THE 67s AND THE VICTORIA LINE
2 – DESIGN & BUILD
by Piers Connor

ORDERS PLACED

The order for the manufacture of the 1967 Tube Stock cars was announced on 10 March 1964. London Transport placed a contract with Metro-Cammell of Saltley, Birmingham for 244 cars at a cost of £2.4million[1]. The cars were to be formed into 61 x 4-car M-T-T-M units. The order was for the cars and bogies only. Traction equipment, auxiliary machines, brakes, doors and control systems were all to be ordered separately. Most of the equipment was to be fitted to the trains at Metro-Cammell's factory but the cars were to be commissioned by the Underground's own staff at Ruislip Depot, as was the custom in those days. At the time of the order, the design details had still not been fixed and it was still not formally confirmed that the trains would be fitted for automatic operation.

Just a month later, on 5 April 1964, London Transport started their first full-scale trial of automatic train control (ATC) on the Woodford-Hainault shuttle service of the Central Line, using 4-car units of specially modified 1960 Tube Stock. With the start of this experiment, the 1960 Stock became the prototype for the Victoria Line's ATC system as well (as we saw last month) as for the car body design.

Static experiments with ATC had started in earnest in mid-1962, which were followed by equipment being fitted to a Wickham trolley that was tried out on the South Ealing test track on the 3 December (Figure 5 in last month's article). By January 1963, they were ready for trials on a train and a two-car District Line R Stock unit, cars Nos. 23207 and 22681, was fitted with the test equipment. Test runs with them began on 23 January. It was used at South Ealing in a 6-car train with the two test cars at the east end. A "virtual station" was marked with timber boards just to the east of the Elderberry Lane overbridge, against which to test the station stopping.

Keith Ware, who was one of the Underground's rolling stock test team at the time writes, "For some mad reason Robert Dell (the Underground's autocratic Chief Signal Engineer) invited LT top brass to observe the first run, with farcical results". It didn't work at first, but they soon got it all working and Dell later persuaded the LT Vice-Chairman, Anthony Bull, to go for ATO on the Victoria Line subject to satisfactory passenger service trials. Keith commented that, when he agreed it was "Panic stations!" for everybody.

TWO BOXES

Automatic Train Control (ATC) has two functions. One is to provide the train's protection from collisions (ATP), much as provided by conventional signalling, while the other is to allow the train to move between stations and to stop at the station in the right place (ATO).

As we saw last month, LT adopted a two-box approach, equipping the train with a "safety box" and an "auto driver box" or ADB. This is generally the philosophy that has been adopted by all subsequent ATC systems.

The advantage of this system is that the ATP system can remain operative if the ATO breaks down and the train has to be driven manually. That said, history shows that the ATP goes critical much more often than the ATO.

ATO TRIALS

Tests at South Ealing went on until there was sufficient confidence to provide a demonstration for the press on 21 March. There was then a rapid move of the test equipment to the section of the eastbound District Line between Stamford Brook and Ravenscourt Park where it had been decided to set up a trial with a passenger train, commencing on Monday 8 April. It was arranged that the Railway Inspectorate would get to see it on Sunday 7 April so that the train could go into service the next day. What faith – and justified, since it all worked and got approved that afternoon as planned. I can't begin to imagine how long it would take to do all that today.

[1] "Underground", No.28, April 1964.

The on-board test equipment was fitted to a different 2-car R Stock unit for the public trial, largely because it had to fitted under the car instead of inside the saloon. The train selected had the two-car R Stock test unit (23580+22682) at the east end. It ran in the working of Set 123.

Over the next 12 months, the experiments became focussed on the Central Line. The Woodford-Hainault section was fitted with the signalling equipment needed for automatic train operation and five 4-car trains of 1960 Tube Stock out of the fleet of six went through an on-board conversion. One of the motor cars on one train had the leading passenger section, between the driver's cab and the first pair of doors, sectioned off from the rest of the car so that the equipment could be made visible to the engineers working on the system.

Passenger service 1960 stock ATC started on 6 April 1964, after the line had been closed for the previous weekend to allow the signalling changeover. This was, as we saw above, just four weeks after the order for the new trains had been placed.

67 STOCK FEATURES

In March 1965, LT issued a technical press release describing some of the features of the new trains being ordered. The trains were in build by this time and delivery of the first was expected in May 1967. It didn't arrive until December.

The design, see diagram on page 9, was based on the 1960 Stock but there were some refinements and improvements. The bodies were to be built with unpainted aluminium alloy external panelling riveted to an aluminium body frame mounted on a steel chassis. The carbody would have a steel underframe of riveted and welded construction with steel floorplates. The body panelling was to be the by now standard ⅛ inch unpainted aluminium sheets. The panels were to be treated with a finishing process with an orbital sander to give what was called a "satin" finish to the car.

A new feature was the aluminium alloy body framing. Previous tube stock with aluminium body panels had been built with steel body framing and the use of extruded aluminium alloy body frame members was a new departure. It was hoped that it would, one day, open up the possibility of welding the body panels to the frame which, they imagined, would eventually reduce costs and improve appearance. The body panels were mostly riveted to the frame for this build with special countersunk rivets, a system that was to remain standard on the Underground until the welded bodies of the experimental 1986 Tube Stock. Certain parts were welded but this was confined to small areas only.

Figure 1: Interior of 1967 Tube Stock trailer car, instantly recognisable by the central longitudinal seats. Note the lovely, varnished, grooved maple wood floor standard at that time. The motor cars had transverse seats between the double doors. The doors had glazing that was extended up into the roofline to provide better visibility of station names for standing passengers. The maps over the windows are pasted on to the tilting ventilator covers. They show the Central Line, since the 1967 Stock was being used on the Woodford – Hainault shuttle before it was transferred to the Victoria Line. Above the maps are the illuminated advertisement panels adopted on this stock for the first time. This unit is being used for testing and has been commandeered by the publicity department for a photo shoot. The photo shows a few seated "passengers" but the unit's use is betrayed by the electrical cables dangling from the ceiling. The exterior view shows that the train is in Northfields depot. Photo: LT Museum.

The cant rails[2] were to be aluminium alloy extrusions with special slots machined into them to suit the new ventilator design. Having the ventilators actually in the bodywork over the side windows was a

[2] The cant rail is the dividing member joining the side and roof of the vehicle.

new idea. Since the stock was to have the same double glazing feature as the 1960 Stock and the usual toplights over the windows would disappear, a new ventilation system was needed. This involved an opening over the windows with a cover which tilted inwards like the old toplight. This one was not glazed but was used to display the line map. The design was intended to eliminate the necessity for all the toplights to be closed before the train was passed through the washing machine[3]. In this it succeeded but its in-service performance as a ventilator proved to be very limited.

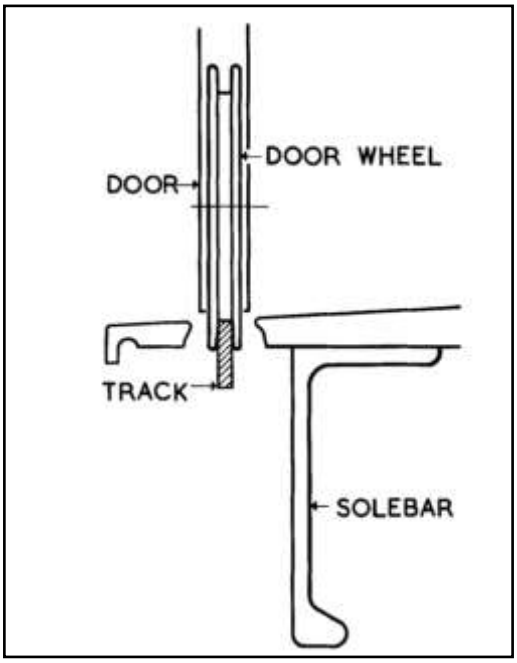


Figure 2: Diagram showing the arrangement of the solebar and door track for 1967 Tube Stock. Drawing, Webster (1969).

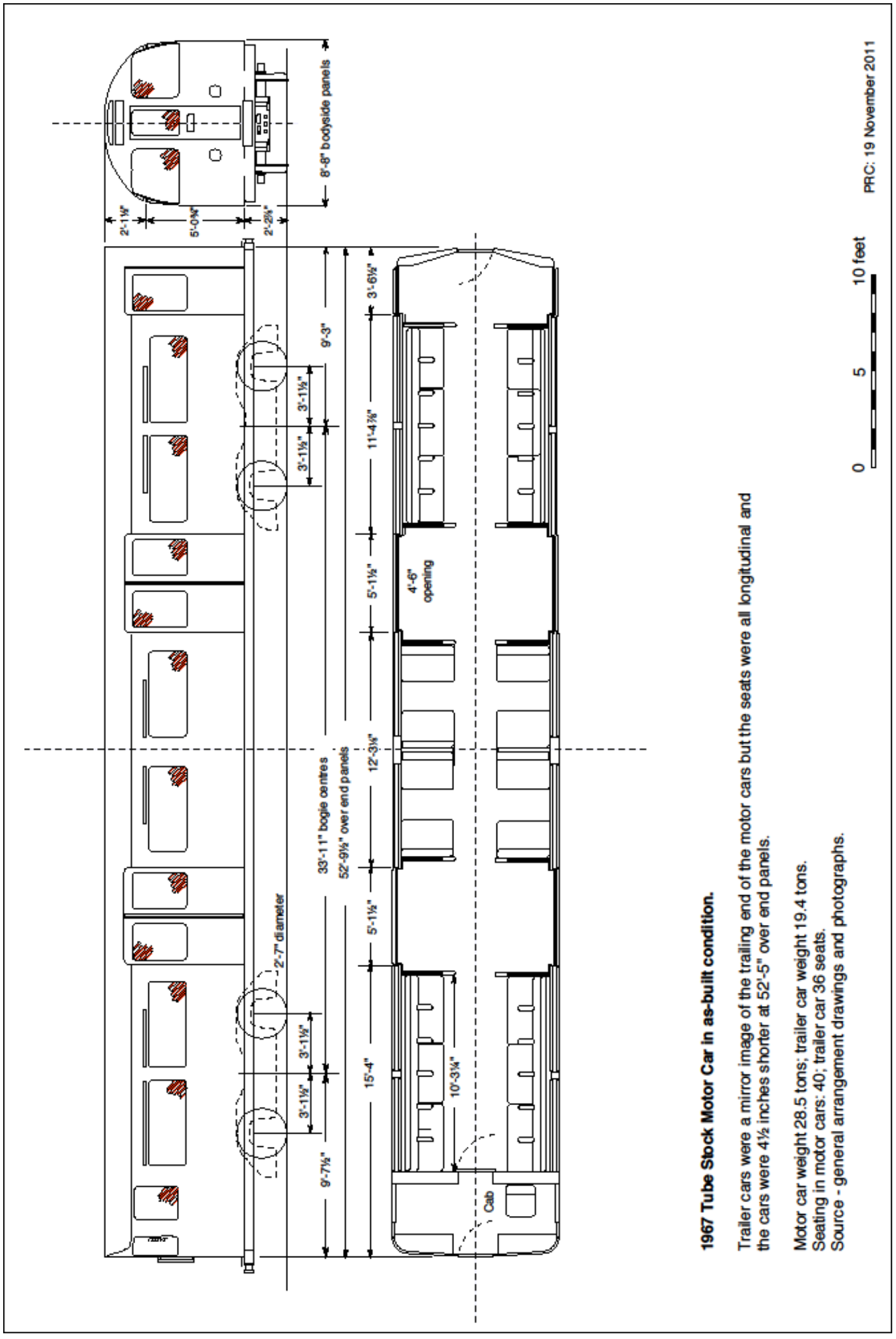
A new feature for the stock was the design of the door tracks. One of the persistent problems with car doors was jamming due to obstructions in the bottom tracks. The grooved tracks of pre-World War Two stocks were replaced by flat tracks on post war cars and these offered some improvement but did not provide the long sought after cure. For the '67 Stock, a new design appeared as shown in Figure 3. The solebar was reversed so that the door track could be opened up with slots to allow small objects like matchsticks could drop through. It was reasonably successful but it didn't survive to appear on the next new Underground design, the C Stock. Of course, matchsticks eventually became a thing of the past following the smoking ban of 1984.

The appearance of the cab end of the driving cars presented a huge visual improvement compared with earlier Underground stock. The new cars had wrap-round windscreens on each side and there were none of the usual corner pillars.

The cabs had no side doors. As we saw last month, it had been decided it wasn't safe to have a door that the driver could open while the train was moving and he didn't have to have his hands on the controls. In spite of this, it was a requirement that the driver had to be able to look out, back down the train during station operations. This arose because of the operating philosophy and the limits of the technology of the day.

Figure 3: Official photo of 1967 Tube Stock 4-car unit showing the original cab front, ventilation slots above the windows and the curved door glazing. The body was unpainted, sanded aluminium and the roof black. The photo was most likely taken in December 1967, shortly after this unit (3006) was delivered to Ruislip Depot. Photo: LT Museum.

[3] There was a procedure for this. When a train came out of service and was due for washing, the service driver stopped on the approach to the washing machine to pickup two cleaners and swap with the shunting driver. The cleaners were armed with rags wrapped round one hand, one left handed and one right handed. The left handed guy walked through the train closing the left side toplights by punching each one with his protected hand, while the right handed guy did the other side. When they were finished, the left handed guy yelled down the cab to cab phone from the rear cab, the shunter leaned out of the cab to get a wave from the other guy to confirm they were both off the train and then took the train through the washing machine. All he had to do was to remember to ensure that the cab windows were shut.



1967 Tube Stock Motor Car in as-built condition.

Trailer cars were a mirror image of the trailing end of the motor cars but the seats were all longitudinal and the cars were 4½ inches shorter at 52'-5" over end panels.

Motor car weight 28.5 tons; trailer car weight 19.4 tons.
Seating in motor cars: 40; trailer car 36 seats.
Source - general arrangement drawings and photographs.

OPERATING PHILOSOPHY

The operating philosophy that existed on the Underground in the 1960s might be meat and drink to old lags like me (and our esteemed editor) but I'm sure there will be some who have only vague recollections of the pre-OPO Underground and maybe even some who never saw it, so it is worth, perhaps, a brief recap on train crew functions of that era. On a two-man train (all trains were manned by men in those days), the guard, positioned at the rear of the train, had control of the passenger doors and his own. The driver, at the front, had manually operated hinged cab doors that opened inwards.

When arriving at a station, the guard was supposed to open his door as the train drew to a stop, check that it was OK to open the passenger doors and then open them. He observed the platform by looking along the train from his position at the front end of the rear car. There was no CCTV, no markers and, outside the peaks, rarely any platform staff to assist. Assuming the starter was off and the passengers had been given enough time to get on and off, you closed the doors, waited for the "pilot light", indicating all passenger doors were closed and then pressed the button which operated the starting bell in the driver's cab. Hopefully, if the driver was awake, he would immediately start the train. The guard would check the train as it started to see no one was trapped in the doors or fell between the cars and then duck inside his doorway and close his door – preferably before the end of the train entered the tunnel[4].

Bearing this and the need to protect the driver from falling out of a moving cab in mind, with no guard, the design of the Victoria Line's 1967 Stock had to change. The solution was found in fitting side droplights. Each side of the cab was fitted with a large droplight that the driver could open at the station. It was large enough for him to lean out and look back down the platform. He was also provided with a CCTV monitor, fitted to the platform wall opposite the point where the cab should stop. The monitor was fed from a camera mounted at the rear end of the platform, to allow a better view from that end when it was crowded.

Another protective feature of the '67 Stock was that the leading cab door (M Door), was provided with a locking device that ensured the door could not be opened whilst the train was moving.

FRONT END

The '67 Stock front end followed the principles started on the 1960 Stock, with a more stylish approach nicely rounded cab roof dome incorporating the destination roller blind with a ventilator grille above it. The cab profile was rounded above the waist level and it incorporated wrap round windows for the cab windscreen. These windows were a rather complex shape and were undoubtedly expensive but they gave the front end of the stock a unique and iconic look that was so successful that it didn't date over their 40-plus years in service.

Innovations were the large bright headlights, designed to illuminate the interior of the tunnel a little better that you would expect from the traditional marker lights of older stocks and the aluminium handrails either side of the cab door, the offside one incorporating the train whistle as well. The orange calling-on light (that I mentioned in last month's article) was mounted on the nearside of the destination display. The train number was displayed in an opening provided in M Door, using the traditional number plates.

CAR INTERIORS

All cars were provided, as usual, with three seating bays, separated by the double doorway vestibules. The seating layout was standard in the motor cars, with longitudinal seats in the end sections of the saloon over the bogie boxes and transverse seats between the double doors, giving 40 seats in each car. Trailers had only 36 seats and all were longitudinal in an attempt to provide more standing between seats. The cars retained this layout to the end of their lives.

The passenger doors had windows that curved up to the top of the door, following the body shape. This was done following a trial carried out on 1938 Tube Stock car No.10306 in November 1949 that proved to be popular with passengers. I can only assume that it appeared on the '67 Stock first, and not earlier stocks, because of the expense of manufacturing the curved glass and doubts over the

[4] Occasionally, a guard didn't and, during my time on the trains, I heard of two cases where the guard hit his head on the headwall. One survived, almost unscathed apart from a serious headache, the other, sadly, was killed.

tolerances. In my view, it's a backward step that this design feature has been abandoned since the mid-1990s largely, perhaps, because of the poor quality fitting of the Central Line's 1992 Stock curved saloon windows and the consequent leakage and corrosion[5]. Problems with tolerances again.

The floors were covered with the Underground's standard grooved maple wood boards bedded on canvas impregnated with red lead. The floors looked a beautiful varnished gold when the cars were new but they quickly degenerated to a dull grey after a few weeks' use.

The cars had two sets of fluorescent lighting. The main lighting consisted of exposed tubes fitted in sunken ceiling units and positioned along each side of the car roughly over the line of the seat edges. A second circuit was provided for illuminated advertisement panels fitted in pairs over each set of seats, giving 12 per car. These were fed off a separate circuit so that they were never switched off when the main cars lights were. Although they were meant to provide a little extra revenue, they were not that successful. They were larger than the traditional car cards that every advertiser knew and supplied and they looked out of place next to the traditional cards that they shared space with. Their lighting tubes were shrouded in opaque glazing that soon became even more opaque with the collection of tunnel dust. They also took time to remove when a tube needed changing and, as a result, they were often left alone and ran with defective tubes. They disappeared when the cars were refurbished in the early 1990s.

The interiors were otherwise fairly traditional. The seating moquette was the same red/black/grey pattern as that used for the Metropolitan Line's A Stock, even though a new green/blue pattern had been designed and approved in May 1965 for all LT vehicles (bus and train). It was too late to be fitted to the stock when new but it did appear on many trains up to the mid-1970s.

Stainless steel handrails were provided at doorways next to the draughts screens and the then traditional flexible handgrips were fitted along the ceiling next to the lighting troughs. Fixed handgrips were provided over doorways.

The armrests were unusual in that they had a two-tier design to allow adjacent passengers to rest their arms separately, without a battle to get space. Originally it was intended that they should be trimmed in red leather but cost ruled this out and they were delivered in moulded plastic. The design was really rather successful but it was prone to damage by criminals and fell by the wayside. It was replaced on 1990s stock by the ugly and uncomfortable type now seen on the Northern and Jubilee lines.

The interior bodysides and ceilings were finished in panels of grey or white melamine-faced hardboard and a dark, rubberised kicking strip was applied at foot level. Coverings for the doorway pillars were made of moulded glass reinforced plastic. The tops of seat backs were covered in red leather. This was a useful feature provided to allow the tops edges to be easily cleaned of dust. Of course, it is not done today, since seat upholstery is so thin that it hardly has enough of a top surface to allow dust to settle.

At doorways, draught screens were of the usual Underground arrangement with toughened glass but they were set back from the doorway by about 6 inches to allow passengers to stand without obstructing the doorway too much. This worked with the design of ceiling adopted for the '67 Stock but the idea has been sterilised on more recent cars where ceilings have become so chunky that it's impossible for a person of normal height to stand upright near the doorway.

Heating was provided in the form of low temperature panels fixed to the gangways side of each seat riser. These were something of an improvement on the previous small heater units stuck under seats wherever space was available, which led to an uneven distribution of heat – such as it was. The Underground was always nervous of in-car heating circuits since they operated at the line voltage of 630 DC and were necessarily above the floor and close to the passengers. The heater fires experienced on the District line's R Stock were fresh in people's memories and the idea of low current panels was a much more attractive proposition.

COMMUNICATIONS

Car interiors were equipped with a public address system, allowing the driver to make announcements to the passengers. A special handset, supplied, I remember, by a company called

[5] Indeed, one might be tempted to comment at length on the overall quality of the 1992 Tube Stock build but one must resist.

Nelson Tansley, was provided in the cab that was used for this and for communications between cabs (if required in emergency) and between the driver and the control room using a new system described as “carrier wave”.

The carrier wave communication system was a first for the Underground as it was the first time that a driver could communicate with the controller whilst on the move. The system used the traction current rails as the transmission medium. The train equipment consisted of a barrier or isolating unit, connected to the collector shoe circuits, feeding into the cab equipment which could be removed as a “plug-in” unit. The system operated at 130kHz from the control room to the train and at 150kHz in the opposite direction. Whilst all trains in a given section could hear a message from the control room, they couldn’t hear other trains. Contrary to popular belief, the driver didn’t speak to the line controller but to the signalman, who was then referred to as a “train regulator”, since his purpose was not to signal trains under normal conditions, as this was done by programme machines.

The big drawback of the carrier wave system was that it didn’t work if traction current was switched off and short circuit devices had been put down across the current rail to provide protection. Happily, such circumstances were rare but were a particular inconvenience during suicide recovery.

A train-to-train radio system was also provided. The purpose was to allow the driver on one train to exchange messages with another close behind him during push-out operations. Various system design options were considered, largely with a desire to avoid paying for the licence required for each instrument by the then regulator, the General Post Office. In the end, the only suitable design was a short wave radio, with a range of 50 feet – all that was necessary to allow a transmission from an aerial in the rear cab to the reciever in the leading cab of the assisting train. Webster, in his paper to the Institute of Locomotive Engineers[6] observed, “A maximum range of only about 50 feet is required and this is achieved by attenuating the output signal by the use of an inefficient aerial which takes the form of a metal drawer handle mounted on the rear wall of the cab!”

BOGIES

From the late 1930s up to the early 1960s, tube car motor bogies were designed with a traction motor on one axle of the two and for the car weight to be greater on this axle to improve adhesion. The bogie wheelbase was therefore asymmetrical, with the motored axle closer to the bogie centre than the unmotored axle. Trailer bogies were standardised by being designed the same way.

With the 1960 Tube Stock (and the Metropolitan’s new A Stock), the traditional arrangement of two 600v motors per motor cars was abandoned to allow the use of four 300v motors, so that each axle on a motor car was motored and the bogie design became symmetrical. This setup was adopted for the ‘67 Stock. The motors, described by the Underground as type LT115, were nominally rated at 80hp.

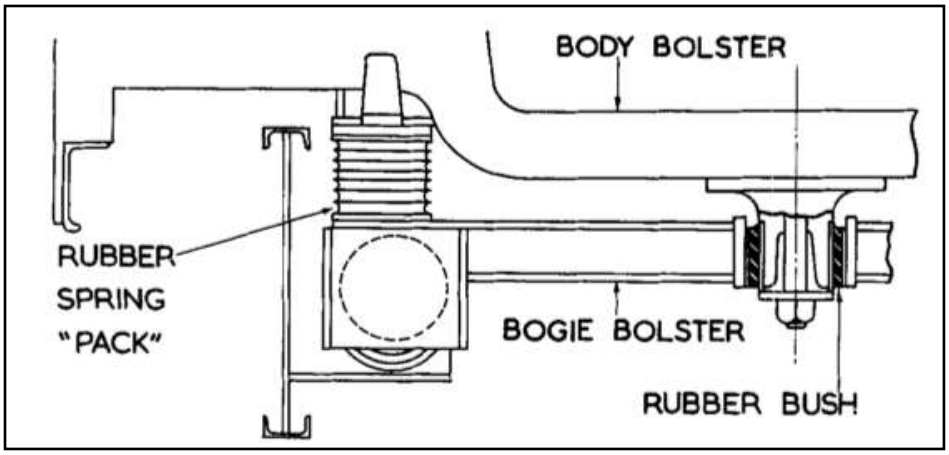


Figure 4: Diagram of rubber suspension units that replace the steel side rollers and centre bearing on the 1967 Tube Stock. The rubber side bearers carried the car body weight. They were flexible enough to allow the bogie to turn up to six degrees from the centre.

Drawing: Webster (1969).

Bogie frames were steel, using welded and riveted construction except for the headstocks and axlebox yokes which were forged aluminium. The motors were the traditional, nose suspended type, mounted on forged steel suspension sleeves using taper roller bearings, with the motor nose supported on the transom by links incorporating rubber bushes at the pivoting points.

[6] Webster, E., (1969) Design Considerations for New Rolling Stock for the Victoria Line, London Transport Railways, Institution of Locomotive Engineers, London.

The Underground had been using rubber for the susupension of carbodies and bogies since trials started in 1947 with the experimental fitting of rubber packs on the bogie bolster of a Q Stock trailer car on the District Line. Because of the hope that there would be a reduction of the number of parts requiring regular maintenance and even that there would be quieter running, there was a gradual extension in the use of rubber. The 1959/62 Tube Stocks and A Stock incorporated rubber in the suspension of the axleboxes, the bogie bolster, the traction motor nose and shoebeams.

Later, a 1962 Tube Stock car was modified with rubber "packs" replacing the traditional steel roller side bearers and a rubber pivot in place of the conventional centre bearing. The trial worked well engough for the ideas to be included in the '67 Stock (Figure 4), together with rubber springing for the intercar couplers and buffers.

Webster (1969) described the design where, "These springs carry the whole weight of the carbody and have sufficient flexibility to allow the necessary turning of the bogie through an angle of six degrees from the centre line. They thus eliminate the small clearance which previously existed between the carbody and the roller side-bearer which was a source of considerable noise and an item requiring maintenance".

He went on, "Since the carbody weight is supported by the side-bearers there is no longer a need for a load carrying centre-bearing and this has been replaced by a rubber-bushed centre spigot which locates the bogie and transmits traction and braking forces. In the past, centre-bearings have been another source of considerable noise and wear."

RHEOSTATIC BRAKING

The 1967 Stock had rheostatic braking. This was the first tube stock to have such a system. The idea was based on the now well-known idea that a train's motors could be used to provide braking effort. If the motors are reconnected to become generators during braking, the power they produce can be fed into an on-board resistor and dissipated as waste heat. The objective was to reduce the use of friction braking, a long standing source of dust and wheel wear.

The idea was tested on a specially formed 4-car unit of 1960 Stock. It was made up with its usual two Standard Stock trailers replaced by two 1962 Stock trailers to give the formation 3910-2736-2734-3911. It was taken to the South Ealing test track and, during the summer of 1963, several weeks of trials took place. The test results were sufficiently encouraging to allow a redesign of the traction and braking system intended for the 1967 Stock. The rheostatic brake could be used at speeds above 20 mph, definitely useful on the Victoria Line since it was being designed for a top inter-station speed of 50 mph and, as a result, it was decided to reduce the number of friction brake shoes by 50%. Instead of the standard two shoes per wheel, the new stock was to have only one. Tests showed that this would provide sufficient brake effort for an emergency stop if it was required.

The introduction of the "rheo brake" as we all called it, meant a redesign of the traction control system. The Underground's standard PCM (Pneumatic Camshaft Control) system used camshaft operated contactors, arranged with a single camshaft that rotated in one direction for the control of the series contactors and in the opposite direction to control the parallel contactors. With the introduction of rheo braking on the '67 Stock, two camshafts were used, one for series control of both motoring and braking, the other for parallel control of motoring and braking.

The rheo brake system was entirely controlled by relays. One of these was known as the Rheostatic Brake Proving Relay (RBPR) and it was connected to the braking control on each motor car with the idea that, if the rheo brake failed to produce a brake effort, it would make the electro-pneumatic (e.p.) brake apply automatically. The trouble was that if the rheo brake failed to register on one car, the RBPR cancelled rheo brake on the whole train. There was then a lag while the e.p. brake tried to play catch-up and get the brakes on to match the lost rheo effort. This was not an easy task and there was a considerable lurch forward during the process. The result was often an overrun of a platform stopping mark. Drivers soon learned to compensate for this by applying the emergency brake as necessary[7].

[7] Keith Ware, one of the Underground's senior engineers at the time, wrote to me "I think the bulk of these [overruns] were due to an intermittent open circuit in one of the ADB components, causing a brake release shortly before standstill. This was a persistent problem – I thought 'if only I could be in the cab when it occurred, I could understand what happens'. Eventually I was, and all I knew was that the brakes had released at a critical point – no help at all.

A further consequence of the use of rheostatic braking is the adoption of solid wheels on the motor car (previously confined to trailer cars only) since it is now expected that the reduced wear will make wheel changing, in place of re-tyring, an economic proposition. Some improvement in tyre condition and reduction in brake block wear is also expected from the better cooling of a solid compared with a tyred wheel.

The use of a single brake block per wheel caused a considerable increase in the brake forces and it was necessary to compensate for this by altering the angle of the rubber axlebox suspension packs from 2° to 10°. This was done because of fears that the brake cylinder slack adjustment would operate “irregularly”. With soft rubbers, the slack adjuster would take up a notch on every brake application and eventually lock the brake on permanently.

To be continued …….