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Paper 4

The Multiple Unit Trains

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1 Introduction

The object of this paper is to explain the basis upon which the ratings of the very large fleet of multiple-unit train equipments for various duties were determined and also to compare the principal features of the various types which are the subject of Papers 24 to 27 inclusive.

2 The Basis of Rating

As soon as the decision to adopt the 25kV 50 cycle system had been taken, involving a decision to convert the existing Eastern Region 1,500 volt D.C. suburban electrification to the new system, it was necessary to place on order a very large number of multiple-unit trains for important suburban electrifications based on the Eastern Region London terminals at Liverpool Street and Fenchurch Street, for the suburban requirements originating at Manchester (Piccadilly) Station, and for the electrification of the Glasgow Suburban Lines.

Experience already obtained with three types of equipment by the conversion of the Lancaster – Morecambe – Heysham line from 6,600 volts 25 cycles to 6,600 volts 50 cycles was of considerable value, confirming as it did the wisdom of the decision to adopt direct current motors for the suburban trains in line with the decision to use them for locomotives. This experience was limited to three of the four contractors with whom bulk orders were placed and very strenuous efforts on the part of all concerned were necessary to develop the situation so that a fleet of over 400 motor coaches could be available during 1960 making allowance for conversion, whereas only three equipments existed when orders for the fleet were placed at the beginning of 1957.

The suburban electrifications themselves differed considerably in character, both as regards station spacing and speed restrictions and the schedule speed considered to be commercially economical. The Chief Electrical Engineer's specification for the equipments, whilst bearing this aspect in mind, set out a single set of parameters on which the offers received from the various manufacturers could be judged, and made provision for some adjustment of the characteristics to meet the special requirements of particular services.

The performance requirements were stated as follows:—

(*a*) Maximum service speed of 75 m.p.h. with wheels worn to $36\frac{5}{8}$ inches diameter (40 inches new).

(*b*) Mean starting acceleration of 1·1 m.p.h.p.s. for a loaded 4-coach unit.

(*c*) With 22·5/5·6 kV line voltage, with half worn wheels, with normal full seated passenger load, and observing all speed restrictions, ability to perform the following:—

(i) Normal run from Liverpool St. to Southend (Victoria) in 60 minutes, with six intermediate stops of 30 seconds each, and with sufficient coasting to give 8 per cent make-up time.

The stops are approximately 6 miles apart and the duty represents a schedule speed of 40 m.p.h.

(ii) After two normal round trips as above, an emergency run from Shenfield to Southend (Victoria) and back without any coasting and with six intermediate stops of 20 seconds each on each trip.

The stops are approximately 3 miles apart.

(*d*) Ability to start a loaded 4-coach unit on a gradient of 1 in 70 with two motors cut out.

The rating was to be based on a 4-coach unit tare weight of 144 tons. After the specification was issued, it was decided to use bogies of double bolster type to give improved riding qualities as compared with previous electric stock and to use thermal and sound insulation in the vehicle bodies. These increased the actual tare weight to 153 tons.

The use of the motor coach specified in a 3-coach unit formation gives an increased performance compared with the 4-coach unit and the ability to make more frequent stops without overloading for an inner suburban duty, such as on sections of the Glasgow Suburban Lines with 0·8 miles between stops. With the 3-coach unit the acceleration is 1·35 m.p.h.p.s.

The performances of 3 and 4-coach units are compared by the speed-distance curves shown in fig.1.

The train equipments limit the maximum line current demand for each equipment to 250 amp on a 6·25 kV line (62·5 amp on a 25 kV line) by reducing the rate of acceleration between 20 m.p.h. and 30 m.p.h. The increase in running time is less than 3 seconds at each start.

3 The Specification for the Electrical Equipment

The first specification described the supply system adopted, defined the performance required as described in section 2, and laid down certain features definitely required.

The latter included the following:—

(*a*) All power equipment to be underframe mounted except H.T. roof equipment, which was to be connected to the main transformer by rubber insulated cable.

(*b*) Forced oil air blast cooled main transformers.

(*c*) Rectifiers to be used in conjunction with D.C. series traction motors.

(d) Details of control and auxiliary equipment already established in existing D.C. electric rolling stock.

Principles of design set out in the specification included: Reliability, high availability for service, simplicity of design, minimum maintenance, accessibility for maintenance and freedom from noise and vibration.

Within the framework of the specification the Contractors were given freedom to develop suitable circuits and equipment under the overall supervision of the Commission's Engineers.

Inevitably, certain equipment is of novel design and not backed by experience with similar equipment so that the Commission and the Contractors have taken a measure of risk in the bulk production of such designs. This approach is justified by the circumstances and the outcome.

4 Equipments Ordered

The introduction of the 50 cycle single phase A.C. electrification has called for large numbers of multiple unit trains.

Contracts placed cover equipments for 361 suburban multiple unit trains (1,301 vehicles) and equipments for the conversion of 124 existing D.C. suburban multiple unit trains (404 vehicles) to A.C. working, and these are listed in the table below.

Service	*Region*	*No. of Units*	*Coaches per unit*	*Coaches built at*	*Electrical Contractor*
London/ Tilbury/ Southend	Eastern	112	4	B.R. York and Doncaster	English Electric Co. Ltd
Glasgow Suburban	Scottish	91	3	Pressed Steel Co. Ltd	Associated Electrical Industries Ltd (M.V.E.)
Manchester/ Crewe/ Liverpool	London Midland	45	4	B.R. Wolverton	Associated Electrical Industries Ltd (B.T.H.)
Liverpool St./ Enfield/ Chingford	Eastern	52	3	B.R. York	General Electric Co. Ltd
Liverpool St./ Bishops Stortford/ Hertford East	Eastern	19	4	B.R. Doncaster	General Electric Co. Ltd
Conversion of Liverpool St./Shenfield	Eastern	92	3	Converted at B.R. Stratford	Associated Electrical Industries Ltd (M.V.E.)
Conversion of Liverpool St./Southend (Victoria)	Eastern	32	4	Converted at B.R. Stratford	Associated Electrical Industries Ltd (M.V.E.)
Liverpool St./ Chelmsford/ Southend (Victoria); Colchester/ Clacton etc.	Eastern	42	4	B.R. York	English Electric Co. Ltd

5 Standardisation

Throughout the design of the trains, the advantages of judicious standardisation have been sought.

The vehicles are built to conform to the standard loading gauge, and conform to general designs established for all classes of coaching stock on British Railways.

As described in detail later the vehicles are built to many standards applicable to locomotive hauled stock. Standardisation between the A.C. locomotives and multiple unit trains extends to pantographs, circuit breakers, automatic power control and certain drivers controls and procedures. Many auxiliary machines, relays and contactors are interchangeable between certain locomotives and multiple unit trains.

Within the group of A.C. multiple unit trains all procedure for the preparation and disposal of trains is standard, together with all the other essential duties to be carried out by the motorman or guard.

Other standard features to be described later include driving positions, instruments, auxiliary voltages and multiple operation.

6 Description of Suburban Vehicles

Following the customary practice of British Railways, it was decided to build new rolling stock for these suburban electrifications and to build the greater part of it in railway workshops. Because of the pressure on these workshops to build a large fleet of new stock for other purposes as well as for electrification, it was considered essential to use standard designs of rolling stock with a minimum of essential modifications. Differences in matters of internal arrangement and appearance were permitted and special arrangements were made for the Glasgow suburban electrification.

Some consideration of general design treatment has been undertaken by the Commission's Design Panel, who have developed schemes for interior decor, and certain aspects of external appearance, particularly of the leading ends.

The 4-coach units built for the London – Tilbury – Southend service, described below, are typical.

The unit is shown in fig.2 and comprises:—

Battery driving trailer open second class vehicle.
(BDT and so called as it carries the battery, battery charger and main compressor).
Motor luggage compartment second class vehicle (MC).
Trailer composite first and second class vehicle (CT).
Driving trailer compartment second class vehicle (DT).

3-coach units are formed by omission of the trailer vehicle.

Units for all services are formed in this way but have appropriate variations of passenger accommodation.

The following are the main dimensions of the vehicles:—

Length over body of each driving trailer	63′	11½″
Length over body of inner two vehicles	63′	6″
Total length of coupled 4-car unit	265′	8½″
Width of body	9′	0″
Extreme width (over handles)	9′	3″
Height to top of roof from rail	12′	4½″
Height over pantograph in locked-down position	13′	0 9/16″

Overall dimensions of the vehicle in cross section are the maximum possible under B.R. C1 loading gauge conditions.

The 4-car unit has the following seating accommodation:—

Battery driving trailer open second	80 2nd Cl	
Luggage motor second	96 2nd Cl	
Trailer composite	60 2nd Cl	19 1st Cl
Driving trailer second	108 2nd Cl	
a total of	344 2nd Cl	19 1st Cl

Tare weights of individual vehicles are as follows:—

Battery driving trailer open second	35·8 tons
Luggage motor second	54·4 tons
Trailer composite	30·4 tons
Driving trailer second	32·1 tons
Total weight of 4-car unit	152·7 tons

The underframe (as shown in fig.3) is of centre girder design fabricated by welding in jigs and utilising standard rolled steel sections. The underframe is designed to be suitable for an end buffing force of 200 tons. The weight of the underframe itself is 4·95 tons.

The underframe is of overall length 63′ 5″ with bogie centres at 46′ 6″. Automatic couplers of drophead type are fitted at each end of the underframe, leading ends of the unit having rubber spring spindle type extending buffers.

The bogies fitted to the vehicles have double bolster suspension. Main frames of motor bogies (fig.4) are of riveted plate and rolled steel section construction, trailer bogies having pressed steel frame members.

Principal features and dimensions are as follows:—

Wheelbase:	Motor bogies 8′ 9″ Trailer 8′ 6″
Wheel diameter:	Motor bogies 3′ 4″ Trailer 3′ 6″
Type of axlebox bearing	Rigid taper or parallel roller 4⅝″ dia.
Primary suspension	Laminated springs 4′ 6″ length with rubber auxiliary springs.
Secondary suspension	Double bolster suspended on knife edge cotters, suspension links being inclined at 9¼°. Helical bolster springs of Timmis section with overloa drubber spring stops.
Complete bogie springing	Equivalent static deflection of— Trailer bogie 3 3/32 ins. Motor bogie 3¼ ins. Ratio primary to secondary deflection– Trailer bogie 40% : 60% Motor bogie 44% : 56%
Weight	Trailer bogie 6·7 tons Motor bogie (without motors) 9·0 tons

The electro-pneumatic brake with slack adjusters is fitted as standard equipment on the A.C. electric stock. Each vehicle has an underframe mounted brake equipment.

The vehicle bodies are of all-steel standard B.R. welded construction.

Lighting is provided in second class compartments by two roof fittings with 60 watt pearl lamps at 110 volts supply, and in first class compartments by one roof fitting with a 60 watt pearl lamp and four shoulder light fittings with 25 watt pearl lamps.

Heating is supplied by 500 watt heaters at 240 volts, thermostatically controlled by a thermostat in each compartment and saloon.

7 Glasgow Suburban Stock – Special Features

The units for this scheme were the subject of close consideration with the General Manager of the Scottish Region, the Chief Electrical Engineer, the Chief Mechanical Engineer and the Design Panel, to produce a design which would meet the operating conditions and incorporate new features desirable for modern electric vehicles. The Design Research Unit were responsible to them for the final appearance and for interior detail.

The units are of 3-vehicle formation, the motored vehicle being the centre vehicle. All vehicles are built on the standard B.R. underframe as previously described, the 3-car unit being 198′ 7½″ overall length. Body width is 9′ 3″. A special feature is the provision of air operated double sliding doors, recessed within the 9′ 3″ width, thus permitting maximum body width within the British loading gauge. The interior arrangements of seating and interior decor incorporates modern materials.

The exterior profile of the leading ends being of streamlined form gives an improved external appearance (see fig.5).

Seating accommodation and tare weight details of the Glasgow Suburban stock are as follows:—

Battery Driving Trailer	83 seats	37·5 tons
Motor	72 seats	55·6 tons
Driving Trailer	83 seats	33·8 tons

The units are fitted with the same type of double bolster bogies as previously described.

8 Main Line Vehicles

The first group of A.C. electric main line vehicles now being designed are for the Liverpool St. – Clacton – Walton service and are described in Paper 23.

9 Electrical Equipment

Papers 24 to 27 describe the equipments in detail and this paper draws attention to items of particular interest. Section 12 describes the equipment used for the conversion of existing 1,500, volt D.C. trains for A.C. operation.

Fig.6 shows a block schematic diagram of the electrical equipment of a unit and is applicable to all contracts.

9.1 *Performance of Suburban Units*

Although details of the equipments are given in the supporting papers, leading performance figures are tabulated below for comparison.

Service	*Coaches per unit*	*Continuous Rating W.F. at Wheel T.E.*	*Power*	*U.I.C. Rating Power*
London/Tilbury/ Southend	4	6,000 lbs.	770 H.P.	940 H.P.
Glasgow Suburban	3	6,600 lbs.	830 H.P.	912 H.P.
Manchester/Crewe/ Liverpool	4	6,600 lbs.	830 H.P.	912 H.P.
Liverpool St./Enfield/ Chingford	3	7,000 lbs.	800 H.P.	929 H.P.
Liverpool St./Bishops Stortford/Hertford East	4	7,000 lbs.	800 H.P.	929 H.P.
Conversion of Liverpool St./Shenfield	3	5,280 lbs.	628 H.P.	804 H.P.
Conversion of Liverpool St./Shenfield/ Southend (Victoria)	4	4,800 lbs.	696 H.P.	826 H.P.
Liverpool St./ Chelmsford/Southend (Victoria); Colchester/ Clacton etc.	4	6,000 lbs.	770 H.P.	940 H.P.

In Great Britain, the output of an electric vehicle is commonly stated as the continuous rating in weak field at the wheel. For comparison, the U.I.C. ratings are given above, being the one hour test bed rating of the motors measured at the shaft.

9.2 *Transformers*

All equipments have a single forced oil air blast cooled main transformer with a primary winding made up of four equal sections and an electro-pneumatic changeover switch to enable these sections to be connected in series for operation on 25 kV or in parallel for 6·25 kV.

The arrangements of secondary windings are adapted to the method of tap-changing for motor voltage control and to the type of rectifier used.

An additional winding supplies auxiliary equipment at 240 volts.

9.3 *Tap-Changing*

Tap changing is carried out on the secondary side by air break contactors, either camshaft operated, or in the form of electro-pneumatic unit switches, or in combinations of both.

The use of these forms of tapchanger is providing a useful comparison.

The limitation of circulation current between transformer tappings during tap-changing is obtained by chokes or resistors or both, which are also used to obtain intermediate notches between full transformer tappings. Selection of an ideal scheme is a question of economics involving consideration of energy loss, equipment weight, and complexity.

9.4 *Rectifiers*

The decision to adopt the 25 kV 50 cycle system occurred at a time when the semi-conductor rectifier was becoming a practical possibility for traction application and, as a result, one of the first contracts placed included germanium semi-conductor rectifiers (see Paper 24). As a result of further development, and satisfactory experience, further germanium rectifiers and also silicon rectifiers are now being introduced into service in quantity.

Nevertheless three contracts include mercury-arc rectifiers two using air cooling and one using water cooling, and these are performing with satisfaction.

From the railway operators point of view, by comparison with semi-conductor rectifiers, mercury arc-rectifiers must suffer from the following disadvantages: greater size and weight, complexity of ignition and excitation apparatus, and complication in maintaining the rectifiers within satisfactory operating temperatures, involving the provision of heaters.

9.5 *Traction Motors*

The adoption of the D.C. series motor in conjunction with the rectifiers for a 50 cycle system has been justified by experience in this country to date.

The motors are essentially normal D.C. machines but with laminated commutating poles, and in some cases with external non-inductive resistors to divert the ripple current from the main field windings.

The latter is provided to reduce the losses in the motor and to improve commutation, but experience does not indicate that it is an essential for good commutation.

As on the locomotives and as defined in Paper 3, the ripple current is approximately 30 per cent at the rated motor current.

All motors are axle hung with rubber resilient nose suspension.

A proportion of the motors in service have roller axle suspension bearings, whereas most have sleeve bearings. Further operation will provide data to compare the merits of the two types of bearings.

Each equipment has four traction motors. To ensure good qualities of adhesion these motors are connected in parallel (Paper 24), or in pairs in series with their interconnections joined together, (Papers 25 and 26) and in one case also connected to the transformer secondary midpoint (Paper 27).

With the series-parallel arrangement a measure of wheelslip control is provided on two types of equipment (Papers 25 and 26) by detection of current in the centre interconnection caused by unbalance in motor speeds. The relays detecting this current prevent further progression in the tap-changing and in one equipment (Paper 25) a second relay cuts power off if the unbalance current increases still further.

The value and method of application of wheelslip correction for multiple unit trains is still under examination.

9.6 *Roof Mounted Equipment*

Due to the limitations of the British loading gauge, the standard floor height, and the necessity of providing adequate headroom in the guards compartment under the lowered roof carrying the roof mounted electrical equipment, the latter is contained in a space less than 26 inches deep, and is shown in fig. 7.

The supply for the train is collected by the pantograph of Stone/Faiveley design described in Paper 20, and connected through an air blast circuit breaker to the equipment. The circuit breaker is of the type fitted to the locomotives.

A double pole earthing switch, similar to that on the locomotives, engages contacts on each pole of the circuit breaker. This switch is for the protection of personnel working on the equipment, and is mechanically interlocked with the pantograph isolating cock. It is provided with a locking bolt which can be secured by one or more padlocks. Each man working on the train fits his own padlock, and the bolt cannot be released until all padlocks are removed.

The main supply from the circuit breaker is connected to the terminal bushing of the H.T. cable connection to the main transformer.

The H.T. cable is rubber insulated and withstands the specified impulse voltage test of 170 kV. These cables, with rubber insulation over 0·6 inches thick represent an interesting achievement in cable manufacture.

A connection is made direct from the pantograph to the high voltage device of the voltage detection circuit associated with Automatic Power Control, which is described in Paper 3.

9.7 *Electrical Equipment in Motor Coach Guards Van*

The minimum amount of equipment is mounted in the guards van, all other equipment being carried on the underframe or roof.

The guards van equipment comprises a low tension cupboard (containing all fuses, cut-out switches, fault indicators and relays, and a proportion of auxiliary contactors and relays), the internal operating gear of the circuit breaker, the transformer oil conservator, the auxiliary compressor and certain compressed air apparatus for pantograph and circuit breaker operation.

This equipment is contained in a single compartment extending the width of the coach and approximately 18 inches deep.

9.8 *Control Gear*

The control gear is designed in accordance with modern practice with features such as silver butt contacts for non-rupturing power contacts and for control contacts, maximum use of electro-pneumatic devices to reduce electrical control loads, and a considerable degree of miniaturisation.

The control voltage is 110 volts D.C.

Train control is provided through 36 train lines and 36 point couplers.

The use of the train lines, and all other external aspects of the equipments are standardised allowing combinations of any units of different manufacture to be operated in multiple and allowing a standard procedure for the preparation and disposal of trains.

9.9 *Protection*

The first equipments were not entirely standard, and valuable experience is being obtained by comparison of the operation of the protection on different equipments. The following seems likely to be desirable.

(*a*) Primary overcurrent.

(*b*) Secondary overload where the nature of the tapchanger is such that faults may occur which are not covered by other protection.
(*c*) Rectifier fuses for the interruption of reverse breakdown of semi-conductor rectifiers.
(*d*) Rectifier air flow proving device.
(*e*) Motor overcurrent.
(*f*) Secondary earth fault protection by low impedance relay in the single earth connection to the secondary circuits.
(*g*) Transformer oil level switch in the conservator.
(*h*) Transformer oil over-temperature switch in the top of the main transformer.

As appropriate, they will open the air blast circuit breaker, interrupt the traction load only, or give indication only.

In all cases, of operation of the protection, an indication of the fault is given in the motor coach auxiliary cupboard for the information of maintenance staff.

All 240 volt A.C. and 110 volt D.C. auxiliary and control circuits are protected by fuses.

9.10 *Auxiliaries*

The general form of the auxiliary circuits is common to all types of train and is shown on fig.8.

All power originates from the 240 volt A.C. auxiliary winding on the main transformer.

This supply is carried within each unit by means of 2 ways in 4 way couplers between the intermediate coach ends of the unit.

The 240 volt supply is used for all heating, main compressor, battery charger and all auxiliary motors that are not required to run when the line voltage is absent.

Fan motors and the oil pump motor are single phase induction motors with capacitor starting and running.

The main compressor is a Westinghouse type C.M.38 with a D.C. series motor supplied through a bridge rectifier.

The battery chargers are not universally of one make but all are of the static type using a transductor regulated rectifier.

The battery charger charges a 110 volt D.C. battery and supplies the control circuits, all lighting and auxiliaries that are required to run when the line voltage is absent.

The alkaline battery is 72 cells, 80 A.H. Nife type VF7C15.

The auxiliary compressor is a machine of approximately 5 c.f.m. displacement, driven by a 110 volt D.C. series motor. This machine runs only during the preparation of the train to charge the pantograph and air blast circuit breaker system, which is normally fed from the main reservoir system via a non-return valve.

The battery is isolated by a contactor controlled by the CP train line. This arrangement is provided to reduce preparation time to a minimum. It causes the auxiliary compressor on each unit of a train to run as soon as the train line key is inserted. The pantograph is raised, the circuit breaker closed, and the main compressor is run in the shortest possible time.

Changeover contacts on the circuit breaker relay (ABR) transfer the control of the battery contactor to the BP unit line when the ABR is set. This retains the battery contactor and hence the lighting when the train line key is removed (but the pantograph is not lowered), when dividing or coupling units in service.

10 Driver's Controls

The position and nature of the driver's controls are standardised and a typical driving position is shown in fig.9.

The master controller is of the desk type to permit the driver to sit with his knees under it. The main handle incorporates a deadman feature. The reversing handle is not removable. The handle positions are tabulated below:—

Reversing Handle	*Main Handle*
Forward	Off
Off	1. Shunt
Reverse	2. Half Voltage
	3. Full Voltage
	4. Weak field

The brake controller for operation of the electro-pneumatic and Westinghouse automatic brakes has handle positions tabulated below:—

Running
Continuous section for self lapping E.P. brake up to
Full electro-pneumatic brake
Westinghouse brake lap
Westinghouse brake application
Emergency application
Neutral

Both controllers are normally locked in the off or neutral positions and are made operative at the driving position by two small keys carried by the driver. When locked in the neutral position the brake controller has the emergency application position only available.

The controller keys are either issued to the driver when signing on for duty, or a set is provided in the low tension cubicle in the BDT driving compartment. The driver is issued with a personal key to open all low tension cubicles, this key being the same as that used for similar purposes on the locomotives.

Other equipment provided in the driving compartment includes a driver to guard telephone, Automatic Warning System indication and cancelling apparatus, and a hand brake.

The procedure for the preparation of trains for service has been simplified so that the times allowed for this duty for various lengths of train are as follows:—

4 coach train	13 minutes
8 coach train	17 minutes
12 coach train	20 minutes

11 Testing of Electrical Equipment

The testing of the equipment is made in three stages; testing of individual items at the manufacturers works, testing of completed vehicles and the testing and running of the complete units on the electrified lines.

Type testing of at least one of each item is made to check the design and includes impulse test (for H.T. items only), applied voltage test, a rating test, and a demonstration of the characteristics of the item.

The impulse test is made in accordance with British Standards and at a peak value of 170 kV.

For the applied voltage test on H.T. items 59 kV (RMS) A.C. is applied for one minute. Other items receive an appropriate applied voltage test of the order of twice working voltage + 1,500 volts.

Continuous rating tests are made in accordance with the appropriate British Standards and, where required, short time tests are made as well.

Routine tests on every equipment are made to show that they conform to the performance agreed during the type testing. They include applied voltage test, short time rating test on major items only, and a test of characteristics.

The works test of complete vehicles involves the checking of the work involved in the erection and cabling of the equipment and includes an applied voltage test, circuit checking and a simple operational check.

The testing of the complete unit at the running site involves only a brief operational check before raising the pantograph on the live overhead and running the train to check its performance.

12 Operation of Trains

12.1 50 *Cycle Electrification before the Modernisation Plan*
The Lancaster – Morecambe – Heysham line was electrified at 6·6 kV 50 cycles as an experimental testing section. Trial running started in November 1952 and a public service was opened in August 1953.

A total of four multiple unit trains are now in service, three equipments being of English Electric Co. manufacture and one of Associated Electrical Industries manufacture.

All are rectifier equipments with D.C. motors.

The equipments differ from one another and employ both camshaft and E.P. contactor tapchangers, multi-anode excitron mercury-arc rectifiers, silicon and germanium semiconductor rectifiers and other features of an experimental nature.

12.2 50 *Cycle Electrification under the Modernisation Plan*
Of the trains listed in section 4 some units of the London – Tilbury – Southend stock commenced an electric passenger service on the Colchester – Clacton line in March 1959.

In the latter part of 1960 the Glasgow Suburban, Manchester – Crewe, Liverpool St. – Enfield – Chingford – Bishops Stortford – Hertford East, Liverpool St. – Shenfield – Southend (Victoria) lines will open electric services on A.C.

The London – Tilbury – Southend stock will be used temporarily on the Liverpool St. – Shenfield – Southend (Victoria) line immediately after its conversion from D.C. to A.C. operation to cover the period for completion of the conversion of the existing D.C. trains.

The experience of operation to date has confirmed that A.C. multiple unit trains can be as effective and reliable as trains operating on other systems.

12.3 *Maintenance*
Apart from treatment of the transformer oil (thought to be necessary at intervals of not less than 4 years) the H.T. equipment, being static is virtually maintenance free.

Bushings and insulators require periodic cleaning.

Rectifiers and their excitation equipment (the latter being eliminated with semi-conductor rectifiers) require only cleaning and maintenance of relays and small contactors.

Tapchangers are subject to a heavy duty on the rupturing contacts, but experience indicates that tip and arc-chute wear need not be excessive. Existing trains do not need excessive maintenance in this respect but it is considered that development can improve this aspect.

The traction motors operate on undulating current with complete satisfaction and experience indicates that brush and commutator wear will not be worse than with operation on D.C. In the limited service running to date, brush wear better than 90,000 miles per inch is obtained, which remains to be confirmed when extensive service running is started. This figure would be considered very satisfactory for motors operating on a D.C. supply. The motors in an A.C. equipment of the type used, have an advantage in the impedance existing between the motor and the overhead line, so that the effect of line surges is greatly reduced.

The auxiliary machines are mostly single phase induction motors and require periodic lubrication of bearings only.

The main compressor and auxiliary compressor are commutator machines and require appropriate maintenance, but consideration is being given to the use of an induction motor for the main compressor.

While day to day maintenance of static devices of electronic type, such as the battery charger regulators, may be very small, it is considered that some care must be taken in the selection and design of such equipment, so that the diagnosis of troubles and failure does not become an expensive process in itself.

13 Conversion of Liverpool St. – Shenfield – Southend Lines

These lines were electrified from Liverpool St. to Shenfield and Chelmsford in 1949 using the 1,500 D.C. system, and the electrification was extended to Southend in 1956.

As part of the application of the 50 cycle A.C. system, these lines are being converted from the D.C. to the A.C. system. For various reasons, including the time available, it was decided to convert the D.C. multiple unit trains to be suitable for A.C. working, by adding converting apparatus to the trailer coach adjacent to the motor coach in each unit.

92 3-coach units and 32 4-coach units are involved, and a contract for the total of 124 conversion equipments was placed with the Associated Electrical Industries Ltd.

The existing D.C. equipments are retained except for the pantographs, M.G. sets and certain minor items.

Stone-Faiveley pantographs and A.E.I. air blast circuit breakers are being supplied and the new contract covers the supply of main transformers and accessories similar to the standard equipments but with a simple secondary winding to give a 1,500 D.C. output from the rectifiers also supplied.

The rectifiers are air-cooled germanium semi-conductor type and similar to those supplied by the same company for the Manchester – Crewe – Liverpool stock.

Static battery chargers are supplied to replace the original motor generator sets, as these are unsuitable for operation on the undulating current supply.

New master controllers and other items of control gear are also supplied to bring the driving and preparation into line with the new A.C. units which will run over the same lines.

The 32 4-coach units are being additionally modified to use 110 volts D.C. instead of 52 volts for control and lighting, and to have the new standard 36 way control couplers throughout, so that they may work in multiple with standard units.

The 92 3-coach have air operated sliding doors and are not required to multiple with other types of unit.

14 Conclusion

The multiple unit trains described in this paper represent the first of a large group which will be built as part of the A.C. electrification.

Since orders for electrical equipment were placed early in 1957, design and construction work has been carried through so that by the end of 1960 over 400 units will be operating on the A.C. system.

Satisfactory trial running is already obtained with over 300 of these units containing examples of all types under construction.

SUMMARY

The paper concerns the large fleet of about 400 multiple-unit trains required for the suburban services of the electrification schemes and indicates those already in service.

It explains how a single set of performance requirements was used in the specification on which the first contracts were based, and how these were adapted to meet the diversity of duties involved. It lists the trains built or under construction, compares the performances and electrical equipments which are described in detail in Papers 24 to 27 and comments on the differences between certain equipments.

Attention is drawn to the extent of standardisation adopted.

A short description of the vehicles is given, noting that these conform to established standards for British Railways coaching stock. Mention is made of the special features of the Glasgow Suburban trains.

A description is given of the auxiliary circuits, testing of electrical equipment, and driver's controls.

Reference is made to running experience and maintenance.

The paper describes the method of conversion of 1,500 volt D.C. trains for A.C. operation on the Liverpool St. – Shenfield – Southend Lines.

RÉSUMÉ

Cet exposé décrit le grand nombre d'environ 400 rames automotrices nécessaires pour les services de banlieue des projets d'électrification et donne des indications sur celles qui sont déjà en service.

Il explique comment un seul groupe de performances a été utilisé dans la spécification qui a constitué la base des premiers contrats et comment ceux-ci ont été adaptés pour faire face à la diversité des conditions rencontrées. Il donne la liste des rames déjà construites ou en construction, compare les performances et les équipements électriques qui ont été décrits en détail dans les exposés 24 à 27 et commente les différences entre certains équipements.

L'attention est attirée sur l'étendue de la standardisation adoptée.

Une courte description des voitures est donnée faisant remarquer que celles-ci sont conformes aux normes établies pour les voitures des Chemins de fer Britanniques. On mentionne les caractéristiques spéciales des rames de la banlieue de Glasgow.

On décrit les circuits auxiliaires, l'essai de l'équipement électrique et les manipulateurs. On se réfère aussi aux expériences de service et de maintien.

Le rapport décrit finalement les méthodes de conversion des rames automotrices 1500 V courant continu de la ligne Liverpool Street – Shenfield – Southend pour le fonctionnement en courant alternatif 50 Hz.

ZUSAMMENFASSUNG

Dieser Bericht befasst sich mit der grossen Anzahl von Triebwagenzügen (ungefähr 400), die durch den Elektrifikationsplan für den Vorortsverkehr benötigt werden, und gibt an, wieviele Züge schon in Betrieb genommen wurden.

Der Bericht erläutert ferner wie eine einzelne Gruppe von Leistungsanforderungen in die Spezifikation aufgenommen wurde, auf welcher dann die ersten Verträge basierten, und wie diese Anforderungen bearbeitet wurden, um der Mannigfaltigkeit der gestellten Erwartungen gerecht zu werden. Die Züge, die unter Konstruktion sind oder gebaut wurden, sind in einer Liste aufgeführt. Weiter werden die Leistungen und elektrischen Ausrüstungen, welche in den Berichten 24 bis 27 ausführlich beschrieben sind, verglichen, und die Unterschiede zwischen gewissen Ausrüstungen erläutert.

Unsere Aufmerksamkeit wird ebenfalls auf die angenommene Normalisierung gelenkt. Die Fahrzeuge sind kurz beschrieben mit dem Vermerk, dass sie mit den festgesetzten Normen für Rollmaterial der Britischen Eisenbahnen übereinstimmen. Spezielle Kennmerkmale der Glasgow – Vorortszüge sind erwähnt.

Eine Beschreibung der Hilfsstromkreise, der Prüfungen der elektrischen Ausrüstung und der Führerstandausrüstungen ist angeführt. Betriebserfahrungen und die Wartung sind ebenfalls erwähnt.

Die Methode der Umstellung der 1500 V Gleichstrom – Züge auf Wechselstrombetrieb der Linie Liverpool Street – Shenfield – Southend wird diskutiert.

RESÚMEN

Este informe se refiere al parque muy amplio de unos 400 trenes de unidades múltiples (autoferros) necesitados por las líneas de cercanias, a las cuales las esquemas de electrificación se extienden, y hace mención de los que ya están funcionando sobre tales líneas.

En el informe se aclara cómo un juego único de características del rendimiento exigido era utilizado en la especificación empleada como base de los primeros contratos, y cómo esas sufrían variaciones para llenar la diversidad de exigencias de la explotación. El informe contiene también una lista de los trenes ya construidos o en construcción actualmente, hace una confrontación de las características y equipos eléctricos descritos en detalle en los folletos 24 a 27, y comenta las diferencias entre varios equipos.

Se nota expresamente la importancia de la normalización aplicada en este ocasión.

Una descripción breve de los vehículos hace claro que estos conforman con las especificaciones normalizadas ya estabelecidas para el parque de coches de los Ferrocarriles Británicos. Se mencionan también las especialidades, que caracterizan los trenes de las líneas de cercanias de Glasgow (Escocia).

Se halla una descripción de los circuitos auxiliares, de los métodos de ensayar los equipos eléctricos y de los mandos a mano para el maquinista.

Se refiere también a las experiencias de la marcha y a la cuestión del mantenimiento.

El informe describe además el método de modificación de los trenes, que operaban por corriente de 1500 c.c. para su funcionamiento por corriente alterna, desde la estación terminal Liverpool Street (Londres) sobre las líneas a Shenfield y a Southend.

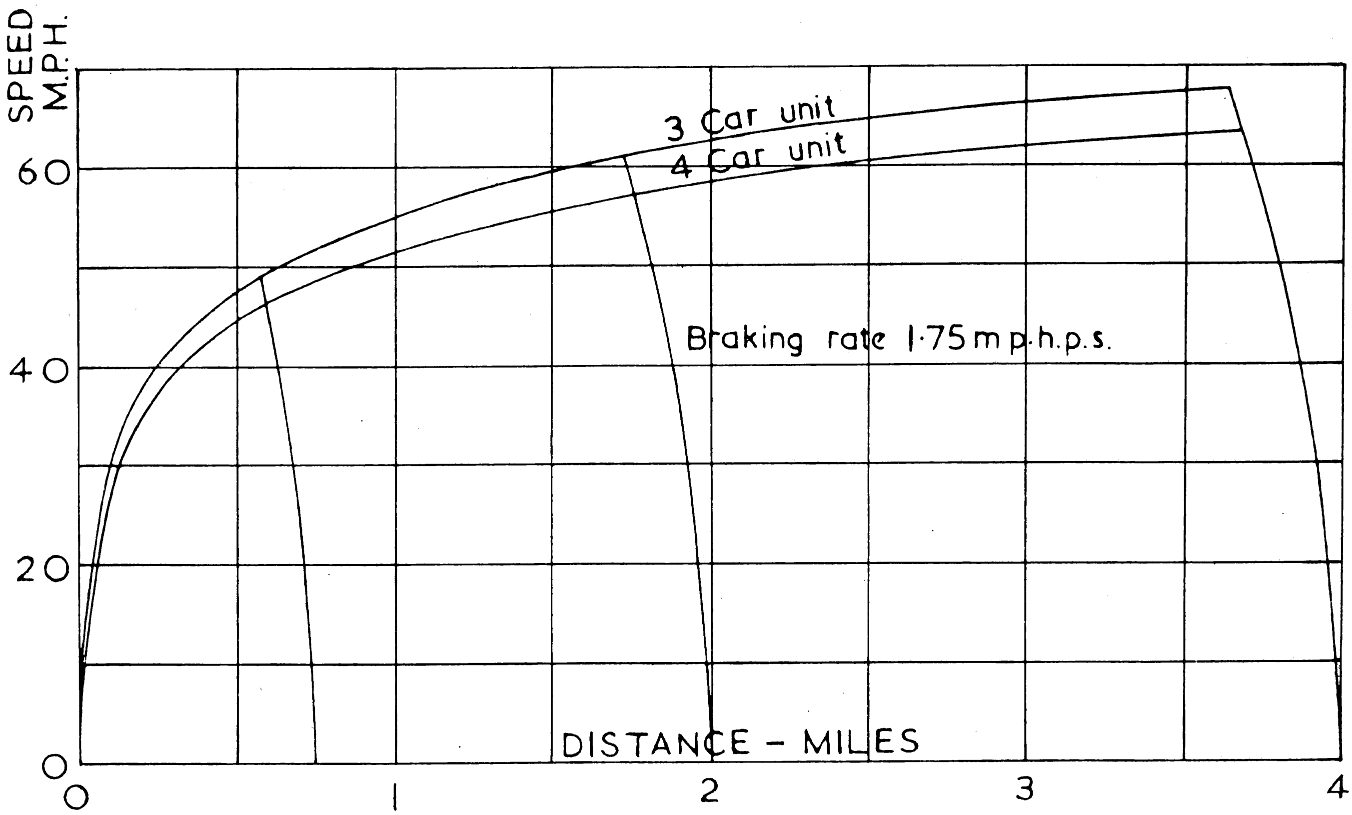


Fig.1 Speed-distance curves on level track for multiple unit trains.

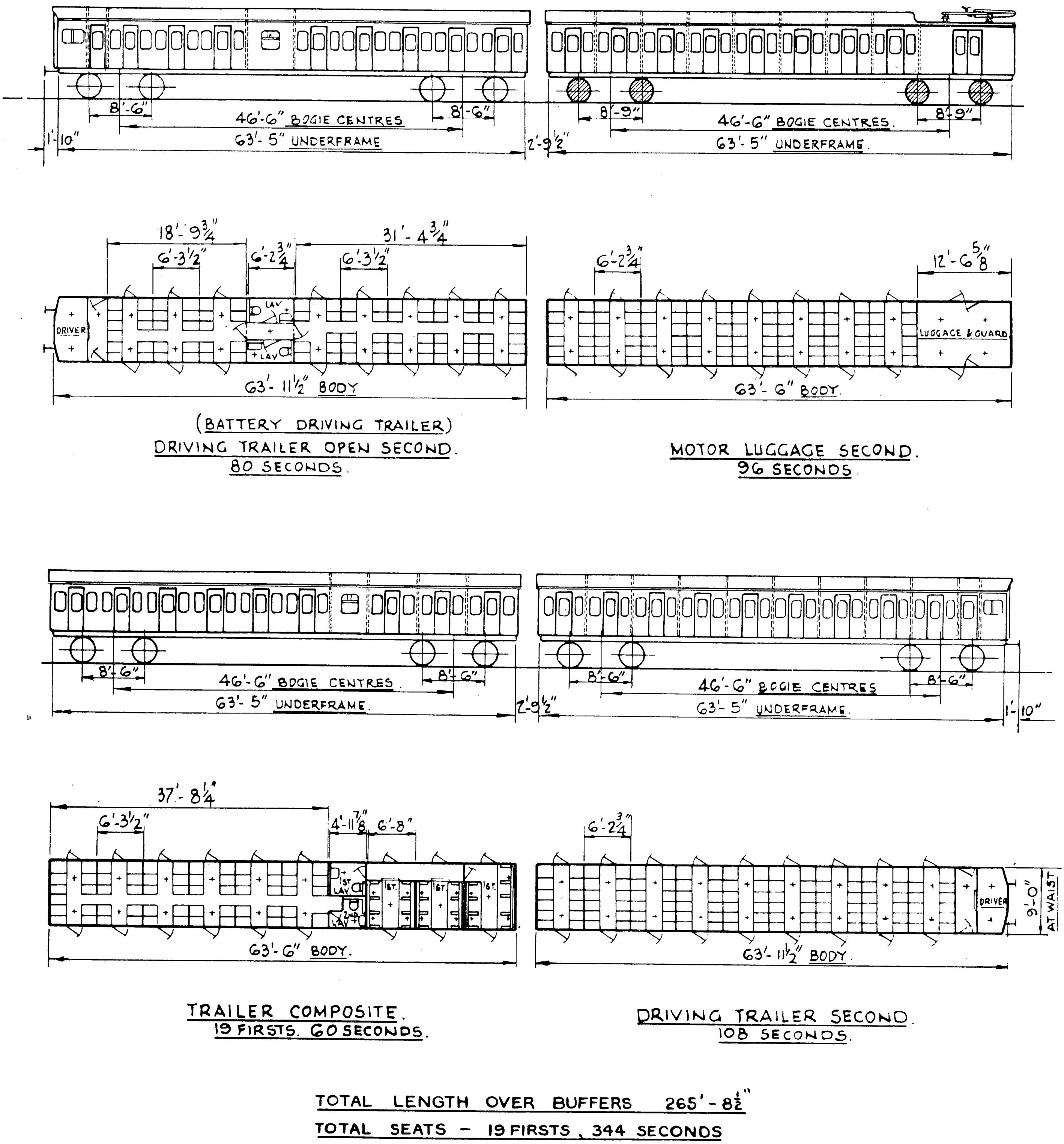


Fig.2 Four car set-suburban electric for London-Tilbury-Southend services.

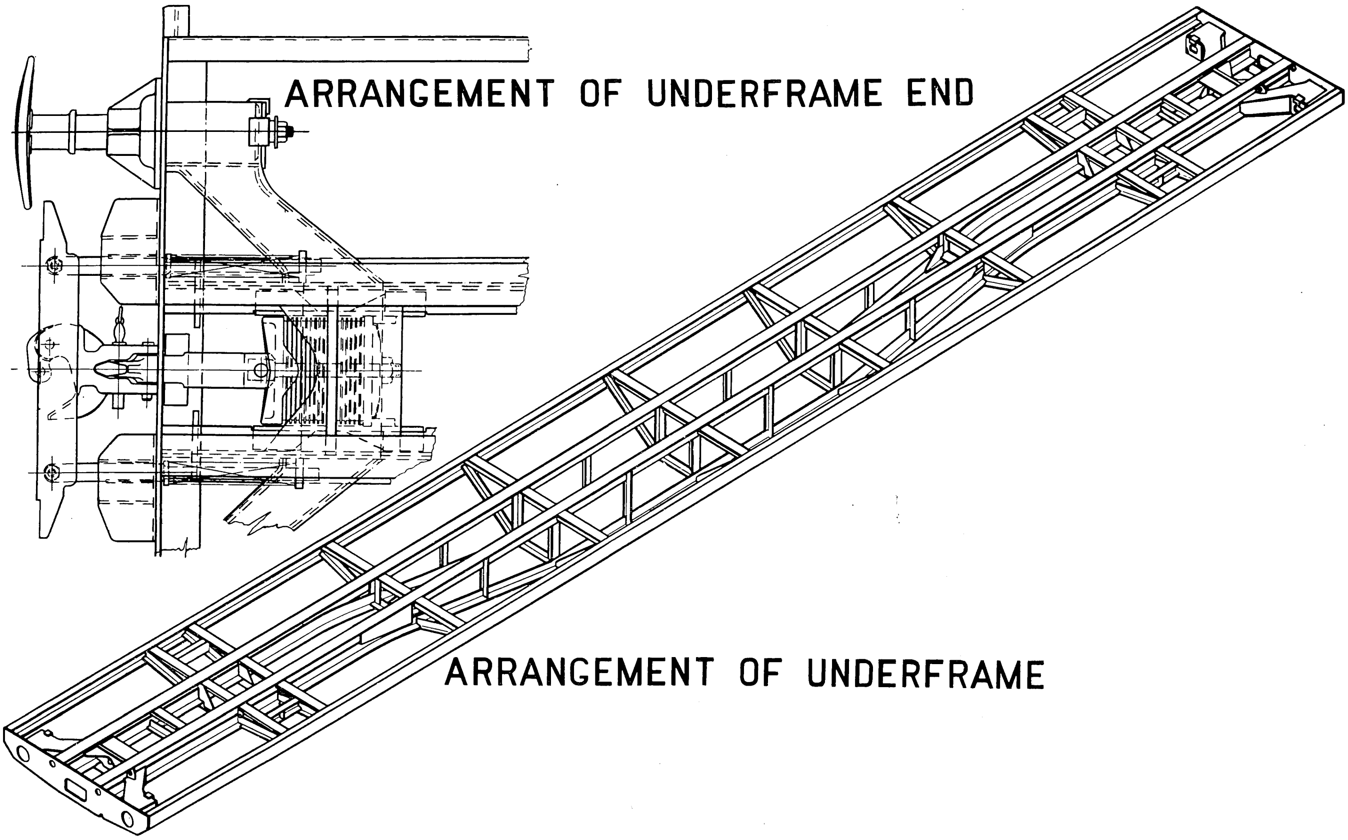


Fig.3 B.R. standard underframe for multiple unit trains.

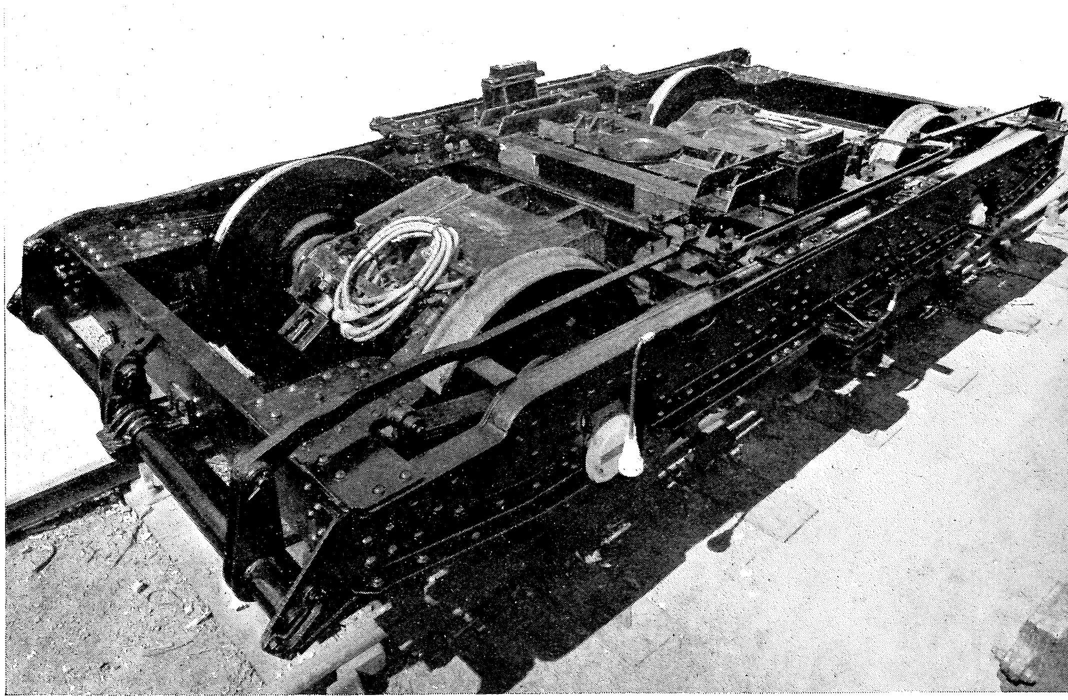


Fig.4 Motor bogie for multiple unit train.

Fig.5 Glasgow suburban unit.

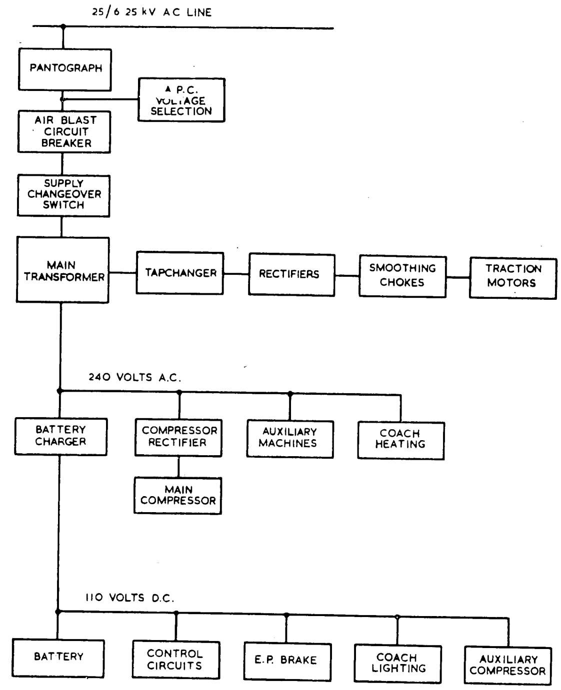


Fig.6 Block schematic of electrical equipment for multiple unit trains.

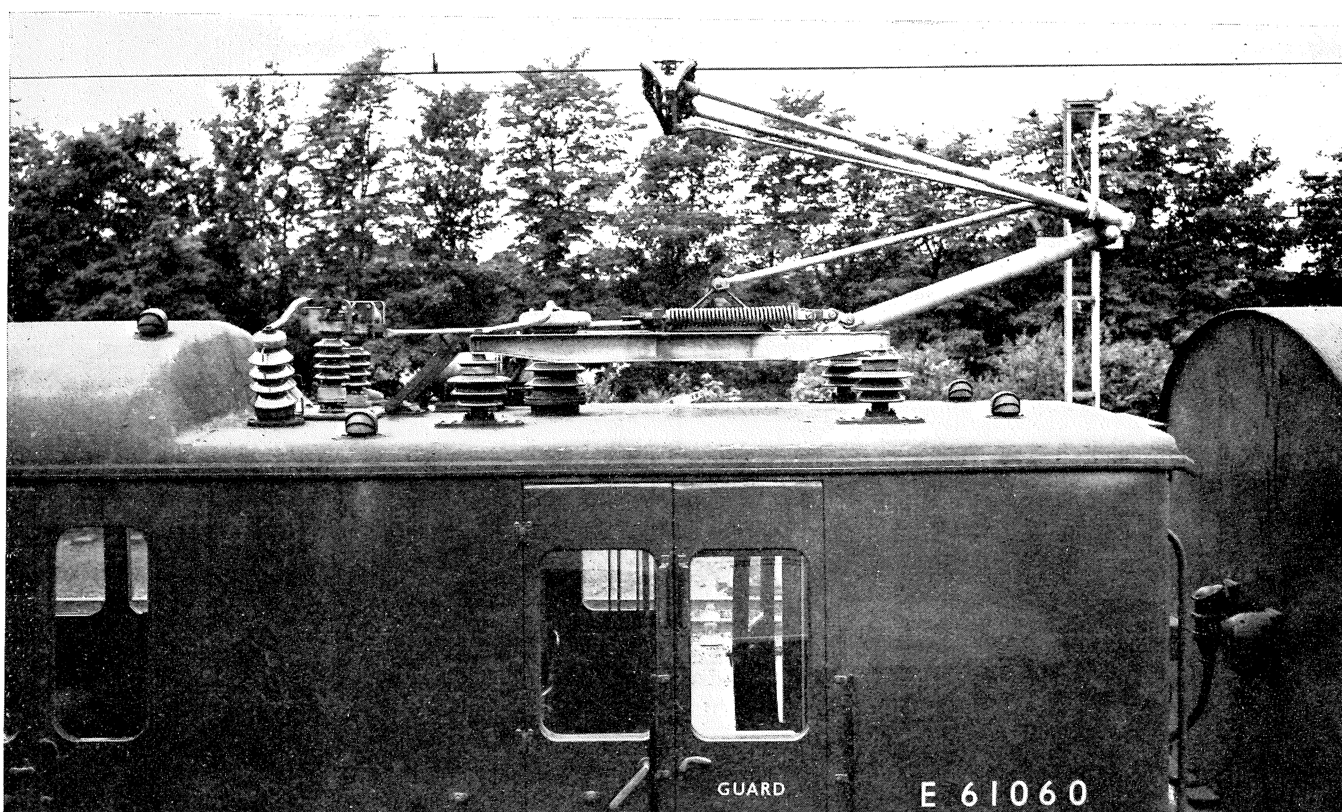
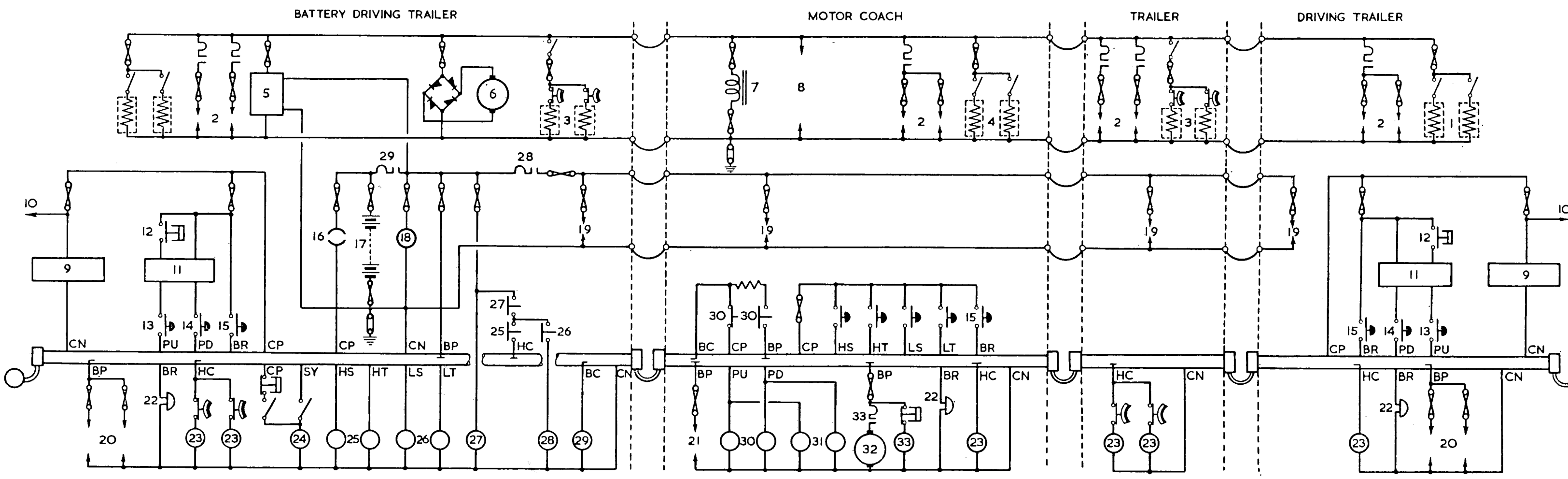


Fig.7 H.T. roof equipment on a multiple unit train.



TRAIN LINES THUS

CP CONTROL POSITIVE
CN CONTROL NEGATIVE
PU PANTO. UP & RESET
PD PANTOGRAPH DOWN
BR BELL

HS HEATING SET
HT HEATING TRIP
LS LIGHTING SET
LT LIGHTING TRIP
SY COMP SYNCHRONISE

UNIT LINES THUS

BP BATTERY POSITIVE
BC BATTERY CONTACTOR
HC HEATING CONTACTOR

1 CAB HEATERS
2 COACH HEATERS
3 WATER HEATERS
4 GUARDS HEATERS
5 BATTERY CHARGER
6 MAIN COMPRESSOR
7 MAIN TRANSR. AUX WDG
8 TRACTION AUXILIARIES
9 BRAKE CONTROLLER
10 A.W.S.
11 MASTER CONTROLLER
12 CONTROL CCT. GOVERNOR
13 PANTO. UP BUTTON
14 PANTO. DOWN BUTTON
15 BELL PUSH BUTTON
16 TRAIN LINE KEY SW
17 BATTERY
18 BATTERY VOLTMETER
19 PASSENGER LIGHTS
20 CAB LIGHTS
21 GUARDS VAN LIGHTS
22 BELL
23 COACH HEAT CONTACTOR
24 MAIN COMP. CONTACTOR
25 HEATING RELAY SET & TRIP
26 LIGHTING RELAY SET & TRIP
27 BATTERY VOLTAGE RELAY
28 LIGHTING CONTACTOR
29 BATTERY CONTACTOR
30 CIRCUIT BREAKER RELAY
31 PANTOGRAPH VALVE
32 AUX. COMPRESSOR
33 AUX. COMP. CONTACTOR

Fig.8 Schematic diagram of auxiliary circuits for multiple unit trains.

Fig.9 Driving position of multiple unit train.

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