DID L.C.C. KILL OFF THE STUD?

by John R. Prentice

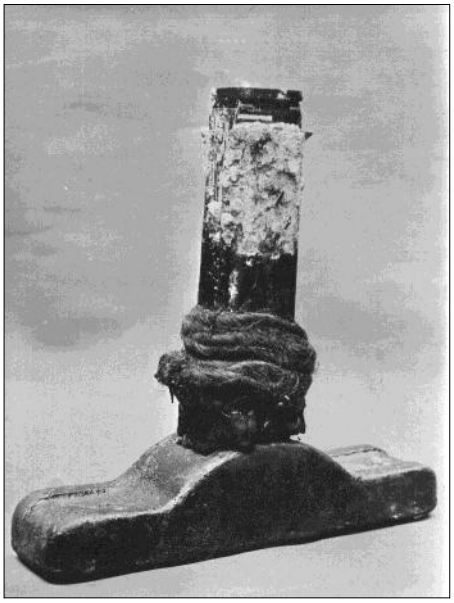
In 1961 in his book “The Golden Age of Tramways”, transport historian Charles Klapper describes the London County Council Tramways’ surface contact current collection line as, “one of the few striking engineering failures of the century, comparable with the atmospheric railway of seventy years earlier, even if not of the disastrous nature of the Tay Bridge collapse”. Strong stuff indeed. What is true is that details of the failure of the London Griffiths-Bedell system has had more written about it than all the other stud systems put together (I have noted at least 8 sources in modern times and, in addition to Klapper’s, recommend for more detailed histories L.C.C. Tramways Vol. 2. by E.R.Oakley and L.C.C. Electric Tramways by R.J.Harley). In this article, together with a brief overview of the history, I have set out to look at how this stud worked and possible reasons for such a dramatic failure.

The interested crowds watch a stuck L.C.C. E/1 910 being manually pushed onto the next live stud in July 1908 during the ill fated trial. Note also the typically large amount of muck in the road to the bottom left of the view.

History

Benjamin Harry Bedell was an engineer and inventor. William Griffiths, originally a stone merchant, provided the finance. Around 1902 Bedell invented a form of improved current collector for magnetic surface contact systems, suggesting possible versions suitable for use with Lorain studs (as in Wolverhampton 1902-21) and for the Lineff system (tested in Chiswick Depot of the West London Tramways in 1890). He went on to in 1903 to produce designs for his own stud which was to become the Griffiths-Bedell (G-B) system. In 1904 an oval demonstration track 0.2 mile long was laid at the rear of 49 Wanstead Park Road in Ilford, the home of Griffiths-Bedell & Co. Ltd.’s manager, Edmund Izod. A 4-wheel double-deck Preston car ran the trials. Representatives from Lincoln visited this site and in November 1905 the City of Lincoln Tramways opened using the G-B system. It is reported that gas could leak into the system and ignite causing spectacular problems, but after initial teething

troubles the system settled down and ran until 1919, when studs were replaced by overhead due to them being worn out and as by then new parts were not available.



A Griffiths-Bedell stud, probably one removed from Bow Depot in 1939 at the time it was being converted for trolleybuses.

In May 1907 The London County Council Tramways were considering the electrification of the tramway along the Mile End Road and Bow Road to provide a though route from Aldgate to join up with the West Ham Tramways at Bow Bridge. Under the Mile End Road was the roof of the District Railway's "cut and cover" Underground line. It was thought that there was insufficient clearance for a conduit system and it would be too expensive to alter the tunnel roof. Stepney Council staunchly refused to let overhead wires in their area. In addition the Moderate party had gained control of the London County Council in February 1907 and were determined to cut the costs expended by the ousted Progressive party. Conduit cost £17,000 per single track mile. Overhead was £9,500. It was claimed that a stud system would cost £10,500 (in fact it worked out at £11,000), so the L.C.C. made a visit to Lincoln and later contracts were let to Dick, Kerr & Co. to carry out the roadwork and to G-B to supply and install the stud mechanisms and supply the current collectors for 48 trams, although in fact only three cars of the new E/1 class from the six allocated to Bow depot (907-912) were ever fitted and used in service. The line was installed between Whitechapel Church, where there was a simple conduit change pit, and Bow Bridge. The line was flat and straight with no junctions, only crossovers and the turnout at Bow depot, i.e. ideal for stud current collection.

As in Lincoln there were problems during testing with gas leaking into the system and forced ventilation of the pipework had to be used, but in June 1908 the Board of Trade gave approval and the service started on 25th June 1908 with the three stud cars mixed in between horse trams. There then followed masses of cases of lost contact with the studs, the tram having to be manually pushed, and with studs remaining live after the car had passed. By 21st July the service was withdrawn. Over the next few days after much work from G-B, L.C.C. and with help from Mr W.M.Mordey, president-elect of the Institution of Electrical Engineers, the line worked intermittently, but on 31st July was closed with a full service of horse cars being reinstated. On behalf of the Progressive party Sir John Williams Benn MP vigorously attacked the system. In the short time since opening there were 927 cases of studs remaining live and sounding the alarm (728 had cleared themselves, 185 cleared after being hit with a rubber hammer in the approved manner), there were seven accidents, with one person and several animals having received electric shocks and one horse had been killed.

John Benn

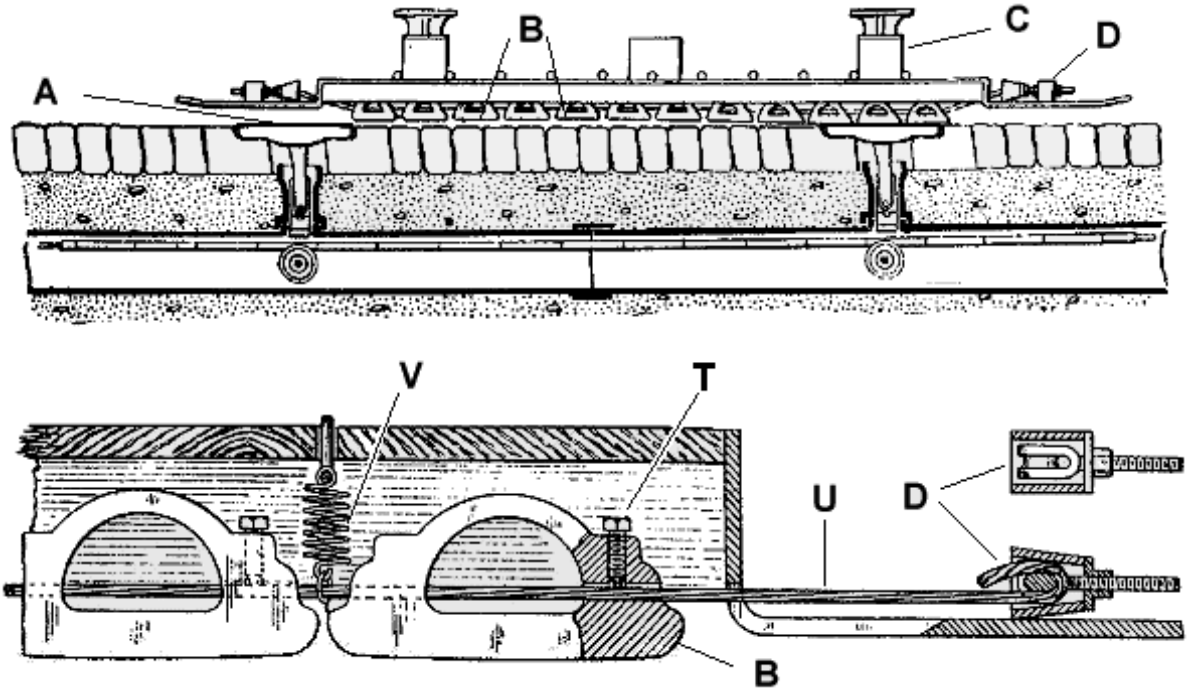
In October Mr Mordey was retained on a fee of 250 guineas to try and sort out the problems on an independent basis, and between then and March 1909 he conducted tests, improving the insulation round the studs and adjusting the current collectors,

with G-B replacing the badly worn cast iron segments used in them with steel ones. His main improvement was to fit electrostatic condensers (capacitors) of 5-10 microfarads joining the current collector to a to a pick-up brush mounted between the live detection alarm brush and the end of the current collector. This quenched any arcs that formed at the stud contact points due to earth leakage. In the early hours of 5th and 6th March he did manage some 16 miles of successful running, although one horse received a shock from one of the studs that was on a section not actually under test. But by now the Council had had enough. In April Stepney Council finally gave way to overhead which was installed in the east from Bow to Mile End Station, where there was a change pit. The road was modified and conduit was installed from there to Whitechapel. The line re-opened to electric trams on 21st July 1909.

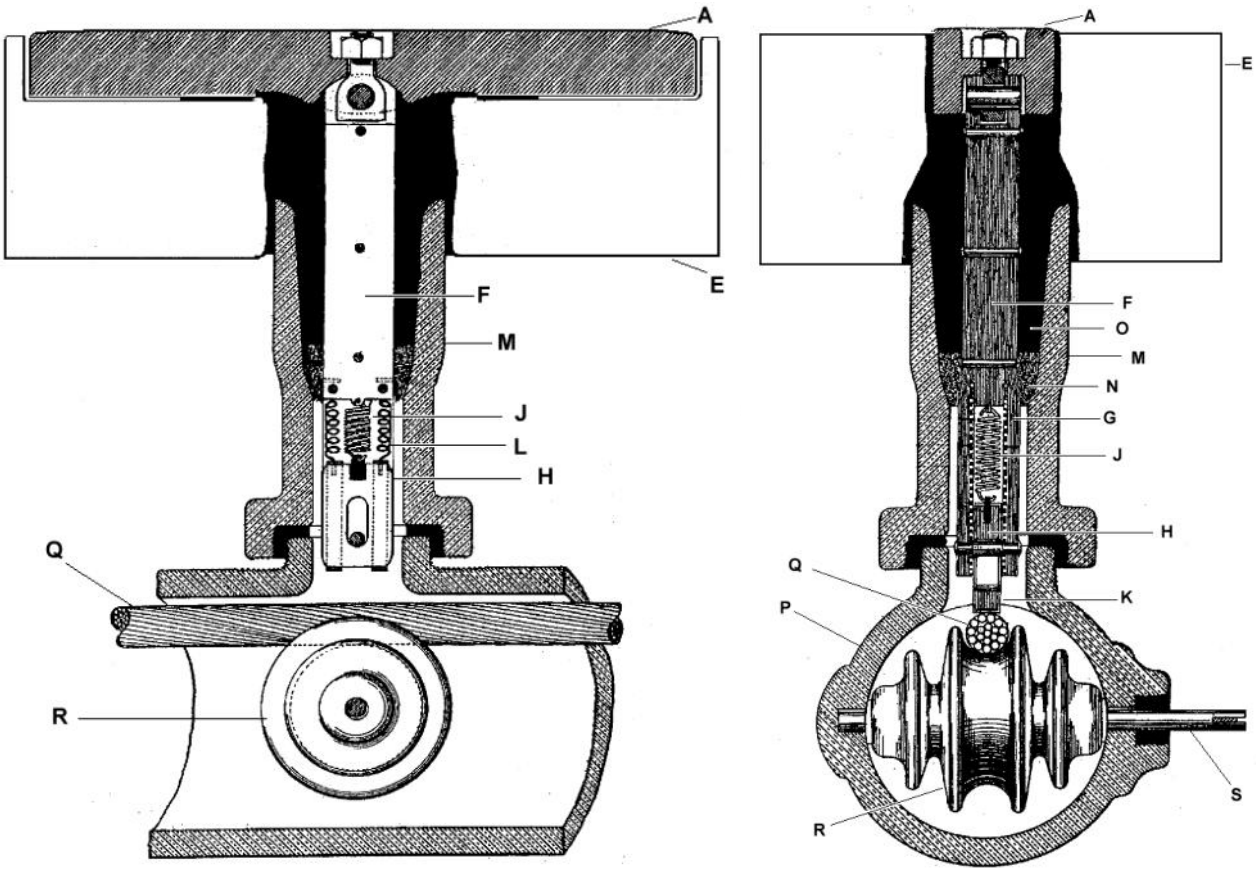
Griffiths-Bedell had wanted a high profile installation to give their system credibility. In fact they had been humiliated. They sort legal damages against John Benn accusing him of making libellous statements and ruining the Company, since L.C.C. had modified their installation from the patents without permission. They were awarded £12,000 in damages, but this was later overturned on appeal on the grounds that the jury had been misdirected and this was upheld by the Lords. It was deemed that Benn's attack was not on the G-B Company but was against the Moderate Party for wasting ratepayers' money.

How it worked

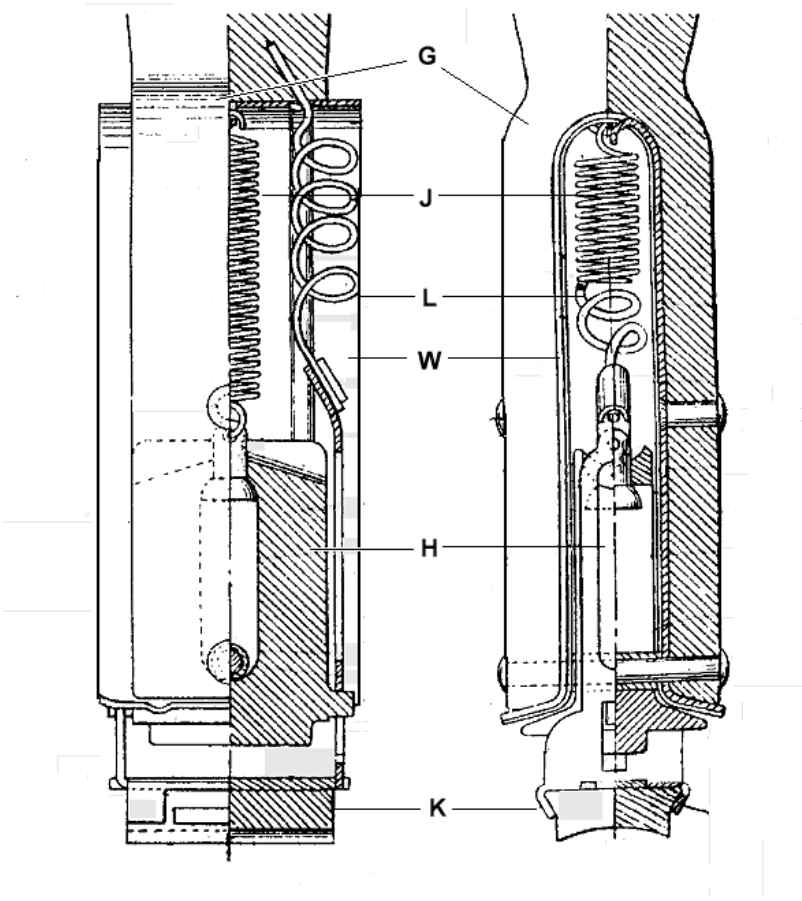
As in all magnetic stud systems, the basic principle is that the tramcar carries a current collecting shoe or skate which is magnetized by powerful electromagnets. When the skate is over the stud the electric circuit is completed by movement of an armature and the stud becomes live, supplying the car with power. Once the car has passed the stud becomes dead again. In the case of the G-B system there was a wire brush device at the end of the car and if the stud was still live when the brush touched, an alarm bell sounded on the car to warn the crew.



The current collector mounted on the car *(the diagram above shows the original G-B design, as used in Lincoln)* consisted of a number of iron shoes [B on the diagram] fixed with pinch bolts [T] to a hemp-cored wire rope [U] that was made off at the ends to insulated shackles [D] and held up at intervals by springs [V]. As the collector passed over the stud head [A], the magnet field from electromagnets [C] caused the iron shoes above to be drawn down and make electrical contact with the stud head at the same time as the stud was switched on. The electromagnets (initially four) were powered by the traction supply, with a rechargeable battery for when there was a supply interruption.



The G-B stud head [A] *(drawings above based on the original patented design)* was made of cast iron, and was 2.5 wide inches by 10 inches long, supported by 8 inch by 16 inch granite blocks [E]. Attached to the head by an eyebolt was a stalk [F] formed of laminated iron plates. At its lower end it formed a fork [G], the insides of which were lined with brass plates [W]. Between these was the switch armature [H] made of galvanised soft iron plates. The armature was suspended from the stalk by a copper plated steel coil spring [J] adjusted to just support the armature at its highest position. It was insulated from the armature to avoid current passing through it. There was a slot in the armature where a pin passed through to limit the armature movement. At the bottom of the armature was a carbon block [K] held in a copper clip (copper contacts in the original design) to provide the electrical switch contact. Electrical connection was made to the head by flexible copper conductor leads [L]. Once magnetized by passage of the skate, the armature moved downwards to contact the cable below, with it being drawn upwards by the spring when the tram



Drawing of the L.C.C. style of armature, where it could move by about a quarter of an inch inside the clip holding the carbon contact.

had gone. It was suggested by the designers that residual magnetic flux would blow-out any arc that might form. The whole assembly was contained in a stoneware pipe [M]. At the bottom of the stalk the space between it and the stoneware pipe had packing [N] driven in and the space above up to the head was filled with melted bitumen [O].

The studs were laid at about six feet intervals fixed to a horizontal stoneware oval conduit [P] about 6 inches by 5 inches through which ran a galvanised stranded steel power supply cable [Q], one and three sixteenth inch in diameter. It was this cable that the armature was attracted to. The joint between the stud and the conduit was sealed with bitumen. Under each stud the cable was supported by a circular insulated roller [R]. The centre support for this insulator was a galvanised steel pin [S] which was earthed to the rails by galvanised iron strips for safety. The original idea was that the cable could occasionally be pulled through the conduit by a small amount to bring a new contact surface into use. In practice it was found that the electrical contact with the irregular shaped cable was unreliable, so after 1907 the cable was fitted with a galvanised iron sleeve at the contact point. At intervals along the line there were access boxes (20 on the L.C.C. trial route) were the cable was divided and where the conduit could be drained of any water that had got in.

In common with all magnetic stud systems, pieces of metal rubbish in the roadway such as hat-pins, nails, bolts, wire, pieces of scrap iron etc., are attracted and stick to the car magnets. At crossovers and junctions, when the skate has to cross the running rails, this rubbish can cause short circuits. On the G-B system stud heads at junctions were supplied via resistances which would limit the current flow in the event of a short, but at the same time would pass sufficient current to slowly move a tram across the junction.

Why it failed in London

At this distance in time it is difficult to be certain and much of what follows is only interpretations by others and my own opinions. At first sight when comparing the G-B designs with those of Diatto, Dolter and particularly the successful Lorain system, my thoughts are not why the G-B failed in London, but how did it ever work at all in Lincoln. Since it did for 14 years we perhaps need to concentrate more on the differences between Lincoln and London, although Mr W.M.Mordey in his report states that due to the much heavier traffic levels, "if the Lincoln line could be bodily put down in the Mile End Road, it would not run satisfactorily as it is now".

Track with granite blocks ready for receiving studs near Mile End Station

In all the other studs the moving armature is attracted upwards towards the stud head by the magnetic field. When the field passes the armature falls back by gravity (in Lorain assisted by a spring) breaking the electrical circuit. In the case of G-B the whole stud head and armature become magnetized and the armature is attracted downwards against the pull of a spring to make contact with the cable below and is broken by the spring pulling it back. In addition, with the other stud types the head is split into sections with these forming the north and south pole. The armature bridges these poles and completes the field in much the same way as a keep plate is attracted to the poles of a horseshoe magnet. This is a very powerful attraction. In the case of the G-B stud the whole stud forms one pole and the field is completed via the supply cable and the earth back to the tramcar. This is rather like picking up a piece of metal with the end of a bar magnet, a much weaker attraction. I feel that these factors suggest that the accurate positioning of the stud mechanism with respect to the collector magnets, both in height and laterally, would be very critical. Part of G-B's complaint in London was that the system installation was not done by them as in Lincoln but Dick, Kerr & Co., largely unsupervised, and was not as it should be. Dick, Kerr were very reputable contractors, but may not have been fully aware of the accuracy required. I have studied the G-B patents of the stud but the drawings there do not materially differ from the L.C.C. drawings of the installed unit, so I think it is unlikely that L.C.C. themselves modified the actual studs.

During the libel action by G-B against Sir John Benn, F.E.Bedell spent some twelve hours in the witness box during which he complained that his company had not been given a fair chance to demonstrate their system due to L.C.C.'s modifications. He

Rails in position in the Mile End Road opposite the Paragon, *(left)* **and track ready to receive conduit pipe opposite the Anchor brewery.** *(right)*

complained that the conduit and access boxes (an L.C.C. standard type, not the G-B recommendation) were not water and air tight as was a requirement, causing the gas leaks and explosions. Boxes had been badly located causing shorts. He commented on the numerous modifications to the car magnets and the problems with their installation, stating that bad fitting caused a great deal of sparking which onlookers took to be the cars on fire. He said that the L.C.C.'s live stud detector, not to the standard G-B design, did not work correctly. He claimed that none of this would have happened the system had been installed as invented by the patentees. He also complained that for the resistance studs at junctions he had not been given access by the L.C.C. to the relevant current requirements of the cars and he had worked on 60 amps for starting whereas the actual figure turned out to be 100 amps and as a result they burnt out. Negotiations had been carried on with Oxford, York, Luton, Folkestone and Paris, but these had all fallen through subsequently to the alleged libel, whilst there was direct evidence that a South American scheme had been broken off, due to the allegation that "the system was a live stud system". In conclusion he estimated that his company patents had been worth £100,000 when the L.C.C. took up the system but that they were now valueless.

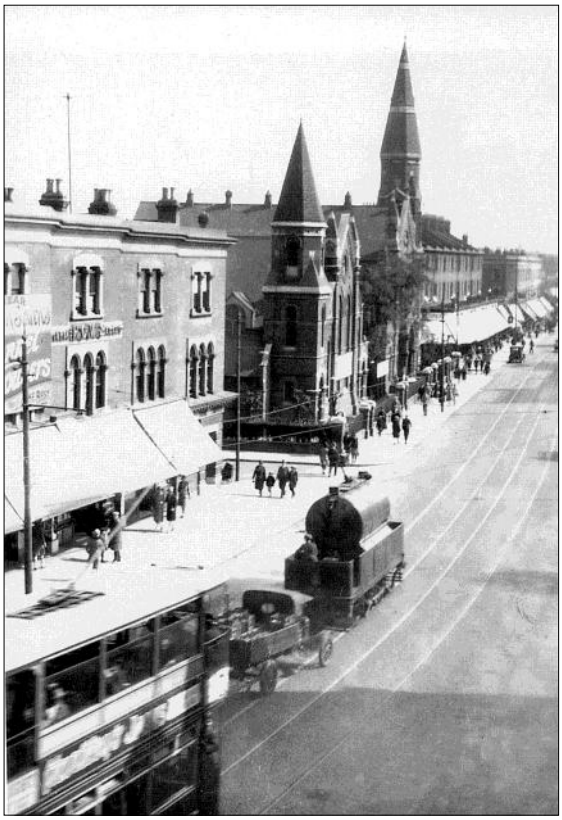
A 1904 G-B patent and the L.C.C. description shows that the armature could move by about a quarter of an inch inside the clip holding the carbon contact, to provide a "backlash" creating a quicker make and break. This was not however part of the original 1903 patent drawings. After experimentation, Mr Mordey advised its replacement by a larger armature as it seemed not to have any effect and in his view the studs thus modified would be more sensitive and would work with a smaller magnetic field.

In the Mile End Road with the granite boxes ready to receive studs, *(left)* **and with the road surface made up, the and studs are actually being.** *(right)*

A big difference between London and Lincoln was the use of bogie trams. In most other stud systems the cars were four-wheelers. The pick-up skate could be fixed to the truck frame. The height would then be fairly constant except for the axlebox springing and the collector would be central between the tracks. In the case of a bogie car the skate assembly would have to be fixed to the car body and would thus be more liable to change position with respect to the studs as the car cornered or as it bounced on its springs. William Brown of Lorain Steel had certainly appreciated this, for in 1907 he had patented a form of support for the car magnets which was fixed by pivots to beams mounted on both the bogie ends and thus closely followed the track centres. G-B it seems did not use anything like this. Here London presented an extra problem in that between the bogies a space had to be left for the plough carrier for the conduit current collection, with a path for the plough to be removed (at this period the plough carrier was fixed to the end of one bogie). To achieve this, the current collector for the stud system had to have a gap in the middle, or put another way was in two halves. Initially it was found that the magnets were not powerful enough, possibly due to the weak field problems mentioned in the previous paragraphs, so stronger ones were tried and then the magnets experimentally doubled (temporarily fitted in the space where the plough carrier should go and preventing conduit running). The collector was considered to be too close to the trucks. There were several cases of short circuits occurring. It is in the context of these modifications, which were largely done by the L.C.C., that G-B claimed the faults lay and their patents were not complied with. I cannot help but feel that if four-wheel cars had been used for this trial (after all East and West Ham were to use 4-wheelers at first for their contribution to the through route), then the outcome might have been different. A design such as the LCC Class 5 truck as used on the “M” class cars (alas two year in the future in 1910), had a plough carrier at each end and a space in the middle (used by the slot brake on the Highgate Hill versions) where the stud current collector would have fitted nicely.

During the four weeks of the trial some 130 stud heads (on nearly 5,000 studs) had been broken, whereas in Lincoln there had been only 24 broken in three years, despite some heavy traction engine traffic over them. The Lincoln stud heads were malleable cast iron, case hardened on the top. Those in London seemed to be ordinary cast iron. Mr Mordey suggested that cast mild steel would be and improvement, being stronger and having better magnetic qualities, but despite him requesting this several times it was not tried. It was found that the vibration of hitting the stud head with a hammer could briefly make the stud live, but tests of running a traction engine over a three inch by three-quarter inch bolt and allowing its wheel to drop onto the stud head did not produce the same result. Mr A.L.C.Fell, L.C.C. Tramways' Chief Officer, questioned if the action of a horses hoof on the stud might be similar in action to that of a hammer, but tests confirmed that this was not the case.

As can be seen from the design, the armature in the G-B stud was a fairly light iron construction, snugly fitted between brass plates. Clearly if any water or dirt got in, there might be corrosion and sticking or jamming causing the stud to stay dead or remain live. Any arcing inside the stud would certainly cause havoc with such a delicate mechanism. Mr Mordey had severe concerns on this point. He explained that the road conditions were far worse on the Mile End Road than they were in Lincoln and the street cleaning was far less. He commented that at certain times of day, many market-garden wagons return to the country with loads of stable manure, this often increasing the dirtiness of the road. Indeed there was a much higher level of horse road traffic than Lincoln. Mile End road is in fact the main truck route between the City of London and East Anglia, following as it does the alignment of the Roman road to Colchester. It should be remembered that West Ham Tramways needed two water cars to keep the streets clean in their borough and incidentally one of the few photos of these actually in use is on this same route, albeit much further to the east in Romford Road *(left)*. The horse traffic stirred up "street mud" consisting of general dirt, horse droppings, urine and rain. This could form an insulating slurry on the stud heads and at the same time worked its way into the stud mechanisms. Mr Mordey considered the most serious problem to be electrical leakage from a correctly live stud to earth via a wet dirty street, causing any arcing at the contacts to be sustained long after the car had passed, leaving the stud "live" (which he could cure with the condensers fitted to the trams as mentioned above).



Conclusion

The Griffiths-Bedell stud was not the best product available at the time. The Lorain studs in Wolverhampton and the Diatto studs in France were both better designed. It is also certain that the political pressure brought to bear on this trial greatly contributed to its rapid termination. A three month trail of the improved system would have been much fairer. The main victims in this and other stud systems was the poor old horses which kept getting electric shocks, sometimes fatal. If it was excess horse traffic and the associated muck that caused the failures, then there is a measure of poetic justice - Dobbin's Revenge!

Did the bad publicity of the L.C.C. trials kill off the surface contact stud method of current collection? Well prior to L.C.C.'s involvement there had been some dozen new installations of magnetic stud systems in England and France. After the L.C.C. fiasco there was not a single new system installed. What is more, of these existing stud systems, within four years of the L.C.C.'s abandonment of the trial just two systems were left running (Wolverhampton and ironically the G-B system at Lincoln). Perhaps the whole concept of studs was flawed and certainly the Dolter and Diatto systems had their own problems. But you cannot help but wonder, and maybe tramway managers of the day did, that if the mighty London County Council Tramways couldn't get studs working well, then who else stood a chance.

Post Script

After publication of the first section of this article, the question was posed as to whether the change pit mentioned was the first in London and was it in fact ever used. The change pit (I use the American term, L.C.C. preferred "ploughshift") for the stud experimental line was quite unlike the ones familiar to Londoners for the connections with the overhead system. It was located near Whitechapel Church and was a simple arrangement whereby the conduit was diverted from the centre and then crossed the tracks in a sort of turning circle. It was installed early in 1908. It would probably have been constructed from standard short yolks and would have had a normal hatchway for removal of ploughs. The first true conduit / overhead pits were those used in servicing the overhead section on Coldharbour Lane, Brixton which opened at the end of 1908, i.e. after that at Whitechapel.

As to whether it was used in public service, this is less certain. The trial only used three cars and these were mixed in with horse trams to provide the service. The change pit must have been used under test and was not excluded from the Board of Trade inspection. But right from the start, as mentioned in the foregoing article, the current collectors on the cars were troublesome and at some early stage of the trial, probably during the first few days, additional magnets had to be added to rectify this. These magnets obstructed the plough carrier and so from that time onwards the cars could not run on the conduit. This is confirmed by the W.M.Mordey's report to the L.C.C. of 1st October 1908, where he points out that his suggestions for modifications to the studs would require less magnetism in the collector and stated "It will no doubt be possible to remove the additional exciting coils, and so to find room for the plough carrier to enable the cars to run over the conduit system as originally intended".

The L.C.C. were fairly secretive about what changes they were making and what faults were occurring, with G-B complaining bitterly, both at the time and later during the Benn legal action, about being kept in the dark. It is difficult to be quite certain of facts, but my guess is that L.C.C. probably tried to run cars through to Aldgate via the change pit, but not very hard and not for very long.

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