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Paper 25

Multiple - Unit Train Equipment for London - Tilbury - Southend Line (E.E. Co.)

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1 Introduction

In January 1957 the B.T.C. ordered 112 sets of equipment from the English Electric Company Limited for multiple unit stock. Each unit consists of four cars of which one is a motor coach with four motors. The stock is intended for eventual use on the London – Tilbury – Southend line; from March 1959 it has operated a public service on the Colchester – Clacton – Walton line and will be used temporarily on the London – Chelmsford and Southend line. These services include both semi-fast and suburban duties. Higher performance on either type of duty can be obtained by removing the non-driving trailer and operating as a 3-car unit.

Two or three units can be operated in multiple. The equipments can also multiple with those of the three other manufacturers.

The coaches were designed and built by British Railways at Doncaster and York. The mechanical parts are described in Paper 4 which also covers the specified train performance and items common to other manufacturers' equipment.

A 4-car unit is shown in fig.1.

2 Leading Particulars

The principal data, based on a 4-car unit with all seats occupied, a line voltage of 22·5 kV, 100 per cent secondary tappings and half-worn wheels, are as follows:—

Vehicle	*Unladen Weight*	*Laden Weight* (all seats occupied)
Battery Driving Trailer	35·8 tons	40·8 tons
Motor Coach	54·4 ,,	60·4 ,,
Non-driving Trailer	30·5 ,,	35·5 ,,
Driving Trailer	32·1 ,,	38·9 ,,
Total	152·8 tons	175·6 tons

Other principal data for the 4-coach unit with all seats occupied (16 passengers taken as 1 ton), a line voltage of 22·5 kV, 100 per cent secondary tappings and half-worn wheels, are as follows:—

Maximum axle load	=	15·3 tons
,, service speed	=	75 m.p.h.
Balancing speed on level tangent track	=	67 m.p.h.
Acceleration on level tangent track	=	1·1 m.p.h./sec.
Average accelerating tractive effort	=	22,100 lbs.
Continuous rating at wheel in weak field:		
Tractive effort	=	6,000 lbs.
Speed	=	48 m.p.h.
Power	=	770 h.p.
Total weight of electrical equipment	=	21·1 tons

The performance curve for the equipment under the above conditions is shown in fig.2.

Additional tappings are provided on the secondary windings

to give approximately 5 per cent increase in voltage if required, i.e. 105 per cent.

The main transformer and the traction power equipment are mounted under the motor-coach underframe, as shown in fig.3. All other items of h.t. equipment are mounted on the motor-coach roof above the guard's compartment. The main compressor, battery and battery charger are mounted under the underframe of the battery driving-trailer. The positioning of items of equipment has been influenced by consideration of weight distribution between axles.

3 Description of Circuits

3.1 *Power Circuits.* These are shown in fig.4

Current passes from the pantograph through the air-blast circuit breaker to the supply changeover switch on the main transformer. The switch operates off load, and connects the four sections of the primary winding in series (for 25 kV operation) or in parallel (for 6·25 kV operation). The return path to the rails is through an insulated brush box on each traction motor.

Each phase of the bi-phase secondary winding of the transformer consists of two portions – one with tappings and one without. The tapped portions are used twice during notching – firstly in series with the reactors and secondly in series with the untapped portions. The change of connections is effected by the winding grouping switch, which does not make or break current; the supply to the traction motors is not interrupted.

On-load tap-changing is performed by contactors in conjunction with reactors, which are left in circuit on alternate notches to give pseudo-mid-tappings; tap-changing reactors rather than resistors were chosen to keep the starting losses low. On the lower notches the inherent voltage regulation of the transformer is low, hence additional impedance is provided to reduce the number of notches to a practicable value. Reactors rather than resistors were chosen to keep the starting losses low.

The decision to use contactors instead of a camshaft for tap-changing was influenced by the fact that notching back was not required; electrical interlocking is therefore not difficult.

The tap-changer feeds two pairs of excitrons, each pair connected bi-phase. Bi-phase connection was chosen rather than bridge so that the output voltage is the minimum possible, consistent with operating the rectifiers at a high peak-inverse voltage. The use of a high peak-inverse voltage is necessary to obtain the required power output from the four rectifiers.

The rectifier output voltage was considered to be too high for optimum motor design; the traction motors are therefore connected two in series. Weak-field operation is obtained by tapping rather than by diverting the field in order to reduce the risk of flashover without resorting to inductive shunts. The field is not provided with a ripple divert, since it was possible within the chosen frame size to allow for the additional field losses due to ripple, and commutation is excellent without the divert.

The two motor strings are connected through a common smoothing reactor to the centre point of the secondary winding. The centre points of the strings are connected by a low-impedance equalising connection, whereby the behaviour of the motors under wheel-slip conditions approximates to that of parallel-connected motors. The equalising connection contains two wheel-slip relays with different settings, and is earthed through a low-impedance earth-fault relay and an earthing contactor. Earthing at this point, rather than at the d.c. negative lead, reduces the voltage to earth of the d.c. circuit.

Motors may be cut out in pairs. A control switch de-energises the coil of the appropriate motor contactor and the excitation of the appropriate excitrons, which then act as isolators.

3.2 *Auxiliary Circuits.* These are shown in fig.5

The tertiary winding of the main transformer supplies heating and auxiliary circuits throughout the unit. Most of the machines are capacitor-start-and-run, with no switching between the starting and running conditions; this arrangement was chosen because of its simplicity. The main compressor motor is series-wound and is fed via rectifiers; this was considered the best way of obtaining, over the wide range of tertiary voltage, the high starting torque necessary. The battery charger is the static type, chosen for its simplicity compared with a motor-generator set and voltage regulator.

The battery charger and battery, in parallel, supply lighting throughout the unit, the auxiliary compressor motor on the unit, and control supplies throughout the train. The auxiliary compressor motor operates initially from the battery to provide air for raising the pantograph and closing the air-blast circuit breaker.

4 Description of Electrical Apparatus

4.1 *H.T. Equipment*

The air-blast circuit breaker is a Brown Boveri type DBTF, and the pantograph a Stone-Faiveley type AMBR. These are described in Papers 3 and 20 respectively.

A roof-mounted capacitor provides a feed to voltage detecting relays as described in Paper 16.

The h.t. current is taken through the guard's compartment by means of a long condenser bushing and then along the underframe to the transformer through a screened rubber-insulated cable supplied by Siemens Edison Swan. Above the roof the bushing is enclosed in an oil-filled shedded porcelain insulators; the bottom end of the bushing and one cable termination are housed in an oil-filled junction box. The other cable termination is inside the main transformer. This arrangement facilitates erection, by allowing the entire cable to be installed before the bodywork is fitted.

The 25/6·25 kV changeover switch is electro-pneumatically

operated and all its h.t. parts are oil immersed. It is mounted on an extension of the transformer tank which also houses the h.t. cable termination.

4.2 *Main Transformer*

The following data applies to the 105 per cent secondary tappings; ratings to I.E.C. 77:

Winding	*Primary*	*Secondary*	*Tertiary*
No. of phases	1	2	1
Rated voltage	25/6·25 kV	1875 + 1875V	284V
Rated kVA	990	1400	105

Mean kVA 1195

The transformer (fig.6) is of shell-type construction; the core is of grain-oriented steel laminations built in two parts, and all joints are interleaved.

The windings consist of rectangular conductors wound in flat coils on a circular former. Primary and secondary coils are arranged in interleaved groups, and spacers between the coils form oil ducts. The insulation is Class A.

Except for the primary connections, all electrical connections are brought out through copper strips moulded into epoxy-resin terminal blocks. This saves space and reduces the number of gaskets compared with separate porcelain insulators.

The cooling oil is circulated through the transformer and the reactor tank to a radiator by a glandless centrifugal pump. The radiator is cooled by air blast. A separate conservator is mounted in the guard's compartment.

Without disturbing the pipework, the oil can be reconditioned by passing it through an external filtration and heating unit.

4.3 *Tap-changer*

This is housed in two cases one of which is shown in fig.7.

The tapping contactors are E.P. operated, single pole, and have a laminated magnetic circuit incorporated in the series-wound blowout system. The auxiliary contacts, mounted at the front, are the cam-operated silver type. The magnet valve, mounted beneath the auxiliary contacts, is the rubber-seating type which does not need grinding in; the coil is potted in epoxy-resin.

The winding grouping switch is an E.P. operated, two-position camshaft; it has four sets of silver-butt main contacts, and cam-operated silver auxiliary contacts.

The tap-changing equipment is provided with full sequence and protective-interlocking by a single time-delay relay and the auxiliary contacts already referred to.

4.4 *Rectifiers*

These are air-cooled excitrons, type AR53, of the sealed steel-tank type. They are of an improved design, based on the type which was fitted in 1955 to a train on the Lancaster – Morecambe – Heysham line. Each is provided with an ignition/excitation anode and a de-ionising grid. The ignition device consists of a solenoid and floating plunger, which causes a jet of mercury from the cathode to impinge on the ignition anode. The cathode plate has cooling fins, and the cylindrical portion of the tank has wire cooling coils brazed to it; these are surrounded by a cylindrical shroud.

The continuous rating of a pair of excitrons in bi-phase is 250 amps d.c. at 1,240 volts d.c., and 35°C ambient temperature. The type tests included repeated loadings at 560 amps for 40 seconds, immediately following load at the continuous rating, and also a cold starting test by applying a load of 560 amps for 40 seconds immediately after the heaters had brought the rectifiers up to the minimum operating temperature from −12°C.

The arrangement of one pair, with their auxiliaries, is shown in fig.8. All the contents are accessible and removable from the front or bottom.

Air from under the floor enters through a grilled opening in the back wall of the case. A fibreglass duct leads the air over a vertically-mounted fan motor to a centrifugal fan mounted in the centre of a steel duct in the floor of the case and provided with dirt-extracting vanes. Each branch of the duct contains air heaters and is connected to a moulded rubber duct which surrounds the cathode of the excitron. The air passes upwards over the cooling coils and leaves the case through a louvred front cover.

The rectifier cooling fan runs at slow speed when the heaters are on and delivers 400 c.f.m. of hot air but, when the heaters are switched off by the thermostats, it runs at high speed to deliver 1,200 c.f.m. of cooling air.

Each excitron is resiliently-mounted from insulators secured to a tray. The tray carries a complete replaceable sub-assembly, and can be slid in and out of the case.

4.5 *Reactors*

All three reactors are oil cooled and are mounted in a common tank.

The smoothing reactor has a continuous rating matched to that of the transformer; it has an inductance of approximately 5 mH at 500A d.c. The other reactors are short-time rated since they are not in circuit on running notches.

All connections are brought out through copper strips moulded into epoxy-resin terminal blocks.

4.6 *Traction Motors*

The traction motors, type EE536A, are axle hung, self-ventilated, 4-pole series-wound d.c. machines. They are continuously rated at 192 h.p. (620 volts 250 amps) when in weak field and carrying undulating current. This rating corresponds to a line voltage of 22·5 kV. The permissible temperature rises of the armature and fields are 120°C and 130°C respectively.

A fan at the pinion end draws cooling air from the vicinity of the motor carcase through a screen into the commutator end. The screen removes the larger particles of dirt. This arrangement avoids the use of flexible bellows.

The motors operate very satisfactorily with a large ripple in their current, approximately 40 per cent. A weak field

running notch is obtained by a field tapping and no field diverts or laminated magnetic yoke are used.

The armature is lap wound, in order to obtain the required power output from the smallest motor, and to contribute to good commutation.

4.7 *Auxiliaries*

With the exception of the compressor motors, which are d.c., all auxiliary machines are capacitor start-and-run induction motors.

These machines are:—

No. off	*Function*	*Output*	*Supply*	*Rating h.p.*	*Speed r.p.m.*
1	Auxiliary Compressor	3 c.f.m.(f.a.d.)	110V D.C.	1·5	—
1	Main Compressor	23 c.f.m.(f.a.d.)	200V D.C.	6·5	—
2	Rectifier Cooling Fans	1,200 c.f.m.	240V A.C.	0·75/·03	1,470/490
1	Oil Circulating Pump	80 g.p.m.	240V A.C.	1·5	1,425
1	Oil Cooling Fan	4,750 c.f.m.	240V A.C.	1·5	1,450

The main and auxiliary compressors are Westinghouse Brake and Signal Company's type CM38 and E5 respectively. The battery charger by the same company, gives 110 volts d.c. transductor-regulated output for lighting, control and charging the Nife VF7C15 80 A.H. nickel-cadmium alkaline battery.

4.8 *Master Controller*

This is shown in fig.9. For driving procedure see Paper 4.

5 Protection

The equipment is protected from line voltage surges by a double rod gap fitted to the porcelain insulator of the h.t. bushing and set to have a 50 per cent flashover at 135 kV peak.

Tripping of the air-blast circuit breaker occurs under the following conditions: overcurrent in the h.t. lead-in (setting 600 amps on 6·25 kV or 200 amps on 25 kV), overcurrent in the tap-changer circuit, low oil-level in transformer, rectifier backfires, traction motor overcurrent, earth-fault in the transformer secondary or tap-changer or d.c. power circuits.

Rectifier under-temperature and over-temperature thermostats remove load from the rectifiers unless the temperature is within the working range.

Operation of protection relays lights a fault indicator lamp in the guard's van and each relay has an indicator flag to assist in locating faults.

Operation of one wheel-slip relay halts the tap-changing progression; if the slip stops, the relay resets and progression continues. If slip is more severe the second relay operates and cuts power off: the relay then resets and progression recommences.

Regeneration via an earth fault when towing a 'dead' unit is prevented by the earthing contactor which is open whenever the unit is shut down. This contactor and one motor contactor must be closed before the air-blast circuit breaker can close.

6 Conclusion

Satisfactory performance of the equipments since the first unit was commissioned in December 1958 has justified the choice of circuitry and the design of apparatus. A further order has been received for 42 equipments to be identical except for the substitution of silicon rectifiers for mercury-arc.

For the results of the System Tests on these trains see Paper 2.

SUMMARY

This paper describes the 770 h.p. equipments built by The English Electric Company Limited following the receipt, in January 1957, of an order from the British Transport Commission for 112 equipments. The equipments are for 4-coach units comprising driving trailer; motor coach; non-driving trailer; driving trailer, arranged for multiple unit operation of up to 3 units. Each unit weighs 175·6 tons including 363 seated passengers. The trains have a maximum speed of 75 m.p.h. and an acceleration of 1·1 m.p.h./sec. Four running notches are provided.

The transformer is oil cooled, with series/parallel primary windings for the 25/6·25 kV supply and with secondary windings tapped for low-voltage control; it is continuously rated at a primary kVA of 990 for traction purposes. Four air-cooled mercury-arc rectifiers of the excitron type are used in two bi-phase pairs, each pair feeding two traction motors in series. The midpoints of the two series circuits are connected together. Each traction motor is continuously rated at 192 h.p. at 620 volts and is a four-pole self-ventilated d.c. machine of conventional construction. Tap-changing is effected by electro-pneumatic contactors, winding group switch, and reactors. These reactors and the d.c. smoothing reactor are oil cooled.

The main air compressor is driven by a d.c. motor fed from selenium rectifiers, and fan and pump motors are single-phase induction motors of the capacity start-and-run type.

The main transformer and reactors, the tap-changer, the rectifiers and the d.c. control gear are all mounted below the floor of the motor-coach.

In December 1958 the first unit was energised; public service commenced on the Colchester – Clacton – Walton line in March 1959.

RÉSUMÉ

Cet exposé décrit l'équipement électrique de 770 h.p. construit par la English Electric Company Limited, à la suite de la réception en Janvier 1957 d'une commande de 112 rames automotrices de la British Transport Commission. L'équipement électrique est destiné aux rames unitaires de 4-voitures comprenant une voiture-pilote, une motrice, une remorque et une voiture-pilote. Les rames peuvent contenir jusqu'a 3 unités. Chaque unité pèse 175,6 tons y compris 363 voyageurs assis. Les trains ont une vitesse maximum de 75 m.p.h. et une accélération de 1,1 m.p.h./sec. Quatre crans de marche sont prévus.

Le transformateur avec refroidissement par circulation forcée d'huile possède 4 enroulements primaires groupés en série ou en parallèle suivant que la tension est de 25 kV ou de 6,25 kV et des enroulements secondaires avec prises pour réglage basse tension. Il est dimensionné pour une puissance primaire continue de traction de 990 kVA. Quatre redresseurs monoanodiques à vapeur de mercure du type excitron à refroidissement par air sont montés en push-pull, chaque paire alimentant deux moteurs de traction en série. Les points milieux des deux circuits de moteurs sont reliés ensemble. Chaque moteur de traction est construit pour un régime continu de 620 volts, 250 ampères et constitue une machine à courant continu à quatre-pôles, auto-ventilée et de construction classique. Le changement de prises est effectué par des contacteurs électro-pneumatiques, un commutateur pour grouper les enroulements secondaires et par des inductances de passage. Ces selfs et la self de lissage sont refroidies par circulation forcée d'huile.

Le compresseur principal d'air est entraîné par un moteur à courant continu alimenté par des redresseurs au sélénium. Les moteurs des ventilateurs et de la pompe à huile sont des moteurs asynchrones monophasés avec condensateur pour le démarrage et la marche normale.

Le transformateur principal et les selfs, le commutateur de prise, les redresseurs et l'appareillage de commande à courant continu sont tous montés sous le plancher de la voiture motrice.

La première unité fut mise sous courant en Décembre 1958; le service public sur la ligne Colchester – Clacton commença en Mars 1959.

ZUSAMMENFASSUNG

Dieser Bericht beschreibt die von der " English Electric Co. Ltd " auf Bestellung der " British Transport Commission " gebauten Ausrüstungen für Triebwagen von 770 h.p. Es handelt sich dabei um 112 Austrüstungen, die im Januar 1957 bestellt wurden. Diese Ausrüstungen sind für Einheiten mit je 4 Wagen, und zwar Steuerwagen, Triebwagen, Beiwagen, Steuerwagen; bis zu drei solche Einheiten können zu einem Zug zusammengestellt werden. Jede Einheit wiegt 175,6 tons 363 sitzende Passagiere einbegriffen. Die Züge haben eine Maximalgeschwindigkeit von 75 m.p.h. und eine Beschleunigung von 1,1 m.p.h./sec. Vier Fahrgeschwindigkeitsstufen sind vorgesehen.

Der ölgekühlte Transformator hat reihen- und parallel-geschaltete Primärwicklungen für die Netzspannungen 25 kV und 6,25 kV, während die Sekundärwicklungen mit Anzapfungen für die Niederspannungssteuerung versehen sind. Die Dauerleistung der Primärwicklung für den Fahrbetrieb beträgt 990 kVA. Die vier luftgekühlten Quecksilberdampf-Excitrongleichrichter werden als zwei Doppelphasenpaare eingesetzt, wobei jedes Paar zwei in Reihe geschaltete Fahrmotoren mit Strom beliefert. Die Mittelpunkte der zwei Reihenstromkreise sind miteinander verbunden. Jeder Fahrmotor hat eine Dauerleistung von 250 A bei 620 V und ist eine selbstventilierte Vierpol-Gleichstrommaschine normaler Bauart. Die Stromanzapfschaltungen werden durch elektro-pneumatische Schütze, einen Wicklungsgruppenschalter und Drosseln bewirkt. Diese Drosseln sowie die Gleichstrom-Glättungsdrossel werden mit Öl gekühlt.

Der Hauptkompressor wird von einem durch Selengleichrichter gespeisten Gleichstrommotor angetrieben, während die Ventilator— und Pumpenmotoren mit Einphasen-Asychronmotoren und Anlauf —und Laufkondensatoren ausgerüstet sind.

Der Haupttransformator, Drosseln, Anzapfschalter, Gleichrichter und die Steuergeräte für den Gleichstrom sind alle unter dem Boden des Triebwagens angebracht.

Im Dezember 1958 wurde der Probelauf der ersten Einheit durchgeführt und im März 1959 wurde der öffentliche Betrieb auf der Linie zwischen Colchester und Clacton aufgenommen.

SUMARIO

Esta memoria describe los equipos de 770 H.P. construidos por The English Electric Company Limited, a raiz de un pedido de la Comision Britanica de Transportes (British Transport Commission) en Enero de 1957 para 112 equipos. Los equipos son para unidades de 4 coches, comprendiendo: coche acoplado de mando; coche motor; coche acoplado sin mando; coche acoplado de mando; equipados para el funcionamiento de unidades multiples hasta 3 unidades. Cada unidad es de un peso de 175,6 tons, incluyendo 363 pasajeros sentados. Los trenes tienen una velocidad maxima de 75 m.p.h. y una aceleracion de 1,1 m.p.h./sec. Cuatro muescas de marcha estan provistas.

El transformador usa aceite por su enfriamiento, con arrollamientos primarios en serie/paralelo para el suministro de 25/6,25 kV y con arrollamientos secundarios con tomas para el control de voltaje bajo; es de clasificación continua a un primario de 990 kVA para fines de tracción. En dos pares bifásicos se emplean cuatro rectificadores de arco de mercurio de tipo excitrón, y de enfriamiento por aire; cada par alimenta dos motores de tracción en serie. Los puntos medios de los dos circuitos en serie están conectados entre sí. Cada motor de tracción es de una clasificación continua de 620 voltios y 250 amperios y es una máquina de corriente continua de cuatro polos con su propia ventilación y de construcción convencional. El cambio de tomas es realizado por contactores electro-neumáticos, interruptor de grupo de arrollamiento, y reactores. Estos reactores y los reactores suavizadores de corriente continua usan aceite por enfriamiento.

El compresor principal de aire es mandado por un motor de corriente continua alimentado por rectificadores de selenio, y los motores del ventilador y de la bomba son motores monofásicos de inducción de la capacidad y tipo arranque-y-funcionamiento.

El transformado principal y los reactores, el cambiador de tomas, los rectificadores y el mecanismo de distribucion de corriente continua están en su totalidad montados debajo del piso del coche motor.

En Diciembre de 1958 se comprobó la primera unidad; el servicio publico principió en la linea Colchester-Clacton en Marzo de 1959.

Fig.1 4-Car Unit, looking from B.D.T. end. London – Tilbury – Southend Line.

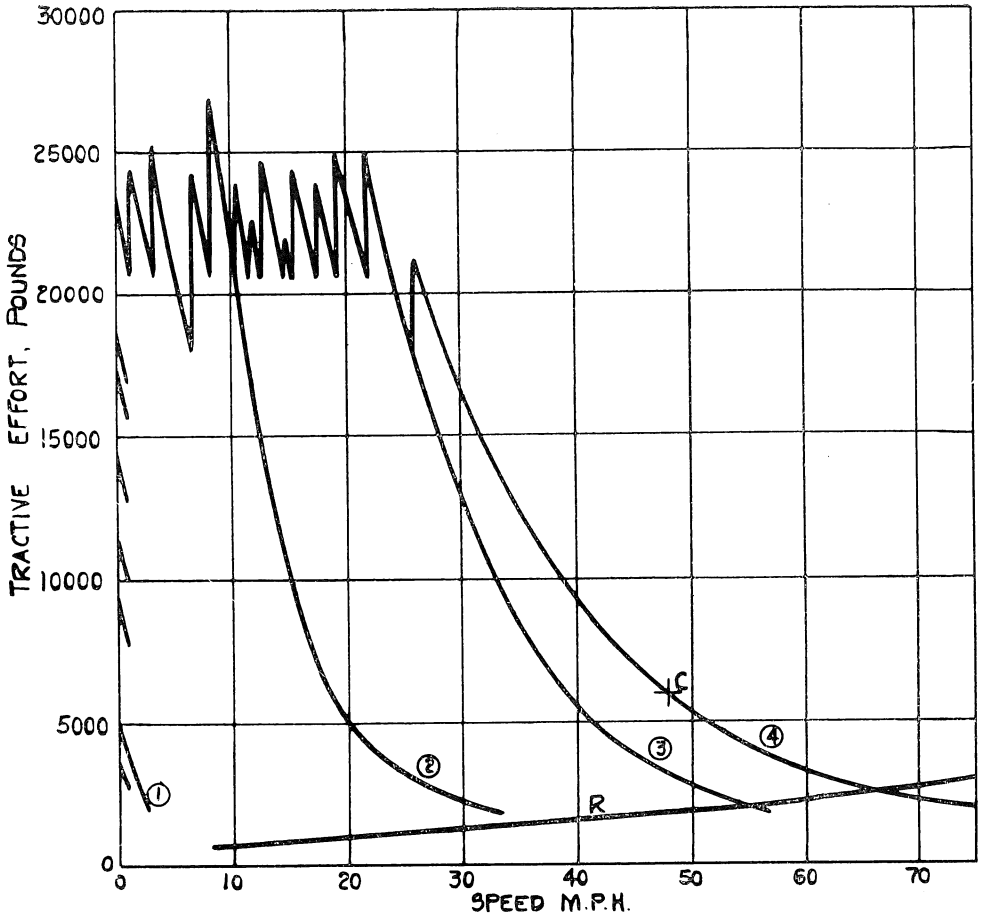
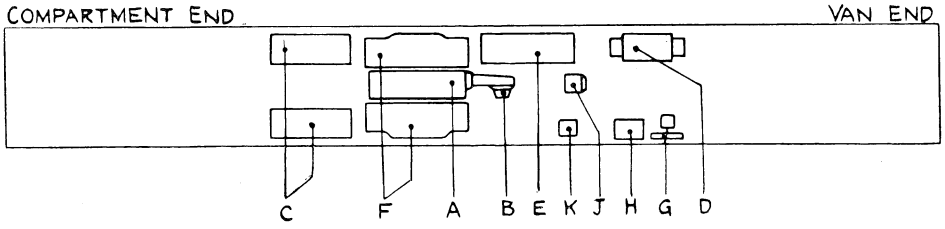
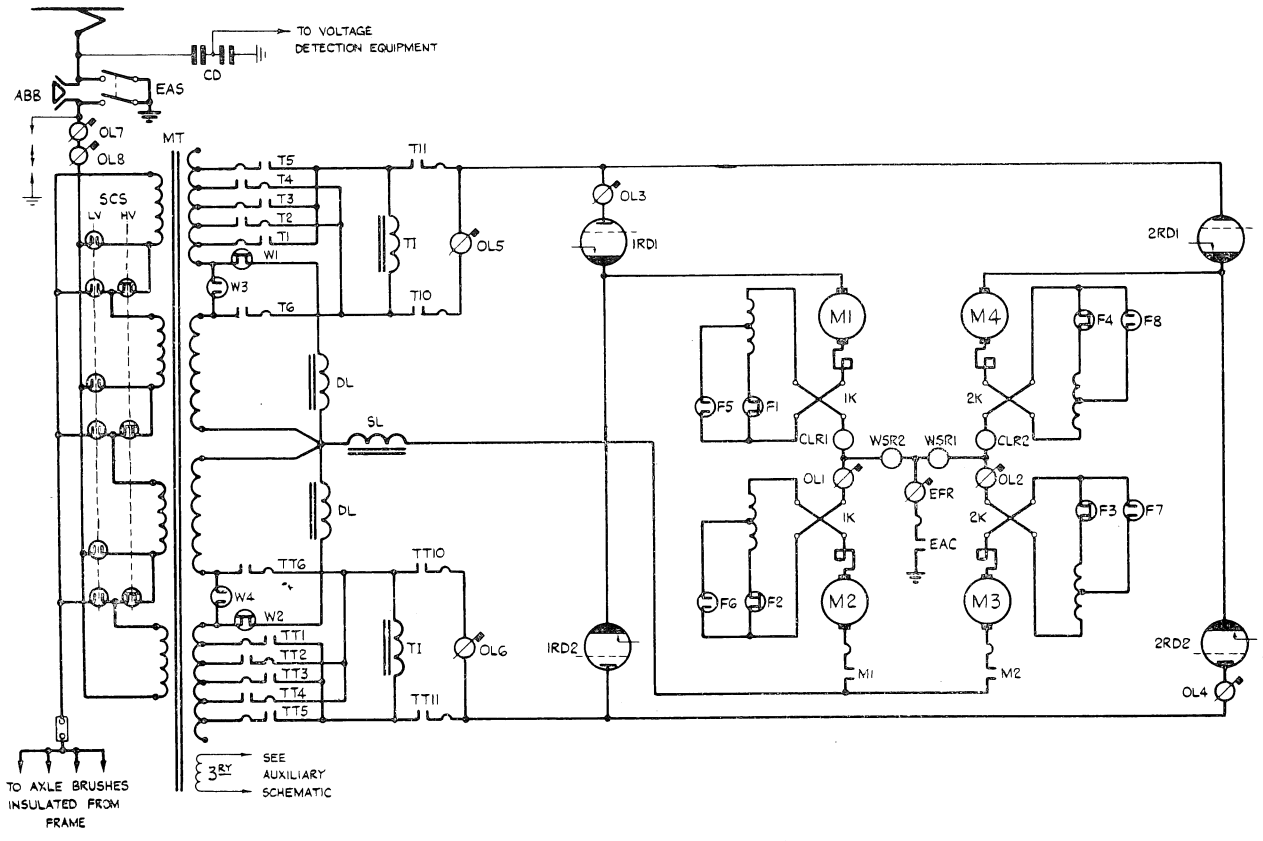


Fig.2 Performance Curves for one 4-Car Unit based on 2·25 kV Line voltage, 100% secondary tappings, half-worn wheels (38 $\frac{5}{16}$″ dia.). London – Tilbury – Southend Line.



A MAIN TRANSFORMER
B SUPPLY CHANGEOVER SWITCH
C TAP CHANGER
D REACTORS
E D.C EQUIPMENT
F RECTIFIER
G TRANSFORMER OIL RADIATOR
H OIL PUMP
J BRAKE CYLINDER
K E.P BRAKE UNIT

Fig.3 Layout of equipment on motor-coach underframe. London – Tilbury – Southend Line.



SEQUENCE CHART

NOTCH		CONTACTORS																GROUP SWS.				ISOLATING CONTACTORS								
																		W		F		MOTORS ALL IN				MOTORS 1 & 2 OUT				MOTORS 3 & 4 OUT		
CONTROLLER	ELECTRICAL	T1	T2	T3	T4	T5	T6	TIO	TII	TT1	TT2	TT3	TT4	TT5	TTG	TTIO	TTII	LV	HV	FF	WF	MI	M2	EAC		MI	M2	EAC		MI	M2	EAC
																		W1-2	W3-4	F1-4	F5-8											
0	0																	●		●				●			⊕	⊕	⊕		⊕	●
1	1	⊕						●		●						●		●		●		●	●	●			⊕	⊕	⊕		●	●
	2	●							●	●							●	●		●		●	●	●			⊕	⊕	⊕		●	●
2	3		●						●		●						●	●		●		●	●	●			●	●	●		●	●
	4		●					●			●					●		●		●		●	●	●			●	●	●		●	●
	5			●				●				●				●		●		●		●	●	●			●	●	●		●	●
	6			●					●			●					●	●		●		●	●	●			●	●	●		●	●
	7				⊕				●				⊕				●	●		●		●	●	●			●	●	●		●	●
	8				●			●					●			●		●		●		●	●	●			●	●	●		●	●
	9					●		●						●		●		●		●		●	●	●			●	●	●		●	●
	10					●			●					●			●	●		●		●	●	●			●	●	●		●	●
	11						⊕		●						⊕		●	●		●		●	●	●			●	●	●		●	●
	12						●	●							●	●		●		●		●	●	●			●	●	●		●	●
3	13	●						●		●						●			●	●		●	●	●			●	●	●		●	●
	14	●							●	●							●		●	●		●	●	●			●	●	●		●	●
	15		●						●		●						●		●	●		●	●	●			●	●	●		●	●
	16		●					●			●					●			●	●		●	●	●			●	●	●		●	●
	17			●				●				●				●			●	●		●	●	●			●	●	●		●	●
	18			●					●			●					●		●	●		●	●	●			●	●	●		●	●
	19				●				●				●				●		●	●		●	●	●			●	●	●		●	●
	20				●			●					●			●			●	●		●	●	●			●	●	●		●	●
	21					●		●						●		●			●	●		●	●	●			●	●	●		●	●
	22					●			●					●			●		●	●		●	●	●			●	●	●		●	●
4	23					●			●					●			●		●		●	●	●	●			●	●			●	●

SYMBOL	DESCRIPTION
ABB	AIR-BLAST CIRCUIT BREAKER
CD	CAPACITOR DIVIDER
CLR	CURRENT LIMIT RELAY
DL	DROPPING REACTOR
EAC	EARTH CONTACTOR
EAS	EARTHING SWITCH
EFR	EARTH FAULT RELAY
F	FIELD TAP SWITCH
K	REVERSER
(M)	TRACTION MOTOR
M	MOTOR CONTACTOR
MT	MAIN TRANSFORMER
OL1, 2	D C OVERLOAD RELAY
OL3, 4	ANODE OVERLOAD RELAY
OL5, 6	SECONDARY OVERLOAD RELAY
OL7, 8	PRIMARY OVERLOAD RELAY
RD	MAIN RECTIFIER
SCS	SUPPLY CHANGEOVER SWITCH
SL	SMOOTHING REACTOR
T, TT	TAP-CHANGING CONTACTOR
TI	TAP-CHANGING REACTOR
W	WINDING GROUPING SWITCH
WSR	WHEELSLIP RELAY

Fig.4 Power Schematic. London – Tilbury – Southend Line.

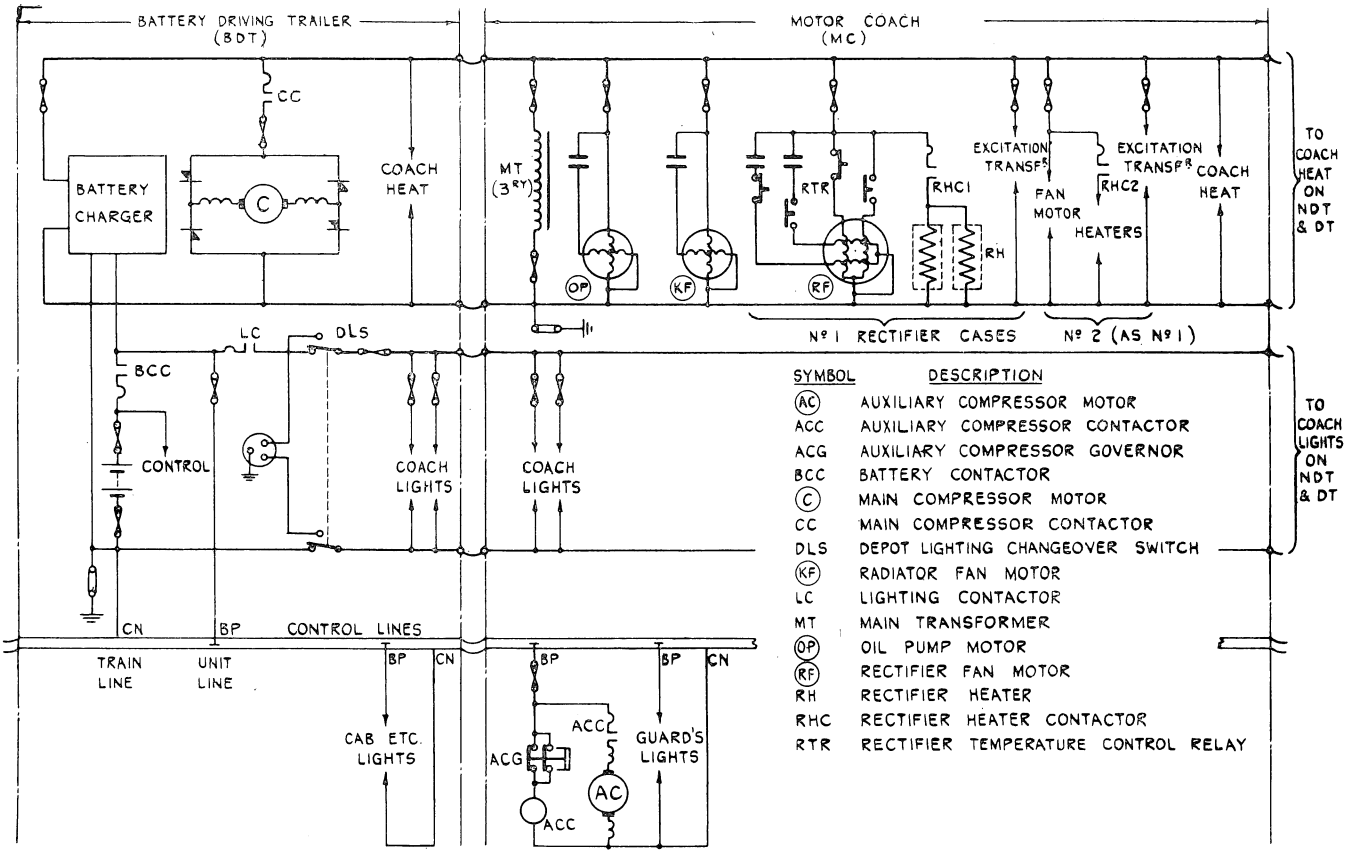


Fig.5 Auxiliary Schematic. London – Tilbury – Southend Line.

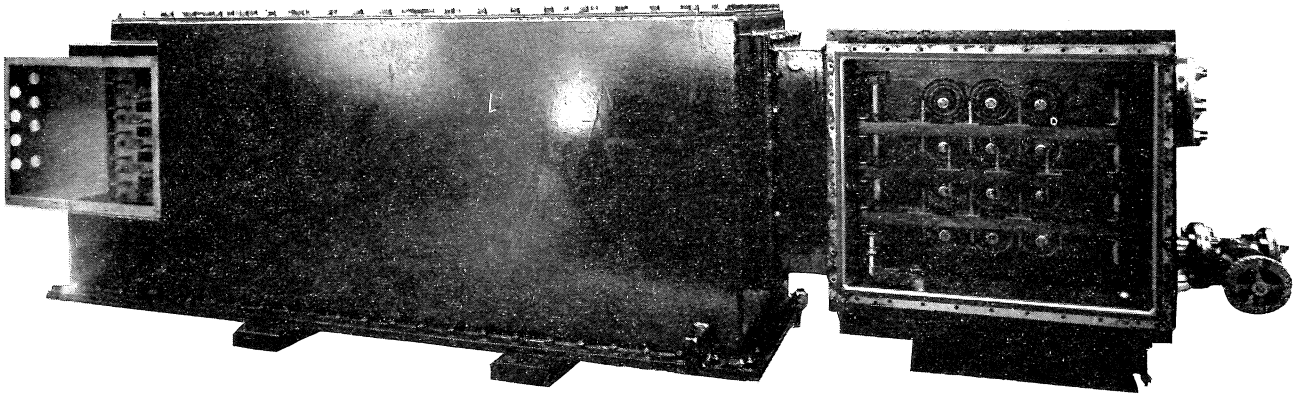


Fig.6 Main transformer, side view, covers removed from secondary terminals (L.H. End) and supply changeover switch (R.H. End). London – Tilbury – Southend Line.

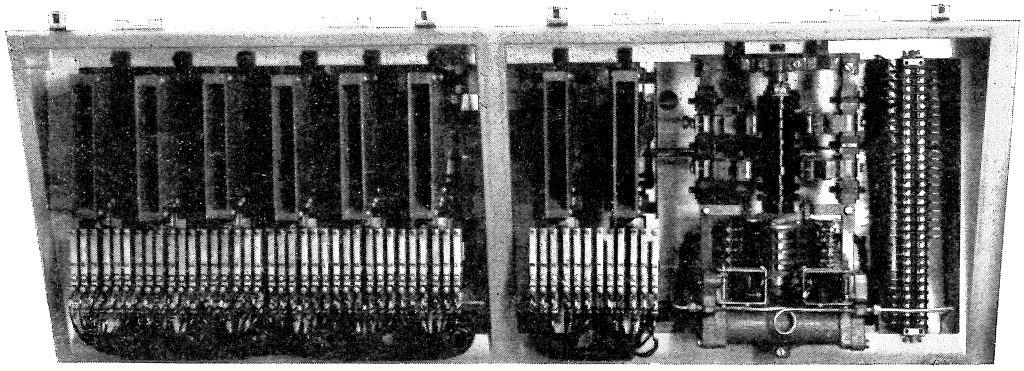


Fig.7 Tap-changer (No.1 case) front view, front covers removed. Winding grouping switch at R.H. end. London – Tilbury – Southend Line.

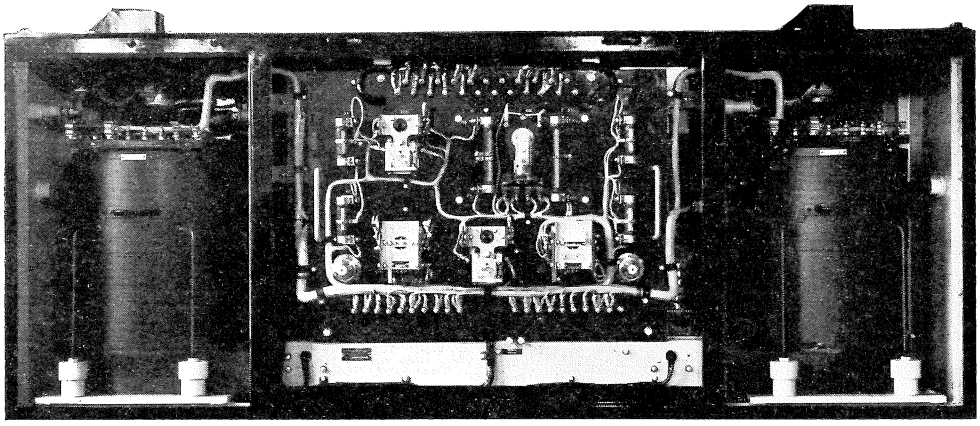


Fig.8 Rectifier case, front view. Front cover removed. London – Tilbury – Southend Line.

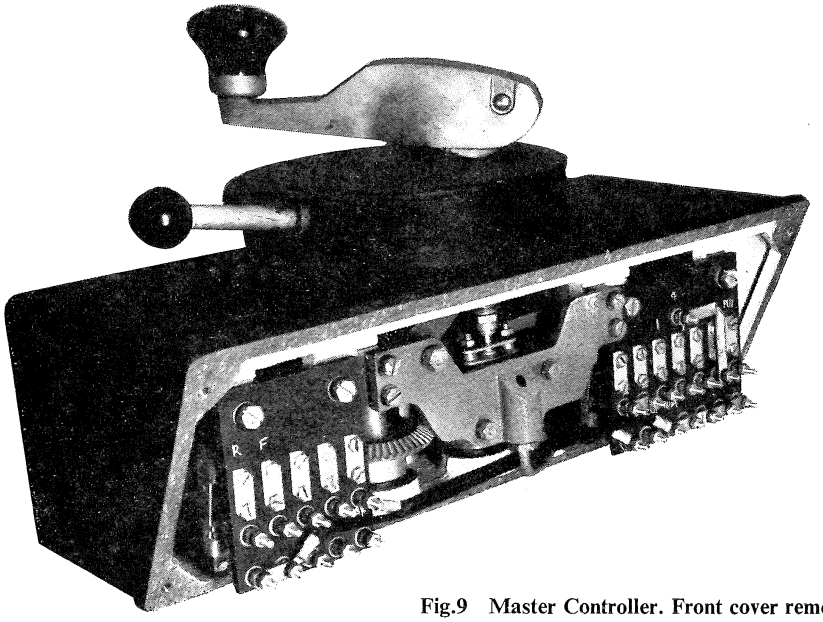


Fig.9 Master Controller. Front cover removed. London – Tilbury – Southend Line.

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