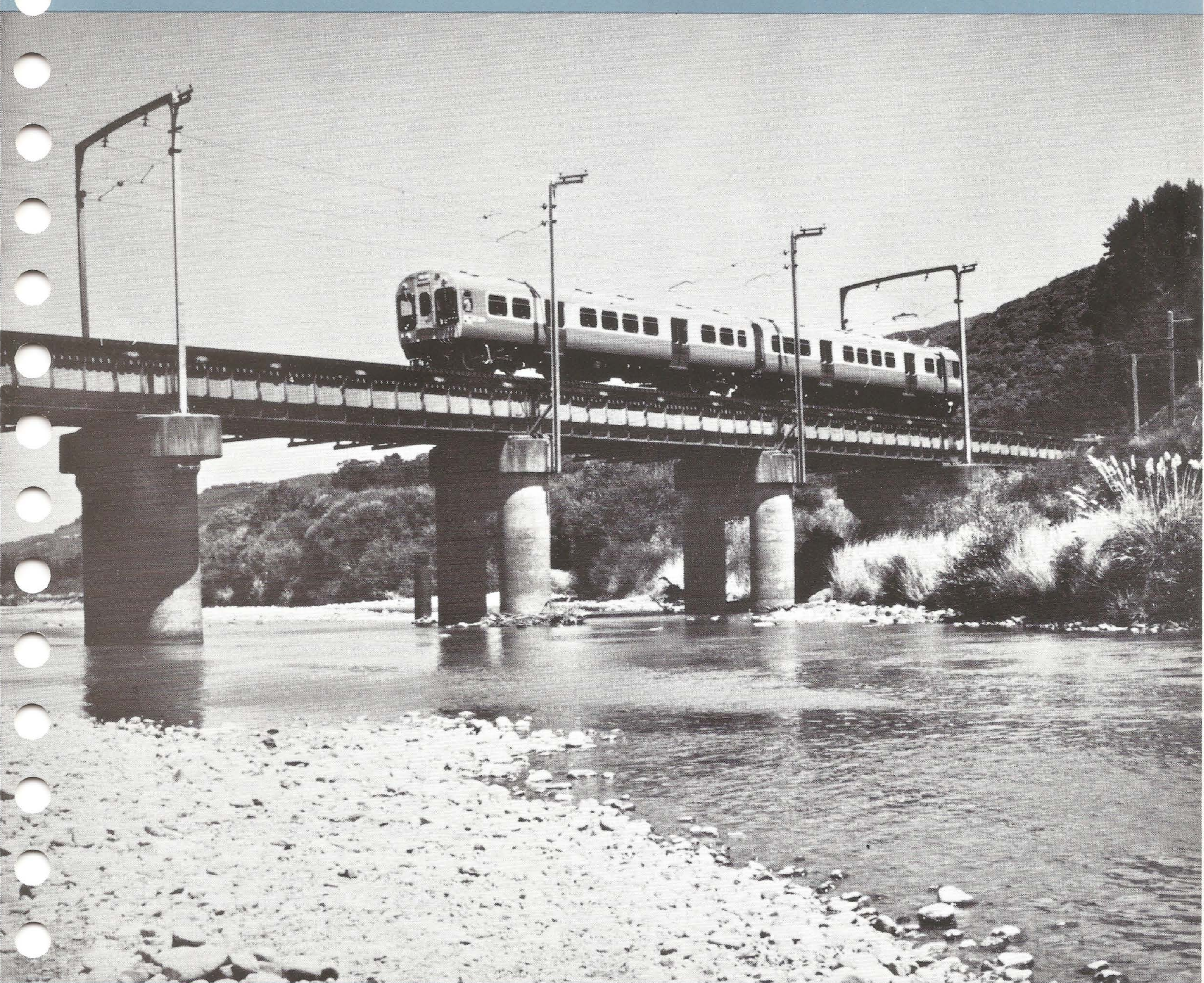
GEC
TRACTION

PROPULSION EQUIPMENT FOR

electric multiple unit trains

FOR NEW ZEALAND RAILWAYS

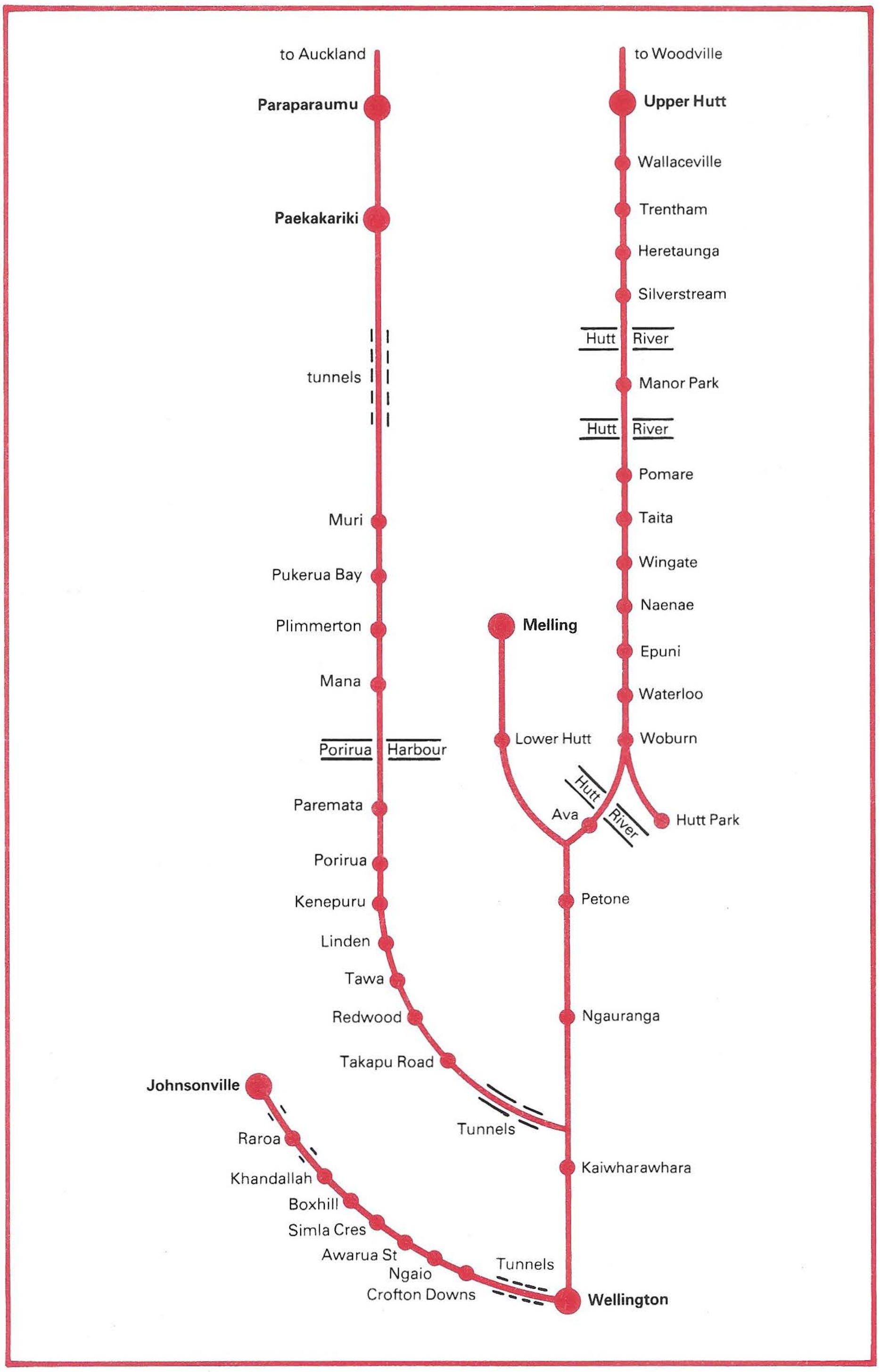


Introduction

Forty-four two-car electric multiple units are currently under construction for the New Zealand Government Railways, for use on the Wellington area suburban system. The electrical equipment has been designed and built by GEC Traction Ltd. in England. The coachwork and other mechanical parts are being designed and fabricated by Ganz Mavag of Hungary, at their Budapest factory with the compressor, doorgear and brake equipment being supplied by Westinghouse Brake & Signal Company.

The project renews earlier associations between GEC Traction and New Zealand Railways (which date back to the early 1920's when they introduced electric traction to New Zealand and the 1950's for diesel locomotives) and between GEC Traction and Ganz Mavag (for the diesel-electric *Transandino* trains supplied to the Argentine in 1961).

1 Schematic diagram of the Wellington electrified railway system.



The Wellington suburban system

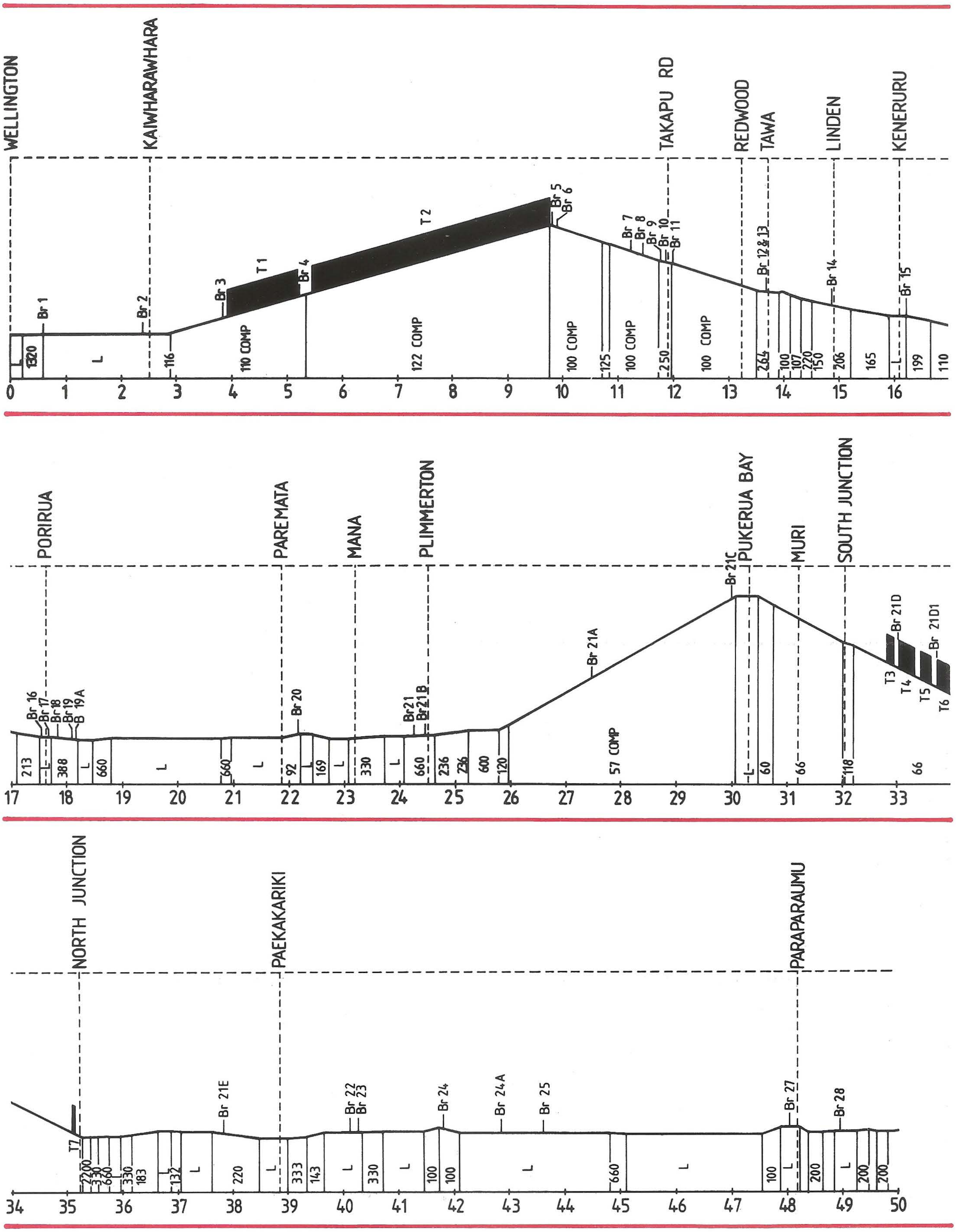
The Wellington suburban system covers three main routes to Johnsonville, Paekakariki and the Hutt Valley. The first service was that to Johnsonville, the line being electrified in 1938 at 1500V dc. This line was originally part of the North Island Main Trunk (NIMT), but was isolated following construction of a deviation from Kaiwharawhara to Tawa. This deviation, which was started in 1934, was also electrified at 1500V dc through to Paekakariki from Wellington in 1940. Two orders for suburban trains were placed with the English Electric Company, in 1937 and 1942. A total of nine motor coaches and eight trailer coaches were supplied, normally formed into two-car units for the steeply graded Johnsonville line which has a ruling gradient of 1 in 36 (2.8%), with many curves of 200m radius and five tunnels of limited clearance.

Trains through to Paekakariki were all locomotive hauled, ten 1,240 hp (925 kW) 2-Do-1 locomotives built by English Electric in 1938 being sufficient to handle all passenger and freight traffic. When the decision was taken to electrify the Hutt Valley lines in 1946, a further forty motor-coaches and seventy one trailer coaches were ordered from English Electric. These were similar to the Johnsonville trains but made up into both two and three-car units. The first of these trains, which arrived in 1949, were used on the Paekakariki line since the Hutt Valley lines were not then electrified. When Hutt Valley services began to Taita in 1953 and Upper Hutt in 1955, the trains ordered for this route continued to operate some services to Porirua and Paekakariki. This meant that many peak hour trains still continued to be formed of pre-war coaches hauled by locomotives. Seven 1,800 hp (1340 kW) locomotives were also ordered from English Electric in 1951 for use on heavier NIMT trains from Paekakariki, but now that diesel locomotives work these trains through to Wellington these Bo-Bo-Bo locomotives are seldom used on other than suburban trains.

A new extension to the electrified system is presently under way between Paekakariki and Paraparaumu. This 9½ km section of the NIMT will be the first electrification on New Zealand Railways for over 25 years. At present there are three through trains each weekday between Paraparaumu and Wellington in peak hours only, which involve hauling coaches or electric suburban units by diesel locomotive from Paekakariki. Electrification will dispense with this complex arrangement and allow a faster, more frequent service of electric trains to be run.

The new Ganz Mavag/GEC units will allow withdrawal of the remaining locomotive-hauled trains and some of the original suburban units. These new trains will operate chiefly on the Paekakariki line, but will also be used on some Hutt Valley services. The longer length of the new coaches, however, means that because of the more restricted loading gauge they cannot use the Johnsonville line.

2 Profile of the Paekakariki route.



Train formation

The new suburban trains are two-car units, consisting of a driving motor car semi-permanently coupled to a driving trailer car. Up to four two-car units are capable of being operated in multiple. A new eight-car formation will seat 592, compared with 600 in a maximum nine-car formation of old stock. The motor car has a luggage compartment, located behind the driver's cab, which is able to carry up to 500 kg. The train guard is accommodated in a section of the luggage compartment, where a tip-up seat and desk are provided for his use. In common with existing stock, four double-leaf sliding doors are provided, two per side. These are air operated, and are controlled by the guard from any door position using a special key, or from the main control panel in the guard's compartment. At this latter panel, the guard also has control of heating and lighting throughout the train. A portable, lightweight ramp is stored in the luggage compartment to aid access to the train for passengers in wheelchairs. Two tip-up seats are provided in the saloon to locate the wheelchairs for the comfort of such passengers.

The trailer cars contain most of the auxiliary equipment, including the compressor, the motor-alternator set and their associated control equipment. The passenger accommodation of the trailers is similar to that of the motor cars, having fixed seating facing the driving positions. Ventilation on all cars is provided by hopper-type window openings and heating is by underseat heaters. Since there is no luggage compartment on the trailer car there are more seats – 78 compared with 70 in the motor car.

Driving position

Every effort has been made on the new trains to design the layout of the cab to minimise driver fatigue; a consultant ergonomist and the NZ Locomotive Engineer's Association assisted at the design stage. All main controls and indicators needing repeated use while the train is *in service* are located on the desk directly in front of the driver. Secondary functions, only needed while the train is being prepared for service, are located at a high level above the cab window. Other equipment, normally used only by maintenance staff, is built into the electrical control cabinet at the back of the cab. Here are located the controls for motor cut-out, control circuit protection and isolating switches, and control equipment for heating, lighting and doorgear.

The master-controller combines power and brake control into one handle. From a central *off* or *coasting* position power is obtained by pushing the handle forward, and braking by pulling the handle back. A second handle selects *forward, reverse, off,* or *isolated.* A third handle locks the controller when not in use. Mechanical interlocking is provided between all handles to prevent improper sequences being selected. When a cab is not in use the controller is left isolated in brake position 6. The key cannot be removed or inserted at any other position, and this ensures that brakes are left on when the train is shut down.

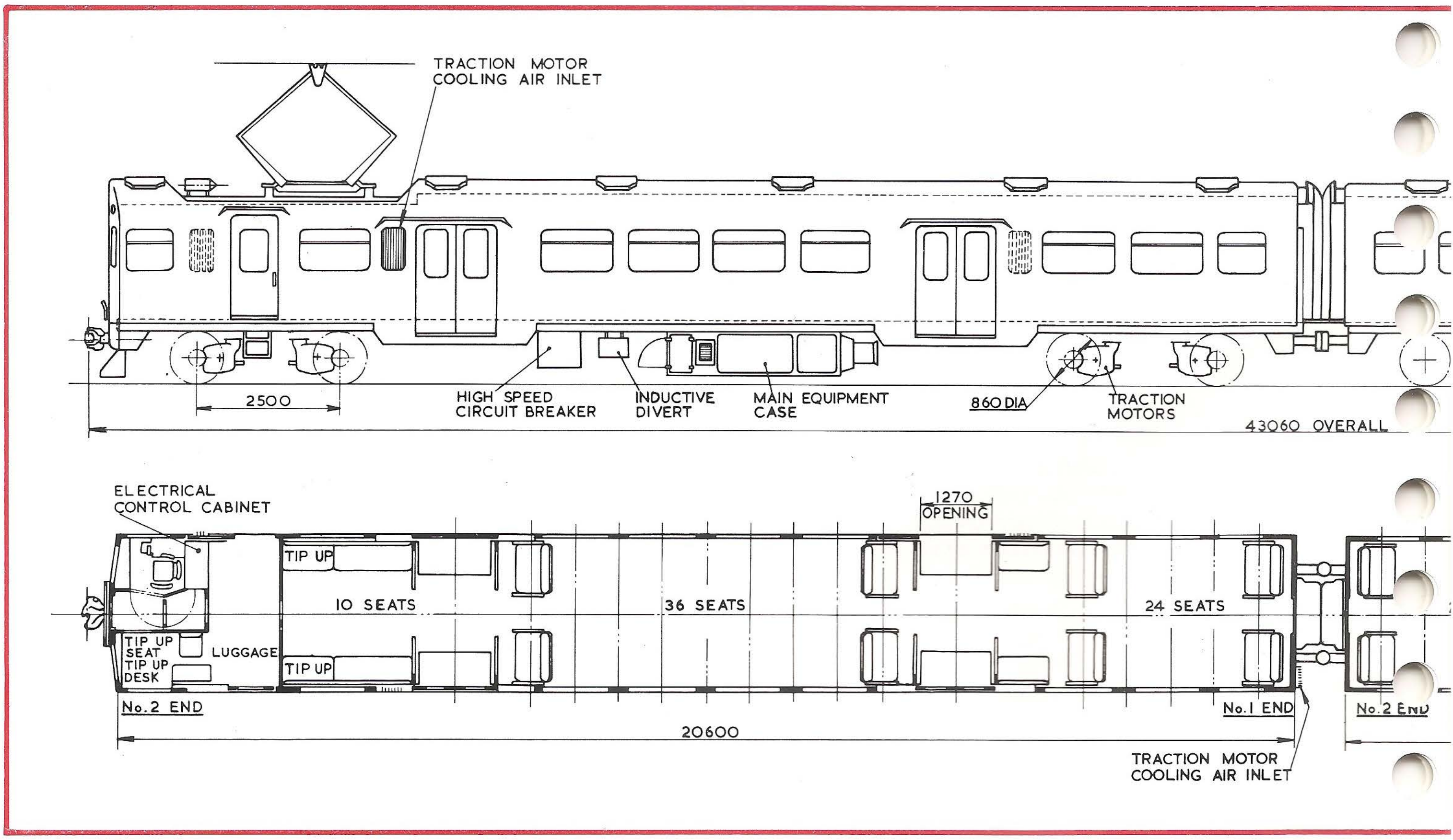
Performance

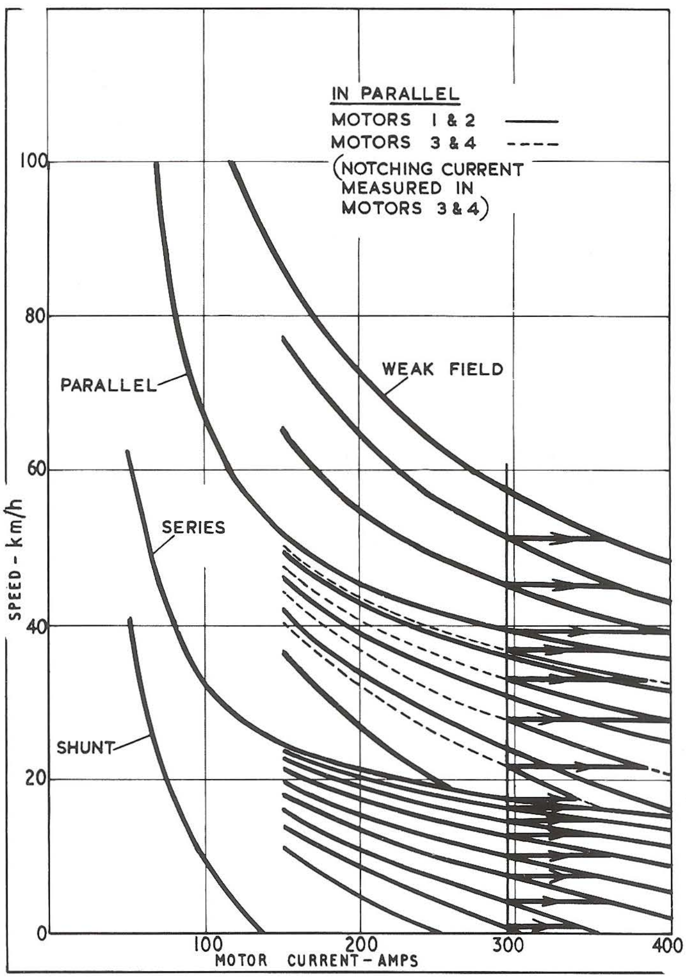
The Wellington area services, by their very nature, have frequent stops, so to maintain good overall timings a high rate of acceleration is called for. This rate is $0.75 m/s^2$ up to 40 km/h and an average $0.44 m/s^2$ from start to 80 km/h. The present maximum operating speed will be 80 km/h, this being mainly limited by a combination of close station spacings and track curvature. The trains have been designed to run at speeds of up to 100 km/h, however, to take advantage of future track improvements.

An essential requirement is for the trains to be able to maintain 80 km/h on the 1 in 110 (0.9%) gradient in the tunnels between Wellington and Tawa. Even when there is only one working motor car in a four car formation, such a train can start on the 1 in 57 (1.57%) gradient between Plimmerton and Pukerua Bay and reach a balancing speed of 72 km/h. The most severe service start is at Muri, on a 1 in 66 (1.5%) grade and a 200 m radius reverse curve. The level of braking called for is a maximum of $1.0 m/s^2$, and the trains must be able to stop from 100 km/h within 460 m, to comply with signalling limitations.

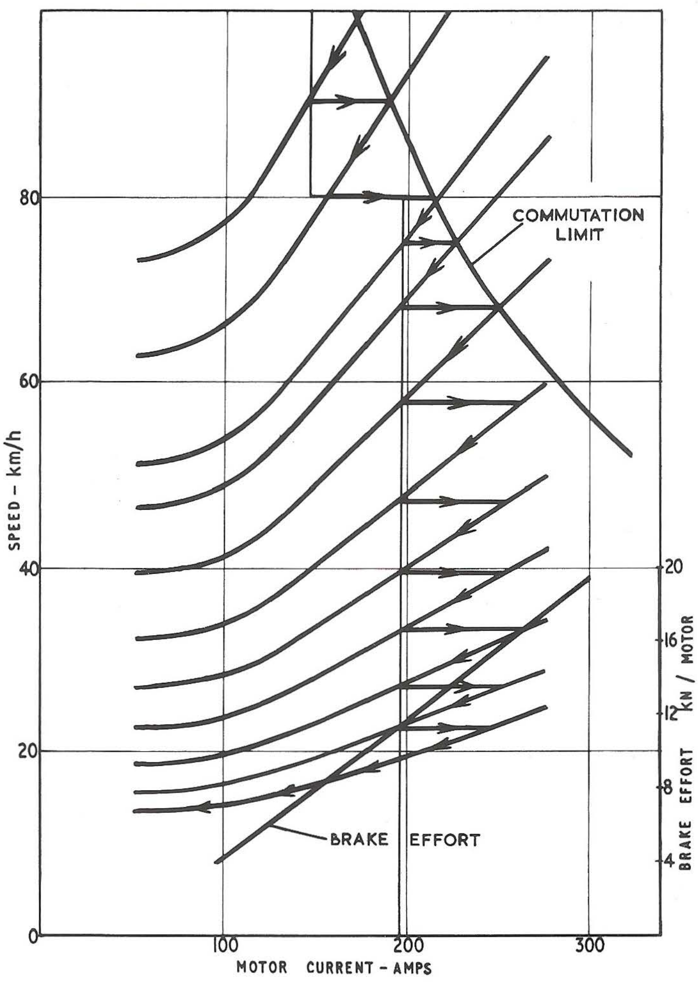
High acceleration with a high maximum speed will mean the trains will give an improved performance on *all-station* stopping trains as well as the peak hour *limited-stop* trains. Some of the latter run non-stop from Wellington to Porirua, a distance of 17 km, over which much 80 km/h running should be possible.

3 General arrangement of a two car train showing disposition of the electrical equipment.

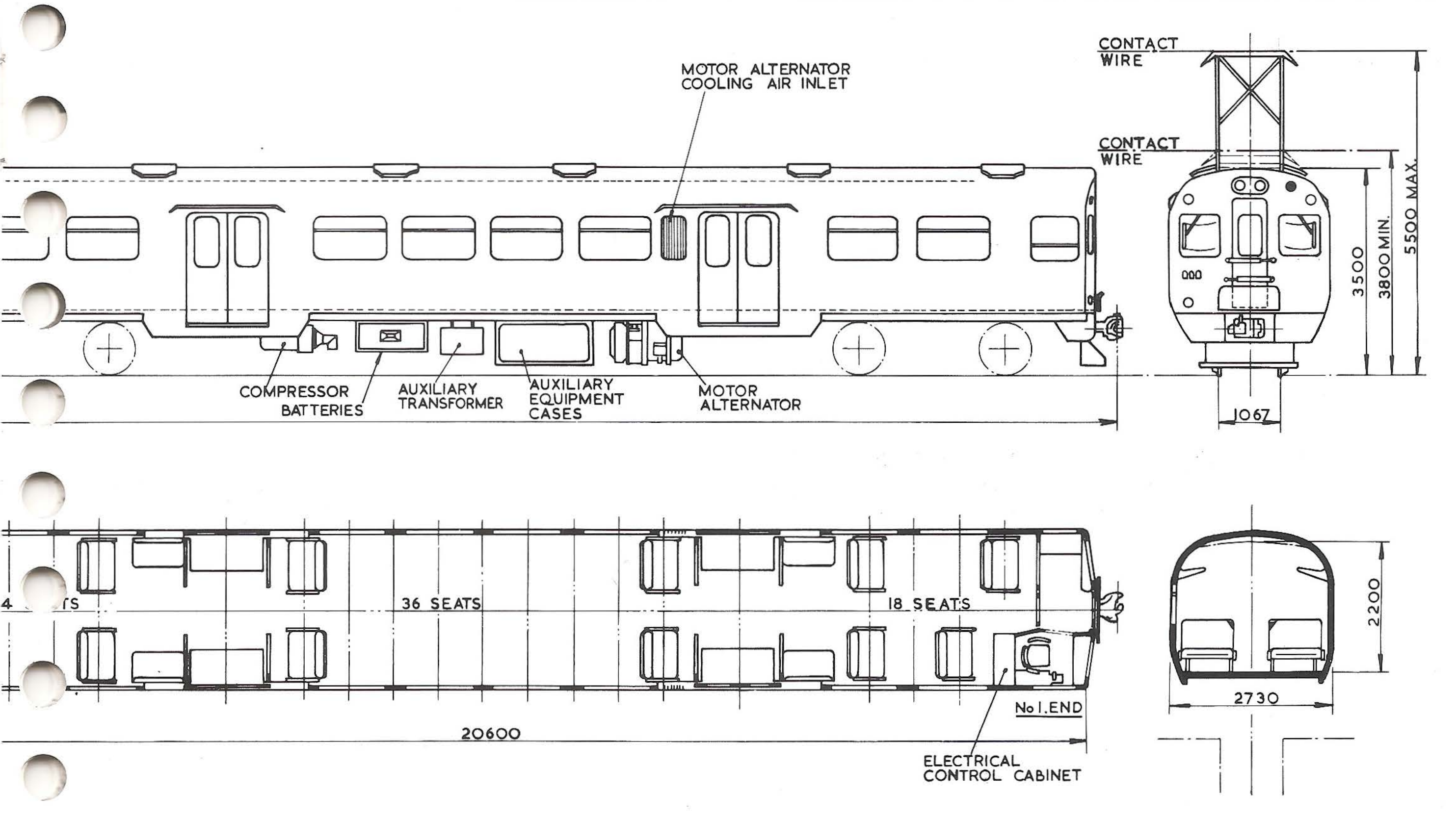




4 Train performance – motoring.



5 Train performance during braking.



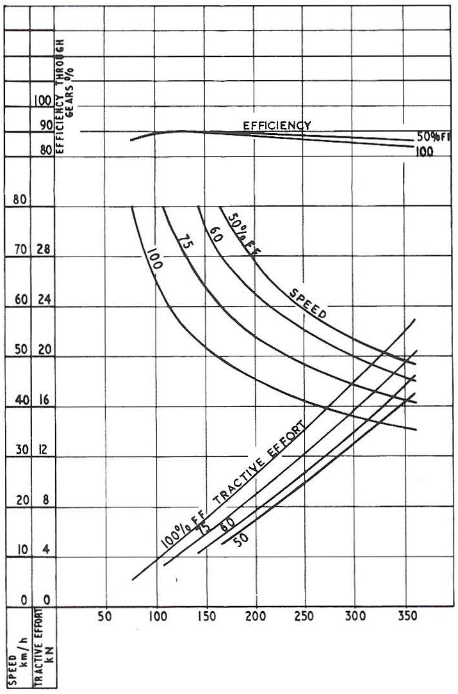
Traction equipment

Each motor car is powered by four GEC type G316AZ traction motors, continuously rated at 100 kW. This motor is a development of the G310AZ extensively used in the latest 1435 mm gauge suburban trains on British Rail, and altered specifically to suit the 1067 mm gauge of the New Zealand Railways. The G316AZ is a four-pole, wave-wound series machine, the armature being insulated with Kapton (Class H) and the fields epoxy insulated and bonded (Class F). Armature windings are TIG welded to the commutator risers. The motor is self-ventilated, filtered air being drawn through ducts from high up on the coach side and exhausted at the drive end of the motor frame.

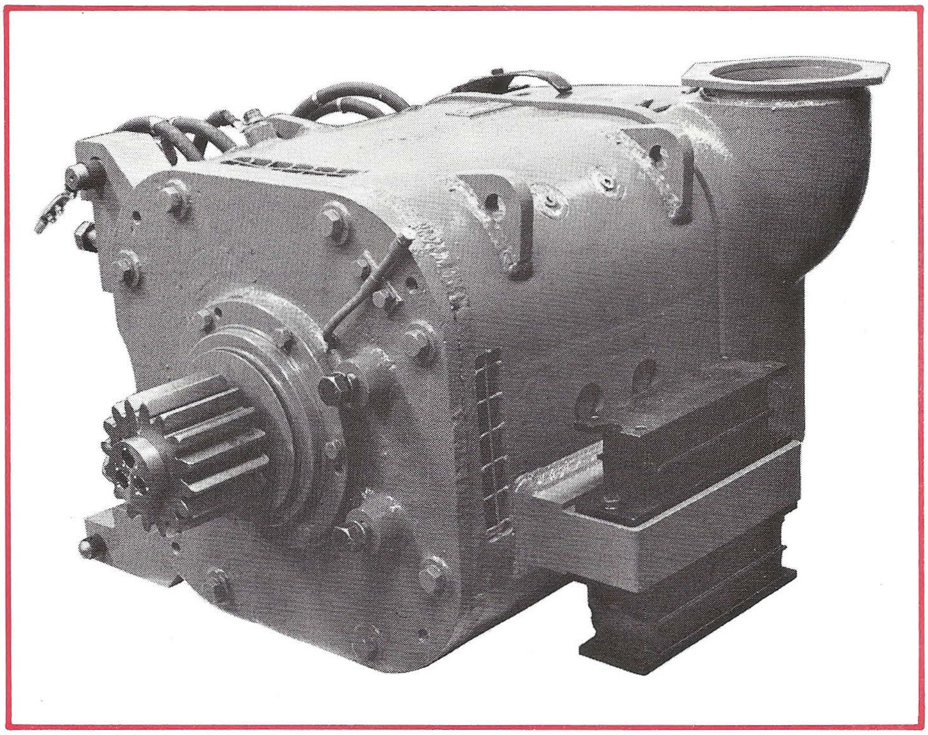
The motors are nose-suspended using a rubber sandwich spring unit. Motor suspension on the axle is by a roller bearing "U" tube, spigotted and bolted to the motor frame. An earth return brush is mounted on the suspension unit to provide a path for traction current to earth through the axle. Transmission is by a pinion, shrunk onto the motor drive shaft, to a reduction gearwheel on the motor.

The traction motors are rated for a nominal 750V and the two motors on each bogie are connected in series pairs. Series/parallel control with bridge transition is employed together with force-ventilated accelerating (and braking) resistances. There are three stages of field weakening.

Control of the power circuit contactors and resistances is achieved using an air/oil engine driven camshaft controller, this in turn

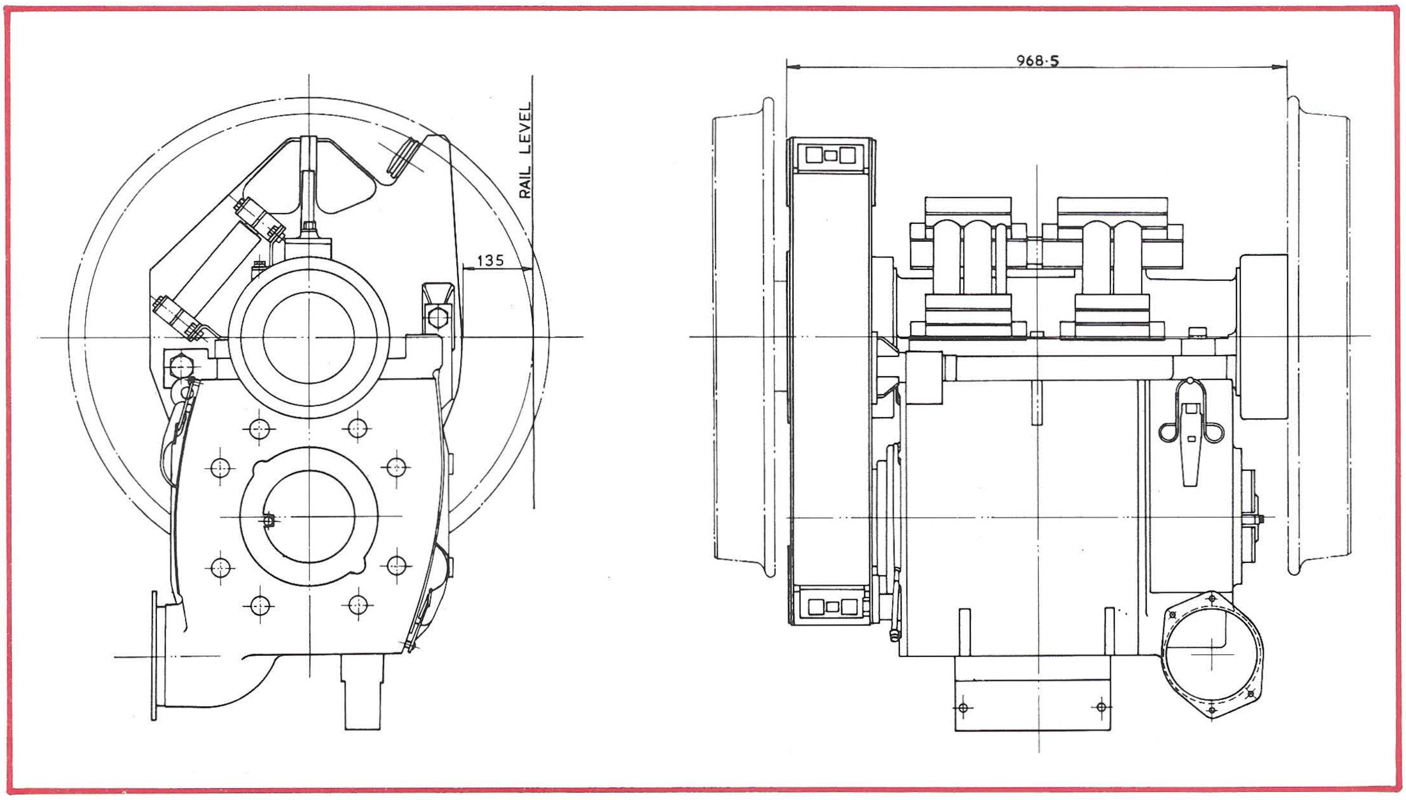


6 Performance curve of the G316 traction motor.

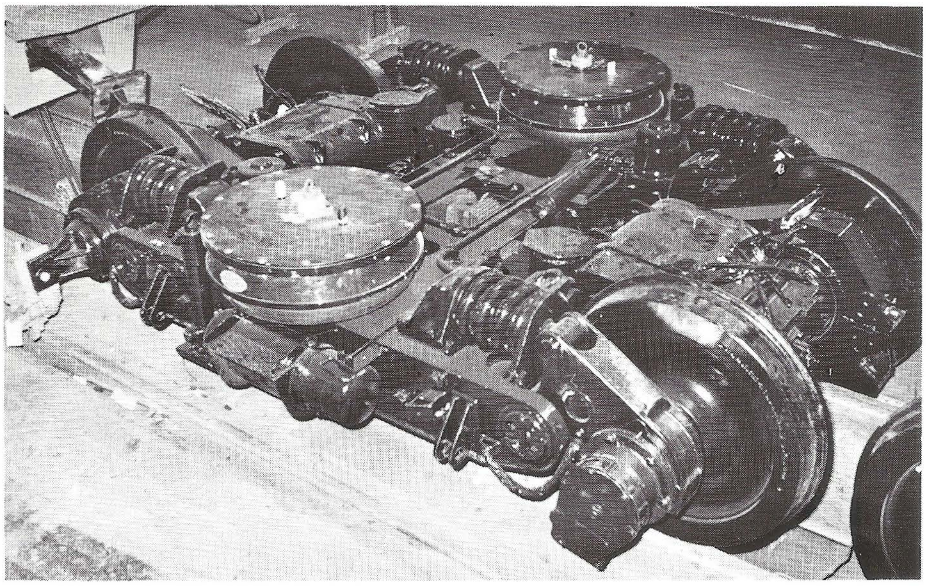


7 G316 traction motor.

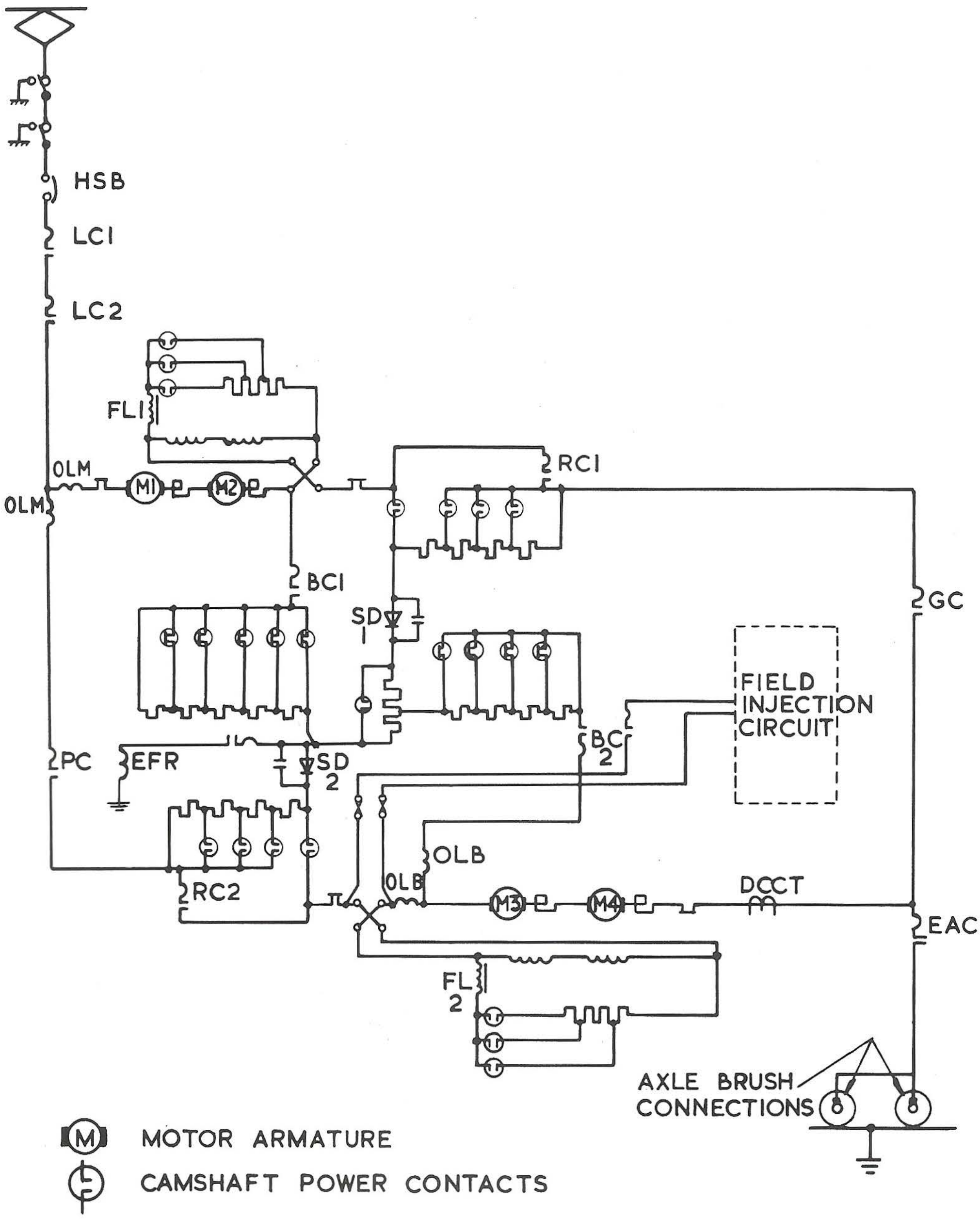
8 General arrangement of the G316 traction motor.



being controlled by an electronic Static Notching Relay (SNR). The SNR monitors the current in the power circuit and compares it with the value demanded by load weighing. When the motor current falls below the demanded level an SNR output allows the camshaft to move on a notch. There are 18 notches or acceleration steps in all. The load-weighing is achieved by a transducer in the SNR which monitors the air suspension bag pressure and in this way it varies the notching current according to the train weight, so keeping acceleration rate constant.

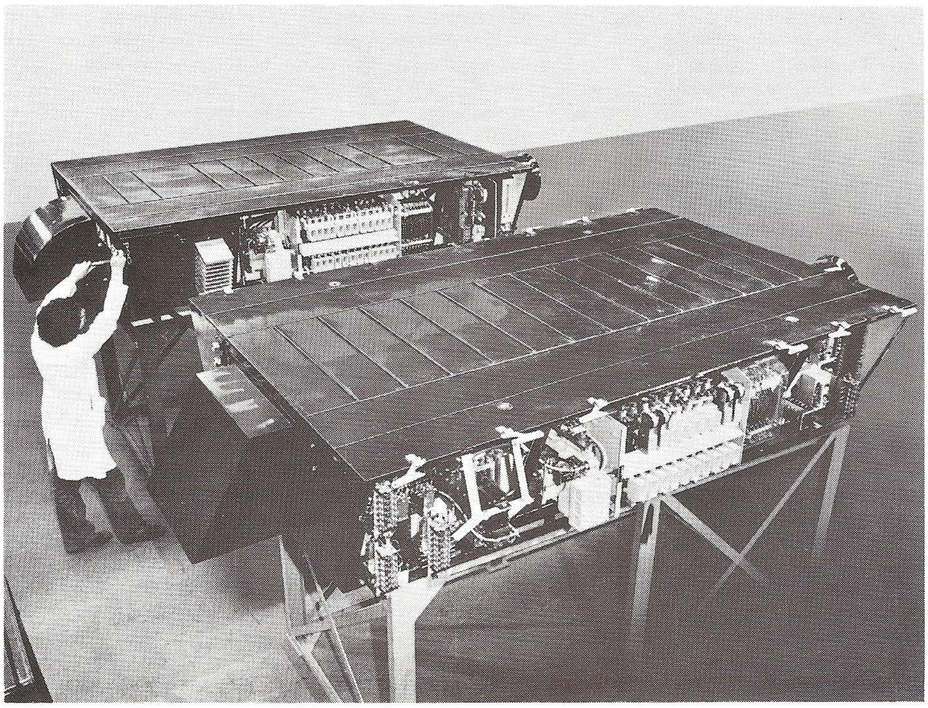


9 Power schematic diagram.



The camshaft and other control devices which govern the power circuit are contained in an underframe equipment case. This is of the full-width *pannier* type, having the resistances in frames mounted in a central portion of the case, and the power equipment mounted at each side and easily accessible for maintenance. This type of case and the control equipment is similar to many others already supplied to British Rail, the Tyne & Wear Metro, Hong Kong Mass Transit and VicRail suburban units during recent years.

10 Full width pannier cases on final assembly.



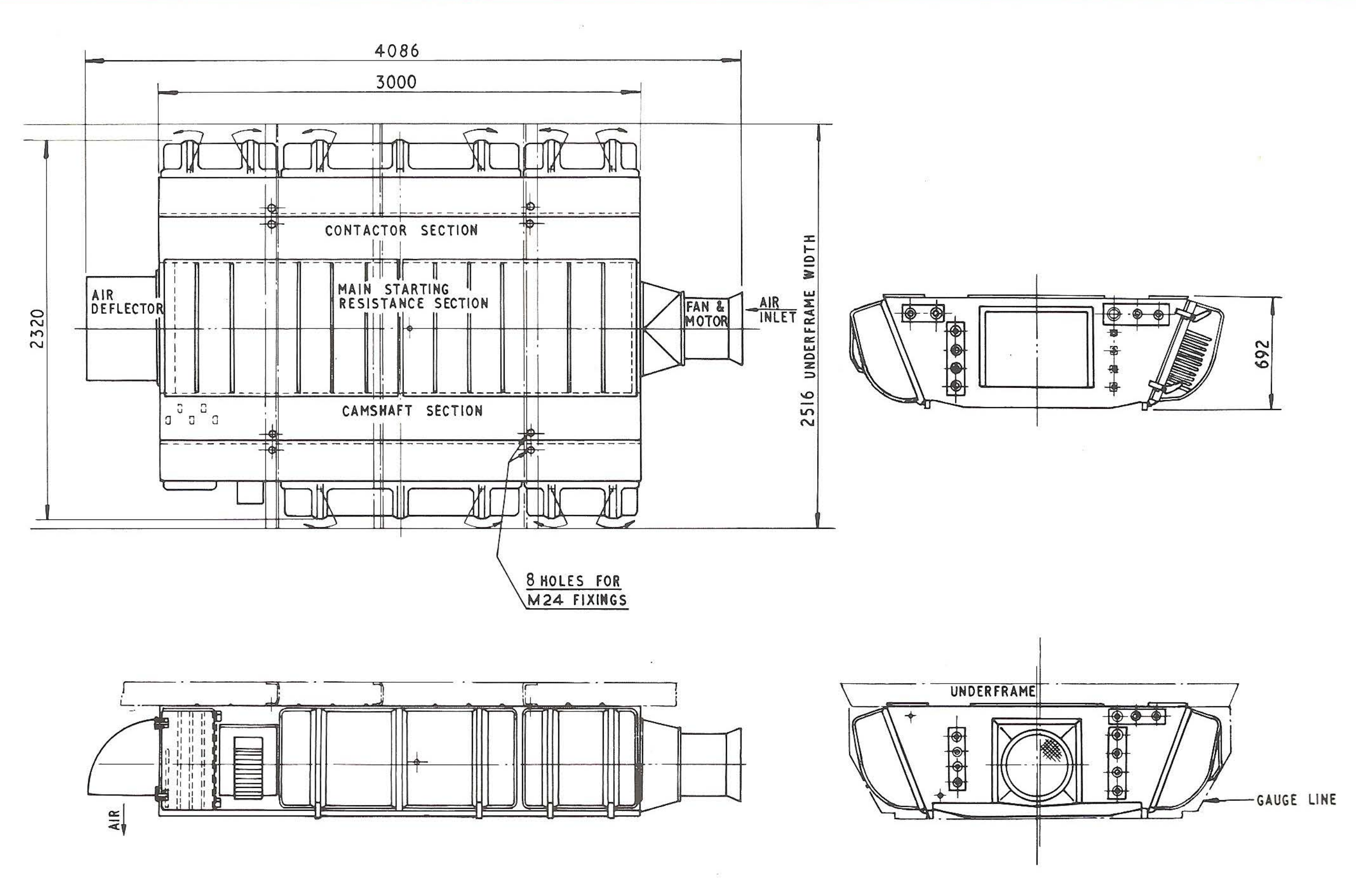
Supply and protection

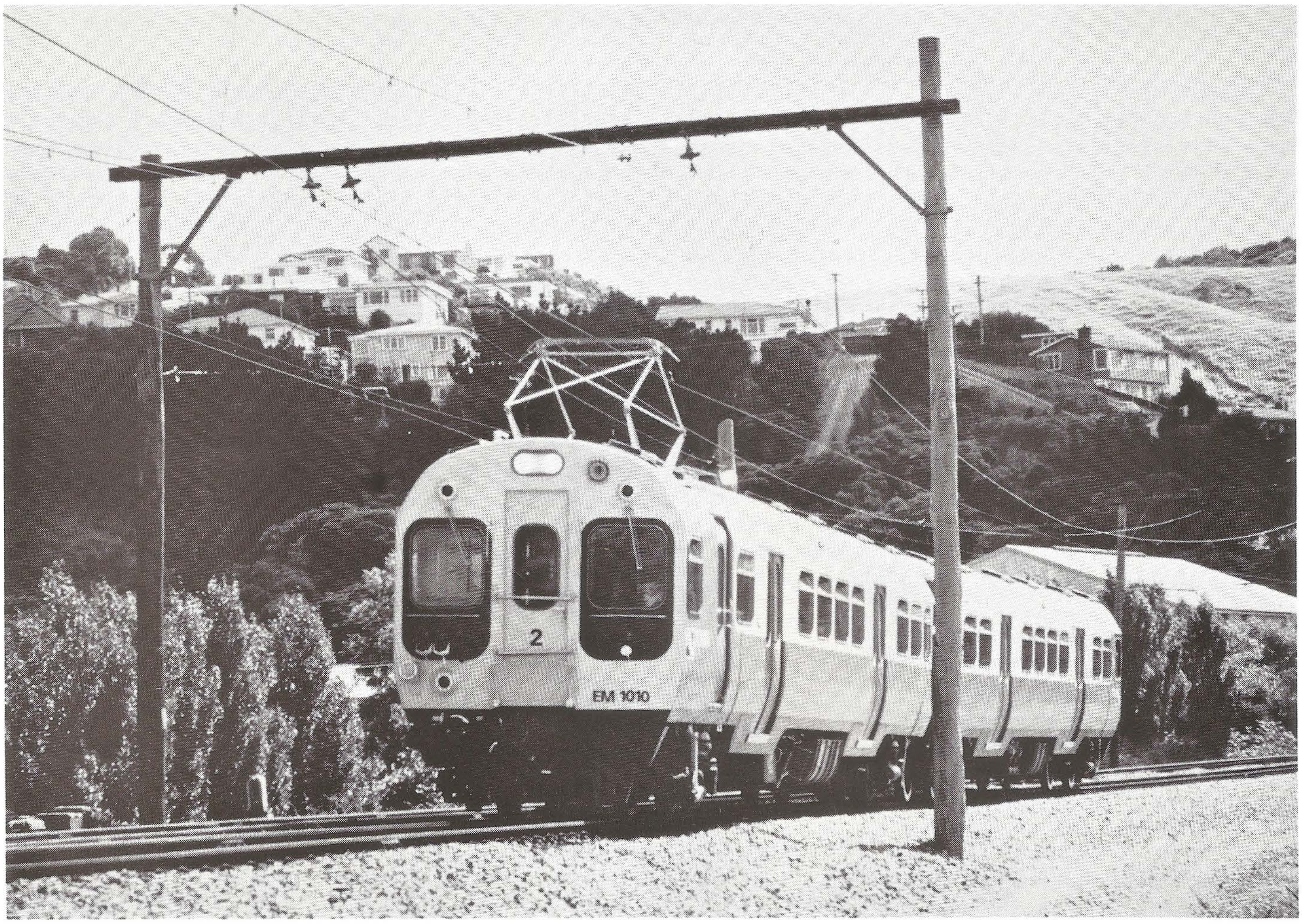
The power supply for the train is collected from the 1500V overhead line using a GEC type 14PP pantograph, mounted at the driving end of the motor coach. A dc surge arrestor is mounted adjacent to the pantograph to protect against voltage surges on the line due to lightning. The pantograph cable is brought down to an HV cubicle in the driver's cab, containing fuses for the motor-alternator and compressor and also isolating switches for traction and auxiliary circuits.

The main power circuit protection is the High Speed Breaker (HSB). This is mounted separately on the underframe, and its operating time is proportional to rate of rise of current. For a di/dt of 5×10^6 Amp/sec, the total operating time is 12 milliseconds at a trip value of 900 Amps. The fast operation will minimise damage to traction motor if a flash-over were to occur. Second-level protection is by a magnetic overload relay in the main equipment case. This will trip the HSB, rather than open the line contactors as is the more usual case. A similar magnetic overload relay is used in the braking circuit which opens the brake contactors in the event of abnormal current.

All 400/230V ac and 110V dc auxiliary circuits are protected by moulded case miniature circuit breakers. Fuse protection is provided on the battery and on the control busbar.

11 General arrangement of the full-width pannier case.

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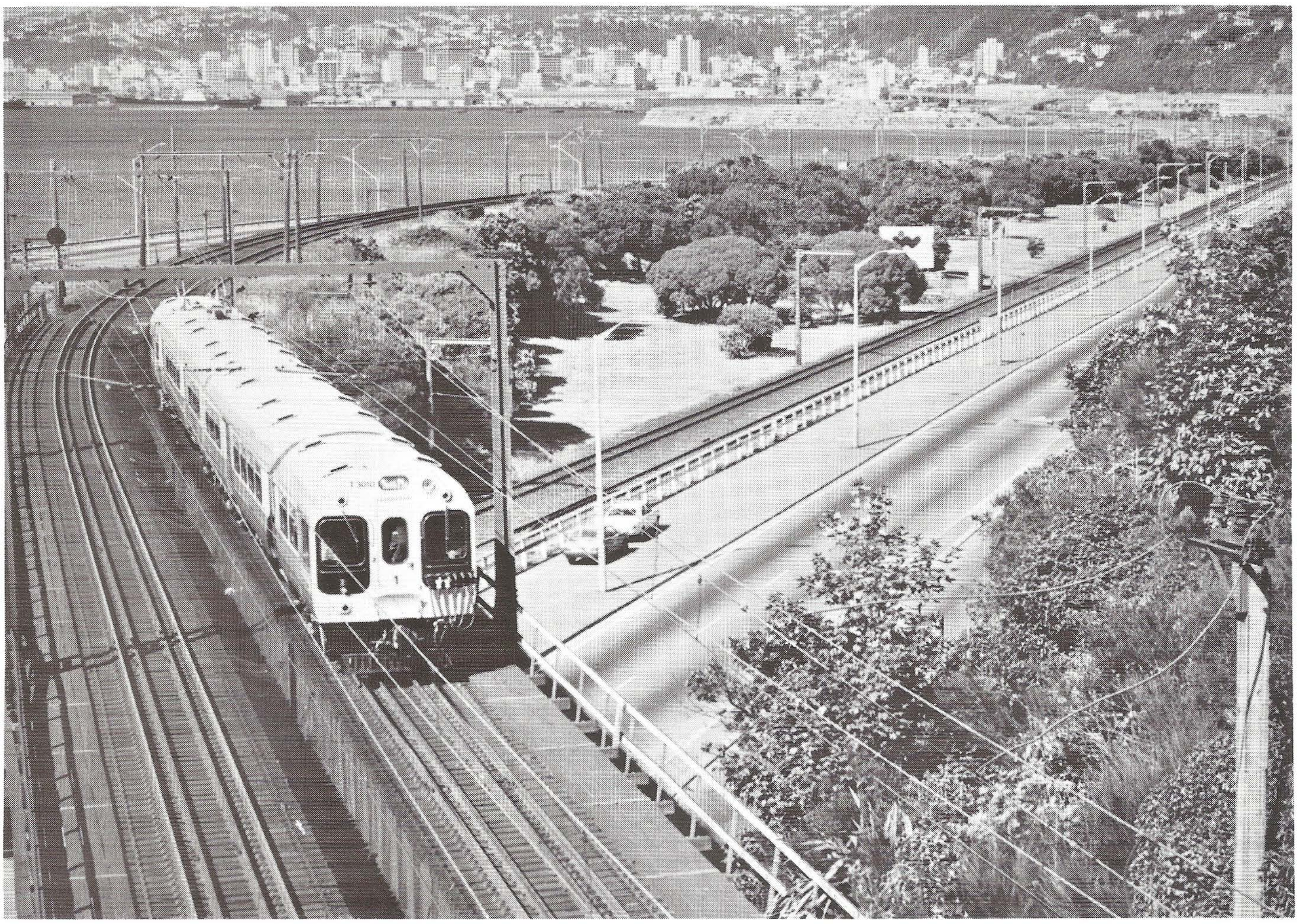


Braking system

The brake system used on the trains is the Westinghouse "Westcode 3+ 3" developed specially for the requirements of New Zealand Railways. This unique system gives six steps of braking corresponding to the six brake positions on the master controller.

In the first three positions, three steps of rheostatic braking are employed, with no brake at all on the trailer. In the next three positions, full electric brake is held on the motor car and three steps of EP brake are applied on the trailer. This has the advantage that for most service applications, only rheostatic brake will be used. It will mean brake wear will be greatly reduced, giving lower maintenance costs and greater fleet availability. The EP brake on the trailer car is applied to discs on the axle, whilst on the motor car it is applied to the wheels by brake blocks.

The driver's controller produces binary-coded signals on four train lines which are decoded at code-conversion units on each car. This decoded signal is received by the EP brake units which supply the brakes on that car with a pressure governed by the demand signal and a load-weighing signal. This arrangement ensures a constant retardation in each level of brake irrespective of the load in the train. On motor cars, the brake cylinder pressure at the EP brake unit is measured by a transducer on the SNR. This signal is used by the SNR to determine the notching level for the rheostatic brake. The brake resistance is then progressively reduced by the camshaft to maintain the desired brake level. When a level of 50A is detected in the brake circuits, a restricted application magnet valve is energised which releases the EP brakes on the motor coach. This has the feature that if rheostatic brake should fail to build up, then the EP brake will automatically apply on the motor car at the correct level. An automatic brake system is also provided on the train.

If the 110V control supply to the brake control circuit fails for any reason, this releases the lock-out magnet valve on the master controller. The driver can then make a direct air application through the air brake valve coupled to the master controller and an indication of EP brake failure is shown. Emergency brake application is made by pulling the master controller handle right back to the *emergency* position. A full, straight air application is made and both rheostatic and EP brakes are cut-out.

Wheelslip/slide control

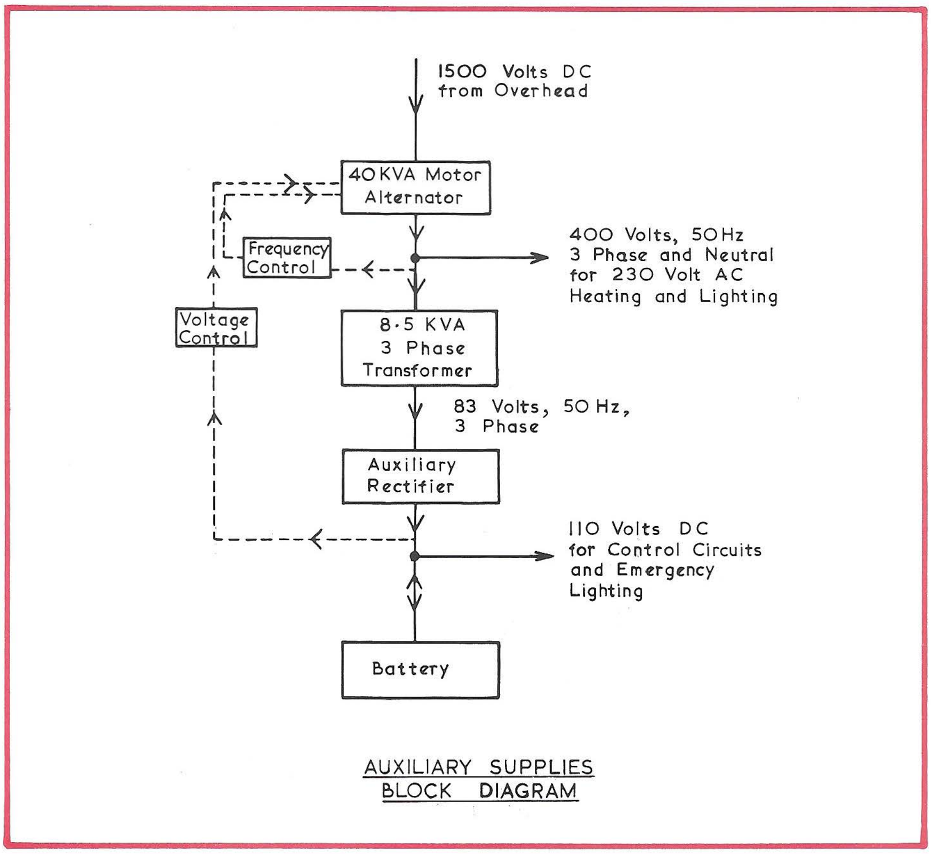
A Westinghouse supplied system of wheelslip/slide control is provided on the motor car, with wheelslide control on the trailer car. These units compare signals from axle-end frequency generators on each axle and detect slip or spin while it is still at the incipient stage, so that corrective measures can be taken before a critical stage has been reached. On motor cars, during motoring and rheostatic braking, the unit provides an output which halts the camshaft to correct the slip or slide. This same unit provides speed-spotting signals which assist control of the rheostatic brake. The units of both cars, during braking, operate dump valves on the EP brakes to check wheelslide and also provide an indication to the driver. Each unit also provides a drive for the GEC speedometer in the cab of that car.

Auxiliary supplies

Auxiliary supplies on the unit are provided by a GEC type G788BY motor-alternator set mounted on the trailer car, providing 40 kVA at 400V, 3-phase, 50 Hz. The motor is a 1500V dc compound machine and the alternator is brushless. These sets are virtually the same as the G788AZ supplied for the Hong Kong Metro cars, which are 440V, 60 Hz machines. The 3-phase ac from the MA set is used for heating, saloon lighting and other auxiliary functions. It also supplies a 8.5 kVA 3-phase transformer, and through a rectifier, this supplies 110V dc for train control circuits and battery charging.

The frequency and voltage of the MA set is controlled by an electronic unit. It regulates the frequency by varying the motor field according to the frequency error, and so controls its speed. The output voltage is controlled by feeding back a 110V dc signal from the control busbar and varying the alternator field current to maintain the control voltage. The ac output can vary slightly with dc control load, dependant upon the regulation of the transformer. For the purpose of exciting the MA set and to provide an emergency supply, a 110V battery is float-charged on the control busbar. In the event of an MA failure, the battery will continue to provide power for train control and emergency lighting in order to allow the train to complete its journey. Alternatively, if two or more units are working together, an emergency jumper can be used to connect

12 Auxiliary schematic.



the ac busbar of adjacent units, so restoring ac power to the defective unit. In this condition, the heating of both units will be automatically cut-out to prevent overloading the working MA set.

Starting of the MA set is under the control of the driver, using pushbuttons available in any of the driving cabs. Initially a large series resistance is inserted into the circuit, and is automatically removed as the starting current falls. A permanent series resistance is included on the positive side of the motor to limit any fault current. Both these resistances are mounted in open, naturally-cooled frames on the underframe of the trailer car. Protection is provided by means of an over-current relay and a fuse on the 1500V supply, with a 90A miniature circuit breaker on the 3-phase output.

Lighting and heating

The car interior lighting is fluorescent, the majority of the tubes being supplied directly by 230V ac, with six tubes per car being supplied by inverters from the 110V dc control supply. In the event of an MA set failure, the inverter-supplied lights will remain on for thirty minutes and then reduce to two tubes per car in order to conserve the battery. A pushbutton is provided which restores full emergency lighting for a further period of thirty minutes.

The car heating is provided by 800W, 230V ac panel heaters, 14 on the motor car and 16 on the trailer car and mounted under the seats. The heating is available in two steps; the half heat option providing thermostatic control of half the heaters only, and full heating providing permanent heating from half the panels with thermostatic control on the remainder.

Air system

The air supply for the two-car units is provided by a Westinghouse type 3HC55 compressor, which maintains the main air reservoir between 875 kPa (127 lb/in^2) and 975 kPa (141 lb/in^2). The compressor is powered by a four-pole series dc machine, supplied from the 1500V line, and running at 1150 rev/min. The compressor supplies air for braking, door gear and control equipment. When starting a train which has been left dead for a period, it is possible that there is insufficient pressure to raise the pantograph and so start the main compressor. For this contingency, a small auxiliary compressor has been provided which operates from the battery. The compressor is started by the driver, and continues to run until the pantograph air reservoir has been charged to 650 pKa (94 lb/in^2) enabling the pantograph to be raised.

Propulsion equipment for electric multiple unit trains for New Zealand Railways.

Electrified lines of the Wellington electrified suburban railway system are shown in red.

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