon and adapted by P. Connor.

The bolster suspension on the trailer bogies used a steel coil system as shown in Figure 1 but the original 1904 Saloon Stock motor bogies had substantial sets of twin leaf springs that protruded outside the side frames of the bogie (Figure 2). This is likely to have been because of weight considerations. Fox's bogies under a Bogie Stock coach needed to cope with about 20 tons of weight, less the mass of the bogies. A Saloon Stock motor car was around 40 tons overall including bogies, a testament to the capability of the Fox design form. The heavier car body and equipment is a good reason why the secondary springs would need a radical change if designing for them to go under a motor car: to give more load-bearing ability plus some friction damping in the leaves. Curiously, the 1905 electric locomotives didn't have this design, they had coil bolster springs. In any case, the design was abandoned for the 1905 Stock. This stock and subsequent orders were provided with steel coil bolster springs like the 1904 trailers and the 1904 motor bogies were soon altered to match.

It seems likely that the reason for the change was related to the problems with shoegear which, as we've seen in earlier articles, had to be substantially modified immediately after the 1904 Stock went into service As the stronger leaf springs protruded outside the envelope of the bogie frames, they would move laterally with the spring planks, outwards and slightly upwards or vice-versa. The lower-set, smaller cross-section steel shoebeam originally used was needed to stay clear of the springs in all dynamic conditions and perhaps this explains the original use of a steel section. Sadly, we've found no picture or time evidence that would link the shoegear changes to bogie design changes. However, it's not difficult to suppose that there's most likely a connection with the change in shoegear design, since the re-located axlebox mounted shoebeam would be getting close to being foul of the leaf springs. For a permanent, District Railway-like solution, the leaf springs had to go and were replaced by a nest of steel coils to take the loads.

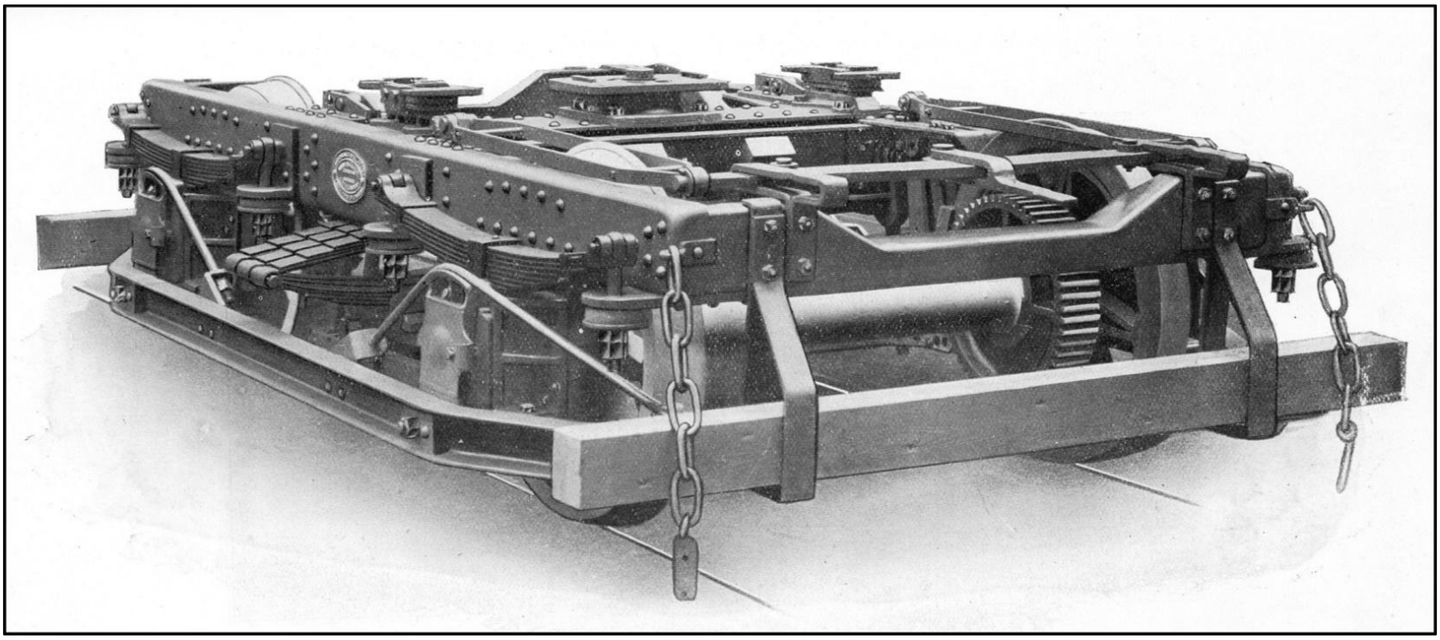

Figure 2: A photo of a Met. Railway 1904 pressed steel motor bogie, before the fitting of motors and shoegear. The gear wheel for the motor can clearly be seen on the nearest axle. The curved edges of the frame members, typical of pressed steel, can be seen on the corners. Both axles had motors. The wooden shoebeams are mounted across the end of the bogie frame, supported by channel steel beams hung from the axleboxes. Note how additional security for the beam is provided by the looped straps suspended from the bogie headstock. The shoes were attached to the wooden beams, a positive shoe at each end and a negative shoe in the centre. The safety chains hanging from the bogie frame were secured to the car underframe to prevent the bogie separating from the car in the event of a derailment. The laminated bolster springs originally fitted are clearly seen protruding from the centre of the bogie. Photo: Tramway & Railway World.

The Fox pressed steel design formed the basis of the Metropolitan's bogie procurement for the next 35 years, at least for the trailer bogies. However, after some years in service, it became apparent that the lightweight design of the Fox bogie was susceptible to fatigue fractures, particularly on the motor cars, and the pressed steel design was abandoned for new motor bogies in favour of a much heavier, rolled steel, plate framed design[1]. As described in last month's article, this first appeared in 1913 on the new Saloon Stock delivered that year. It was more robust than the pressed steel type and later versions of

[1] The District Railway also found trouble with pressed steel bogies. They ordered the type for their 1910-13 steel bodied cars and later found the same fatigue fracture problems as the Metropolitan.

it provided a more stable base for the heavier motors needed for the new stocks required in the late 1920s.

CRADLES

There were some unusual features of the Metropolitan's early electric traction equipment. As we have seen, the original current collection shoegear proved problematic, the Westinghouse turret controllers were so unreliable they had to be replaced and, as mentioned in last month's article, there was a forced cooling system that was applied to the first electric locomotive and then abandoned, only to be resuscitated a few years later. In addition to these innovations, there was also a novel motor suspension system originally fitted on the first batch of British Westinghouse equipped trains. This was known as the 'Cradle' system and it has an intriguing history.

The original Westinghouse traction motor suspension system used on the Metropolitan was described as a 'cradle' system or, in the design used on the Metropolitan, as the 'Gibbs' Cradle suspension'[2]. In one source[3], it was described as the Baldwin-Westinghouse suspension as it was applied to a bogie designed in the US by the Baldwin Locomotive Works of Philadelphia, Pennsylvania. The design was also used on the bogies supplied for the new electric trains introduced on the Mersey Railway in 1903. George C. Gibbs, the engineer who designed it (see box), worked for Baldwin at the time. It appears that there were a number of earlier versions dating back to 1883. Some of them, although called 'cradle suspension', were more of a reverse form of nose suspension, where the motor nose was hung from a transverse beam at the outer end of the bogie frame. Gibbs' version, which he first patented in 1898, was rather different in concept as shown in Figure 3. In 1900, he patented a modified version and it was this design that was supplied to the Metropolitan on their early British Westinghouse equipped cars and, possibly, also on the original BW equipped electric locomotives (Figure 5).

GEORGE GIBBS (1861-1940)

George Gibbs is best remembered in railway engineering history as the pioneer of the use of steel in passenger cars and for the introduction of the iconic Pennsylvania Railroad's GG1 electric locomotives. His all-steel design for the Interborough Rapid Transit company in New York did much to convince railways that all-steel cars were a practical option. It was his lead in this field that led the London Underground to adopt steel cars for the tube lines in 1905-07.

Gibbs was born in Chicago and graduated from the Stevens Institute of Technology with a degree in mechanical engineering. He worked for Thomas A. Edison for several years, then he took a position with the Milwaukee Road, where he worked on electric lighting and steam heating for trains. In 1897 he joined the Baldwin Locomotive Works, working with heavy electric traction. In 1912 he established the firm of Gibbs and Hill, Consulting Engineers with his friend Rowland Hill and he continued working in the area of railway electrification. He established the consortium that led to the electrification of the Pennsylvania Railroad in the 1930s.

He was granted a patent for his first cradle suspension system in 1898 but this had some issues that were resolved in a second patent granted in August 1900. It was this design that was adopted on the Metropolitan.

GIBBS' PATENT

By the time the first batch of the Metropolitan's Saloon Stock motor cars was being designed in 1903, direct current motors for electric trains were usually geared, so that the motor speed at the pinion was between three and four times the required wheel speed. This gave better starting characteristics and reduced the dead weight compared with the alternative design of motor with the armature mounted directly on the axle.

Geared motors on electric railways were usually 'nose suspended'. In this design, one side of the motor rested on two bearings mounted on the axle being driven, while the other side had a 'nose', a casting on the motor case, that rested on the bogie transom. The motor had to retain its position relative to the axle to allow the drive from the pinion to mesh with the gearwheel on the axle regardless of the movement of the bogie frame. By carrying the other side of the motor on the bogie frame, a large part of the weight was carried by the bogie suspension. This reduced the deadweight on the axle and the vibration transmitted to the track and it thus helped reduce rail wear. It was a neat design and it worked well on electric railways for over a century.

---

2 Ashe, S.W. and Kieley, J.D. (1905), '*Electric Traction*', D. Van Norstrand Company, New York, 1905, p.200.
3 Wilson, E. and Lydall, F. (1907), '*Electrical Traction*' Vol.1, Edward Arnold, London, 1907, p.343.

The system devised by Gibbs was an alternative method of mounting the motors in the bogie. It involved the use of a rectangular steel frame, the 'cradle', which was indirectly suspended from the axles. The idea behind the arrangement was that it allowed the whole bogie frame to be lifted up from the two axles, leaving the motors free for examination or removal (Figure 7). With the standard nose suspension system, you had to take out the motors before removing the bogie frame.

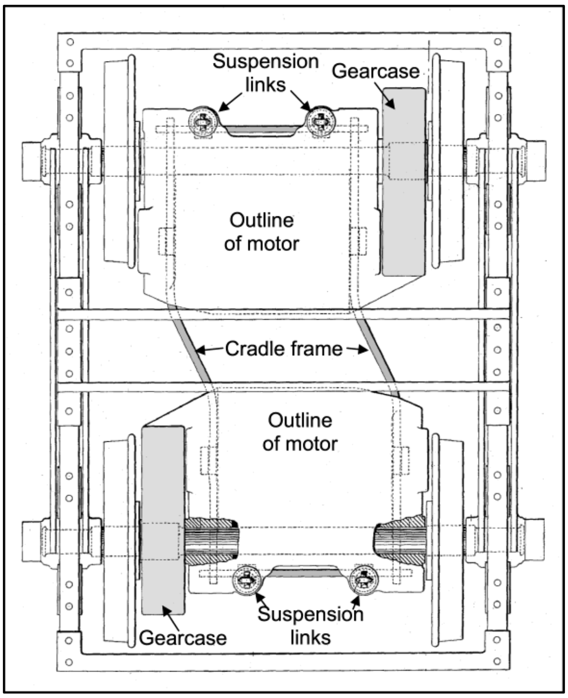

Figure 3: The original Gibbs' cradle suspension as illustrated in his US patent of 1898. In order to get it to fit around the motors the cradle frame had to be joggled as shown. A later version of this design could have been applied to the Mersey Railway electric stock built in 1903. Drawing from US patent 656635A, modified by P. Connor.

THE MERSEY LINK

There is some evidence that a version of Gibbs' cradle suspension first appeared in Britain on the Mersey Railway. The railway, serving the area around Liverpool, was electrified in 1902-03. The electrification was actually funded by Westinghouse, who were looking for ways to expand their influence in the British electric traction market. They chose the Mersey because it was bankrupt at the time and because it needed electrification to revive its fortunes and to get rid of the steam locomotives using the tunnel under the Mersey River. New trains were built using Westinghouse electrical equipment and they adopted the Baldwin-Westinghouse bogie design. It was based on a standard American cast steel, equaliser bar design. None of the descriptions of the Mersey Railway version mention the cradle suspension system but contemporary drawings show it and the dimensions match the Mersey specifications, so it seems it likely it was provided.

The original Gibbs design required the cradle frame to be joggled so that the two motors and their gearcases could fit in the bogie frame. This created points of weakness in the cradle frame that Gibbs solved by asking Westinghouse if it was possible to design the motors so that the gearcases were both on the same side of the bogie. Apparently, it was, so the next iteration of the design, patented in 1900, had the motors 'handed' – there was a left hand motor and a right hand motor. This was the arrangement used on the Metropolitan Railway version. The result was that the cradle frame was a proper rectangle, not joggled but it was offset from the bogie centre line (Figure 5).

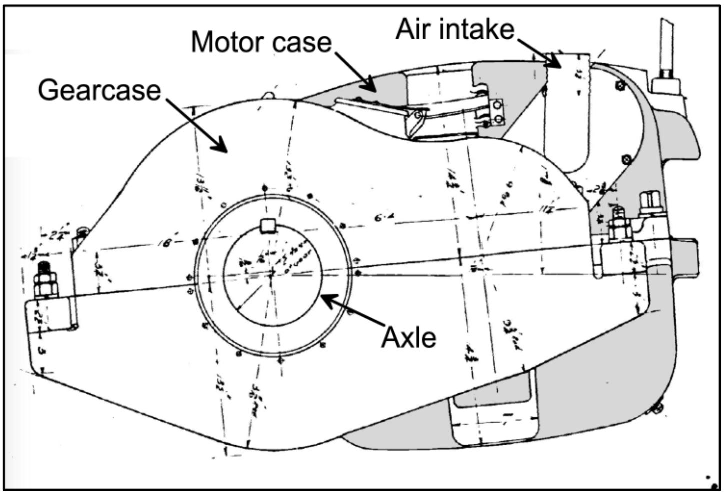

Figure 4: Side view of British Westinghouse Type 86M 200hp motor showing air intake provided for the forced cooling system provided on the 1913 equipment supplied for the 1913 Saloon Stock and the refurbished Locomotives Nos.11 to 20. Drawing from Metropolitan Railway drawing No. 5665D, dated 9 March 1926, modified by P. Connor.

HANDING AND BLOWERS

The 'handing' of traction motors is very unusual. The Metropolitan may be the only railway in the UK where it was applied. We know it wasn't applied on the Mersey Railway[4]. A trawl through the surviving Metropolitan Railway drawings of the two types of British Westinghouse motors supplied to the railway, the Type 50M 150hp and the Type 86M 200hp, shows that they were both designed with a left hand and a right hand version[5]. Since both

4 Kirker, H.L., 1904. Mersey Railway – multiple control. *Journal of the Institution of Electrical Engineers*, *33* (168), pp.979-993.

5 One drawing of the Type 86M 200hp motor, has an additional sketch showing two motors labelled 'Plan View LH Motor' and 'Plan View RH Motor' but with the motors shown with the RH motor on the left and the LH motor on the right. Obviously, nobody in the drawing office thought to check it, even though the drawing is signed as 'passed'.

versions were supplied in 1904-5 for the Saloon Stock and the BW locomotives, it is possible that the cradle suspension was also provided on both.

Another aspect of this story we should bear in mind is that, apart from the ability to accommodate the cradle suspension, the handing of the motors played a part in the design choices for the forced cooling system originally designed for the 1905 BW equipped locomotives and later, for the new BW traction equipment supplied in 1913[6]. The Type 86M 200hp motor was supplied originally for the 1905 locomotives and the 'handed' design influenced the blower system intended for them. As shown in contemporary drawings[7], the blower ducting was limited to one side of the locomotive underframe. A similar arrangement would have been necessary for the blower ducting fitted to the 1913 Saloon Stock vehicles which had the new Westinghouse equipment. The ducting had to be positioned along one side of the underframe because the layout of the motors put the air intakes of both motors on the same side of the bogie. A drawing of the 86M motor dated 1926 shows left hand and right hand versions but, interestingly, there is no evidence of the necessary fittings for the cradle suspension (Figure 4). The drawing shows that the motor was designed for the standard nose suspension.

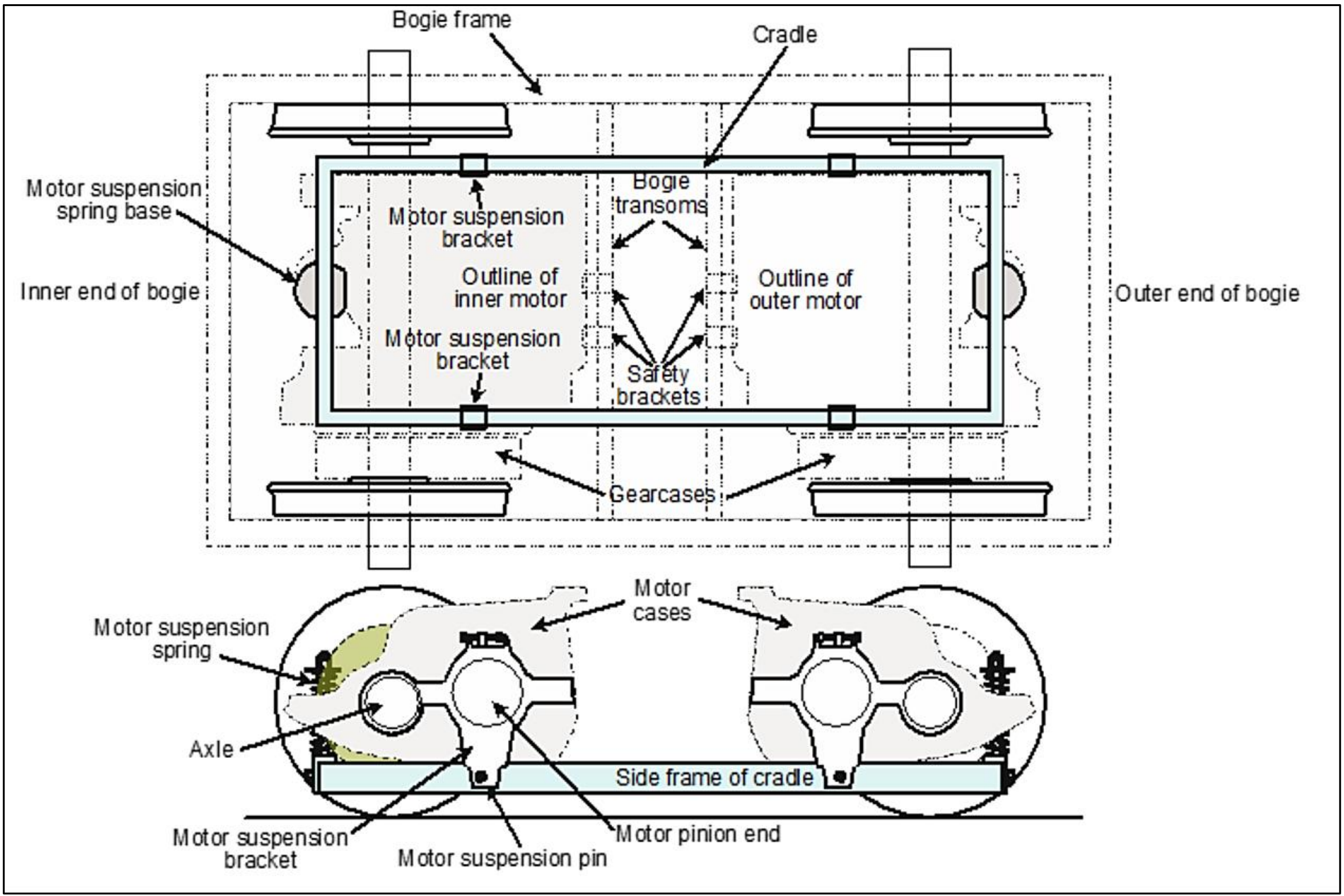

Figure 5: A schematic of Gibbs' traction motor cradle suspension system showing how it was mounted in a Metropolitan Railway bogie. Each motor (outlined in grey) was pivoted round its axle in the usual way, while the armature end rested on the side frames of the cradle (in blue), secured to it with pins. The transverse end of the cradle was suspended from a sprung mounting bolt attached to a lug on the outer end of the motor. A feature of this layout was that the motors were 'handed', i.e. the drives (in the gearcases) were both on the same side of the bogie. Note the safety brackets provided on the bogie transoms to prevent the motor dropping onto the track if the cradle fixings were lost. Drawing: P. Connor.

RESEARCHER BEWARE

One of the interesting things about writing a history such as this is discovering the reasons as to why things were done on the railway, how they were done, whether new ideas worked, how they behaved in operation and what became of them over time. From such work, we can learn lessons and we can develop solutions to more modern problems with the benefit of historical knowledge. To try to get

---

6 See Article 6 in this series.

7 The Engineer (1905), 'Electric Locomotive for the Metropolitan Railway", Vol.100, 22 September 1905, p.295.

accuracy and clarity, we've much time is spent researching documents, drawings, books, papers and journals and cross checking sources. Despite this, there are times when the researcher can get caught out, me included.

I have known, for a long time, a photograph of a bogie with a caption that said it was of a type provided for the Metropolitan Railway (Figure 6). It was in my copy of 'Electric Traction on Railways' by Phillip Dawson (1909). I always regarded Dawson as pretty much infallible since he was an eminent electrical engineer of the time, he was in charge of the installation of the overhead system built for the London, Brighton & South Coast Railway and later, he got a knighthood for his services to the government during and after the First World War. However, I was always a bit suspicious of the photo. I didn't know what it was but there was something not quite right about it. Recently, since starting my quest for more information on the cradle suspension and because it looked as if it had that system, I decided to look at it in a bit more depth.

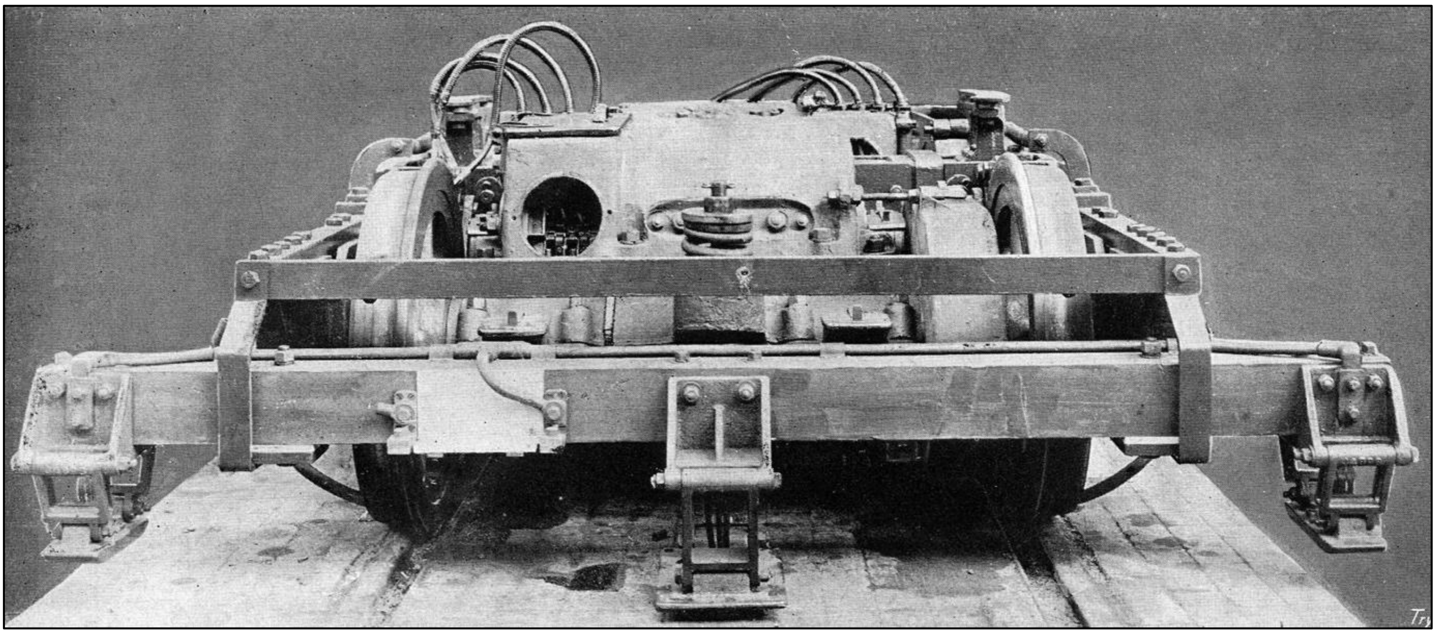

Figure 6: A photo from Dawson, 'Electric Traction on Railways', incorrectly labelled as a Metropolitan Railway motor bogie. It has Gibbs' cradle suspension system. The top of the spring loaded bolt securing the cradle and the lug carrying it on the motor case can be seen behind the negative shoe. However, it differs in a number of ways from the Metropolitan's early motor bogies and is actually of a Mersey Railway motor bogie. The same photo appears in a detailed description of the Mersey Railway in The Electrical Review, Vol.52, Issue 1330, 22 May 1903, p.877 and again in 'The Electrician' of 22 May 1903, p.202.

In the photo, despite the Dawson caption defining it as 'Metropolitan Railway', the parts of the bogie frame you can see are not at all like the pressed steel frames used on the Met. Then, I noticed the attachment on the shoebeam, which appears to be a shoe fuse holder. This wasn't something I'd seen on the Met. versions in this location. And, the positive shoes are a long way outboard of the bogie frame too – too wide apart for the Metropolitan. Also, the motors are not handed but they do appear to have the end fittings for the cradle suspension. Then, the photo shows 4-rail current collection. So, if it's not Met. where is it from? Then it clicked; the Mersey Railway – they had 4-rail traction but the positive rail was further out from the running rails than on London Underground, which is why it looked odd to me. They had Westinghouse type 83M 100 hp motors and the bogie was a cast steel, equaliser bar type, designed by Baldwin. This led me to a drawing of the Baldwin-Westinghouse suspension in Wilson and Lydall's 1907 book and the graphic in Ashe and Kieley's 'Electric Railways' (Figure 7).

DRAWBACKS

In Gibbs' introduction to his patent, he offered the following statement: "*The object of the invention is to provide a convenient and economical form of suspension which is independent of the framework of the truck, does not interfere with the action of the springs supporting the body of the vehicle, relieves the truck from undue strain and generally so supports the motors that their power is applied to the operation of the vehicle with the least disturbance to the easy-riding qualities thereof and at the same time relieves the track and motors from undue pounding*." This was an unfortunate statement of faith since the reason for the system's demise was that it did exactly the opposite in every respect.

Despite its inventor's pedigree, Gibbs' suspension system didn't perform in the way he had sold it. Significantly, shortly after it arrived on the Metropolitan, some sources in the US were suggesting that the cradle concept, already tried in various versions over the previous ten years or so, was beginning to be regarded as an expensive addition to the bogie that added weight and did not, as claimed, make maintenance of the motors any easier. It was also said to have had some effects on track wear. Examination of Gibbs' version shows that the criticism was valid.

Curiously, in a paper read to the Institution of Civil Engineers on 24 February 1914[8], William Willox, the Metropolitan's Chief Engineer, described how, since electrification, rail life had halved from 5-8 years to an average of three. The trouble had started as early as 1906[9]. In some places, along the busiest tunnel sections, curved rails were being replaced every 13 months and crossings every 6-12 weeks[10]. How much of this was due to the cradle system, it's impossible to tell but, given its design, it certainly would have increased the deadweight on the driven axles when compared with conventional nose suspension.

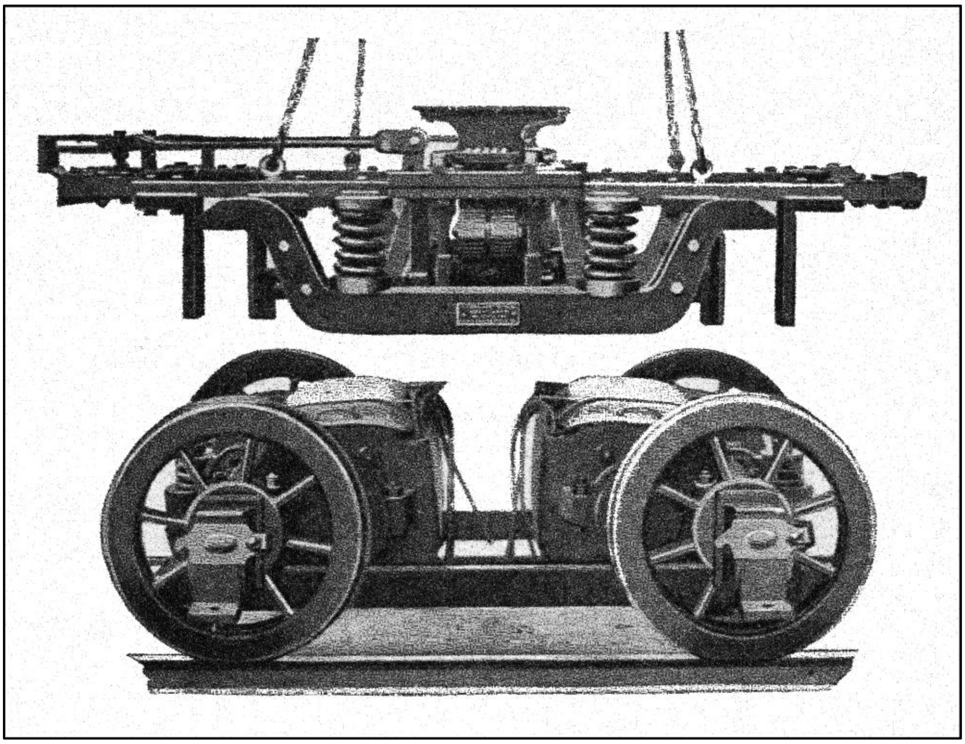

Figure 7: A graphic of the Baldwin-Westinghouse cradle suspension system similar to that applied to the cast steel equaliser bar bogie provided on the Mersey Railway 1903 Westinghouse equipped motor cars. It shows how the bogie frame could be lifted without removing the motors. The side frames of the cradle can clearly be seen under the motor cases. Graphic: Ashe ibid.

Willox described a series of experiments with different types of steel to see if he could find a better mix that would stand up to the battering from his electric trains. Although he did acknowledge that the unsprung weight of the traction motors had an effect on rail wear, he didn't mention any experiments to see if modifying the trains had any effect. In the discussion following his presentation, there were hints from some members of the audience that part of the problem could be related to the bogie design but no one pressed it and Willox didn't pick up on it.

If we were addressing this issue today, the first point of call would be the rolling stock. Before going through the expensive process of examining and testing rail steel composition, a thorough investigation of the wheel profile, the ride, the weight distribution and the suspension would be carried out, followed by consideration of train performance and running speeds. Sadly, Willox gives the impression that he was rather obsessed with steel composition and that he wasn't bothered about any detailed consideration of the rolling stock effects.

Another potential drawback of the cradle system was that, if the motor springs or their associated linkage failed, that end of the cradle was liable to drop and the motor, pivoted on the axle, would drop too. This would not be a good failure mode. However, it seems that there was safety backup. Drawings[11] show that both types of BW traction motors incorporated two cast-in lugs on top edge of the motor case. Also, there were two small appendages at the centre of each bogie transom member, either side of the pivot area (also see Figure 5). It is likely these were intended to catch the two motor lugs in the event of

---

8 Willox, W. (1914) 'Rail-Steels for Electric Railways', *Minutes of the Proceedings of the Institution of Civil Engineers,* Volume 197, 1914, pp.79-89.

9 The Electrician', Vol.58, February 8, 1907, p.630.

10 It is interesting to note that Willox referred to the section between Farringdon and Aldersgate Street (now Barbican) was the worst section of the Met. for rail wear and that, despite almost a century of experience, it was still that way up to a few years ago.

11 Dawson, P (1909), 'Electric Traction on Railways', The Electrician, 1909, p.265

cradle failure. There was nothing else for them to do in that position. They might get in the way of the bogie frame 'lift-off' feature but this was much less of a problem than a cradle failure. Finally, since most major motor troubles would require the motor to be removed from the bogie anyway, the proposal that removing the frame first was necessary was basically flawed.

Looking back now, with such evidence as is available, we might reasonably conclude that both the initial 1904 batch of Saloon Stock, which had the elliptical leaf bolster springs (Figure 2), and the BW locomotives, had Gibbs' cradle suspension as built but that it wasn't fitted to later stock and was subsequently removed from the cars that had it. They were modified to a conventional nose suspension system. It would have been a relatively simple job and was most likely done during the first overhaul in 1907, if not earlier when the shoegear was modified. The legacy was the 'handing' of the BW motors, which remained to the end of their lives.

To be continued …