GEC

ELECTRICAL MULTIPLE UNITS FOR SOUTH AFRICA

GEC Traction Limited

ENGLISH ELECTRIC | AEI

GEC Traction Limited supplies equipment for 479 motor-coaches and trailers for SAR 3-ft 6-in 3,000-V d.c. suburban lines. Performance specified consistent with existing stock but 24 sets to incorporate choppers following prototype success. Dusty high-ambient conditions and electric storms dictate special provision whilst low seasonal temperatures on the Reef System require passenger heating

Latest SAR electrical equipment for multiple-units includes 24 chopper sets

With the order just placed with GEC Traction Limited by South African Railways for electrical equipment for 119 motor-coaches and 360 trailer cars, it is now over half a century since this railway administration first awarded a contract for multiple-unit electric stock to English Electric Co. Ltd., now a constituent of GEC Traction Limited. It is technically significant also that this latest order includes 24 chopper equipments which follow the success obtained with the two prototype choppers supplied by GEC Traction. All will be used in the Capetown area.

SAR awarded English Electric its first order for that 3-ft 6-in gauge railway administration in 1927. It comprised 95 1,500-V d.c. equipments—later converted to 3,000 V—and this was followed by another on Metropolitan Vickers and others on companies now constituent GEC Traction companies, as was Metropolitan Vickers. In fact this pattern of supply has become almost traditional when one considers that 1127 motor-coaches and 2,507 trailer cars have been supplied or are on order since 1927.

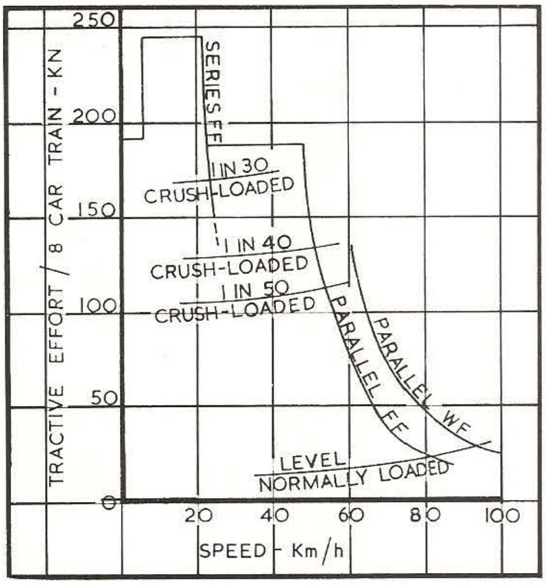

Fig. 1. *Performance of eight-car train showing balancing speeds on various gradients*

These trains are in service in all the three electrified areas of SAR, the Reef (greater Johannesburg area), Natal (Durban) and Cape Western (Capetown). Initially the rolling stock was built entirely in the United Kingdom but since 1960, the body-work and running gear have been built in the South African Republic by the Union Carriage & Wagon Co. Ltd., Nigel, whilst an increasing proportion of the electrical equipment is also being manufactured in South Africa by GEC Engineering (Pty) Ltd.

The new trains are required for services on the Eastern Transvaal, Natal and Cape Western sections. The last 24 motor coaches comprising nine first class and 15 third class units to be fitted with the new GEC thyristor chopper equipment will go into service with trailer coaches on the Cape Western system. This equipment has been designed so that it can be installed in existing motor-coaches and satisfactory operation of the fleet of 24 chopper-equipped multiple-units will enable SAR to consider extending chopper control to its entire multiple-unit fleet.

The SAR suburban services operate using fairly standardised groupings of train formations, two motor-coaches plus four or six trailers, or three motor coaches plus eight trailers, the balance between first and third class coaches varying to some extent with the area.

These trains all exhibit a strong line of continuity, the motor characteristic and major control wire functions have remained virtually unaltered from the inception of 3,000-V suburban operation in South Africa, despite a continuous up-dating of components. Thus a motor coach supplied today could operate in multiple with one built in 1957 and could control one built in 1954, the power door

SAR 3,000-V d.c. suburban multiple-unit train

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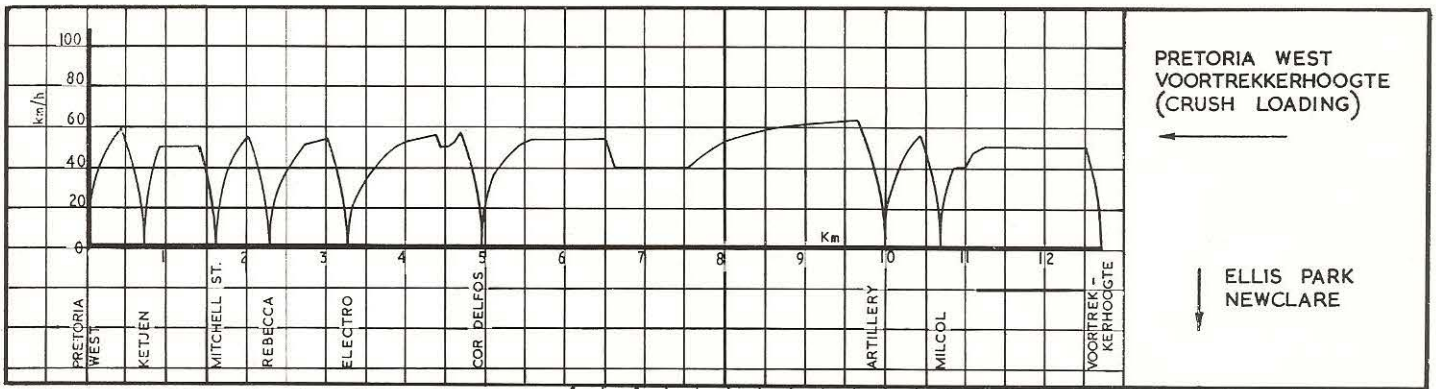


controls being the only obstacle to the reverse process.

The services worked are often very heavily loaded, so that the weight of a third/lower class trailer coach is nearly doubled under crush loading conditions and this requires all equipment to be very amply rated for its duties. In addition, both the Reef and Natal areas are subject to frequent, violent electrical storms and these require electrical equipment with ample creepage surfaces, air gaps and insulation, to cater for the 8·5 kV d.c. impulse level on the train.

There is a considerable number of individual coach types, and features vary between first and third class, motor and trailer coaches. The various coach types however, follow these principles:

1. all first class coaches have fluorescent lighting;
2. all third class coaches have incandescent lighting;
3. motor coaches do not have lavatories;
4. all Reef area coaches have 3,000-V saloon heaters.

By virtue of the common motor characteristic, coaches supplied since 1954 have very similar overall performance.

A normally loaded eight-car train (two motor-coaches) accelerates at an average rate of 1·6 km/h/sec up to 40 km/h on level tangent track and balances at 93 km/h. A similar train, but crush-loaded, is capable of accelerating up a 1 in 30 gradient with 120-m radius curves. Because of the very high ratio of crush loaded total train weight to motor coach tare weight and because load weighing is not employed, the mean accelerating tractive effort is closely restricted to avoid exceeding normal adhesion limits.

The three areas in which the coaches operate vary in height from sea level to 1,800-m altitude, while ambients can range from 0 to 40 deg C. Furthermore while much of South Africa is generally dry and dusty, the Reef area in particular suffers from a heavily dust-laden atmosphere. The lines served abound in severe gradients and sharp curves, so that speed restrictions are frequent and often are more important than train performance in determining running times.

Coach layout

All 3,000-V motor-coaches of SAR follow the same general layout of equipment. A pantograph collects power from the overhead wire and it is passed via the roof through insulator to the auxiliary and main H.T. isolating switches, located in the Auxiliary H.T. Compartment. Traction current then passes to the main H.T. compartment which houses the main H.T. switchgroup. The auxiliary H.T. compartment also houses the H.T. control protective equipment for the motor-alternator or motor-generator set, while an L.T. cupboard accommodates 110-V equipment. The balance of the coach equipment, i.e. main resistors, motor generator or alternator set, compressor and exhauster, is suspended below the coach floor.

Air for ventilation of the traction motors and for pressurisation of the H.T. compartment is drawn into the coach at roof level, passes into an air settling chamber and is then drawn through a group of nine oil-wetted panel-filters into an air intake chamber. Here it is drawn into two motor-driven axial flow fans and passes into air ducts leading to the four traction motors. A separate filter in this compartment

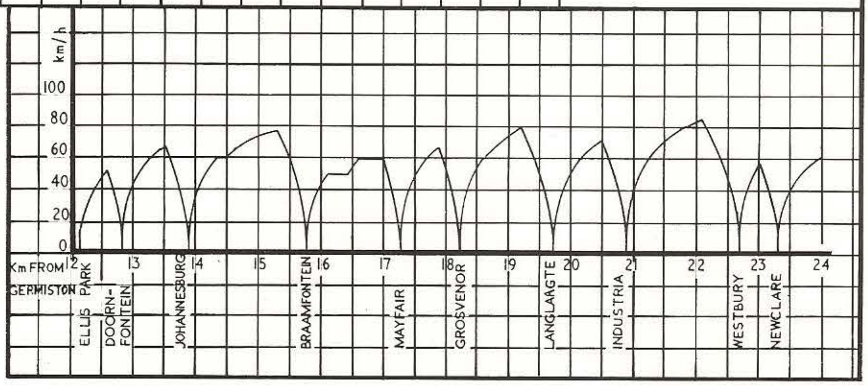
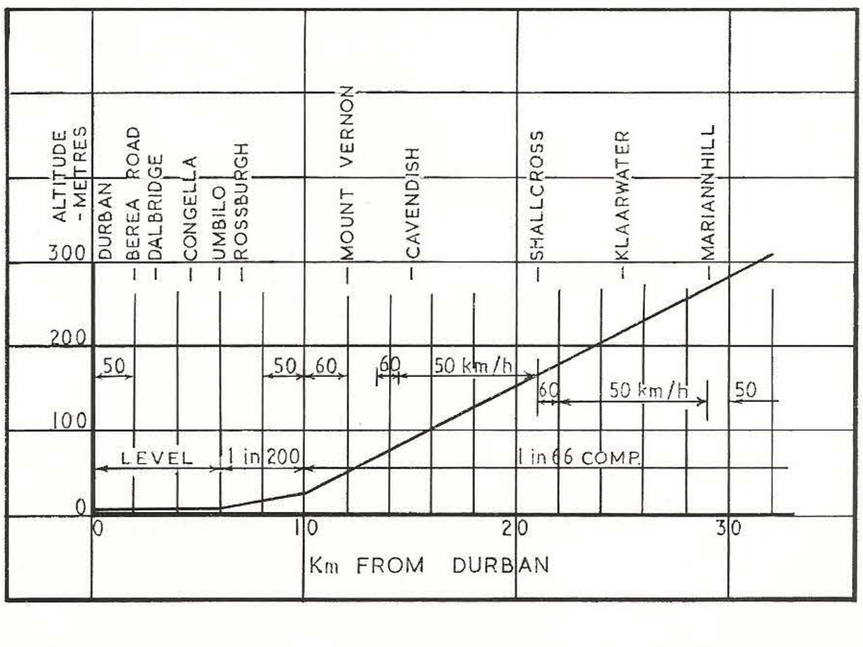


Fig. 2. *Speed/distance curves for typical routes in the Johannesburg area*

Fig. 3. *Gradient profile, from Durban towards Pietermaritzburg*



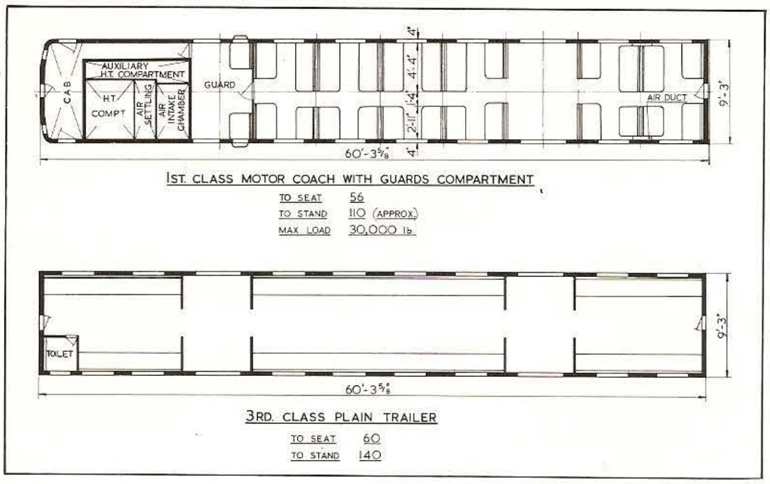


Fig. 4. *Layouts of typical motor and trailer coaches*

cleans air entering the duct to the motor generator or motor alternator set, while a separate motor driven centrifugal fan and filter panel ensures that the H.T. compartment and also the Auxiliary H.T. compartment are slightly pressurised with filtered air.

Control equipment

The pantograph is raised by compressed air and connected electrically through the roof to the high tension equipment. Inside the coach the current first passes through the auxiliary H.T. isolating switch in the Auxiliary H.T. compartment. This switch is mechanically operated, the linkage being so arranged that the switch can only be closed when the compartment door is closed and locked. Similarly, the door can only be opened after two movements of the locking handle, operated by the drivers controller key. The first movement vents the air supply to the pantograph, so that it leaves the overhead wire, and also causes the motor alternator/generator main H.T. contactor to open, whilst the second movement opens the isolating switch and also earths both the roof H.T. connection and the motor alternator/generator positive connection so that dangerous voltages cannot be produced as the machine runs down.

A similar arrangement is used for the main H.T. compartment, but if this door is unlocked a limit switch is operated which allows the control circuits to be energised and the equipment to operate for test purposes, with the H.T. supply to the equipment isolated in the locked Auxiliary H.T. compartment. The equipment can only be made live when the door is closed and fully locked, this action again requiring two movements of the locking shaft, which also operates the main H.T. isolating switch. This arrangement ensures that the auxiliary machine can be run to generate L.T. current to operate the contactors for test purposes, there being no batteries on these coaches, with all live H.T. connections behind locked doors.

Power circuit protection is given by four line-contactors connected in series. In the event of a fault, two of these contactors open in sequence inserting current-limiting resistors in the circuit and the other two contactors then open simultaneously to clear the fault. These contactors are of adequate capacity to clear the current under all ordinary fault conditions before a sub-station breaker trips.

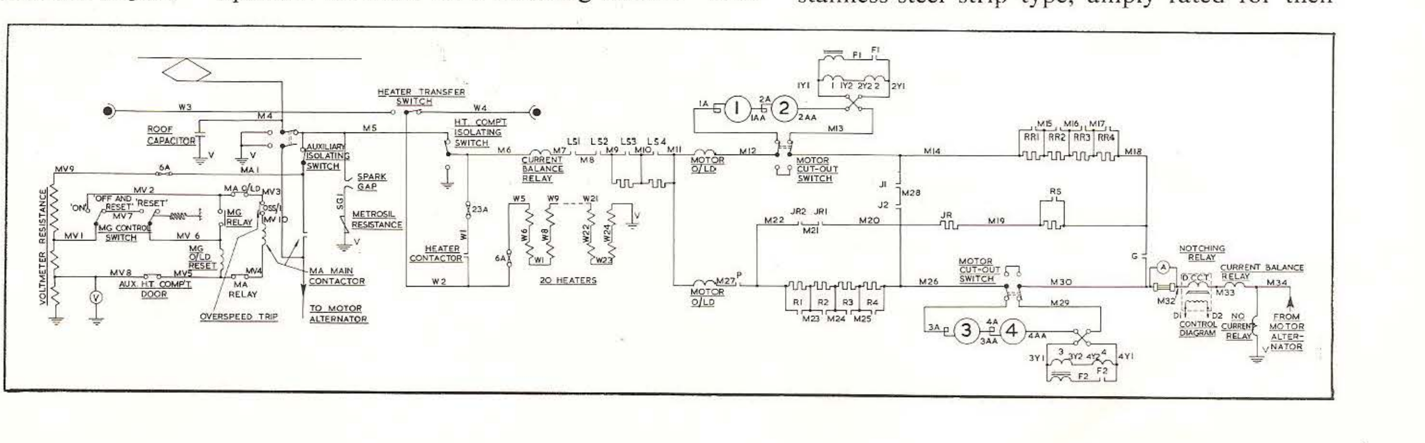
The H.T. control equipment uses electro-pneumatic contactors for line, combination and resistance switching, all these contactors being similar to each other but varying in size, blow-out characteristics and arc chute. The traction motors are connected in two permanent groups each of two motors in series and the two groups are connected either in series or parallel across the supply, transition being by the 'bridge' method. The accelerating resistors are grouped in a block of four sections in series with each pair of motors and these are progressively switched out by contactors during acceleration under the control of a static notching relay. Direction of motor rotation is controlled by an electro-pneumatically operated rotary reverser. Protection is provided against overloads, current unbalance between incoming supply and earth return circuits and loss of line voltage.

The train is controlled by the drivers master controller, situated in the cab of a motor-coach or driving trailer. This controller has two shafts, the "accelerating" shaft, whose handle incorporates the "dead man" controls and the "forward-reverse" shaft. This latter shaft is operated by a key which is removable only in the "off" position, in which position the accelerating handle is mechanically locked at "off". The mechanical interlocking also ensures that the reverse shaft cannot be moved to "off" unless the accelerating handle is also at "off". The accelerating handle has four operating positions, "shunt" (all motors and resistance in series), "series" (resistance out), "parallel full field" and "weak field" and the equipment automatically notches through to the condition selected.

A pair of traction motors can be isolated, if necessary, by the operation of a cut-out switch in the H.T. compartment.

The main resistors are of the edgewise wound stainless-steel strip type, amply rated for their

Fig. 5. *Power schematic diagram*



duties, (to cater for successive starts on the worst gradients) and separated from the coach underframe by three separate groups of insulation in series.

Thyristor ("chopper") control

Two GEC prototype thyristor-controlled motor-coaches have been running very successfully on SAR for some time, and a further 24 are on order. The attractions of this type of control lie in the notchless regulation of motor current and in the elimination of energy dissipation in accelerating resistors. These points are particularly important where the specific (train) weight per motor is high, as in South Africa.

These chopper coaches are arranged to operate in multiple with conventional contactor controlled coaches by using common control wire functions, effective accelerating currents and motor supply voltages when in the "voltage-hold" condition.

The thyristor equipment is mounted in a cubicle inside the coach body and is in two groups, each supplying two traction motors connected in series. The thyristor equipment is force ventilated, the cooling air then passing to the traction motors, an arrangement which was adopted to suit the established coach layout rather than adopt a layout involving major consequential changes.

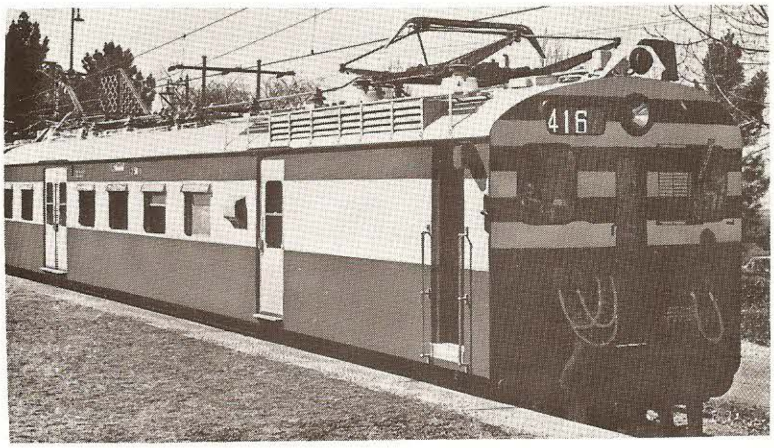
The accelerating currents are maintained at values close to the mean levels obtained with contactor control, but, of course, with much smoother acceleration because of the virtually complete absence of current variation. The initial build-up of tractive effort is at a controlled rate so that smooth break-away is combined with the ability to start on the most adverse gradients.

The reduction in energy consumption, by virtue of the elimination of resistance losses, was calculated to be of the order of 15 per cent on typical SAR services and this forecast has been confirmed by test runs.

Inductive diverts for traction motor field diversion are replaced by cheaper resistive diverts, because of the protection given to the traction motors against line voltage surges by the filter equipment, while maintenance costs are reduced by the elimination of resistance contactors with their wearing parts.

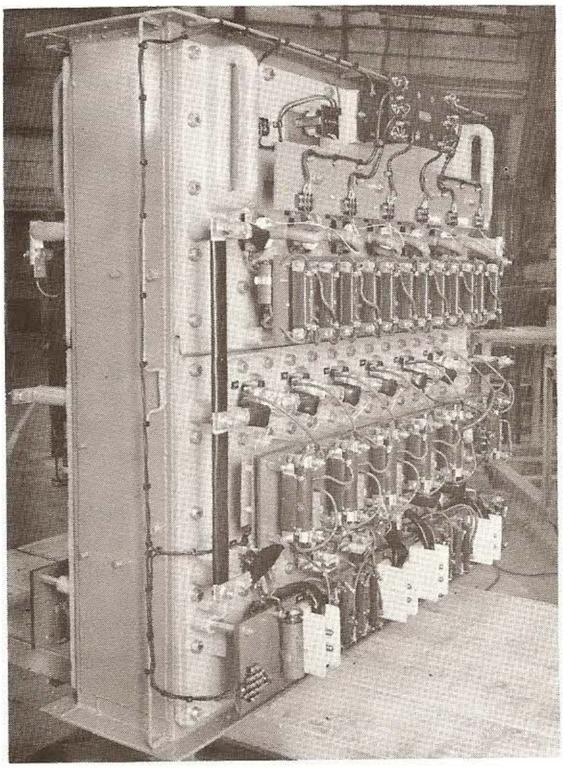
Line switches are retained for fault clearance and the supply to the d.c. switch units is via an inductive-capacitive filter. The d.c. switch units consist of a number of series connected devices together with their appropriate sharing and commutation circuits.

D.C. current monitoring devices provide the current feed-back for the control system and also operate as overcurrent detectors. The control system operates by varying the mark/space ratio of the main thyristors so as to hold the motor current at the correct value for the performance required, until a voltage hold limit is reached, corresponding to the controller position selected. At this point the mark/space ratio is held constant, so that the traction motors then run along a near constant voltage characteristic.

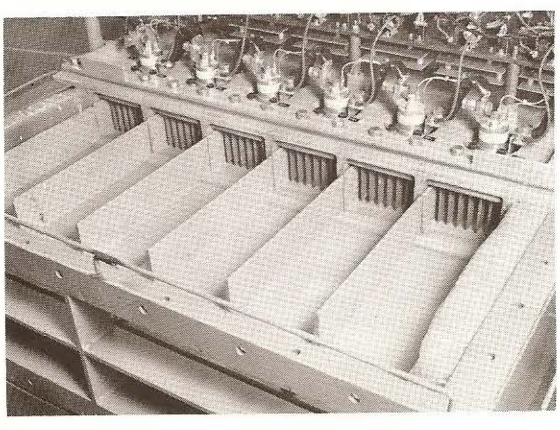


Chopper-controlled 3,000 V d.c. electric multiple-unit power-coach, one of two which have run successful prototype trials

All the auxiliary services on these trains operate at 110 V d.c. and this is supplied either by a motor generator set, on earlier trains, or by a motor alternator rectifier set, on motor coaches now being supplied. In view of the vulnerability of relatively small high voltage machines to damage in the event of a lightning incident, a single motor generator set must, in emergency, supply the compressors, exhausters, traction motor blower/booster fans, control and partial lighting load of an 8 car train. This requirement determined the rating of the motor generator set.



Main thyristor equipment frame



Part of the thyristor frame showing the arrangement of the cooling fins

The recent change to a motor alternator rectifier set for this purpose enables a higher capacity machine to be accommodated to cope with possible heavier auxiliary loads in future. A system of d.c. bus lines ensures that MA or MG sets cannot be paralleled. The output of the generator or alternator rectifier is maintained constant at 110V d.c. by a static voltage regulator of GEC type 20RG11B2 over a very wide range of line voltages and auxiliary loads.

Traction motor

The traction motors of all SAR 3,000 V electric multiple-unit stock have the same effective characteristic and show considerable interchangeability as complete units, but over the years various changes have been made to improve the service performance and reduce maintenance requirements. Thus the insulation system used has progressively advanced from Class B on the earliest motors to the current Class H with Kapton insulated armature conductors and Class F epoxy-bonded field coils. The original sleeve suspension bearings have been replaced by roller-bearings, a radial armature-winding is now used and various other detail improvements have been made. Each motor drives its axle through a keyed pinion and a resilient gearwheel.

Each motor-coach carries a compressor, to supply compressed air for the operation of control equipment and power doors and an exhauster, for the vacuum brake system, in addition to the traction motor blower/booster fans and H.T. compartment pressurising fan already mentioned, all these being driven by 110 V d.c. motors. The Westinghouse DH16 compressor is of the two cylinder, single stage low speed type gear driven by an integral motor.

The Reavell R6X8S rotary exhauster is bedplate mounted and driven by a separate motor. It is arranged to run at two speeds, 'normal' with the motor in full field, to maintain vacuum and 'high speed' with the motor in weak field, for rapid vacuum creation to release the brakes. This exhauster employs a forced lubrication system for the bearings and rotor system and the original total loss system has been replaced by a combined oil separator/silencer. The exhaust is passed through the separator, where the entrained oil is collected on wire mesh, falls to the bottom and is recirculated through the mechanical lubricator. Use of this system has resulted in a great saving in oil consumption and in the cleanliness of the area surrounding the exhauster outlet.

These coaches are fitted with an electro-vacuum brake system, which is generally similar to the conventional single pipe automatic vacuum system but with the addition of electrically-operated admission valves to give simultaneous brake application down the whole train instead of the delayed propagation when air is admitted only at the drivers brake valve. Contacts in the brake valve ensure that the exhausters are speeded up when the handle is moved to the release position.

Coach heating and lighting

The Reef area is subject to temperatures falling to 0 deg. C and so coaches operating in this area are fitted with coach heaters. These are fed from the 3,000-V line, all the heaters in one coach being connected in series. Each motor coach can supply in addition upto three trailers, through a heating contactor and 3,000-V jumper connections. Interlocking is provided on the heater jumpers and individual coach heating fuse boxes to ensure that a motor coach supplies heating to trailers at one end only, and removal of a plug will open the heating contactor before the plug breaks the circuit. Removal of a coach heating fuse box lid will also open the heating contactor before access to the box interior is possible. The remote socket must have its cover closed. The heaters operate under the control of a thermostat in the motor coach saloon.

The third class coaches have incandescent lighting, but the saloons of the first class coaches have d.c. fluorescent lights. To avoid blackening of the tubes at one end, polarity reversal relays are fitted so that the tube polarity is controlled by the direction of travel and so is reversed at the end of each run.

Electric multiple-units for SAR powered by GEC Traction

Number	Equipment and location	Date ordered
Motor Coaches		
95	1,500-V d.c. power equipment (later converted to 3,000-V)	1927/1938
54	900 kW, Reef system	1944
52	940 kW, Cape Western system	1950
20	940 kW, Cape Western system	1952
105	940 kW, Reef system	1955
6	940 kW, Cape Western system	1956
141	940 kW, Cape and Reef systems	1960
15	1,190 kW, Reef systems	1963
80	1,190 kW	1964
70	1,190 kW	1965
98	1,190 kW	1967
55	1,190 kW	1968
69	1,190 kW	1969
2	1,190 kW (Chopper control)	1970
70	1,190 kW	1971
76	1,190 kW	1972
95	1,190 kW	1973
24	1,190 kW (Chopper control)	1973
1127 total		
Trailer cars		
2507 total		

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