GEC

25/6.25 kV 50Hz
Express Multiple Unit Trains
British Rail Class 312
Eastern and London Midland Regions

GEC Traction Limited

BR suburban sets for 145 km/h

Longer distance services from London and the Midlands area are accommodated by open saloon four-car sets, with power car and three trailers incorporating nose-suspended motors

The latest electric multiple-units entering service on British Rail are the Class 312, designed to operate the longer distance commuter services on ac energised lines. They have been constructed mainly at the York Works of British Rail Engineering Ltd (BREL) with the electrical equipment designed and manufactured by GEC Traction Ltd. Formations are made up in basic four-car sets, the motor coach, which is mounted with a pantograph, and the outer cars laid out as driving trailers. Over pusher plates the sets are 80 720 mm long.

Nineteen such sets have been built for Eastern Region services out of London (Liverpool Street) to Chelmsford, Colchester and Clacton, and further units are to be built to work services on this region from London (Kings Cross) to Royston when the Great Northern Suburban Electrification is completed. Another four units are to operate local services for the West Midlands Passenger Transport Executive running between Birmingham and Coventry (on the London Midland Region), serving the new railway station constructed alongside the National Exhibition Centre at Bickenhill.

Their design is based on the Class 310 trains introduced in 1966 to operate LMR London suburban services from Euston, but incorporating a number of improvements. These include the provision of vehicle gangway connections throughout the four-car set (unlike the 310 stock which does not have a corridor connection between the middle two vehicles).

The Liverpool Street sets will operate on lines energised at both 25 kV and 6.25 kV 50Hz and accordingly incorporate a voltage changeover circuit. This feature was not fitted to the earlier Class 310 sets as there is no 6.25 kV supply on the LMR, but provision was made for fitting it at a later date and the transformer has dual windings. The Kings Cross sets and the new quartet on the LMR will only operate on 25 kV lines and the dual voltage equipment is not actually fitted although there is provision for fitting it if required.

The same basic type of traction motor fitted to these vehicles (and the Class 310) is also fitted to the Southern Region's Bournemouth REP unit and the electro diesel locomotives. The motors on the Class 310 trains are designed for a normal maximum speed of 120 km/h, while the Bournemouth sets have a normal maximum service speed of 145 km/h but, in practice, often run at their permitted maximum of 160 km/h. The 45 Eastern Region 312 units have the same gearing as the Bournemouth sets, although the extra LMR units have retained the lower speed gearing in the interests of standardisation.

Each Class 312 unit make up consists of a second-class driving trailer carrying the batteries and charger, a second-class motor coach with a guard's compartment and accommodation for luggage, a second-class trailer and a composite first/second-class driving trailer. All the seating is in an open saloon and all passengers have access to toilet accommodation. Trains can be made up to a maximum of three units in multiple to carry 891 second-class and 75 first-class seated passengers. Each four-car unit weighs 151 tonne tare. There is seating for 297 second-class and 25 first-class passengers in each unit.

Fig 1. British Railways Class 312 suburban electric multiple-unit for longer distance services made up in four-car sets

Power circuit

The power circuit incorporates low tension on-load tap-changing using electro-pneumatic contactors to supply variable voltage to a bridge-connected silicon diode rectifier, which in turn supplies the four traction motors connected in parallel. A single naturally air cooled smoothing inductor is connected in the main supply to the four motors. The series fields of each motor are connected to earth through an earth fault relay and an earth contactor, which opens in the event of an earth fault in the equipment to clear the fault and when the equipment is out of use to prevent circulating current when the

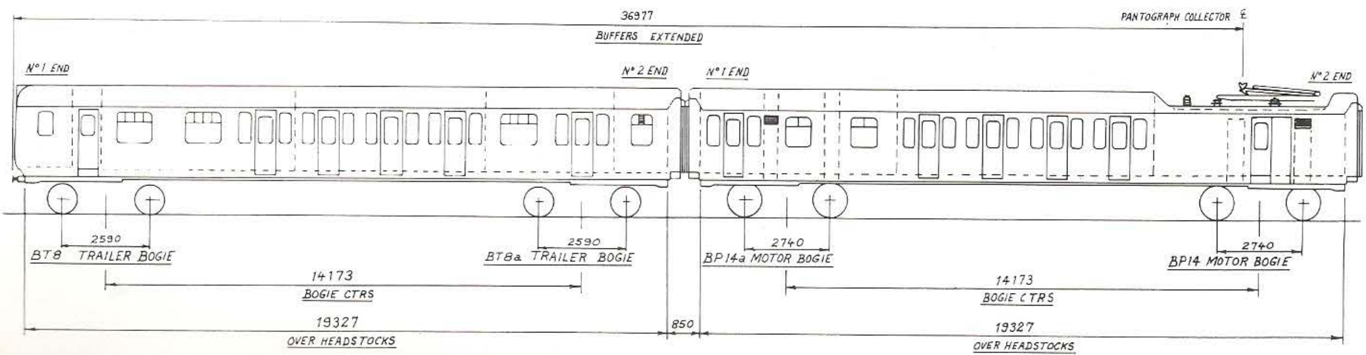

Fig 2. General arrangement of two cars showing the driving trailer and motor coach. The other two cars in the four-car set are a second class trailer and a first/second class driving trailer

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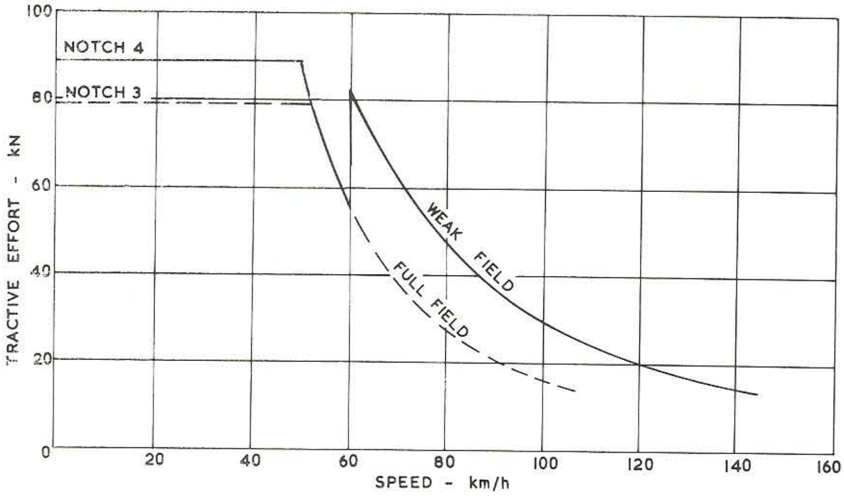


Fig 3. Tractive effort characteristics of the Class 312 motor coach

unit is towed. Surge suppression equipment is in the form of series connected capacitors and resistors connected across the ac supply to protect the rectifier. It is divided into three identical circuits, each of which can handle the suppression duty to give a high factor of safety.

The equipment is arranged for automatic acceleration under the control of two current limit relays each connected in series with traction motors Nos 2 and 3. Only one motor can be cut out in the event of a motor fault so there is always at least one current limit relay in use. Alternatively the whole equipment can be cut out when the set is in a multiple consist and is hauled by the remaining sound units. Two rates of acceleration are provided, the lower one with the master controller in positions up to 'full field' and the higher in the 'weak field' position.

Voltage selection & progression

The voltage changeover circuit on the nineteen Liverpool Street sets consists of a capacitor voltage divider with four voltage sensing relays connected across one section. These relays control the voltage-changeover switch and must be energised in the correct sequence to prevent incorrect operation.

Each voltage changeover point and neutral section on the overhead system is flanked by track magnets which actuate pick-up coils on each coach. The signal from the magnet on the approach to the neutral section causes the main circuit breaker to open and the selector switch to revert to the 'high voltage' position at the neutral section, if it is not already in that position. Passing the second magnet, after the neutral section, enables the breaker to reclose when the relays have determined the voltage level on the overhead section just reached and the changeover switch has thrown to the appropriate position, if necessary.

Should any circumstances cause the voltage sensing relays to throw the changeover switch to the incorrect position for the new section, and the breaker to close, the abnormality will cause a wrong voltage sensing relay of the latching type to operate, which will initiate main circuit-breaker opening and pantograph dropping.

Progression of voltage from the initial low starting voltage to half voltage is carried out by contactors connected to tappings on half of the secondary windings of the transformer. The other half is untapped and is arranged to be connected in series with the tapped half at the half voltage stage, after which progression through the tapped winding is repeated. Transition between taps is by non-inductive resistance.

Tap-changing contactors are electro-pneumatically operated and have de-ion arc chutes. The contactor case is provided with ventilators which are adequate for the relief of arc gases but which restrict the ingress of dirt; all the other equipment including the motor contactors is in dust-tight cases. The circuit is arranged so that all normal circuit rupturing duties are performed by the tap changing contactors. Weak field operation of the motors is provided by field tapping, controlled by an electro-pneumatically operated cam switch.

Transformer

The transformer is naturally air-cooled with forced oil circulation through the windings and cooling tubes mounted on two sides of the tank. It is of the semi-core or shell type having a shaped core with round pancake coil and sandwich windings. The primary is rated at 1326 kVA at 25/6.25 kV with a rating of 1216 kVA on the secondary and 110 kVA on the auxiliary winding. Natural air-cooling of the transformer and rectifiers offers great advantages in simplifying the auxiliary circuits, and this transformer rating is achieved at very low train speeds.

Rectifier

The air-cooled silicon bridge rectifier is based on the design supplied for the Glasgow Suburban Class 303 units in 1968. The insulating wafers are however of boron nitride instead of the beryllium oxide used in some earlier designs. The Glasgow units have given excellent service with maintenance consisting merely of the annual brushing of the fins and occasional inspection of the insulating wafers (the only reason, in fact, for covers being removed).

The rectifier is basically a group of machined aluminium die castings, each carrying four diodes. Each device is mounted directly on a sub-heat sink which is electrically insulated from the die-cast module by a boron nitride disc. The necessary pressure to maintain the disc in intimate thermal contact with the main casting and the sub-heat sink is provided by an insulating clamp block which is pulled down on studs attached to the main heat sink. A degree of freedom for thermal expansion of the assembly is provided by the use of belleville washers on the studs and heat transference is further assisted by coating all contact faces with a silicone heat sink compound.

One of the four cell modules is required for each arm of the four arm bridge, making 16 cells in total. They are bolted within a framework with sealing faces. Hole storage capacitors (which are aluminium cased and epoxy resin sealed) are connected across each diode. Rectifier fuses are not fitted. All cells are interchangeable and arranged so that they can be disconnected and removed from their heat sink *in situ* – the modules can also be removed separately from the cubicle. The diodes themselves are GEC type S1109 rated at 470 A, 4600 PTV (peak transient voltage), while the combined rating of the rectifier is 1360 A, and 700 V mean. The components of the three parallel connected RC surge suppression circuits are located within the rectifier case.

Traction motor & smoothing reactor

The type 546F traction motors are four pole, lap wound, series-connected dc machines suspended by resilient mountings and axle hung by a roller-bearing tube mounted on the axle and bolted directly to the motor-frame. They differ from those fitted to the Southern Region stock, in that they are designed to operate from an undulating supply while the traction motors on the Bournemouth stock are designed for operation from a smooth dc supply. These self-ventilated machines draw filtered air through ducts in the coach side and are continuously rated at 700 V, 350 A, 225 kW with Class B temperature rises (to BS 173). However, the insulation is to Class H standards on the armature and Class F on the field to provide a margin giving ample reserve capacity for hauling in a case of emergency. As a whole they have been designed to be interchangeable, but the armature and gearcase as parts, with the earlier 546 machines fitted to the Class 310 trains although a number of detail improvements have been made such as TIG welding of the armature conductors and glass banding.

The gear ratio for the Eastern Region units is 61:19 (as used on the Bournemouth 160 km/h stock), while the LMR units are geared at 63:17. The solid gearwheel is of carbon chrome steel, induction hardened, while the alloy-steel ring pinion is case hardened and ground on the tooth profile with taper relief.

The dc smoothing reactor is a naturally air-cooled, Class C insulated, gapped-iron-core reactor and is fitted in a ventilated galvanized steel case for mounting underneath the motor coach. Mechanically, it is a duplicate of the Class 310 unit, incorporating the latest modern practices and materials associated with silicone insulation. Very little maintenance is required, only freedom from accumulation of dirt deposits being necessary to ensure free circulation of air.

Electrical protection

Electrical protection embraces a roof-mounted 250 MVA air-blast breaker on the motor coach operated by the primary overload secondary overloads, Bucholz relay or earth fault protection. A spark gap on the primary bushing is provided for line surge protection. No fuses are provided for the rectifiers because they are adequately rated for motor flashover and string failure currents within the breaker operating time. A Buchholz relay and an explosion diaphragm are provided for the transformer and a silica-gel breather on the conservator tank ensures that only clean dry air is in contact with the transformer oil. All but a few of the main power cables are carried in a common duct in the centre of the underframe, and are brought out in flexible conduit to each equipment case.

The battery charger provides a regulated 110 V dc supply together with a smoothed rectified ac supply for the compressor motor and is similar to the units supplied for the Class 311 trains operating in Glasgow. The rectifier equipment supplying dc power to the compressor motor and constant voltage to the coach battery consists of two single phase naturally cooled semiconductor bridges together with a supply transformer and phase control equipment, all mounted in a hermetically sealed case mounted on the underframe of the coach.

The compressor motor rectifier supplies power at a nominal 200 V, 32 A. The battery charger power circuit consists of a half controlled single phase bridge rectifier comprising two thyristors and two diodes.

Phase control is provided to enable output to be maintained at a constant pre-set voltage at 110 V dc under all variations of line voltage and auxiliary loading. Phase control is achieved by feeding pulses, variable in phase relative to the ac supply wave form, to gate terminals on the thyristors and the pulses trigger the thyristors into conduction. The dc output voltage is dependent on the value of a control signal, fed into the phase control circuits, obtained by comparing a stabilised reference voltage to a voltage feedback signal from the charger output.

A current limit circuit is incorporated in the equipment to ensure that the dc output does not exceed a safe level when recharging a flat battery. In the event of malfunctioning of the tap selector on the main transformer when entering a 25 kV section, an over-voltage would be applied to the charger. It is designed to withstand any such over-voltage for a sufficient time until the main power protective circuits operate to trip the air-blast circuit breaker.

Underfloor mounting of equipment

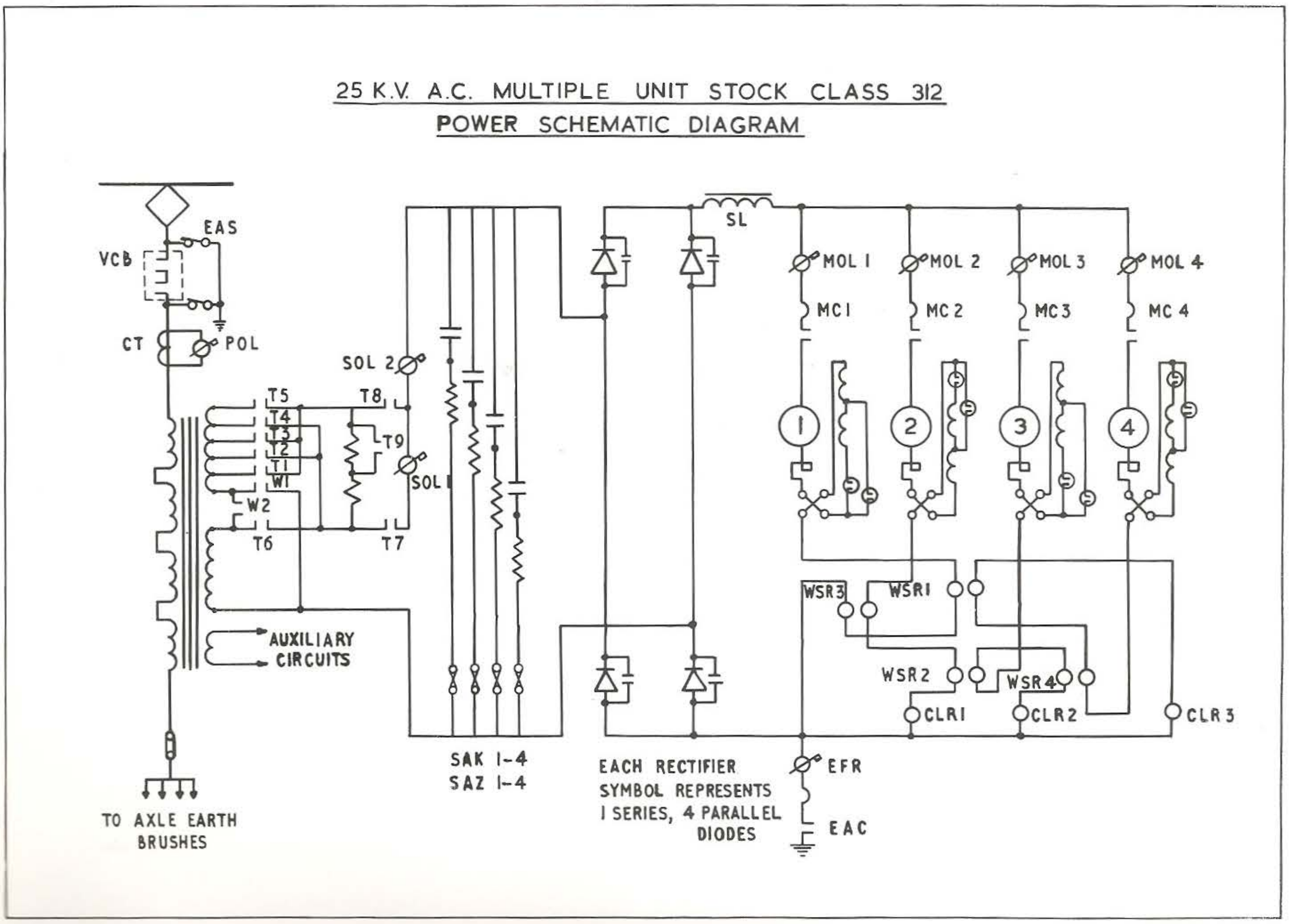
Absence of the usual truss from the underframe because of integral construction has greatly simplified the problem of mounting all the electrical equipment below the underframe. A valuable innovation is the mounting of equipment cases in transverse angle iron frames so that the dead weight is not carried by the fixing bolts; this enables larger items to be replaced by a fork lift truck sliding the unit out on the angles. Only the main transformer is mounted longitudinally because of its size.

Disc braked bogies

Both the motor and trailer bogies are based on the British Railways B4 bogie which has proved so satisfactory on the Class 310 trains and on locomotive-hauled coaches, but the motor bogies have 1016 mm wheels instead of the standard 914 mm wheels. The bolster is suspended on vertical swing links on rubber-mounted knife edge bearings and is secured longitudinally by traction bars. Primary suspension is of the Schlieren pattern using cast steel self-aligning roller bearing axleboxes. The secondary suspension is damped by one lateral and two vertical

Fig 4. Power schematic of power car, BR Class 312 140 km/h multiple-unit

(1)(2)(3)(4)	Traction motors	MC	Motor contactor	SOL	Secondary overload relay
CLR	Current limit relay	MOL	Motor overload relay	T	Tapping contactor
CT	Current transformer	POL	Primary overload relay	W	Secondary group contactor
EAC	Earth contactor	SAK	Surge suppression capacitor	WSR	Wheel-slip relay
EAS	Earthing switch	SAZ	Surge suppression resistor	VCB	Vacuum circuit breaker
EFR	Earth fault relay	SL	Smoothing reactor		



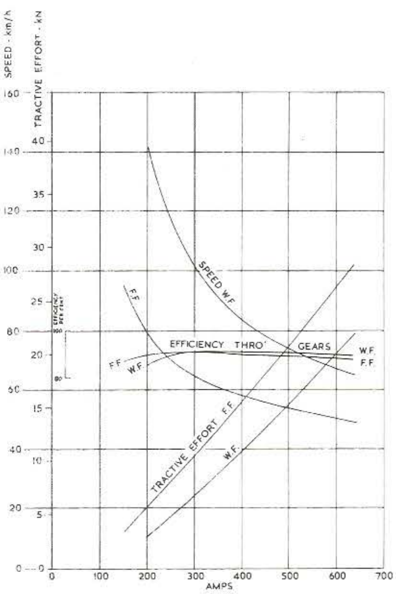


Fig 5. Traction motor characteristics

dampers and a large area of asbestos laminate is interposed between the bogie and underframe centre pivots. All cars are arranged with 14 173 mm bogie centres, but length of body for the driving trailer is 19 851 mm whilst that of the trailer and motor coach is 19 942 mm.

The electro-pneumatic and automatic air brake supply and control equipment is of Westinghouse Brake & Signal Co Ltd design and manufacture. Self-lapping electro-pneumatic brake controllers with six positions enable full service electro-pneumatic and in case of electrical failure, the automatic air brake to be selected. Girling caliper-mounted disc braking is provided acting on wheel-mounted cast-iron discs on each wheel. Operation is by individually-mounted SAB air cylinders incorporating slack adjusters.

Load-sensitive valves regulate the air pressure to the cylinder which achieves a constant retardation under all load conditions of approximately 2.89 km/h/s for full service electro-pneumatic application, and 3.5 km/h/s for an emergency application. The stabling brake is hydraulically operated and is fitted on the driving trailers.

Coach appearance

Externally the coach bodies are rail blue, with yellow end panels, and the open saloon seating throughout is arranged with two and three on each side of the gangway in the second class, and two and two in the first class. They are arranged in facing pairs and have shoulder high backs.The electric heating supply is taken from the main transformer auxiliary winding at a voltage ranging from 175 V to 315 V. Heaters of 900 W are fitted on the body side panels in the space between the seat backs, and 450 W heaters are fitted under some of the seats, in the toilet compartments and in the guard's accommodation. The driving cabs each have a 4 kW warm-air heater and 50 W foot-warmer. Including one-gallon water heaters for the toilets, the total heating load for a four-car set is 70 kW. Thermostats fitted in each saloon and toilet are set to maintain the temperature at 20°C.

Fluorescent lighting is provided in the saloons comprising continuous 1220 mm 40 W warm-white tubes enclosed in fittings running continuously along the centre of the roof, with the control gear housings interposed between the tube covers. The ballast gear is located in the control gear housings, which have ventilation slots cut in the sides and are connected by ducting to the standard ventilators on the carriage roof thereby helping to ventilate the coach interior. The fluorescent lighting is supplied from a battery-fed inverter on each vehicle located on the underframe of the trailer cars and in the conservator compartment of the motor coach.

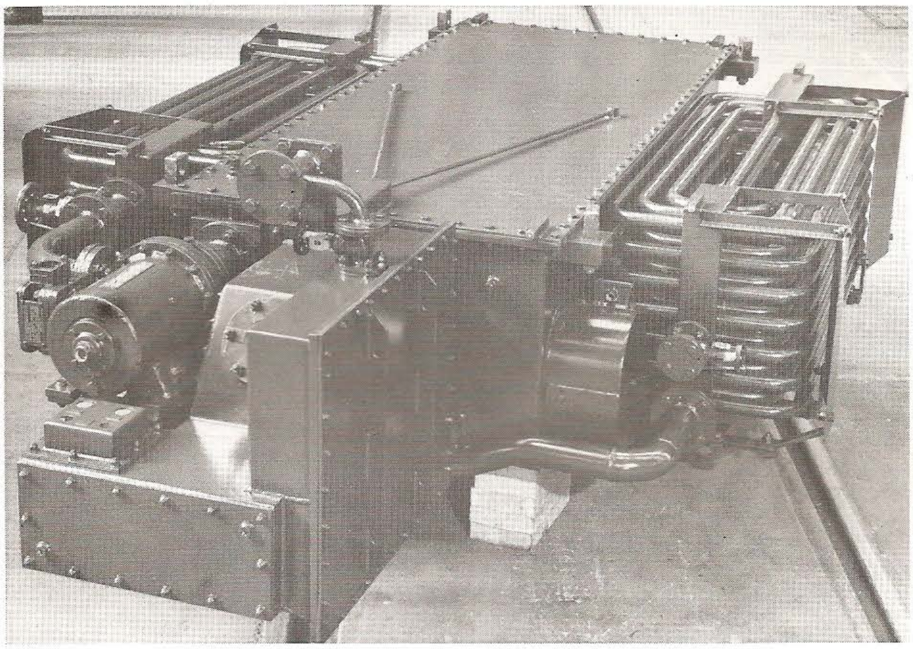
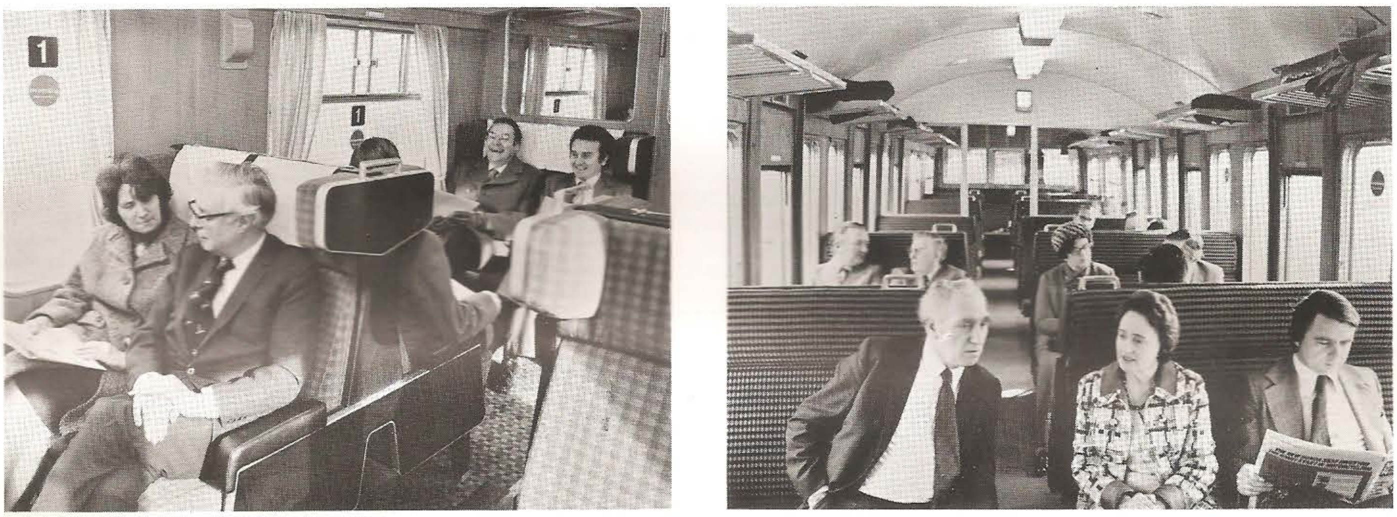


Fig 8. GEC air-cooled forced-oil circulation transformer, primary rating 1326 kVA at 6.25/25 kV and 1216 kVA on the secondary

Fig 7. Internal views of passenger saloons, (left) first class and (right) second class



World experience with multiple units

25/6.25 kV ac multiple units for British Rail alone with motor coach power equipments supplied by GEC Traction.

Quantity	*Operating area*		*BR Class*	*Region*	*Date ordered*
3	Lancashire Morecambe & Heysham 6.6 kV, 25 Hz			LM	1908
4	Lancashire Morecambe & Heysham 6.6 kV, 50 Hz		301	LM	1956
112	London Tilbury & Southend		302	E	1956
91	Glasgow suburban		303	Sc	1956
45	Crewe – Manchester/Liverpool 25 kV only		304	LM	1956
74	Enfield Chingford		305	E	1956
92	Shenfield		306	E	1958
65	GE Outer Suburban		307	E	1958
45	Shoeburyness		308	E	1960
23	Clacton Express		309	E	1961
50	Euston suburban	25 kV only	310	LM	1964
19	Glasgow suburban		311	Sc	1969
1	Thyristor control		311	Sc	
19	Kings Cross Outer Suburban	25 kV only	312	E	1973
26	Liverpool Street		312	E	1973
128	Kings Cross Inner Suburban	25 kV/750V dc	313	E	1973
4	Birmingham – Coventry		312	LM	1975

Plus – 10,074 further dc multiple unit motor coach equipments in Britain.

Plus – 5,459 further ac and dc multiple unit motor coach equipments for export.

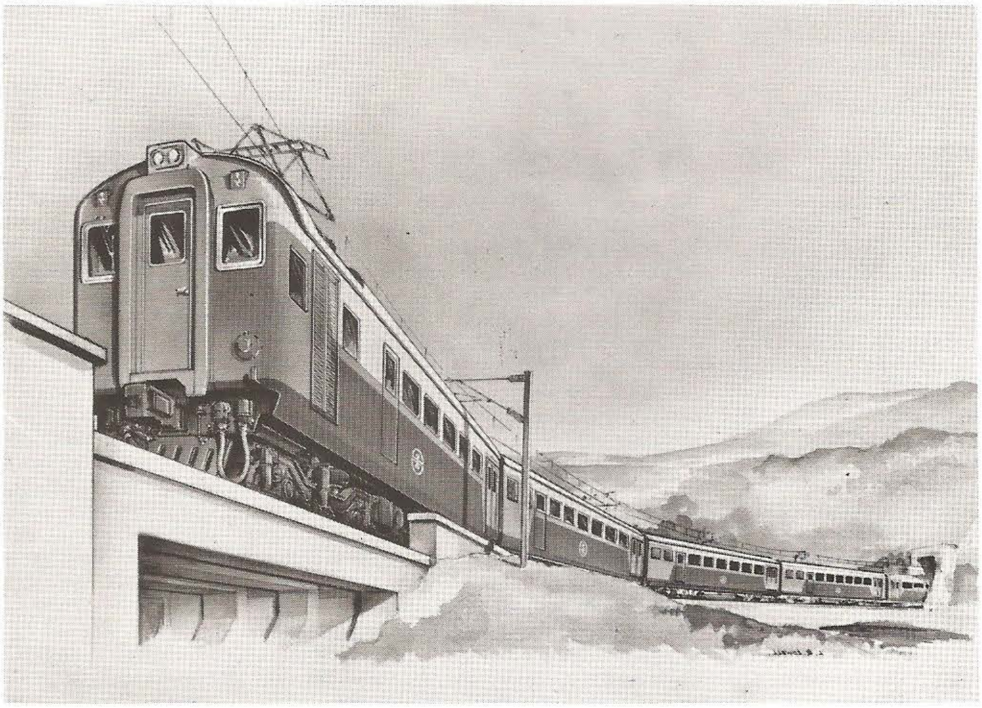
Thyristor Control

Thyristor controlled electric multiple unit trains powered by GEC Traction are currently in service or being built for the following system voltages:

600/750, 1500 and 3000V dc

25/6.25 kV 50 Hz

25 kV 60 Hz



Artist's impression of thyristor controlled ac multiple unit train for Taiwan

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