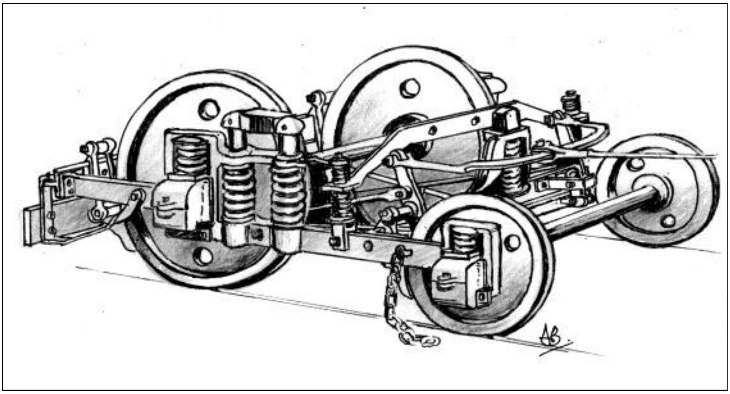
Brill 22E Trucks - A Model Maker's View

Ashley Best builds a pair in 1/16 scale

In the early days of electric tramways in Britain, the American influence was huge, and this mostly to be seen in the choice of trucks. There were some British designs, but mostly they were less successful than American imports that dominated the market. Of the several competing products, those of two companies stood



Above: Fig.1 A sketch of the Brill 22E maximum-traction truck but shown without motor fitted.
Below: Fig.2 A Peckham Girder Truck *Bottom*: Fig.3 A standard Brill 21E truck.

Drawings by the author
Photos by Ann Best

out - Edgar Peckham and J.G.Brill. Peckham trucks were riveted girder constructions that could be assembled from standard cast pedestals and girders of any required length to suit the wheelbase *[Fig.2]*. The rival company, Brill, adopted a different and ultimately more successful product with solid forged robust side frames *[Fig.3]*. Brill, in competitive advertisements asserted probably erroneously, that their rival's trucks lacked lasting rigidity because they relied on rivets.

There was even a court case between the companies over this assertion which Brill lost. Nevertheless, Edgar Peckham soon gave up in America and moved to England where he subsequently developed most successful designs.

The Brill Company became increasingly successful and produced a number of different truck designs for tramcars alongside products for mainline railways. In America, the rapidly expanding interurban systems ran large single deck vehicles that were effectively trams and these were expected to run at higher speeds than those to be found in purely urban systems. Brill made truck designs especially for this higher speed application.

J.G. Brill, car and truck builder of Philadelphia, had origins in 1868 and started building horse, steam and cable cars before moving into the electric era which had the first, somewhat experimental, beginnings in 1886. It was not until 1890 that the concept of the maximum traction truck was realised. The first design, No.11 was in many ways a bit like a Peckham truck. It relied on girders and plates riveted and bolted together, but the main principle of large driving wheels, smaller pony wheels and no central kingpin and bolster was established. Development was rapid and, before 1895, the main features of what was to become the 22E truck had been established. There were developments and some improvements, but the main design remained substantially the same until 1927/8 when, as far as I can tell, the last British tramcar application of 22E trucks appeared when Bolton bought its final batch of new trams. They were also the last typical traditional products from the English Electric Co. *[Fig.4]*.

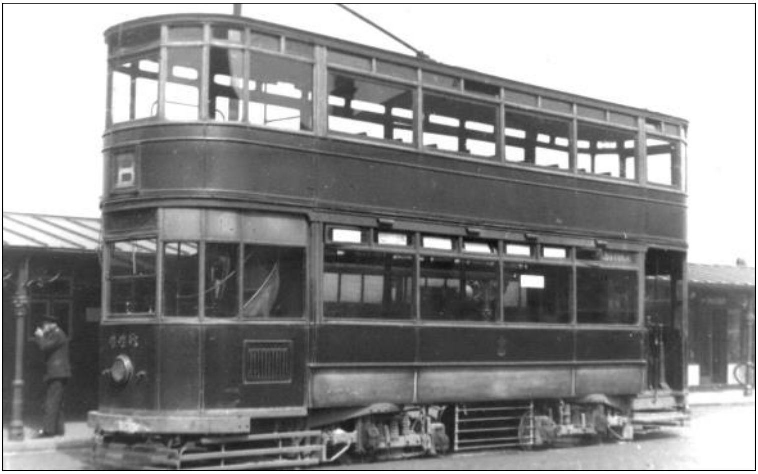


Fig.4 Bolton enclosed bogie car 448 of 1927 with Brill 22E trucks (after renumbering from 138 in 1940).
Author's Collection

These were Bolton's only enclosed cars and were equipped with trucks supplied by Brush, but they were, of course, actually Brill 22E designs. Apart from a small number of second-hand cars, all Bolton's bogie cars used 22E trucks.

A point has to be made here about the way in which ideas were shamelessly copied by the early tram builders and Brill suffered badly from this. The 21E truck design was copied almost exactly, sometimes with small alterations often with details that lacked any obvious reason. Many companies were responsible and those in Britain were especially guilty. The Brush Company effectively produced 21E and 22E trucks which bore a Brush standard truck-maker's plate. Brill had problems and law suits at frequent intervals, but had little luck. Its products were so good that to make improvements would have been more than difficult.

Street Tramways

Street tramways present particular problems not encountered on interurban systems. These can be summed up as road surface grease and dirt, sharp curves, steep gradients and, often, tracks of indifferent quality. Thus, problems of adhesion and ride quality were, and indeed still are, foremost. A four-wheel tram with each axle motored has maximum adhesion, but limited length of wheelbase provides a poor ride quality. The 21E truck was robust, simple and reliable, but even at maximum wheelbase, was only suitable for small tramcars. Bogie cars were needed for cars of higher capacity and although these rode better, they were heavier and, being more complicated, required more maintenance. These sorts of problems led many tramway undertakings, even large ones, to keep things simple and stick with four-wheel cars.

One of the problems suffered by bogie cars was that, unless fitted with a motor on each axle, there was a serious lack of adhesion. Obviously four motors increased running costs, maintenance and complication. It also necessitated a higher than desirable underframe to allow sufficient clearance for the wheels to swing out on curves. It was to overcome some of these problems that the maximum traction 22E bogie was developed. It was a brilliant, truly elegant engineering design which managed simultaneously to overcome otherwise difficult constraints.

It made possible a bogie car with almost the same adhesion as a four wheel tram, but with a much superior ride quality and an underframe not excessively high. It did this by a radical change in thinking that abandoned the traditional bolster and kingpin, thus creating space for a large, powerful single motor driving standard large driving wheels and replacing the second pair of wheels with unpowered pony wheels of smaller diameter. 75% of the weight of the vehicle was carried by the large driven wheels hence the appellation of "maximum traction" *[Fig 5]*.

Brill achieved the ability to produce solid forged side frames for their products. In view of the complicated shape of the 22E truck, this was a remarkable achievement. The product was offered as the solid forged version with long life expectancy: the 22E "Eureka" truck or as the cheaper, simpler cast version Brill 22 truck with a shorter life expectancy. Both versions were identical in appearance and performance and were generally referred to as Brill 22E trucks.

The 22E was one of several tramcar truck designs and was especially suitable for large systems with sharp curves and gradients. Places with few of these features were able to employ other Brill designs with equal-wheel bogies equipped with four motors or even just two which left one pair of wheels to idle. This helped the ride but not the adhesion or height of the underframe.

The 22E early teething troubles were soon corrected. The most significant problem was a tendency for the pony wheels to derail mainly because of the uneven weight distribution with 75% on the driving wheels. This was solved by a spring plunger post close to the pony wheels acting against a V-shaped plate under the mainframe so that as the pony wheels swing out, the plunger pressed against the plate with increasing pressure the further the swing, thus increasing the downward force on the wheels. Other improvements concerned the addition of strengthening bars inside the underframe. In models, these bars can be left out as they are unlikely to be seen easily. The brakes which act both on the driving wheels and pony wheels require differential forces because of the different wheel diameters and weights. Early 22E trucks overcame this problem to an extent by a spring system designed to apply less force on the pony wheels than on the driving wheels. It was soon realised that this was not a satisfactory way of achieving the desired result and the improvement came with a system of compensating levers *[Fig.6]*. The Brill catalogue made the optimistic claim that this new system eliminated the problem of wheels locking up resulting in flats. In model format 1/16 scale, all the main truck features can be included and the trucks will then function and perform in miniature exactly as do the real things. Making them is not something that can be done quickly and it does require basic engineering facilities.

Making the Truck

Principally, this article is about the making of a model Brill 22E truck in 1/16 scale. It is a miniature engineering project following original prototype design features as far as possible, within the constraints of building a model. I have been fortunate in being able to build up my workshop over many years. I was also fortunate to begin with having

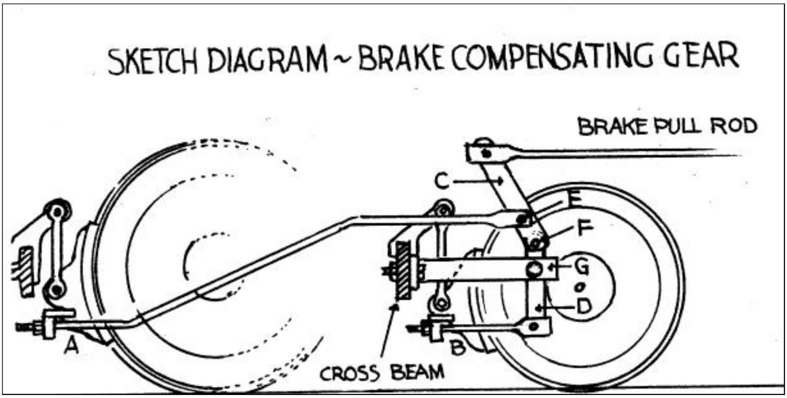
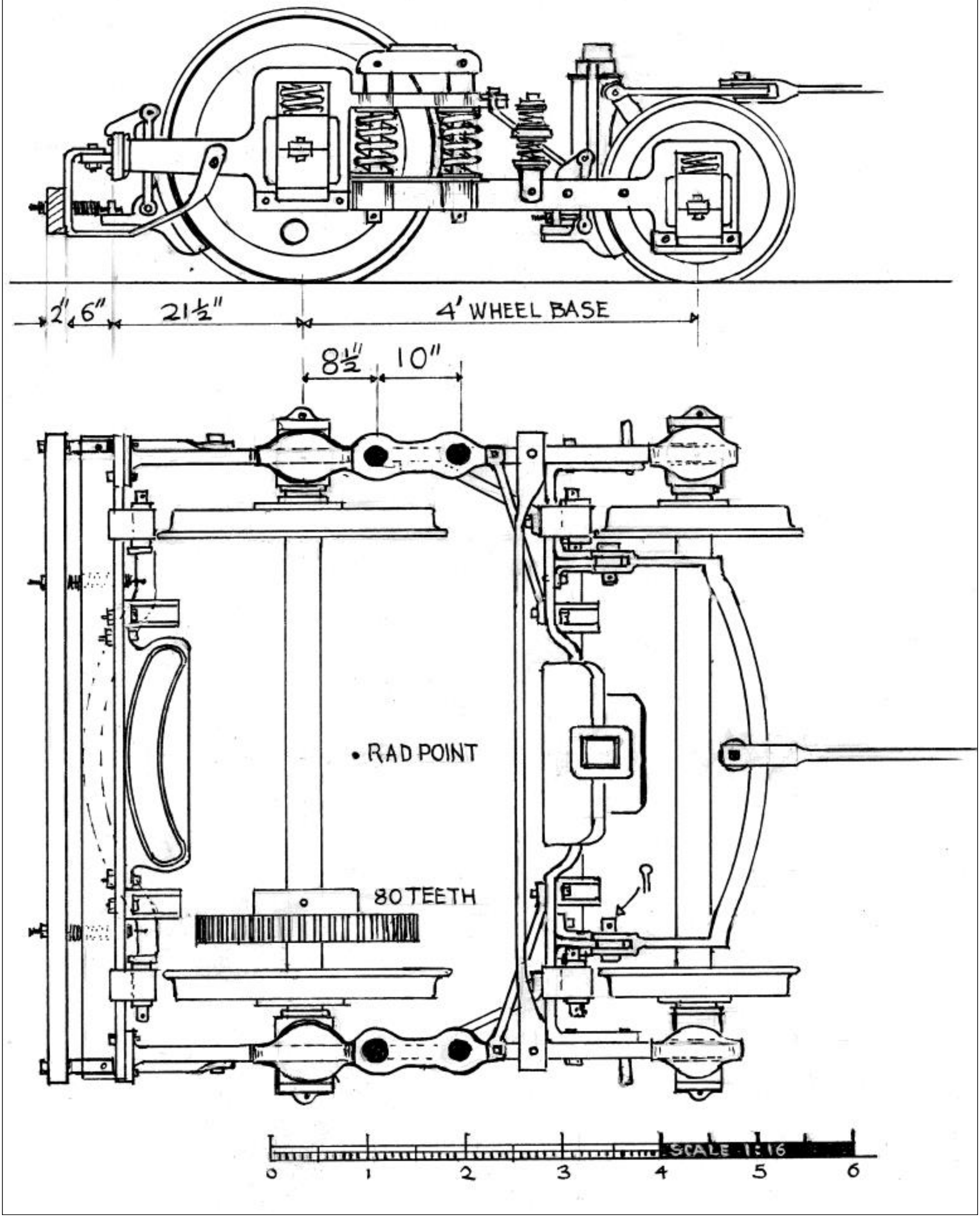


Fig.6 The brake compensating mechanism.

Fig.5

BRILL 22 E "EUREKA" 1:16 SCALE
MAXIMUM TRACTION TRUCK



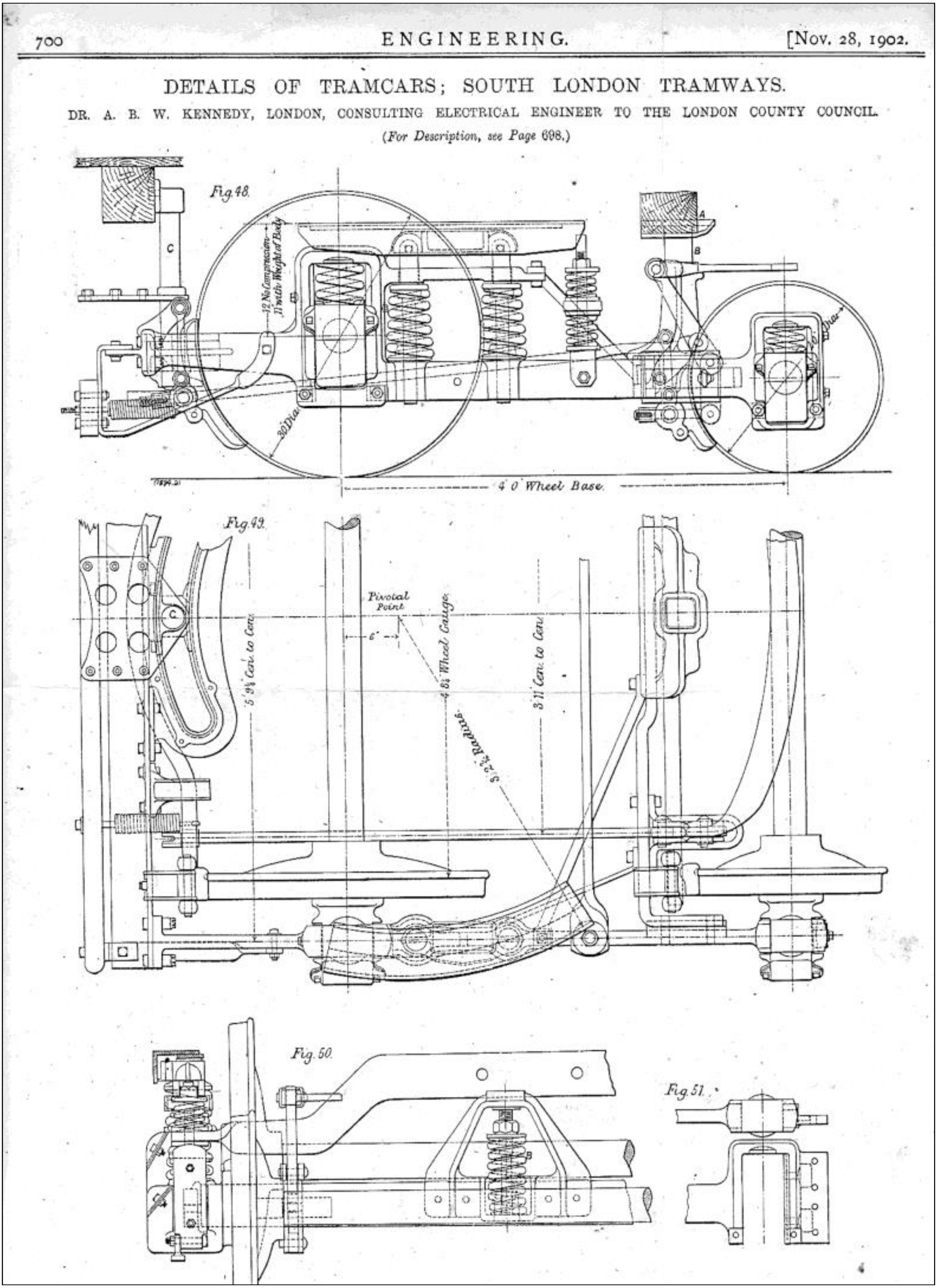


Fig.7 The original general arrangement drawing of a Brill 22E truck from ‘The Engineer’ in 1902.

a teaching job with access to metal-working facilities for after-work activities. I now have my own small lathe – a Hobbymat – a home-made propane-fired brazing hearth for silver soldering, a recently acquired small milling machine and a large collection of hand tools plus a bench vice, hammers, pliers, dividers, a height gauge and surface plate. Other essentials include a BA tap and die set, appropriate nuts and bolts (mostly 6, 8, 10 & 12 BA) together with small brass and soft iron rivets in my stock. I also made a sturdy workbench and a number of jigs and tools for repetitive work. Without at least some of these things, I realise that engineering would be difficult or impossible.

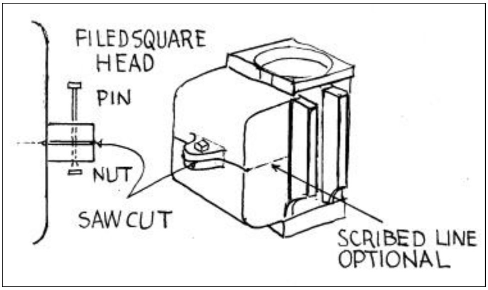
To make this 22E truck, I first produced full-size working drawings derived from many sources, but mainly from a page from the 1902 "Engineering" magazine on which all dimensions were not shown, but those that were missing could be worked out from those that were shown *[Fig.7]*. Wheel sets and gears were made first but, before fixing to the axles, I cut the gears on my recently acquired milling machine. I found this a difficult task which required a long period of uninterrupted concentration to cut the 80 tooth large gear with one tooth every 4½° - and the 12 tooth pinions *[Fig.8]*. My early models used gears supplied by the society which are, of course, still available.

The axle boxes are fabricated and have a hollow end which is packed with oil soaked wadding *[Fig. 9]*. The side frames are assembled from brass parts built up and silver soldered *[Fig. 10]*. It has been suggested that these should be milled, but to me this seems very difficult and wasteful. The made-up side frames replicate, in miniature, Brill's solid forged items *[Fig. 11]*.

The Cross Beams

The side frames are held apart by a T-section beam at the front and a cranked crossbeam at the rear. Before initial assembly, all the appropriate holes that were needed for final assembly were drilled and tapped as required. The rear beam carries a lot of equipment including a spring-post which is the device with a spring plunger acting as a weight transfer mechanism to increase downward pressure on the pony wheels as they swing out on curves *[Fig. 12]*. The cross beam has to be an exact fit between the side frames and it has a cranked central recess to accommodate the spring-post. The beam also supports the brackets for the brake compensating levers, which system, although a bit fiddly, is not difficult to make and works well. The front beam was fabricated by silver soldering the central strip to form a T-section. This beam supports the front brake hangers, brackets for the pilot board and, most importantly, the curved radius slot through which protrudes the king-post from the car underframe *[Fig. 13]*. This slot determines the radius swing of the truck and, of course, transfers the thrust of the truck to move the tram. Close to the axle boxes is a pair of spring-posts supporting the body support bearers which slide

Above: Fig.8 Cutting the main gear wheel.
Below: Fig.9 Detail of an axle box.



Below: Fig.10 Exploded view of the truck side elements

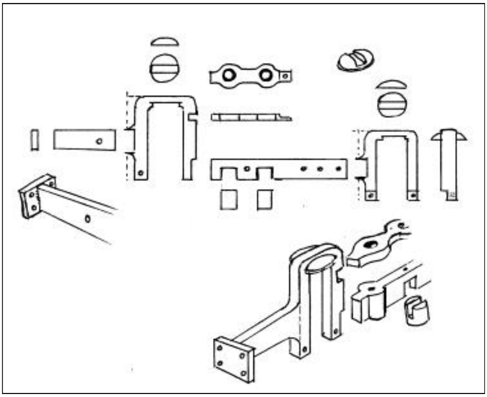
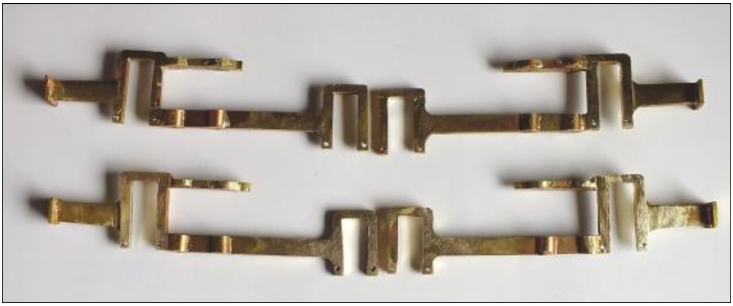


Fig.11 A completed set of model 22E side frames.



in the guides fixed to the car underframe *[Fig. 14]*. These guides are to the exact radius derived from the pivot point, a scale 6 inches behind the centre line of the drive axle. The guides are flanged to ensure that the truck is kept correctly in position.

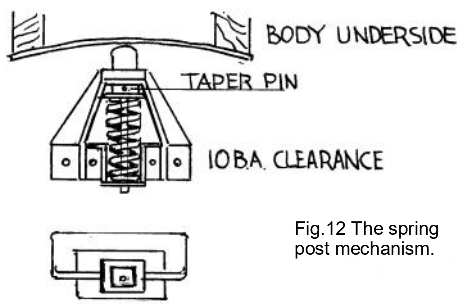
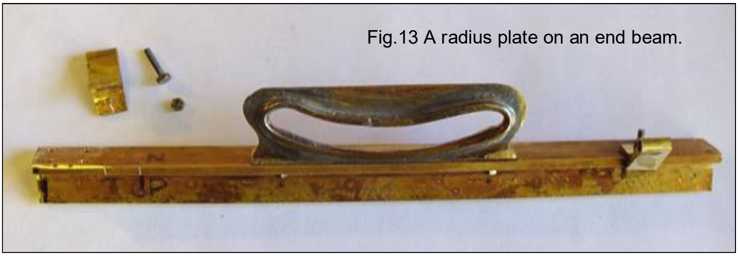


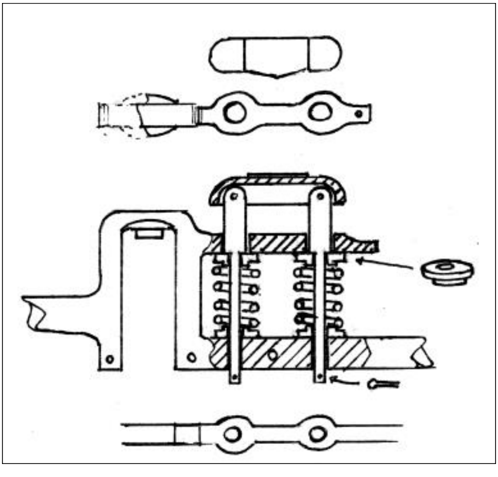
Fig.12 The spring post mechanism.

To facilitate fixing the rear cross beam to the side frames, the beam was bent to a right angle at each end. The bends were made by filing a 45° groove almost through before bending and then silver soldering inside the angle. This made a very strong, rigid unit. It had to be an exact fit between the side frames. The accuracy is essential and should an error occur and the beam end up too long or too short, all is not lost because corrections are possible with a bit judicious cutting to remove the excess or to insert an additional section. The wonder of silver solder can then be employed to correct size and strength with invisible jointing. The beam is fixed to the side frame by 10BA tapped holes in the beam ends, two on each side frame. The front fixing was made with a small-head 10BA bolt, but the rear fixing bolt was made with a ring for eventual attachment of the safety chain *[Fig. 15]*. It was easier to fit all the equipment supported by the beam before finally bolting in place. The front beam was joined to the flanges on the ends of the side frames by 12BA hex bolts with nuts screwed on the inside. Again, I fitted the brake hangers and the radius plate before fixing the beams.

Fig.13 A radius plate on an end beam.



Below: Fig.14 Sectional view of weight bearers.



Motor fixings

5U motors are ideal for these 1/16 scale models as they do not run at excessive speed and they fit between the wheels almost as in the prototype, but are a little over scale. I make my motor carriages with split bearings to facilitate the removal of a motor if necessary. This is not a difficult job and is the most accurate way to attach the motor and reflects the way it is done on the prototype. These "big-end" split bearings were made by taking two pieces of square section brass sufficiently long to make at least four bearings – two for each truck. These were then soft-soldered longitudinally, then marked out and drilled for each axle hole exactly through the centre line of the soldered join. Before separating to create the split bearings, holes were drilled through and tapped 10BA for the fixing bolts *[Fig. 16]*.

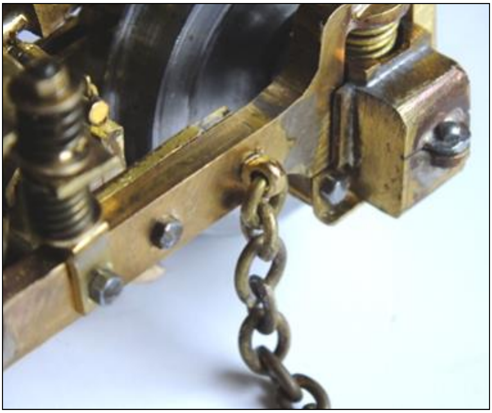
After heating to split the bearings they were cleaned up to remove traces of lead solder, then each was re-assembled, at which point the axle hole had to be reamed to create the true axle diameter. These split bearings last forever as they can be adjusted for wear as were the big end bearings on vintage motor cars.

The assembly

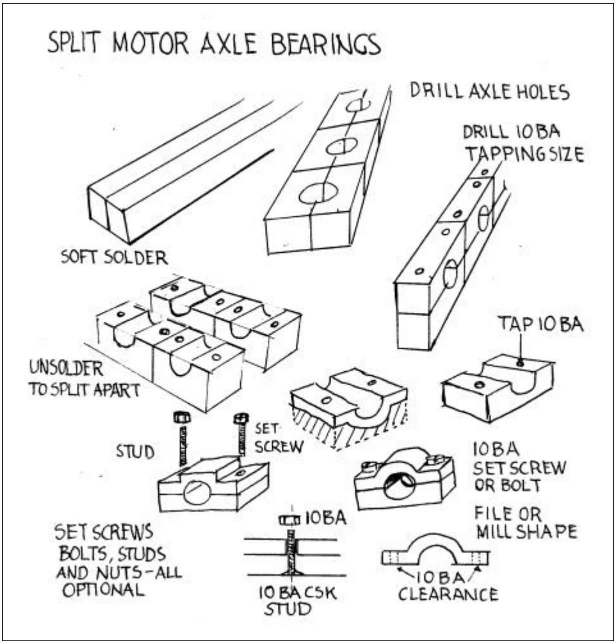
The assembly of the motor carriage and its attendant fixing points is of utmost importance and has to be made to mesh pinion and gear perfectly. It takes time and once it is completed the motor and wheel set can be run in. I gave this a lot of attention and only when satisfied that the mechanism worked properly, did I continue with the assembly of the rest of the truck. Most of the final work was with the brakes springing and final adjustments. Of course the trucks are used as a pair, so the brakes on each truck have to be linked. Each truck has a curved runner with a pull rod that connects to the sway bar and its associated compensation levers at the car's centre *[Fig. 17]*.

This mechanism does not form part of this article but, suffice to say, it is a system of levers that ensures that the brakes on each truck are equalised from whichever end of the tram the brakes are being applied. It is another example of the mechanical genius of Victorian era engineers *[Fig. 18]*.

There are many small, but important, details to consider in assembling the parts for each truck and the motor beam has to be situated according to the size of the 5U motor and carriage. This makes the position of the double-spring mounting column on the truck side, a little out of scale dimension, but it doesn't really show. Axle box keeper bars that prevent the wheels falling out have to be fitted and numbered for each axle. They should, of course, be interchangeable, but



Above: Fig.15 Attachment of the safety chain.



Above: Fig.16 Split motor axle bearings allow easy removal of the motor for maintenance or replacement.

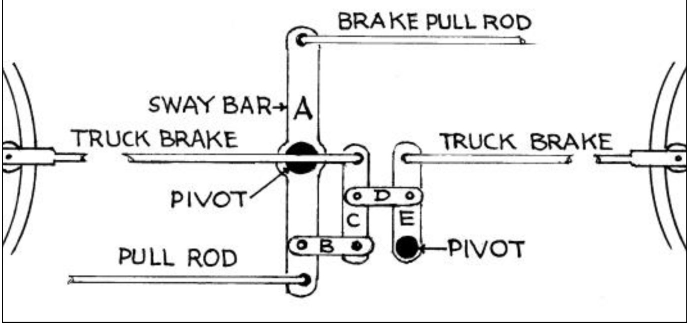
however carefully done, hand working is prone to tiny inaccuracies. Most of the set screws, tapped holes, nuts and bolts on the model are

10BA with small-headed bolts to aid scale appearance. The front beam and some of the internal struts use 12BA and the weight bearing pads above the spring posts are held by 14BA nuts and bolts. These could be substituted by 1/32in. diameter pins. Brake rods have ends threaded 10BA and I have found it necessary, after final adjustment, to lock the nuts in position as otherwise vibration would eventually cause them to unscrew. This can be done with lock nuts or by careful application of a thread-locking fluid.

It is possible to use commercially available springs but these are sometimes a little too stiff and don't always look right. Brass wire can be wound to make suitable springs that look more accurate. A bit of trial and error is required to get exactly the right spring performance and a lot depends on the eventual weight of the finished model tram.

Fig.17 Brake curved runner and pulley.

Fig.18 Central compensating mechanism.



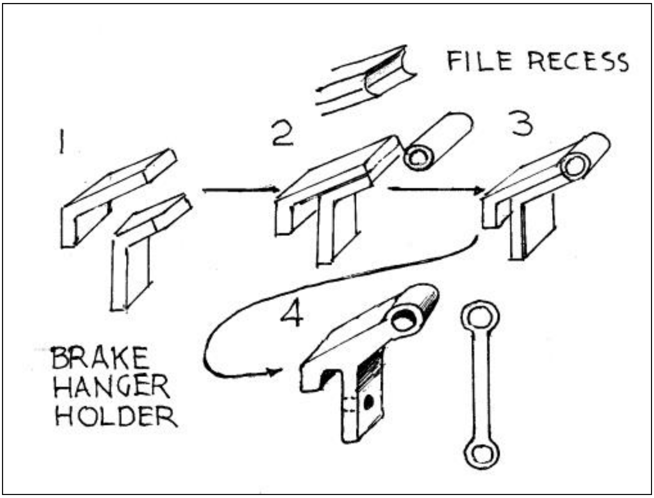
Chains

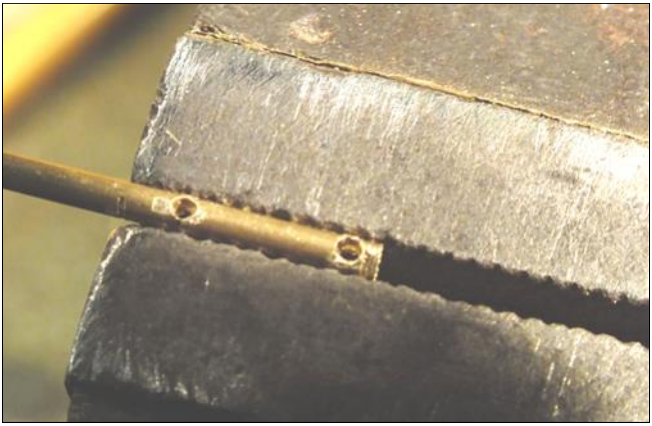
Linkage from brake handles on the platform of a tram to the central sway bar is by lengths of chain attached to brake-rods and the connections to the trucks also use short lengths of chain. Each truck has a safety chain from the frame to a hook under the sole bar. Chains can be purchased from suppliers mostly aimed at model boat builders. However, making a chain is more satisfactory and not difficult. Wire of suitable gauge is wound round a rod or oval bar and then the rings thus formed are cut with a piercing saw to create links which can be made into chains *[Fig. 19]*. Each link can be sealed with a carefully applied spot of soft solder.

The brakes

Brake parts can be made by many methods. I have tried a lot of different ways mainly in an effort to simplify a rather tedious requirement for producing items in quantity. Brake blocks hangers, brackets and clevis pins have to be made individually to be as near identical as possible. This can be achieved with casting in white metal or resin or hand cutting and filing in a variety of materials. I have tried them all. I now make the hanger brackets individually by hand and I make the hangers by hand, either as flat plates with a hole at each end, or more accurately with rods hammered flat at the ends and then drilled to represent the work of blacksmiths *[Fig. 20]*. Brake blocks I now make by hand from cut, filed and sanded close-grain hardwood. This I have found is the best solution to a problem as the blocks are quite an awkward shape and cutting and filing from solid metal takes ages; with timber it can be remarkably quick. I

Right: Fig.19 Making chain links from coil.
Middle: Fig.20 Brake hanger construction.
Bottom: Fig.21 Drilled clevis pin.





find beech to be a useful wood as it is hard and close-grained. The blocks are of different sizes for the driven wheels and the pony wheels. Casting of such parts in rubber moulds is probably the next best solution as only one carefully made pattern is required to enable the production of whole sets of parts.

Hangers with clevis pins can be secured simply with a 10BA nut and bolt, but a more realistic approach is to fit clevis pins held place with tiny split pins. This is not quite as difficult as it sounds and can be achieved with care. Split pins should be made only a few at a time before concentration lapses. The 2mm clevis pins were very carefully drilled through at each end with a 1/32in. (0.8mm) drill *[Fig. 21]*. Split pins were made by filing a length of 1/32in. diameter wire into a half round section and then forming the pin. Filing the wire was done on a piece of scrap steel with a shallow groove sawn along it to support the wire which was then filed with a flat needle file *[Fig. 22]*. It was a laborious process, but achieved in time with a set of at least 22 for each truck. A much simpler method of securing the clevis pins is with a touch of soft solder at each end where it passes through the hanger. This secures the pin, but, unlike the split pin method makes it impossible easily to disassemble the unit.

These model trucks are usually made, even in 1/16th scale, with some of the bracing struts missing as their absence is not obvious to the casual observer.

Right: Fig.22 Filing wire for a split pin.

I did not bother with such refinements on my earliest model, but all recent efforts include everything possible *[Fig. 23]*. During construction it is necessary to assemble and disassemble the parts to make those adjustments that always occur in the construction of any hand-made model machine. The bracing struts, when bolted in pace, make this task difficult. However, despite this, including all the parts is, in my view, worth it because it creates a fully working model truck with its essential, authentic details *[Fig. 24]*.

Large scale modelling, or miniature engineering, is not for everybody, but I hope this article will have stimulated enough interest to encourage some readers to make the attempt.

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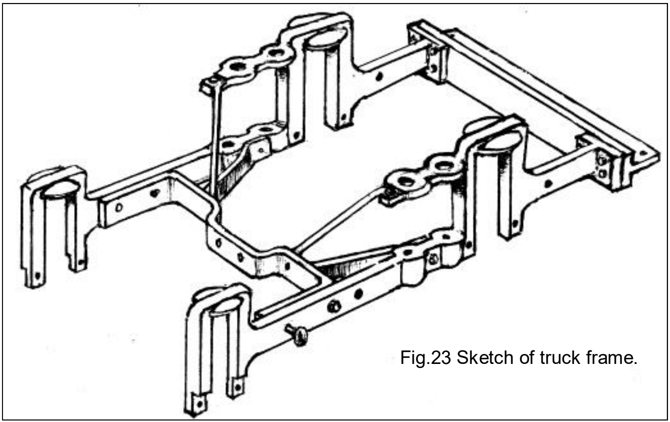

Fig.23 Sketch of truck frame.

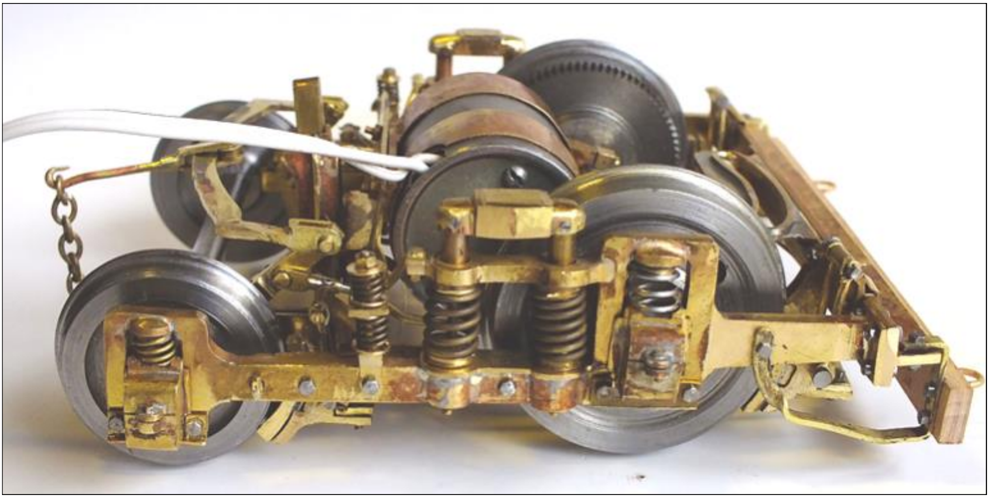

Fig.24 The completed Brill 22E truck in 1/16 scale and a satisfying achievement.