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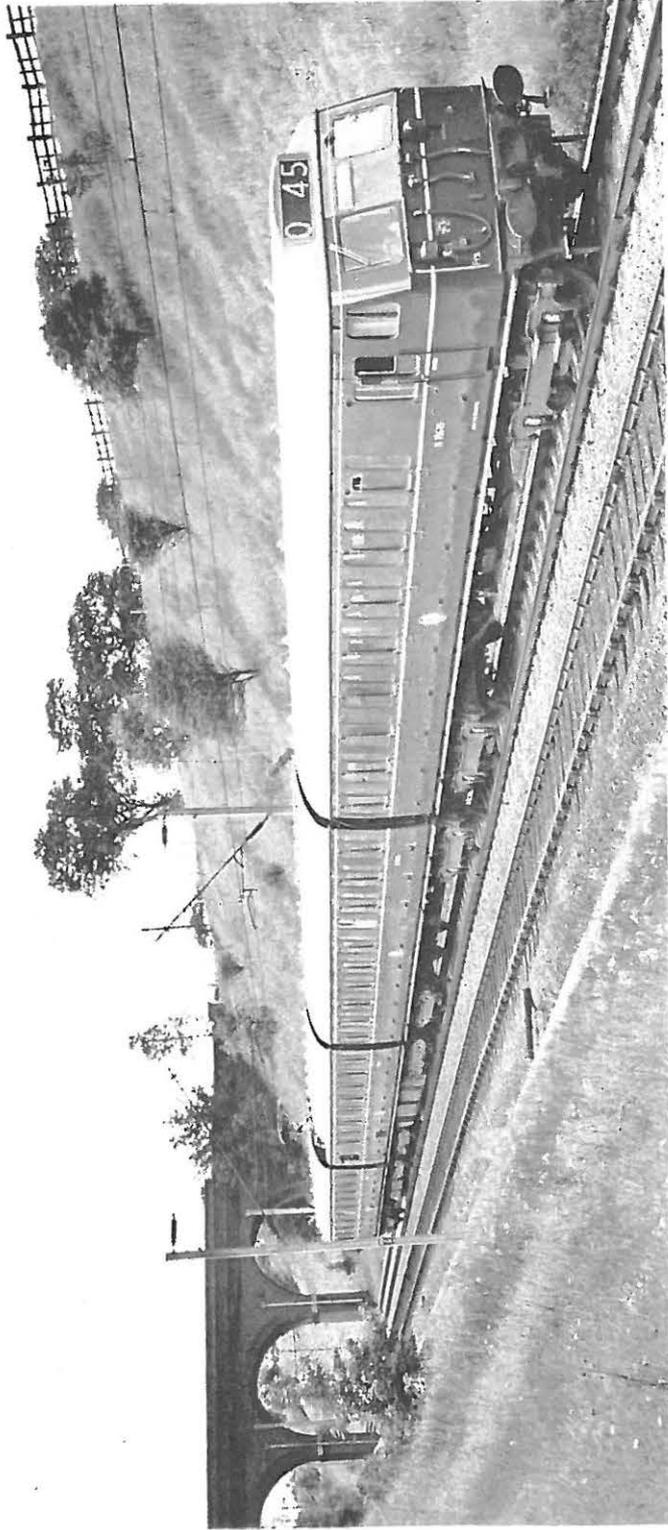
*September, 1960*

# **HIGH-VOLTAGE MULTIPLE-UNIT STOCK FOR BRITISH RAILWAYS**

**Four-car 25-kV. 50-cycle suburban trains**

*Reprinted (with additional photographs)  
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"The Railway Gazette", June 3rd 1960*

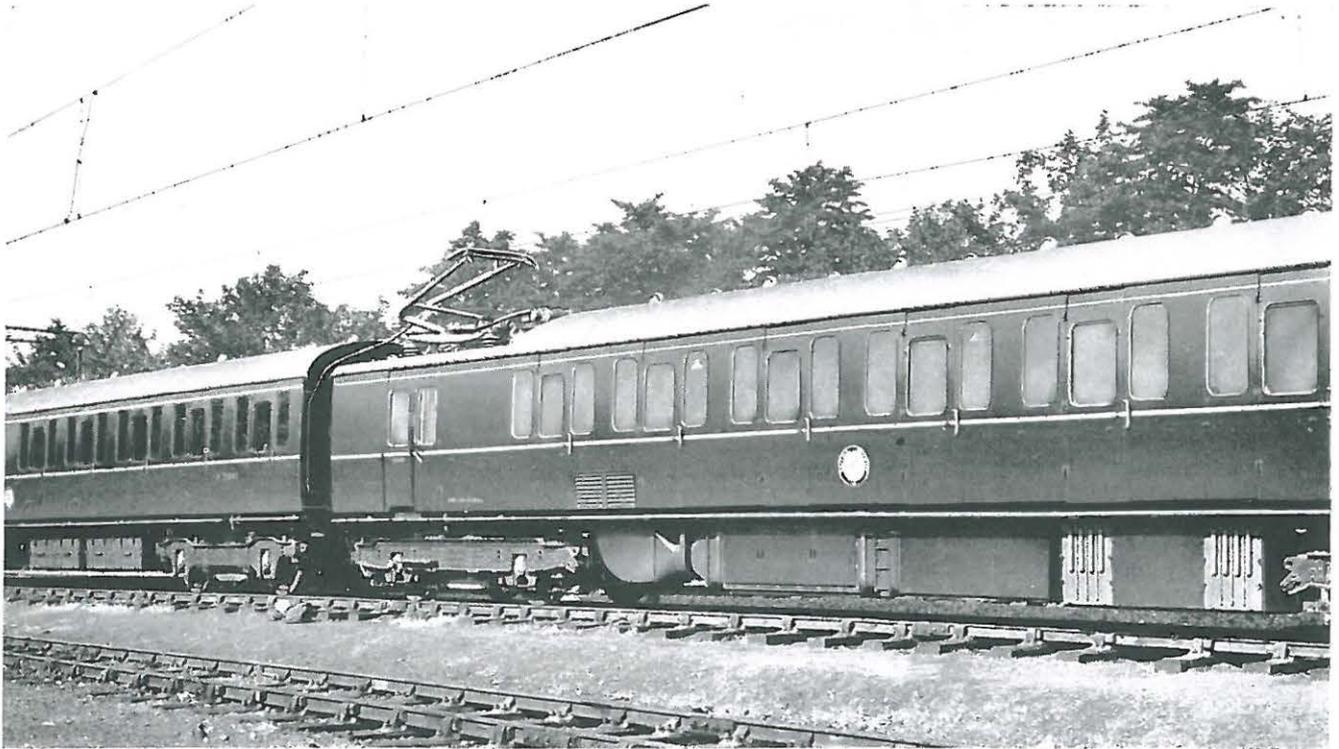
**H.V. MULTIPLE-UNIT STOCK FOR BRITISH RAILWAYS**



*Multiple-unit train in operation on the Styal  
line between Wilmslow and Manchester*

# High-Voltage Multiple-Unit Stock for British Railways

*Four-car 25-kV. 50-cycle a.c. suburban trains for Manchester-Crewe and Liverpool-Crewe service*



*Location of equipment on underframe of multiple-unit stock*

**M**ULTIPLE-UNIT 25-kV. a.c. electric stock in four-car units is now in course of construction and delivery by the Wolverton Works of British Railways, London Midland Region. The electrical equipment has been supplied by the British Thomson-Houston Co. Ltd., now incorporated in the Associated Electrical Industries Traction Division.

The first 15 four-car trains are for operation on the Manchester-Crewe service and a further 20 trains are for the Liverpool-Crewe service. Each train consists of a battery driving trailer open second, motor open second brake, trailer composite, and driving trailer open second brake. The motor second brake on the Manchester trains is arranged with compartment seating for 96 passengers, giving a seating capacity for these trains

of 19 first class and 318 second class. On the Liverpool service trains the motor second brake is an open saloon with seating for 72 passengers and is fitted with a large luggage compartment. The complete train has seating capacity for 19 first class and 294 second class passengers.

The first class seating in the trailer composite car is of the compartment type with corridor access to the toilet. A separate toilet is provided for the second class saloon. Toilets are also provided in one driving trailer. Coupling between the cars is by fixed automatic couplers without side buffers, no through access being provided. The design of this stock to British Transport Commission requirements has been carried out at Wolverton under the general direction of Mr. S. B. Warder and Mr. J. F.

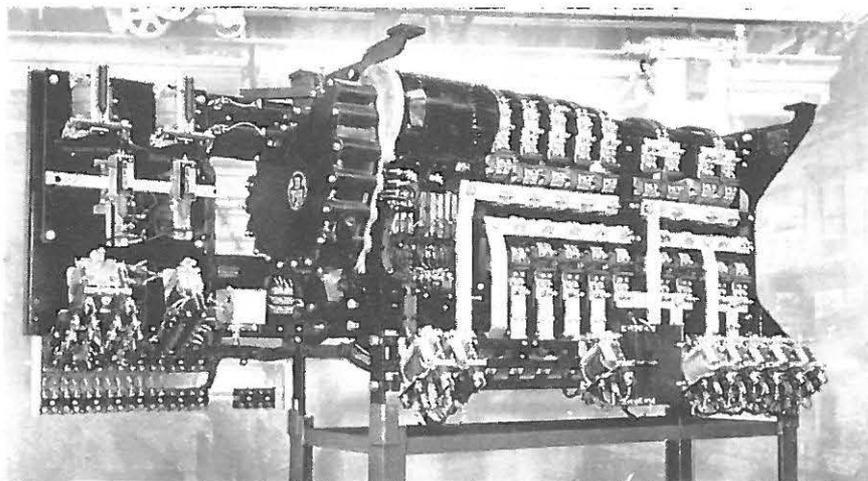
Harrison, Chief Electrical Engineer, and Chief Mechanical Engineer, respectively, of British Railways Central Staff.

Leading particulars are as follow:—

Overall length of train ... ..	264 ft. 6½ in.
Vehicle length over body ... ..	63 ft. 6½ in.
Width over bodysides... ..	9 ft.
Height to roof panels ... ..	12 ft. 4½ in.
Bogie centres ... ..	46 ft. 6 in.
Bogie wheelbase—motor car ... ..	8 ft. 9 in.
Bogie wheelbase—trailer cars ... ..	8 ft. 6 in.
Wheel diameter—motor car ... ..	3 ft. 6 in.
Wheel diameter—trailer cars... ..	3 ft. 6 in.
Maximum service speed ... ..	75 m.p.h.
Tare weights	
Motor car ... ..	53 ton 12 cwt.
Driving trailer ... ..	35 ton 12½ cwt.
Driving trailer—brake ... ..	31 ton 8 cwt.
Composite trailer ... ..	31 ton 5½ cwt.

## Current Collection and Conversion

Current is collected from the overhead wire by the pantograph mounted, with the air-blast circuit breaker, on the roof



*Camshaft control unit, showing motor and reduction gear drive*

of the guard's compartment of the motor car. A special rubber insulated 25-kV. cable runs from the roof gear and plugs into the transformer. The a.c. voltage is then stepped down by the oil-cooled transformer and converted by a germanium rectifier to a d.c. supply for the traction motors.

The equipment is designed for full output at a line voltage of 22.5 kV. or 5.65 kV. The air-operated changeover switch in the end of the transformer casing is automatically controlled by the automatic power control circuit and the voltage selection circuit.

The voltage selection circuit consists of a roof-mounted capacitor in series with the primary winding of a current transformer. The transformer output is fed into a germanium bridge rectifier having voltage selection relays connected across the output. Relay contacts control the selection switch and the air-blast circuit breaker. The main transformer incorporates a 240-V. 55-kW. winding for train heating and other auxiliaries.

The germanium semi-conductor rectifier is made up in a unit of ten trays, each tray carrying 48 cells. The trays are mounted vertically and supported on rails inside a sheet steel cubicle, a simple provision being made for withdrawing each tray for inspection. A fibreglass front cover is fitted to the cubicle.

Cooling of the cells is by a motor-driven Aerex fan, with a delivery of 3,500 cu. ft. per min. The rectifier is

rated at 682 kW., 975 V., 700 A. Advantages claimed for the semi-conductor rectifier are that maintenance is virtually nil, no pre-heating period is required before applying the load, and no temperature control is required.

A further advantage is that efficiency is independent of the voltage. This permits the independent selection of a traction motor having the most suitable overall operating characteristics. The use of germanium rectifiers on this multiple-unit stock is the first bulk order for traction use.

#### Layout of Power Car Equipment

With the exception of a cubicle in the guard's compartment, all the power equipment is installed below frame level, between the bogies. The longitudinal members of the underframe form three bays, in which the equipment is disposed to give approximately equal wheel loading. In the outer bay on one side are the transformer, camshaft cubicle, and resistor bank. On the opposite side are the cooling fan, rectifier, oil radiator, reactor, choke, and contactor cubicle. In the centre bay are the auxiliary and control air reservoirs, air drier, oil filter connections and air-brake cylinder.

The Stone-Faiveley pantograph and air-blast circuit-breaker are mounted on the roof of the guards compartment. In the equipment cubicle in this compartment are installed a fuse panel, the main fault indication panel, motor and equip-

ment cut-out switches, motor-driven auxiliary air compressor, and auxiliary equipment associated with current collection and conversion. The main transformer header tank is also in this compartment.

On the battery driving trailer the main air compressor, auxiliary air reservoir, brake cylinder and battery charger are grouped in the outer bay on one side. In the outer bay on the opposite side are the main reservoir, and the two battery boxes. The 110-V. Nife battery has an 80 Ah. rating. The fuse panel is in a cupboard at the rear of the driving cab. A neat layout of the underframe cables on the motor coach has been achieved by the use of a central steel trunk with moulded polyester side ducting to the individual items of equipment.

#### Control Scheme

The master controller has an Off and four motoring positions marked 1 to 4. Position one is a low-speed manoeuvring or shunting notch; two allows the camshaft to notch up to half voltage on the motors; three allows the camshaft to notch up to full voltage; and four causes the motor fields to be weakened in two steps for higher running speed. All the above camshaft movements are under the control of a current limiting relay, giving controlled acceleration of the train. Three equipments can be coupled together and will operate *via* train line wires from one cab.

The camshaft will move only when the

reverser is set and the motor contactors are closed. It is driven by a d.c. motor through reduction gearing, and the power contacts are connected to tappings on half of the main transformer secondary.

The secondary is connected to operate on the buck/boost system, the camshaft making the reconnection at half voltage, and then running back over the tappings until full voltage is reached. This gives twice the number of notches for a given size of camshaft, compared with a single tapped secondary. Switching is by on-load low-voltage air-break tap changing using a centre tapped reactor.

The four traction motors are connected in parallel. Power is cut off in the event of earth faults, an overload on the transformer or traction motors, high oil temperature or low oil level in the transformer, and failure of air supply for rectifier cooling. Fault location is shown on an indicator panel in the guard's compartment.

#### Cooling and Auxiliaries

Air for the horizontally mounted cooling fan is drawn through two grilles in the bodyside. After passing through the rectifier the air passes through the transformer oil radiator, the tap change reactor, and the smoothing chokes. Neoprene rubber sealing is used to prevent air loss between the separate units. Circulation of oil through the transformer and radiator is by a motor-driven Pulsometer pump. The cooling fan and the pump are driven by A.E.I. flange-mounted single-phase capacitor start-and-run machines.

The main air compressor is a Westinghouse type CM38, driven by a flange-mounted A.E.I. d.c. motor fed from the 240-V. auxiliary supply via a germanium rectifier. A battery powered auxiliary compressor is also fitted. In the event of a fully discharged air reservoir, this is used to supply air for raising the pantograph and closing the air-blast circuit breaker. The battery charger, incorporating a germanium rectifier and magnetat voltage regulator, gives an automatically controlled d.c. output of 110 V. from a supply potential ranging between 192 and 310 V.

#### Traction Motors

The four traction motors are six-pole self-ventilated nose-suspended machines, identical with the motors used on the Glasgow 25 kV. suburban stock. These motors incorporate special features to ensure satisfactory operation on d.c., with a large component of 100 cycles per second ripple current. One section of field divert resistance is permanently connected across each traction motor field. Provision is made for isolating either pair of motors.

The motors are rated as follow:

		Continuous	One hr.
Full field	...	1,320 r.p.m.	1,245 r.p.m.
		190 b.h.p.	212 b.h.p.
Weak field	...	1,695 r.p.m.	1,650 r.p.m.
		207 b.h.p.	220 b.h.p.

Timken roller bearing for traction motor suspension and single-spur reduction gears having a ratio of 17/70 are fitted.

The cab front has been styled to give an attractive appearance and good

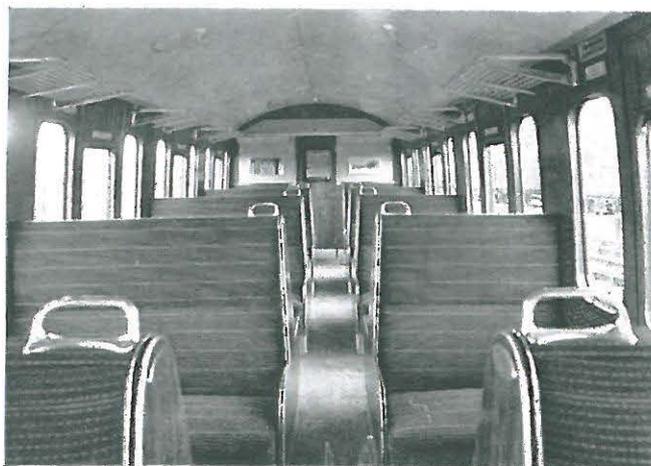
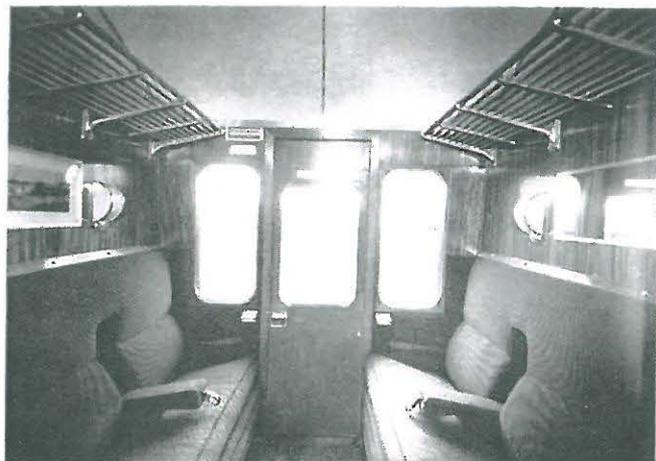
driving visibility. In plan view the cab front is of shallow vee form, with vertical panels from floor to waist height. Above waist height the driving screens slope backwards, and at the top join a vertical panel carrying a four-digit route indicator.

The cab roof and ceiling are polyester-resin mouldings. Mounted on the rear bulkhead is a fully-adjustable seat on the left for the motorman and the assistant motorman's seat on the right. Balanced drop lights are fitted alongside each seat. Driving instruments are arranged on a sloping panel forward of the flat-top desk carrying the push-button controls and light switches.

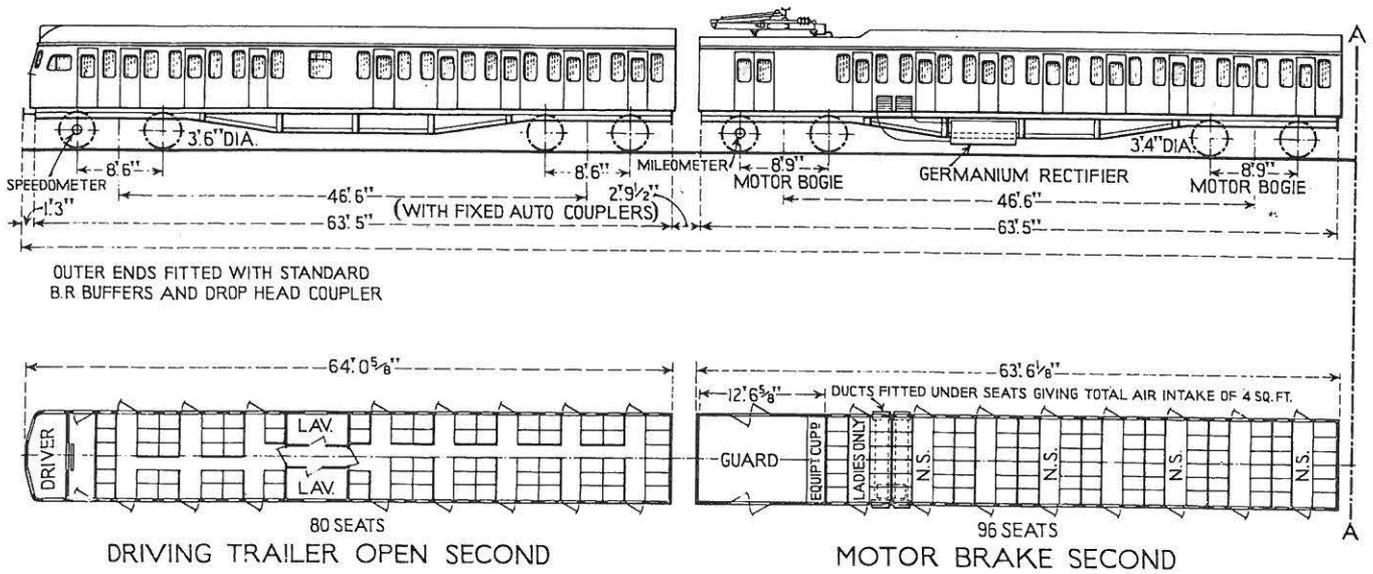
The master controller is located on the right of the driver and the brake controller on the left. Forward of the assistant motorman's seat is the hand-brake wheel. Armour plate glass is used throughout for the cab lights and Trico-Folberth pneumatic screen wipers are fitted. Access to the cab is by a sliding door in the centre of the rear bulkhead. The cab walls are lined with plastic panels and the floor covered in linoleum.

#### Body Construction

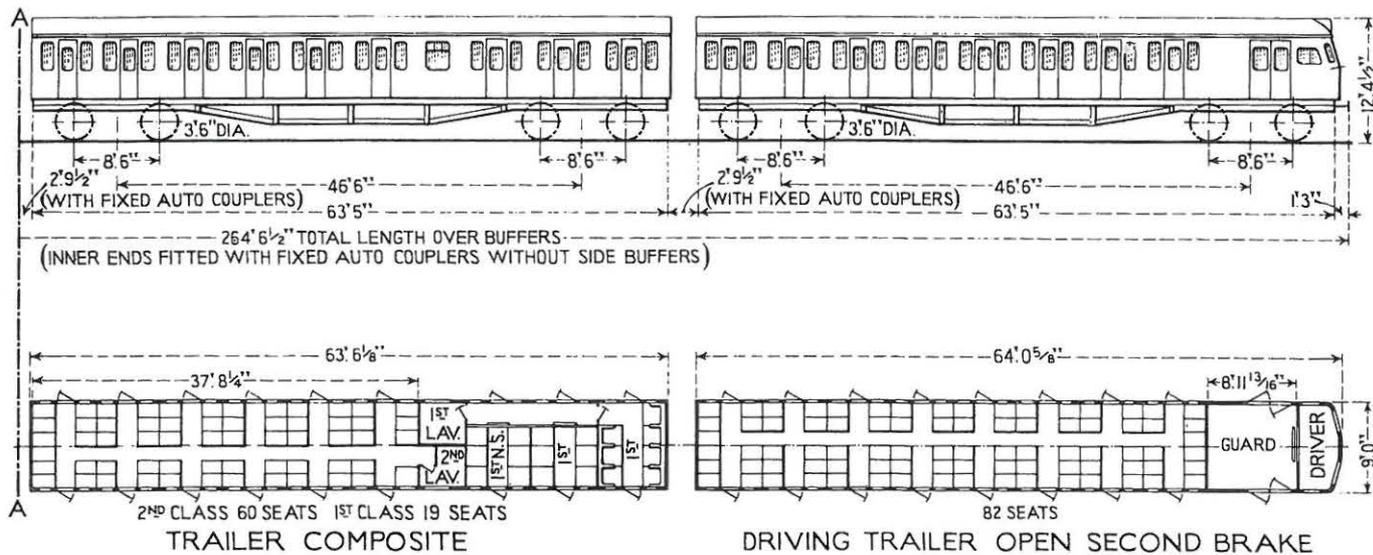
The vehicle bodies are of welded steel construction, using 16-gauge sheet for the bodysides, ends, and roof panels. Under the pantograph the roof is in 14-gauge material. The pillars and rails are  $\frac{1}{8}$  in. "Z" or top-hat sections. On the Manchester trains all cavities in the double skin of the bodysides, ends, and roof are filled with fibreglass wool to provide the maximum degree of sound and heat insulation. On the Liverpool trains sprayed asbestos is used for insulation. Insulating material is also



Interior of first class compartment in trailer coach, left, and second class open driving trailer, right



*Elevation and layout of driving trailer and motor brake coach of Manchester-Crewe train*



*Elevation and layout of trailer composite and driving trailer brake coach*

fitted between the corrugated aluminium floor plate and block-board floor panels. Rubber glazing is used for all windows, the windows on the Liverpool trains being of the wide type extending the full width of the panels between the bodyside doors. All doors are of light-alloy construction. Luggage racks are in tubular light alloy.

The interior finish of all passenger compartments is a blend of timber and plastic-faced panels. The toilets are lined with plastic panels in various colours, with aluminium mouldings and fittings and tiled floors.

#### Heating and Lighting

Current at 240 V. a.c. for heating is taken from a tapping on the main transformer. Passenger heaters are of the tubular type, rated at 500 W., giving a maximum of 45 kW. for each train. Control of the heating is from the guard compartments, with thermostatic control in the passenger compartments. Hot

water is provided in each lavatory by thermostatically controlled 500 W. immersion heaters. A supply of 4.4 kW. is provided for crew compartment heating and in each guard compartment is a 300-W. food warmer.

Incandescent lighting at 110 V. is used throughout, supplied from the battery charger side of the battery contactor. Provision is made for the passenger lighting to be fed from a shore supply during coach cleaning. Each compartment is provided with battery-fed emergency lighting to a total of 150 W., which is available in the event of a failure of the main supply. To prevent excessive discharge of the battery a time delay switch is incorporated in this circuit.

#### Underframes, Bogies and Brakes

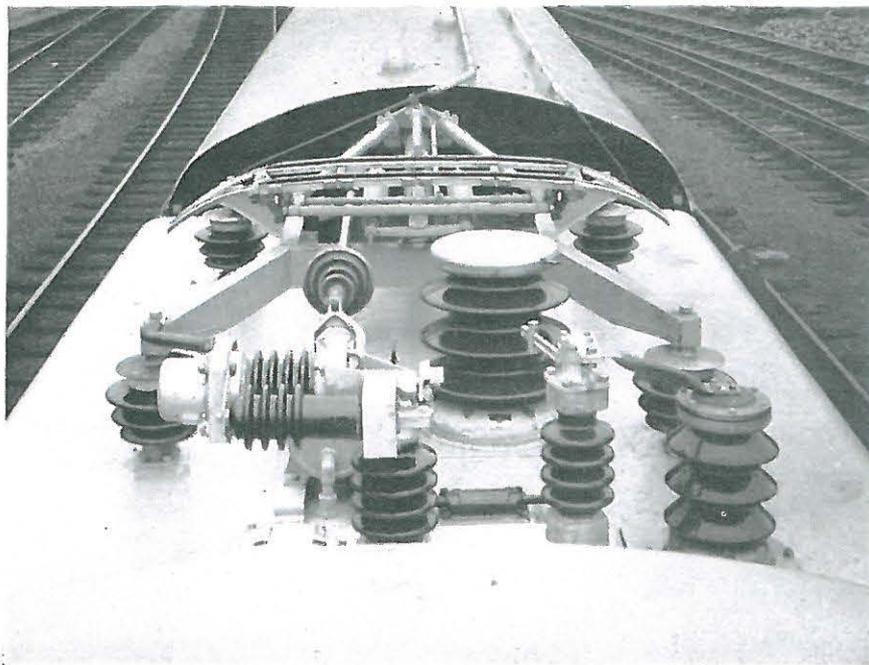
The underframe is a welded assembly of rolled channel, tee, and angle sections to British Railways standard design. The outer ends of each four-car set are fitted with telescopic side buffers and drop-

head automatic couplers. Inter-car couplers are of the fixed automatic type, without wide buffers.

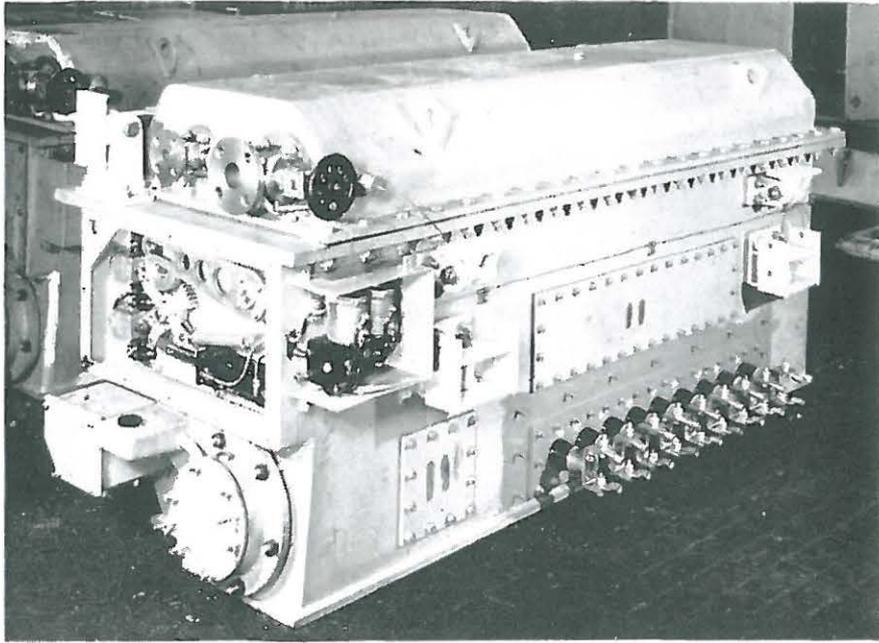
Double bolster bogies with knife-edge suspension are used, the motor bogie frames being built up from steel plates and rolled-steel sections, and the trailer bogies incorporating steel pressings for the main members. The principal members of both bogies are assembled by riveting. Roller-bearing axleboxes are used throughout.

The air brakes, with self-lapping electro-pneumatic control, are operated by a single cylinder through equalised and compensated brake rigging. On the motor car and the battery driving trailer a 16 in. x 8 in. cylinder is used, and on the other trailer cars a 12 in. x 8 in. cylinder. Normal operating pressure is 50 lb. per sq. in. The handbrake in each driving cab operates through the power brake rigging on the wheels of the adjacent bogie.

A list of the principal sub-contractors is given on page 12.



*Pantograph roof of motor car, showing air-blast circuit breaker*



*Main transformer, showing, left, the electro-pneumatic line voltage change-over switch with cover removed*

*As efforts are made constantly to improve both designs and methods of manufacture apparatus supplied may differ in details from the illustrations.*

PRINCIPAL SUB-CONTRACTORS FOR H-V MULTIPLE UNIT STOCK

Axleboxes	...	...	...	...	...	{ British Timken Limited. The Skefko Ball Bearing Co. Ltd.
Wheels and axles	...	...	...	...	...	Taylor Bros. & Co. Ltd.
Bolster springs	...	...	...	...	...	Turton Bros. & Matthews Ltd.
Buffing and drawgear	...	...	...	...	...	{ Laycock Engineering Limited. A. G. Wild & Co. Ltd. The English Steel Castings Corporation Limited.
Windows	...	...	...	...	...	Beckett, Laycock & Watkinson Limited.
Screen wipers	...	...	...	...	...	Trico Folberth Limited.
Bodyside passenger doors	...	...	...	...	...	Dean & Son Ltd.
Interior panels	...	...	...	...	...	{ Bakelite Limited. W. A. Bonnell Limited.
Cab instruments	...	...	...	...	...	{ Westinghouse Brake & Signal Co. Ltd. Associated Electrical Industries Limited.
Heating and sound insulation	...	...	...	...	...	{ Fibreglass Limited. J. W. Roberts & Co. Ltd.
Electro-pneumatic brake equipment	...	...	...	...	...	Westinghouse Brake & Signal Co. Ltd.
Route indicators	...	...	...	...	...	Transport Engineering & Equipment Limited.
Destination indicators	...	...	...	...	...	E. W. Matthews Limited.
Telephone equipment	...	...	...	...	...	Clifford & Snell Limited.
Battery	...	...	...	...	...	Nife Batteries Ltd.
Oil pump	...	...	...	...	...	Pulsometer Engineering Co. Ltd.
Radiator	...	...	...	...	...	J. W. Lawrence & Co. Ltd.
Fan	...	...	...	...	...	Aerex Limited.
Capacitors	...	...	...	...	...	{ British Insulated Callender's Cables Limited. Standard Telephone & Cables Limited.
Control and heating jumper connections...	...	...	...	...	...	{ General Electric Co. Ltd. English Electric Co. Ltd.
Speedometer and mileage recorder	...	...	...	...	...	Associated Electrical Industries Limited.
Pantograph	...	...	...	...	...	J. Stone & Co. (Deptford) Ltd.
Air-blast circuit breaker	...	...	...	...	...	Brown Boveri & Co. Ltd.

Issued by

A E I TRACTION DIVISION

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