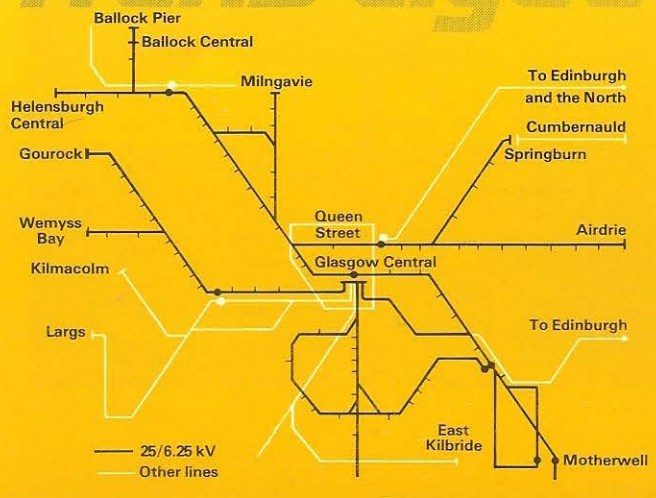
Equipment for High performance ac and dc

emu

trains

Trans-Clyde



GEC TRACTION

high performance ac and dc emu trains

Cover illustration
Route maps for two of the systems involved (Merseyrail and Trans-Clyde) are shown with the electrified lines highlighted.

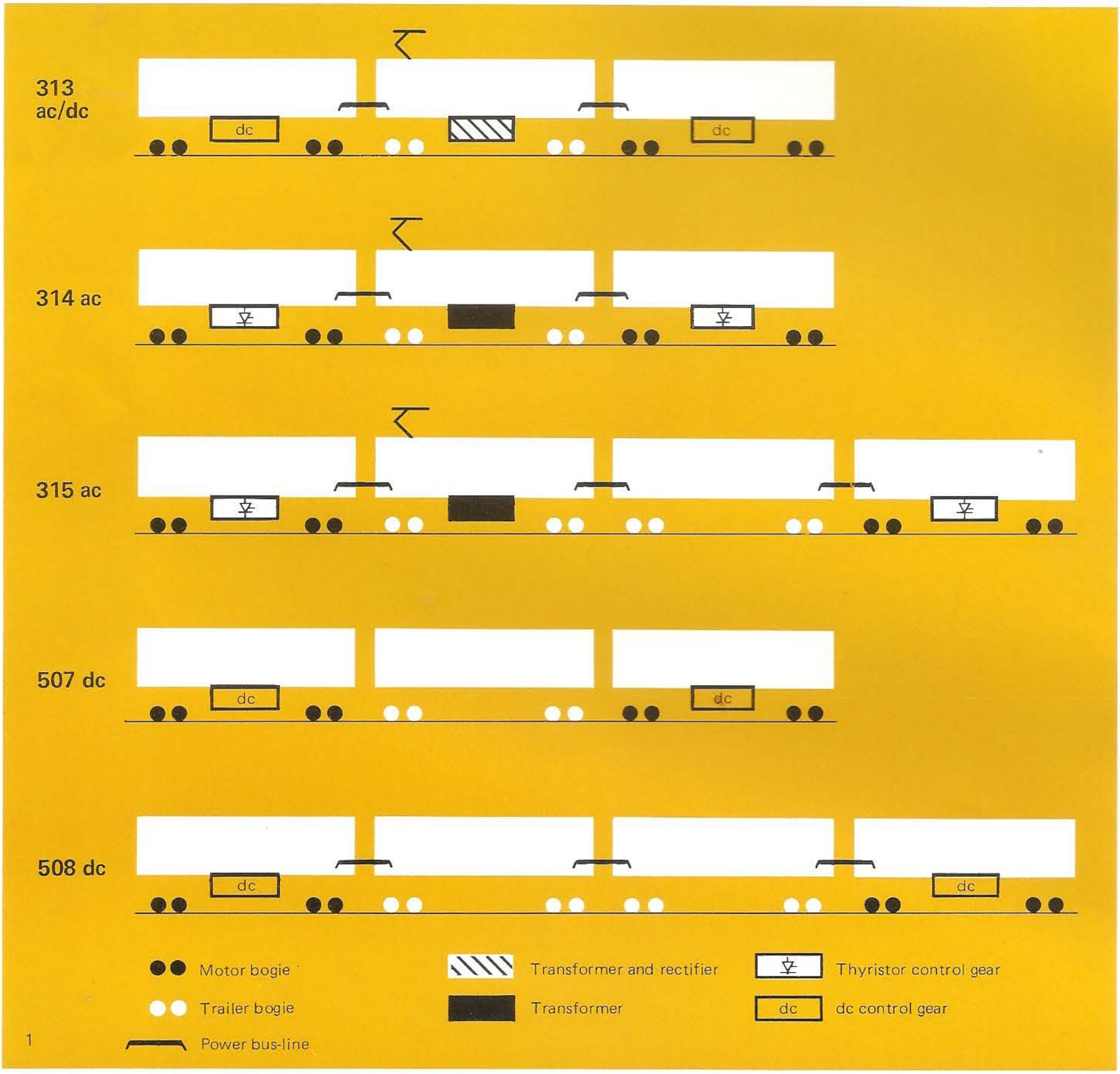
Fig. 1 (below) The different train formations and the layout of their equipments are illustrated in this diagram.

The five latest fleets of inner suburban emu's to enter service in the UK have a high degree of equipment standardisation whilst operating under widely different service conditions. They operate from 25kV overhead lines and on 3rd rail dc systems, in deep-level tube tunnels and on the surface. The basic layouts of the various fleets are shown in Fig. 1 which highlights the essential differences.

The 313 and 315 Classes both operate on the Eastern Region, the former on the Great Northern service from Moorgate and the latter between Liverpool Street and Shenfield. The 314's which operate the cross-river TRANS-CLYDE services in Glasgow (formerly known as Clyderail) were originally designed for dual-voltage operating (25kV/6.25kV) but this requirement was dropped before the units were delivered. The dc units operate on the Merseyrail network of the London Midland Region (Class 507) and the Southern Region (Class 508). It is interesting to note that although the 508's have an extra trailer car their net performance is almost identical with the 507's because of the higher system voltage on the Southern Region.

All the trains have sliding doors and as some of the dc units operate in deep level single-line tube tunnels there is through-access between all cars to facilitate emergency unloading in a tunnel. Tunnel safety regulations do not permit intercar power bus lines during deep tube working and so all the power cars on these trains are electrically independent. The 508's, however, do have power bus-lines to avoid the problems of long gaps in the conductor rails near to the inner-London terminals.

Cars within a train set are semi-permanently coupled but there are automatic couplers at each end of the set which provide air and multi-way electrical connections between sets.



Easier installation

Simpler operation

Less maintenance

The control equipment has been designed to minimise both installation time and maintenance. A frequent bottleneck during car construction has been the cab area with craftsmen from several disciplines all trying to work in a confined space. This problem has been greatly reduced by pre-wiring and pre-piping the control-desk in the factory thus requiring a minimum of final installation. In accordance with current British Rail practice separate power and brake handles are provided, moving in the horizontal plane, but similar desks have been built with a combined controller which works in the increasingly common "fore and aft" mode.

The under-car control equipment is located in full-width pannier cases. These again are pre-wired and require a minimum of connections between case and car. These cases, together with the transformers where fitted, are secured to the underframe by four bolts and can be lifted into and out of position by a fork-lift truck, thus greatly simplifying depot operations.

The control equipment is segregated so that those items which require attention or inspection at more frequent intervals are located at the sides where access is easy from outside the rails. Equipment requiring less frequent inspection, such as chokes, resistors and their fans, is located in the centre of the case and whilst access can only be attained from below the car it is, of course, only rarely required.

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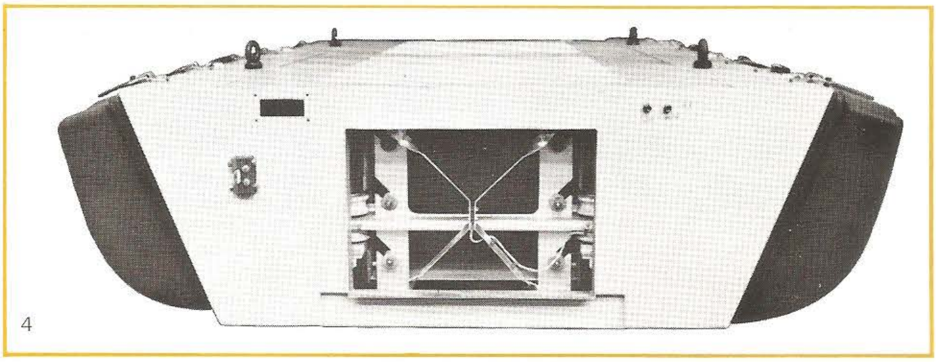

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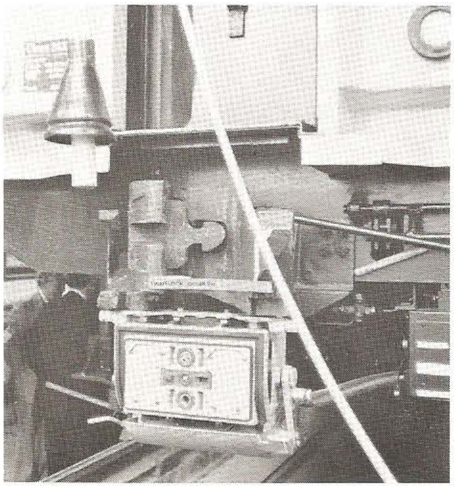

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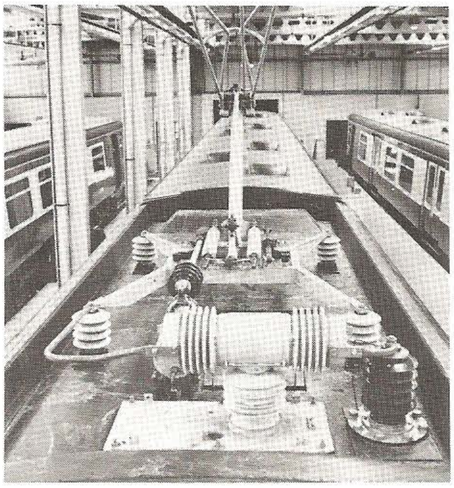

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Fig. 2 & 3 The present standard British Rail drivers desk and (insert) a variation for London Transport showing the combined for and aft controller.

Fig. 4 This view dramatically illustrates the shallow height of the full-width pannier cases. The cases on the ac trains are 3m in length.

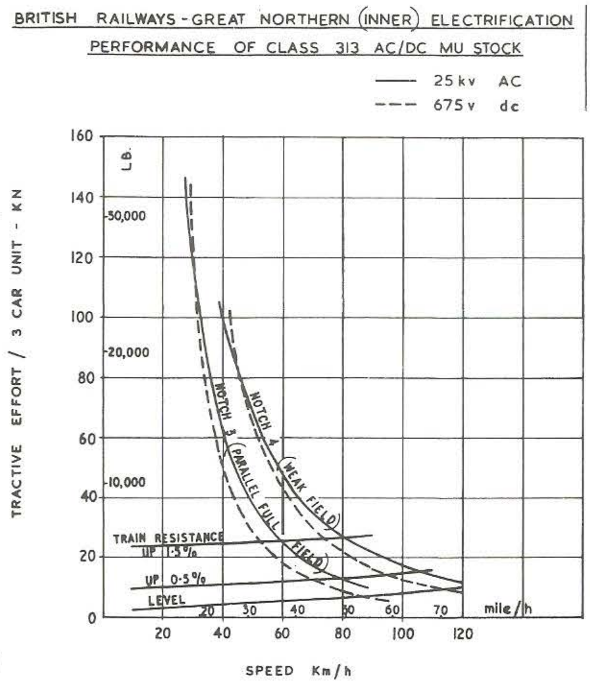
Fig. 5 Rapid coupling and uncoupling in service is achieved by the autocouplers which provide multiway electrical connections as well as air and mechanical functions.

Fig. 6 All the ac trains are equipped with the GEC type 20CB vacuum circuit breakers which reduce maintenance costs when compared with air-blast breakers.

Performance

All five varieties of trains have 8 - G310 traction motors. The train weights vary, however, between the tare weight of some 97 tonne of the Class 507 to the crush-laden 508 at 192 tonne. Many of the trains are equipped with load-weighing which compensates for variations between tare and fully seated conditions whilst the load associated with the extra trailer cars on Classes 315 and 508 is compensated for by raising their accelerating currents (as seen in Fig. 8 & 9).

The individual duties also vary considerably from the close station spacing which is found in the inner city areas (Fig. 10a & 12) to the much longer distances found in the outer suburbs (Fig. 10b). Severe gradients are encountered such as in the Mersey Tunnel (Fig. 13). The effect of working in single bore tunnels is well illustrated in Fig. 14 which shows tractive resistances for trains in the tunnel and on the surface.



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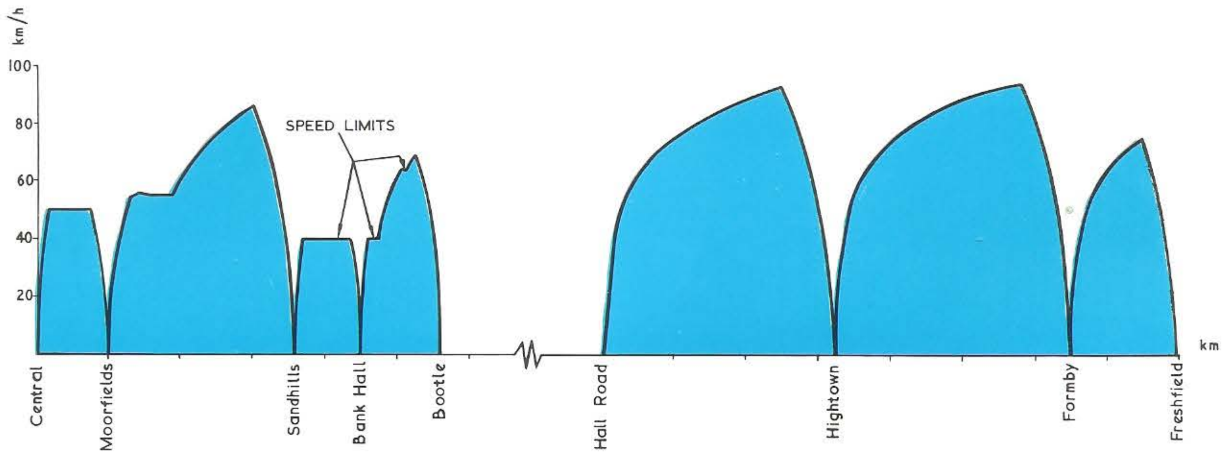

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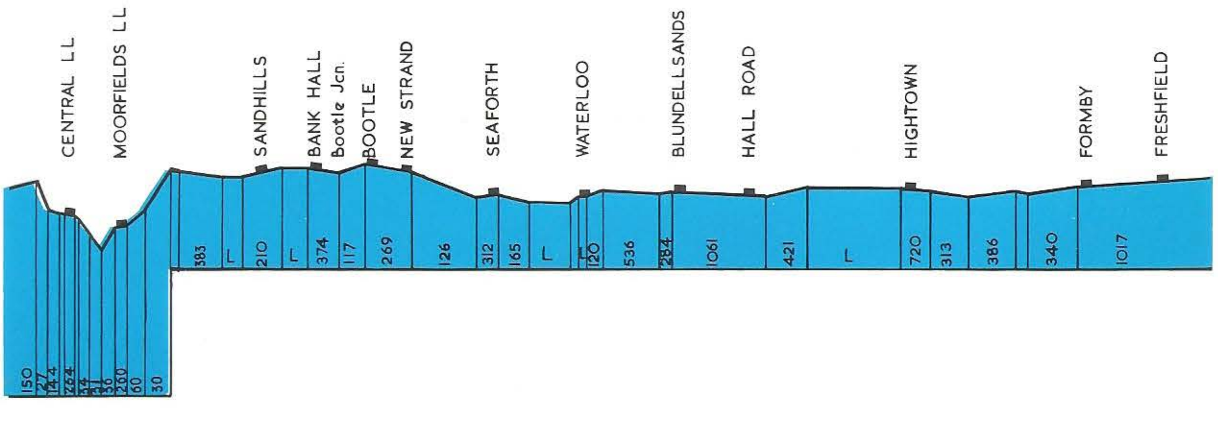

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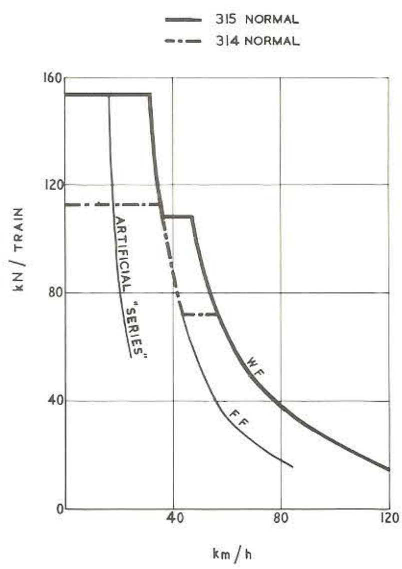

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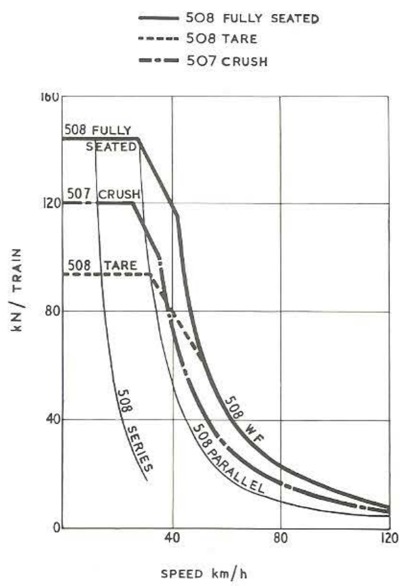

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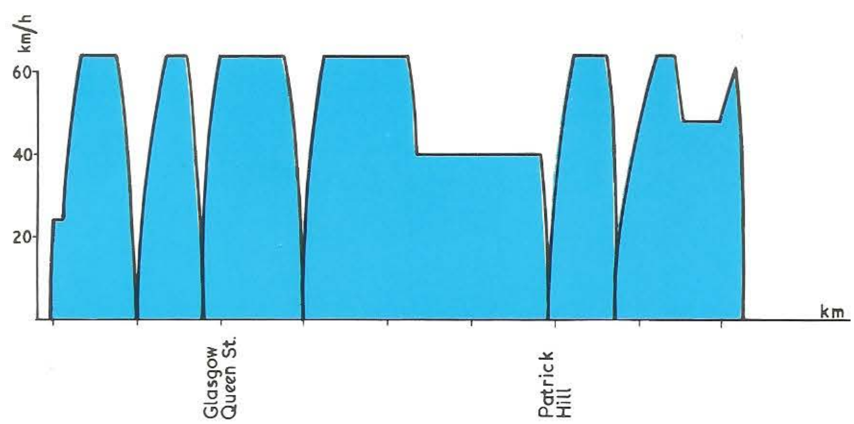

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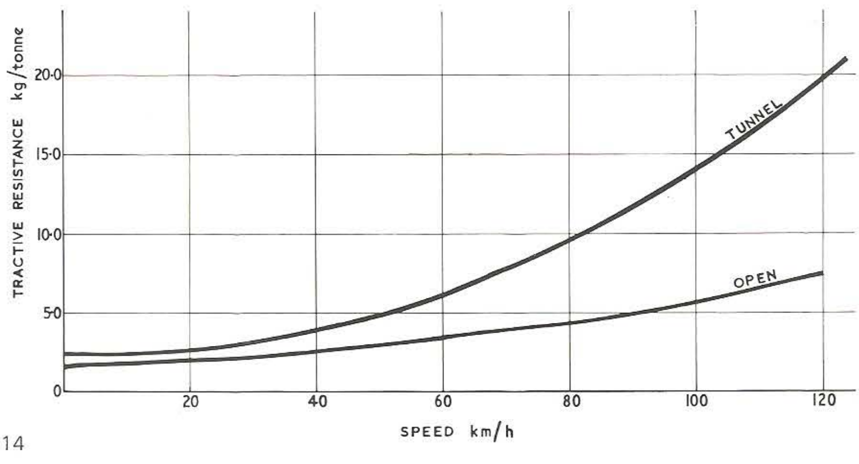

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Fig. 7 The Class 313 trains operate on both 25kV 50Hz supply and from a 3rd rail at 750V dc.

Fig. 8 The Class 314 units (which are 3 car) normally accelerate at a much lower current than the 315's (four car) to match their performance with the existing rolling stock in Glasgow. The accelerating current may, however, be raised in the future.

Fig. 9 Different accelerating currents also apply to the 507's and 508's. The effect of the lower system voltage on Merseyside is apparent from the lower full voltage characteristic of the 507's.

Fig. 10 The Liverpool inner suburbs and outer suburbs graphically illustrate the range of operating requirements demanded of the units.

Fig. 11 A simplified route profile of the line between Liverpool and Southport - mainly level but with some very severe gradients.

Fig. 12 The close station spacing of the inner Glasgow area is apparent from these speed/distance curves for the 314 stock.

Fig. 13 Gradient profile for the section of track under the River Mersey.

Fig. 14 Tractive resistance curves (in tunnel and on the surface) used when calculating train performance.

Undercar equipment

The equipment varies very considerably between ac units and dc. The 314 and 315 ac trains have a "sub-station" trailer car (fitted with a pantograph and a transformer) which sends power at a nominal 1050V 50Hz to converters on the flanking motor cars. The 507 and 508 dc power cars have dc camshaft controllers and collect their current from their own shoe gear. The earlier 313 trains have a *rectifier* transformer on the pantograph car which feeds a dc bus-line (but only during surface operation as tunnel safety rules preclude such a feature when operating in tunnels).

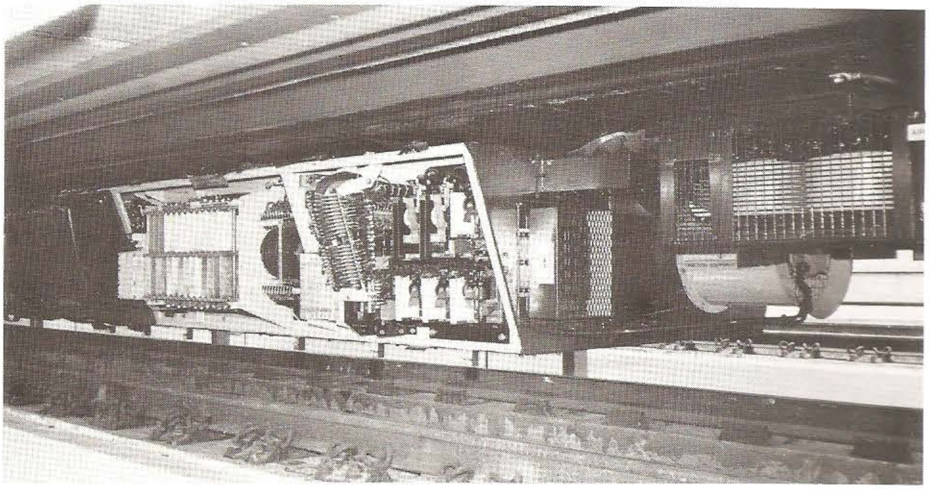
Transformers

The transformers on the 314's and 315's have a single 25kV primary winding wound concentrically with a centre-tapped secondary winding of 525-0-525V which supplies the auxiliary loads as well as the thyristor converters. Electrically these are the simplest coach transformers on British Rail and they are also very simple mechanically.

The transformer is assembled complete with a pair of steel-tubed radiators, one on each side of the tank, and a conservator on top with a Buchholz relay in the conservator feed pipe. It is mounted as a single integral unit without any oil pipe connections having to be made when fitted to the coach. The weight of the core and windings is supported directly by the main transverse steel members which are bolted to the underframe fixing pads. These members also support the radiator cooling banks thus relieving the tank of any main load bearing other than the weight of the contained oil.

The radiators have widely spaced smooth tubes so that they will not collect dirt (as can happen with radiators of smaller close matrix) and the tubes are elliptical in section giving a more compact and lighter installation than is possible with round-section tubes. The whole arrangement gives a robust cooling assembly which requires neither cleaning nor maintenance.

Three trains have been fitted with completely sealed transformers.



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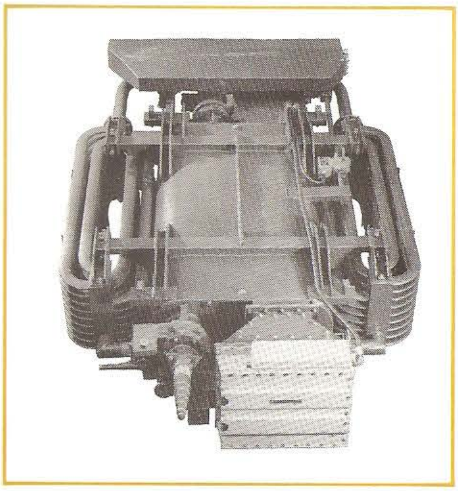

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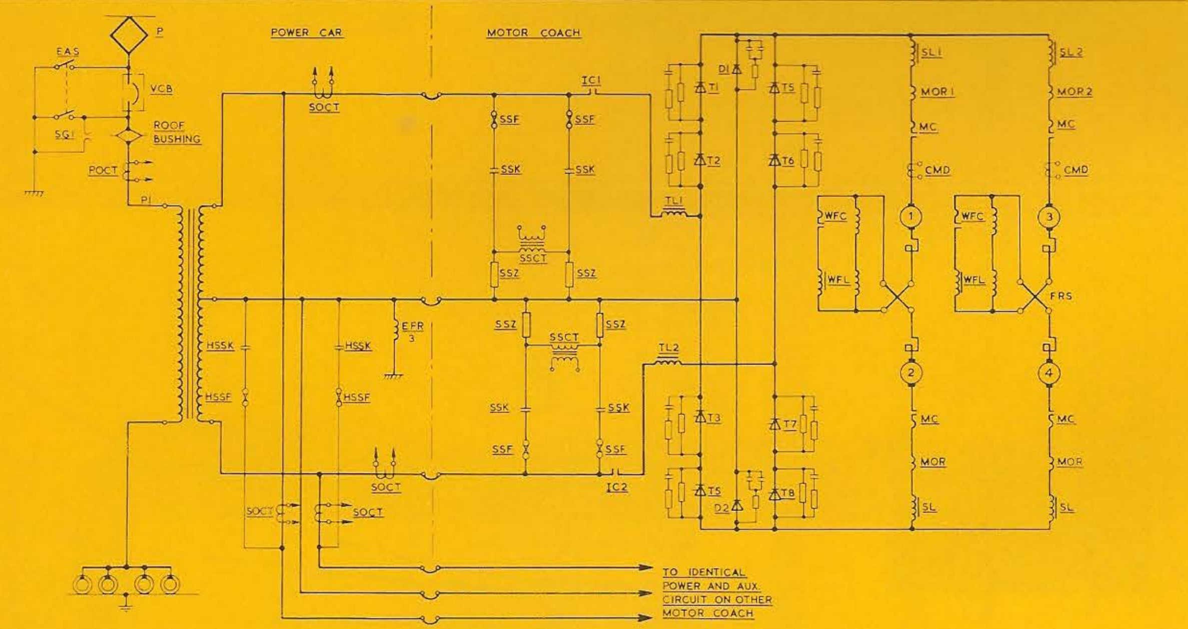
Symbol	Description	Symbol	Description	Symbol	Description
CMD	Current Monitoring Devices	MC	Motor Contactors	SSCT	Surge Suppression Current Transformer
DI	Control Circuit Blocking Diode	MOR	Motor Overload Relays	ssf	Surge Suppression Fuse
D2, 3	L.B.R. Diodes	P	Pantograph	SSK	Surge Suppression Capacitor
EAS	Earthing Switch	POCT	Primary Overload Current Transformer	SSZ	Surge Suppression Resistor
EFR	Earth Fault Relay	SG	Spark Gap	TI-8	Power Thyristors
HSSF	High Freq. Surge Suppression Fuses	SL	Smoothing Inductor	TL	Thyristor Current Limit Reactor
HSSK	High Freq. Surge Supp'n Capacitors	SOCT	Secondary Overl'd Current Transformer	VCB	Vacuum Circuit Breaker
IC	Isolating Contactors				



ac thyristor control

Thyristor converters

The converter power-pack includes all the converter electronic and conventional control equipment to control four traction motors and is contained in a full-width pannier case some 3m in length. The main converter consists of 8 tyristors and 2 diodes arranged in the form of two bridges to give the optimum combination of good power factor and minimum psophometric current. Button-type thyristors and diodes are used with double-sided cooling fins. The devices are mounted on boron-nitride discs and so their aluminium heat-sinks (which protrude through to the outside of the case) are at earth potential. The design is such that satisfactory cooling is obtained at a train speed of only 16 km/h. The devices are assembled in pairs which can easily be removed from the case for routine inspection but the devices themselves are not graded and are interchangeable with similar devices.

The electronic control system employs a current control loop to hold the traction motor current at a preset level (for normal acceleration) with overriding limits on output voltage to give the driver 4 control positions (equivalent to SHUNT, HALF POWER (or "series"), FULL POWER and WEAK FIELD). The system also automatically corrects for wheelslip and pan bounce. In the event of a fault occurring the thyristors are shut down rapidly leaving back-up isolation to the contractors.

The case incorporates a test system which allows a test box to be plugged in to automatically check the operation of the electronic equipment and, in the event of a fault being detected, to indicate which module should be changed. A second test-box can monitor the input and output functions of the modules either statically or with the train in motion.

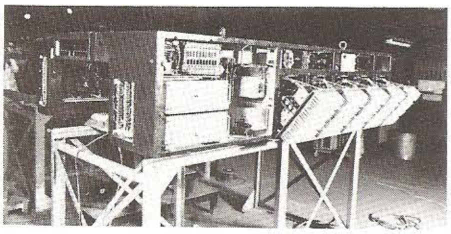


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Fig. 15 In this under car view one cover has been removed from the dc control equipment case revealing the camshaft. The fan for force-cooling the accelerating and braking resistance is seen in the centre of the case (behind the smoothing choke).

Fig. 16 The complete transformer seen from above.

Fig. 17 An ac thyristor case is seen on final test with the thyristor modules themselves partially removed for inspection.

Fig. 18 Final assembly of naturally ventilated thyristor modules.

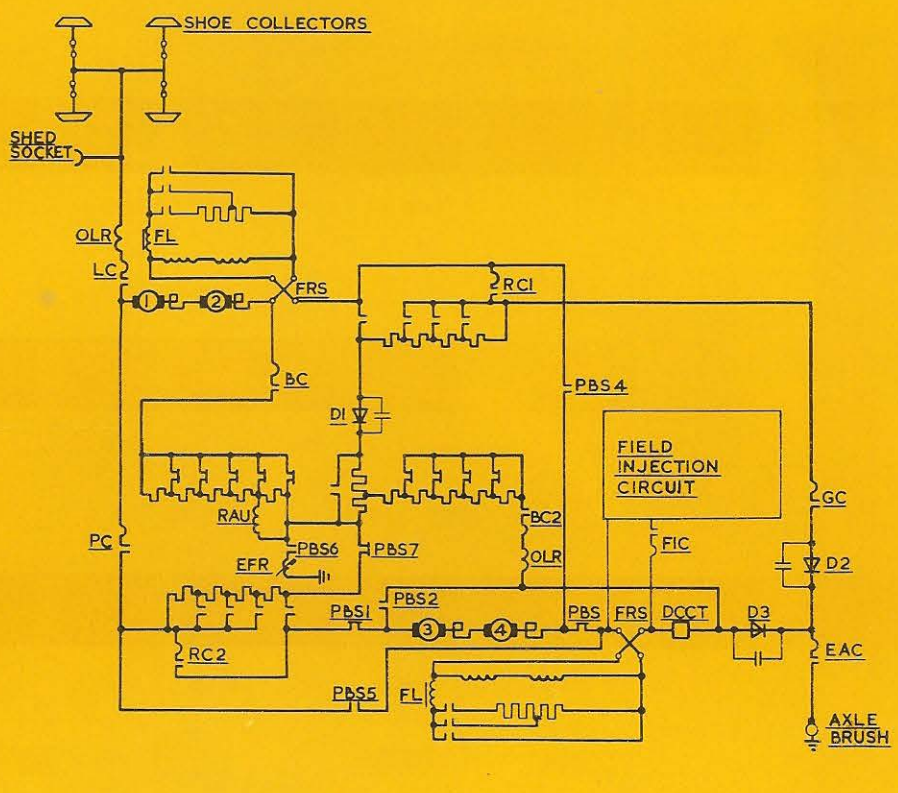
Circuit diagrams

Fig. 19 shows the power circuits for the ac thyristor-controlled Class 314 units. The Class 315's are similar except that there is an additional intermediate trailer car.

Fig 20 is typical of the power circuitry of the dc trains - in this case a Class 507.

LIST OF SYMBOLS

Symbol	Description
BC	Brake Contactor
DI	'S' Diode
P2 & P3	Polarising Diodes
DCCT	DC Current Transformer
FL	Field Inductive Divert
FRS	Forward/Reverse Switch
GC	Group Contactor
LC	Line Contactor
OLR	Overload Relay
PBSI-7	Power/Brake Changeover Switch
PC	Group Contactor
RAU	Restricted Application Unit
RC1 & 2	Resistance Contactor



dc camshaft control

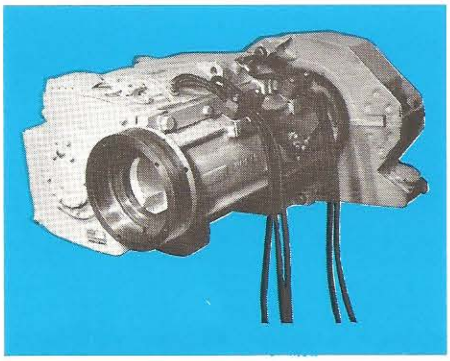
Traction motors

All the trains are designed for a maximum service speed of 120 km/h (75 mile/h) although on many of the routes for which they are designed, lower line limits prevail at present. Even so it was judged prudent to use the same traction motors with the same gearing so that future speed-limit increases could be readily accommodated and, of course, the spares position is greatly simplified.

The traction motors are the type G310AZ which are of the series-wound self-ventilated type. The design was originally developed for this family of rolling stock but with other applications also in mind and to date derivatives of the design have also been supplied for 1500V service in Hong Kong (Mass Transit), Australia (on broad gauge) and New Zealand (a narrow gauge version).

The motor is axle-mounted on a roller-bearing U-tube suspension and is nose-suspended in the bogie by resilient rubber units. It drives through single-reduction spur gearing, ratio 69 : 14 in the case of the British units. It has a high torque, relatively low speed full-field characteristic with a high balancing speed being obtained by field weakening using an inductive divert. Such a characteristic reduces energy and power demand when dc resistance control is used (as with Classes 313, 507 and 508) but is not relevant for units with ac thyristor control. If dc thyristor (chopper) versions are ever built, however, they will require motors with a much higher characteristic.

The electro-magnetic features of the motor, construction, insulation systems and components are designed for high reliability. The motor incorporates Class H Kapton insulated armature coils, glass banding on the armature, commutator V-rings moulded from epoxy glass, armature conductors welded to the commutator by the T.I.G. process, Class F epoxy insulated field coils, PTFE sleeves on the brushgear insulators and PTFE on the extension of the commutator front V-ring. The magnet frame is a steel fabrication to which is bolted a cast commutator chamber. The risk of flashover is minimised by the very low levels of voltage per commutator segment in motoring and moderate values at the high voltage, speed and power developed during electric braking. Stability in weak-field operation is provided by operation at relatively high values of field to armature turns ration. The use of an inductive divert gives good transient response on the frequent supply interruptions due to conductor rail gaps on third-rail dc systems and avoids large variations in percentage ripple with field-weakening on rectified ac.



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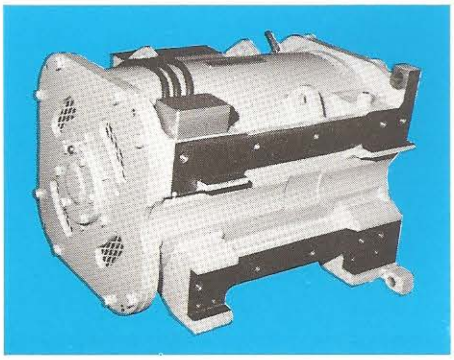

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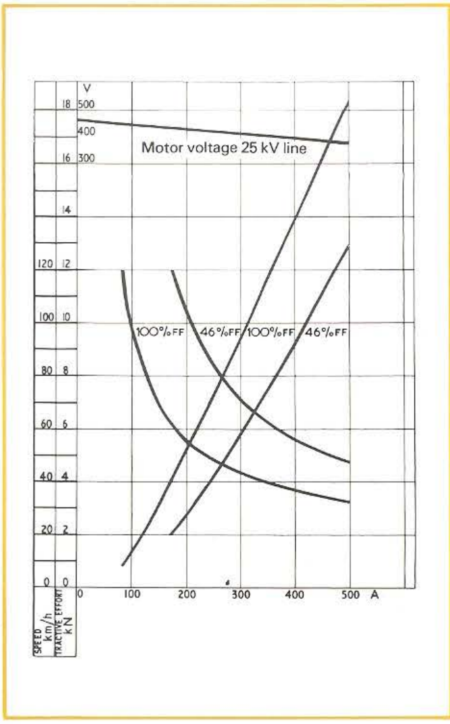
Fig. 21 The type G310 traction motor which powers all five classes of train described in this publication.

Fig. 22 A three-phase ac version of this traction motor has been built: designated G350.

Fig. 23 Typical characteristics for the G310 traction motor



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GEC Traction Limited
Trafford Park, Manchester M17 1PR
Telephone: 061 872 2431. Telex: 667152. Cables: Assocelect Manchester.

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