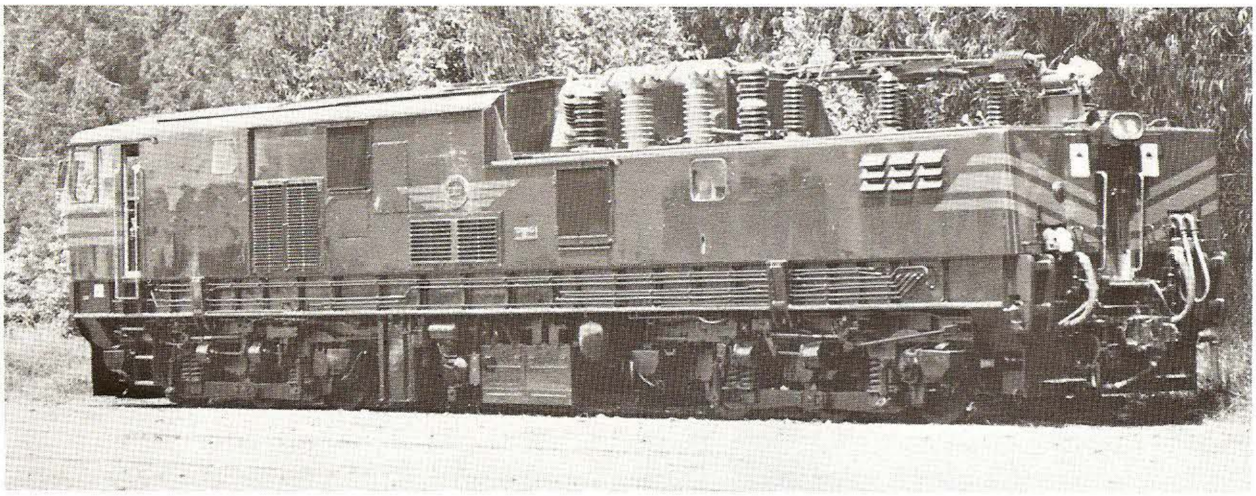
GEC ALSTHOM

50kV Thyristor Controlled Heavy Freight Locomotives

50kV Thyristor Controlled Heavy Freight Locomotives



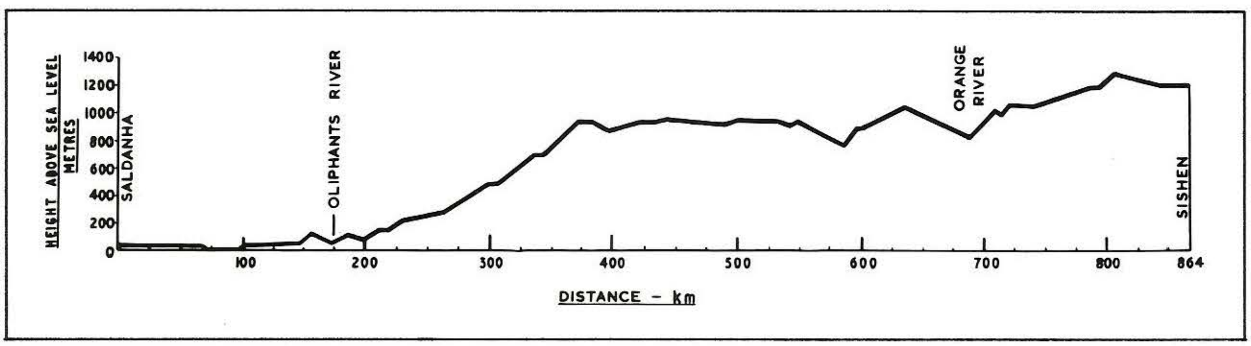
Twenty-five narrow gauge, high power ac electric locomotives are being supplied to South Africa for duty on the new 50 kV, 50 Hz line from Sishen to Saldanha Bay. The line itself was built by the South African Iron and Steel Industrial Corporation (ISCOR) for shipping iron ore from the mine at Sishen but it has been taken over and is being operated by South African Railways. The locomotives are in fact known as the SAR Class 9E.

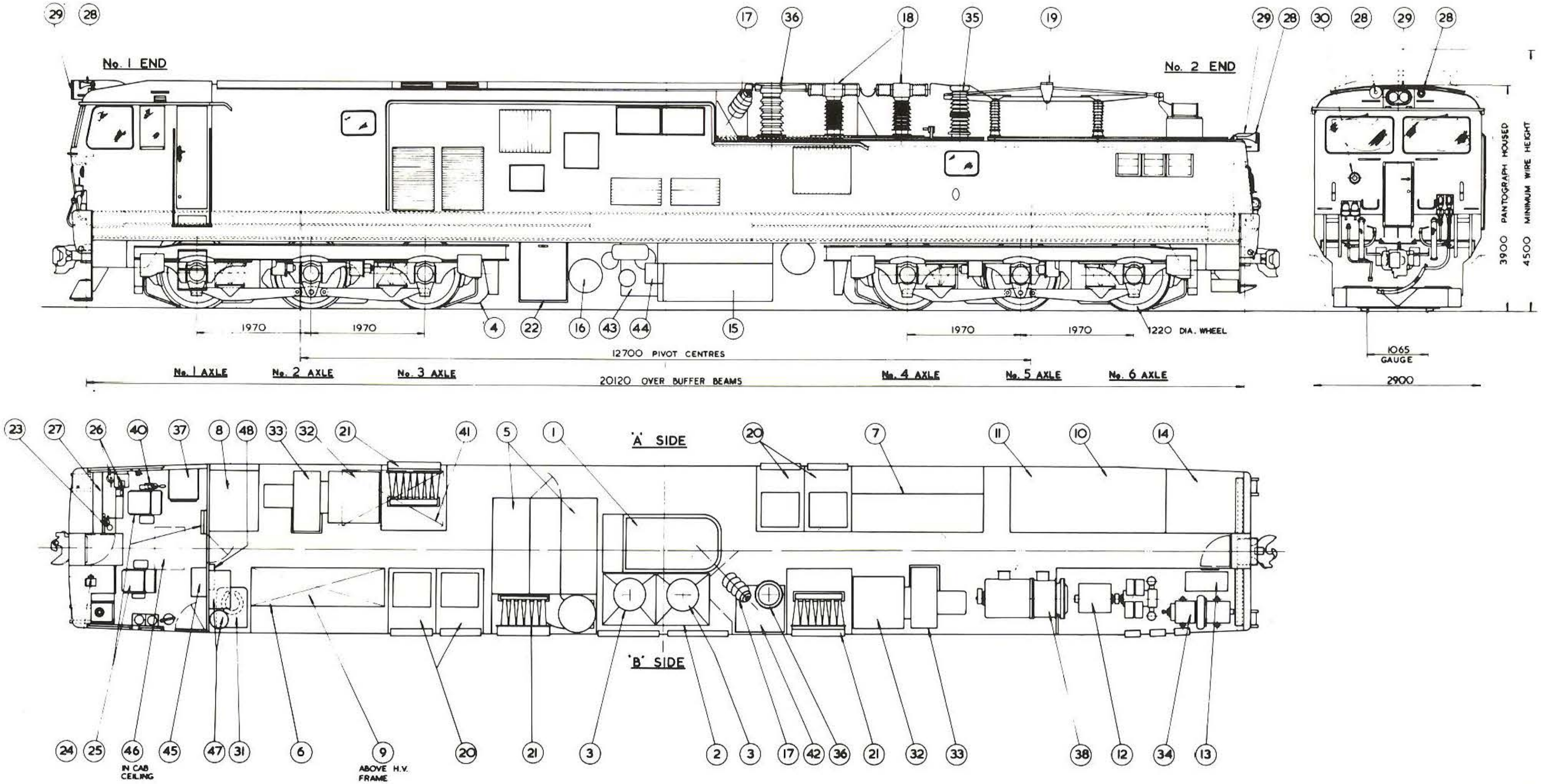
Three of the 168 tonne, 3780 kW locomotives working in multiple haul 202 four axle ore wagons, with a gross trailing weight of 20,200 tonne, over a distance of 846 km mainly through semi-desert scrub country. Most of the route is subject to severe dust and electrical storms and there are also sea mists and a salty atmosphere for some 175 km near the Atlantic coast. The maximum grade against the loaded export trains is 0.4 percent with stretches of up to 50 km averaging 0.37 percent. In the opposite direction the maximum gradient is 1 percent against the returning empties. The line is laid as a single track, with passing loops, with a minimum radius of curvature on the open track of 1,000 metres and on the turnouts of 91 metres. With the exception of one halfway stop to change crew, the loaded ore trains run through non-stop with a journey time of approximately eighteen hours whilst the unladen trains wait in the passing loops.

The locomotives designed by GEC Traction are being built to their requirements, by Union Carriage and Wagon Company (Pty) Ltd at Nigel in the Transvaal. This is the second fleet of thyristor-controlled ac locomotives which UCW have built for GEC Traction, the first being the twenty 25 kV, 60 Hz Bo-Bo locomotives for Taiwan. UCW, however, has been associated with GEC Traction and its predecessors since 1960 from which time well over a thousand 3,000V dc electric locomotives have been delivered to South African Railways and as many 3,000V multiple units, all with electrical equipment supplied by GEC Traction. AC electric locomotives and traction equipment employing semi-conductors have been supplied by GEC Traction since 1958 although, in fact, they supplied their first industrial frequency ac locomotives in 1931.

The present order is the third fleet of thyristor-controlled ac locomotives to be supplied by GEC Traction for export, the others being those for Taiwan (already mentioned) and 25 kV, 50 Hz Bo-Bo locomotives exported to Pakistan in 1969. At 168 tonne and 3780 kW output these SAR locomotives are the heaviest and most powerful yet supplied by the Company.

The 50kV supply system was chosen by ISCOR because it required fewer substations due to the lower voltage gradient along the catenary and contact wires. Under the worst emergency conditions the line voltage may fall to 25 kV and the locomotives are designed to continue operating at this voltage, although at a reduced speed.




No. 1 END
No. 2 END
3900 PANTOGRAPH HOUSED
4500 MINIMUM WIRE HEIGHT
1970
1970
1970
1970
1220 DIA. WHEEL
12700 PIVOT CENTRES
1065 GAUGE
No. 1 AXLE
No. 2 AXLE
No. 3 AXLE
20120 OVER BUFFER BEAMS
No. 4 AXLE
No. 5 AXLE
No. 6 AXLE
2900
'A' SIDE
'B' SIDE
IN CAB CEILING
ABOVE H.V. FRAME

Key for—general arrangement

Ref No.	Description
1	Transformer
2	Transformer Radiator
3	Fan
4	Traction Motor
5	Thyristor/Diode Rectifier
6	High Voltage Equipment Frame No. 1 end
7	High Voltage Equipment Frame No. 2 end
8	Low Voltage Equipment Frame
9	Electronics Cubicle (above High Voltage Frame)
10	Power Factor Correction Equipment
11	Auxiliary Control and Battery Charger
12	Air Compressor—Main
13	Air Compressor—Auxiliary
14	Brake Equipment
15	Battery
16	Air Reservoirs—Main
17	Input Bushing
18	Vacuum Circuit Breaker
19	Pantograph
20	Rheostatic Brake Units
21	Inertia Air Filters
22	Container for Motor Scooter
23	Master Controller
24	Handbrake
25	Seats
26	Brake Valves
27	Instrument Panel
28	Horn
29	Headlight
30	Tail Light
31	Toilet
32	Choke
33	Traction Motor Blower
34	Exhauster
35	Potential Divider
36	Lightning Arrestor
37	Refrigerator
38	Motor Alternator Set
39	—
40	Vacuum/Air Emergency Valve
41	Power Supplies etc. (above No. 1 T.M. Blower)
42	M.A. Set Choke
43	Condensing Unit (Air Conditioning)
44	Battery Isolating Switch
45	Fixed Cupboard
46	Air Conditioning Unit (in cab ceiling)
47	Water Heater & Water Tank
48	Washbasin

General Description

The Co-Co locomotive has a single cab and a full width body as shown in figure 3. The roof at the No. 2 end (the opposite end to the cab) is lowered for nearly half the body length in order to accommodate the roof mounted equipment with sufficient clearance for 50kV. This roof gear comprises the pantograph, a potential divider for voltage measuring circuits, vacuum circuit breaker and a surge arrestor. The high voltage bushing of the transformer also projects through the lower part of the roof and is connected directly to the vacuum circuit breaker and the surge arrestor.

There is a central gangway for access to the equipment. The transformer and rectifier, however, are mounted on the centre line of the locomotive and thus the gangway is displaced at that point. Doors at the ends of the locomotive enable the crew to pass between locomotives coupled in multiple.

The control and dynamic brake equipment is divided into two sets mounted diagonally opposite to each other at each end of the transformer and rectifier together with the traction motor blowers and smoothing chokes associated with each bogie mounted opposite. The chemical toilet and low voltage equipment are located against the cab bulkhead at one end of the locomotive. At the opposite end the motor alternator set and brake machines are mounted on one side with the brake equipment and power factor correction equipment on the opposite side of the gangway.

The battery and main air reservoirs are mounted beneath the underframe between the bogies, where there is also a container for carrying a small motor scooter for use by the crew when inspecting a long train.

The single, spacious cab has been designed bearing in mind the long spells of duty worked by the crews under tropical conditions. There is full air conditioning and a hotplate and a small refrigerator are provided. The driver's controls are grouped on the right hand side with the assistant's seat on the left and an additional folding seat is mounted on the rear bulkhead. Large, adjustable, tinted safety glass sun visors are provided on either side, to cut down the glare from the tropical sun. An air conditioning plant is installed in the cab with the condenser mounted below the underframe between the bogies. It includes both heating and cooling circuits and is fully automatic in operation, maintaining the cab temperature at a pre-selected level, recirculating 75 percent of the air and drawing in 25 percent fresh air from outside. All the air is cleaned by disposable filters mounted in the air conditioner unit.

The cooling air for the transformer radiator is drawn through the body side, past the cooling elements, and is discharged through the roof by two axial flow fans. The four dynamic brake units are each cooled by their own individual fans which draw air from the bottom of the locomotive bodyside and discharge it through gravity operated shutters in the roof. There is one traction motor blower for each bogie which draws its air through inertial filters and the traction motor smoothing choke. The cooling air for the rectifiers is double filtered through inertial filters and high efficiency disposable fabric filters. The temperature of this air is only raised a few degrees above ambient by its passage over the rectifiers and so the air is discharged into the locomotive body to be used to scavenge the body to maintain the temperature inside at a reasonable level.

Brakes

All the locomotives are fitted with locomotive and train air brakes and six of them are also fitted with vacuum brake equipment for use when hauling SAR vacuum braked stock. The ore wagons are fitted with ABD brake valves and the brake pipe pressure is nominally 56 kg/cm^2. The driver's automatic air brake valve controls the train brakes by pressure variation in the train brake pipe and the locomotive brakes through a distribution valve and relay valves. The dynamic brake on each locomotive is rated at 4,200 kW when it is working the locomotive air brakes are cut out and the driver's automatic air brake valve operates on the train brakes only. The locomotive air brakes can also be operated by the driver's straight air brake valve.

Performance

The performance of the locomotive is shown in figure 4 motoring and in figure 5 braking. The 39,042 kg maximum continuous rating at 34.5 km/h, (giving a UIC rating of 3,780 kW), makes this the most powerful 1,065 mm gauge electric locomotive in the world, so that three locomotives in multiple can haul a 20,200 tonne ore train up a 0.4 percent grade within their continuous rating. With a maximum starting tractive effort of 55,440 kg equivalent to 33 percent adhesion, the locomotives are capable of starting the heaviest train on the 0.4 percent grade although this is not normally necessary in service. The use of continuously variable thyristor control of separately excited traction motors, together with continuously variable power control and automatic weight transfer compensation enables the locomotive to be worked up to the maximum available adhesion.

The maximum speed of the locomotive is 90 km/h but the train speed in service is limited to lower values by track speed limits.

The four dynamic brake resistor stacks can dissipate a total of 4,210 kW and braking is controlled by varying the traction motor field current. This brake is used for holding the train on the long stretches of down grade, a consist of three locomotives, braking at 16 percent adhesion holding the 20,200 tonne ore train within the speed restriction of 55 km/h on a 0.6 percent grade. On steeper downgrades the locomotive rheostatic brake needs to be supplemented by the train air brakes.

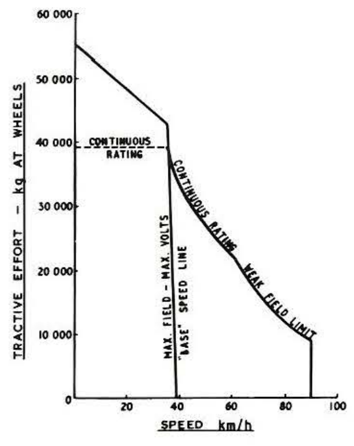


Fig. 4. Locomotive performance—motoring

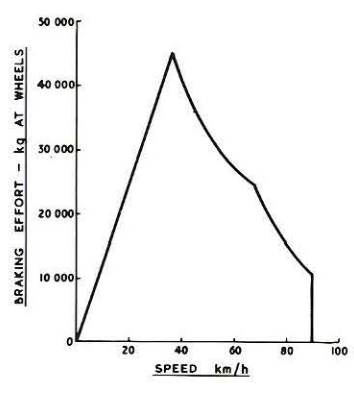


Fig. 5. Locomotive performance—braking

Control

The power circuits are shown in figure 6. The fields are supplied from an excitation winding on the transformer through individual thyristor controlled rectifier bridges and the excitation on individual motors is controlled by varying the firing angle of the thyristors. The motor armatures are connected in two groups of three in parallel, each group of three being connected to the output of two half-controlled thyristor controlled bridges connected in series, each bridge being supplied from a separate transformer secondary winding. The voltage at the motors is increased from zero to maximum by advancing the firing angle of the thyristor bridges in turn, this arrangement improving the power factor more rapidly during acceleration than if a single bridge were used.

Acceleration is under current control. The initial current is selected by the position of the driver's controller, but this value of current is modulated by the speed of the locomotive, reducing linearly as the speed of the locomotive increases. The armature current is maintained at the correct value required by the controller position and locomotive speed by a closed loop control system.

The locomotive is controlled in two modes. Initially the motor excitation is kept constant at its maximum value whilst the armature voltage is increased from zero to maximum, by advancing the thyristor firing angle of the rectifier bridges as the locomotive accelerates. The speed/tractive effort characteristic at maximum field maximum volts is referred to as the 'base speed line' (and shown in figure 4). In this mode, due to variations between motors, the use of a single nominal field current would cause unacceptable variations in motor armature current levels between different motors and to correct for this the three armature currents of a group are compared and the fields on the two motors with the lower armature currents are weakened slightly to increase their armature currents to the value of the highest.

In the second mode of control, i.e. at speeds above the base speed line, the thyristors in the armature bridges are kept fully advanced maintaining the armature voltage at maximum whilst the fields are progressively weakened. Field weakening continues until either the maximum speed is reached or, at full or near full power, the maximum permissible ratio of armature to field current is reached after which the field current is adjusted to keep this ratio constant. To ensure that the motors are not over heated, an overall current limit equal to their continuous rating is applied above the base speed line giving a constant power curve between 34.5 km/h and 62 km/h at full power.

By acceleration at maximum field up to full armature volts, the condition of operation where the armature thyristor bridges are phased back is kept to a minimum, thus reducing harmonics and interference currents to a minimum over the normal running range of the locomotive. Electrical weight transfer compensation is achieved by controlling the motor current on the trailing bogie to a slightly higher value than that on the leading bogie.

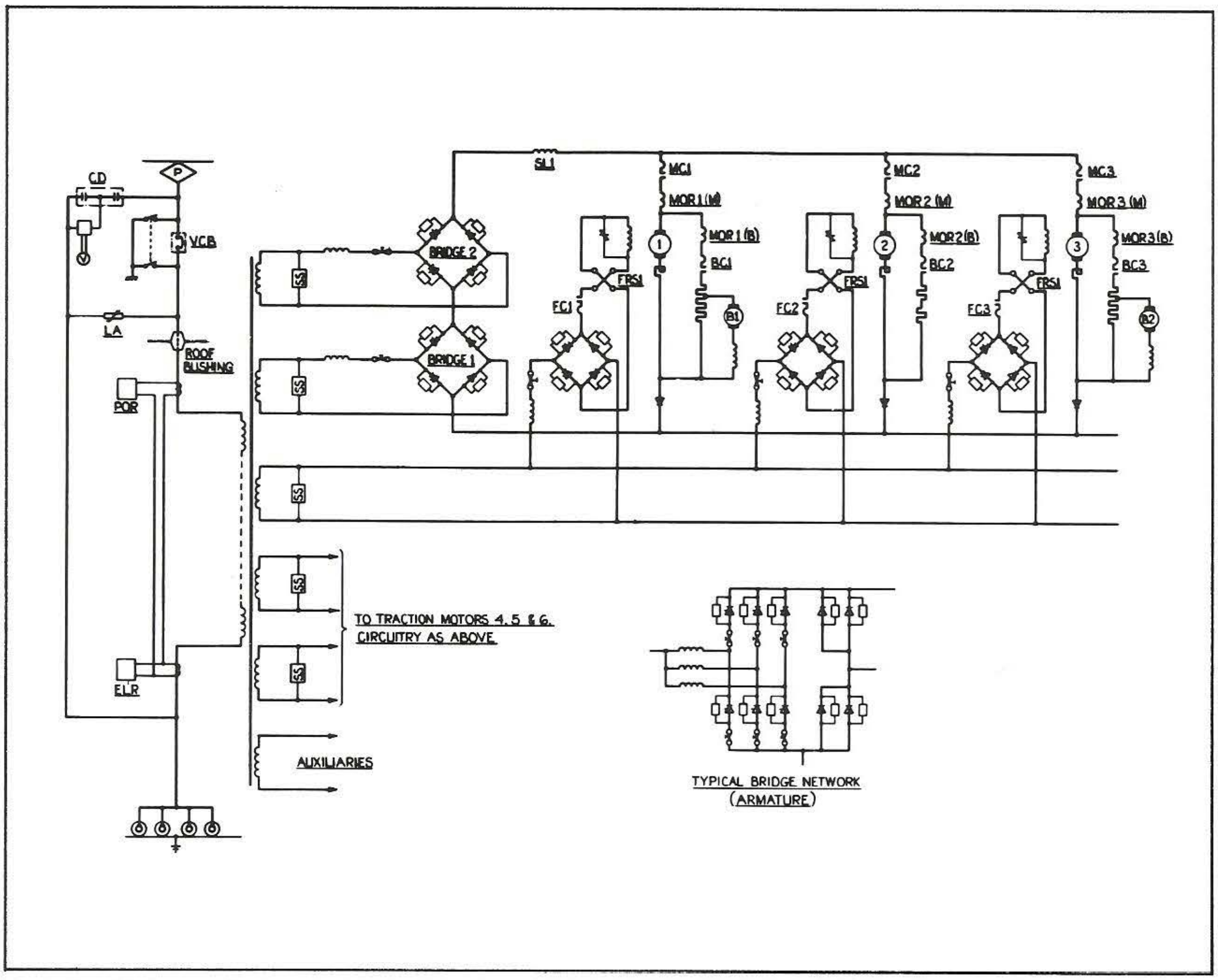


Fig. 6. Simplified power circuit

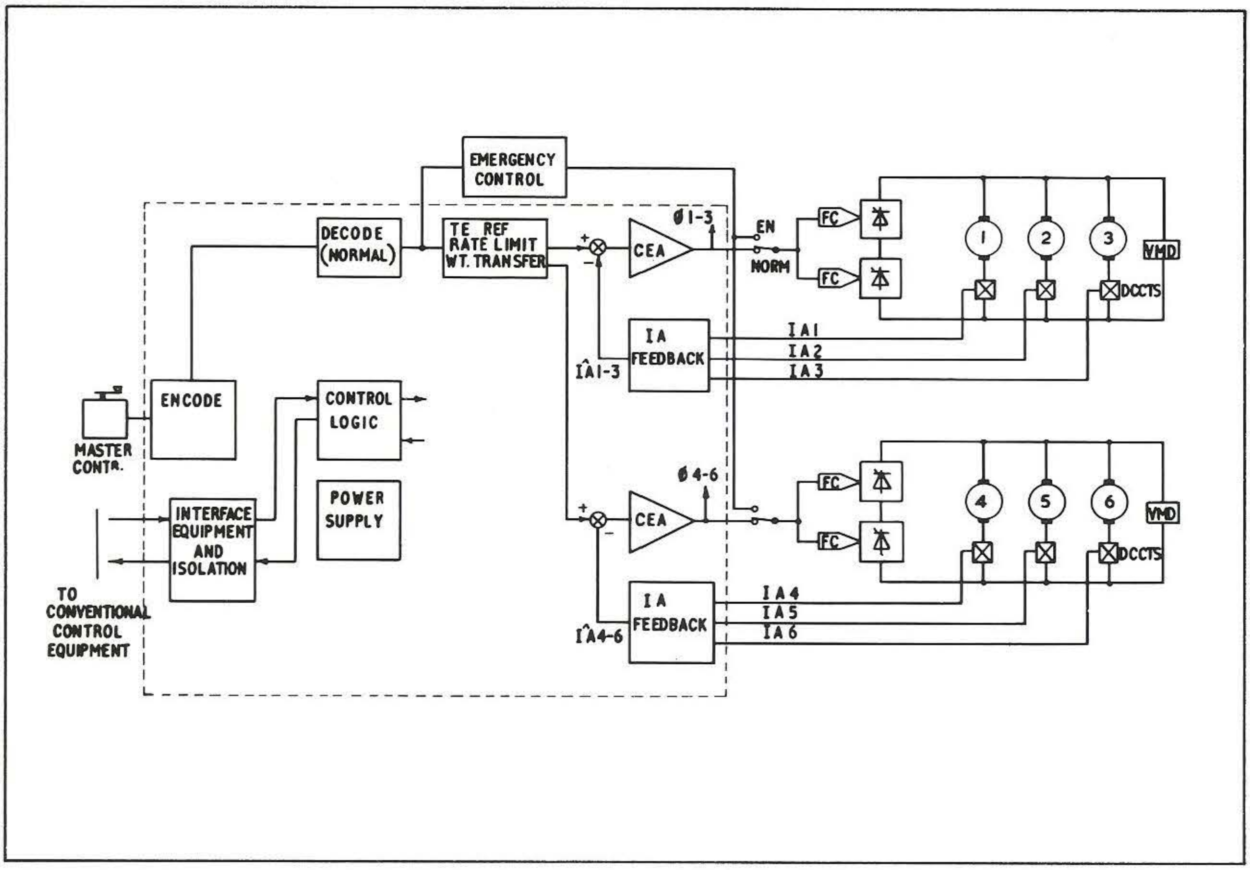


Fig. 7. Armature control block schematic

The electronic control system is constructed on a modular plug-in basis. Each individual electronic circuit is built on a single glass fibre printed circuit card which itself is mounted on a protective metal chassis to form a plug in module. The construction of a typical module is shown in figure 8, and figure 9 shows the two tier rack into which the modules are plugged.

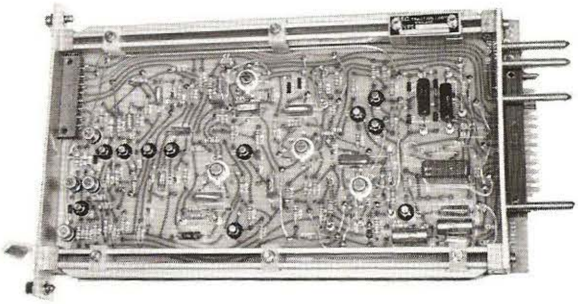


Fig. 8. Typical module

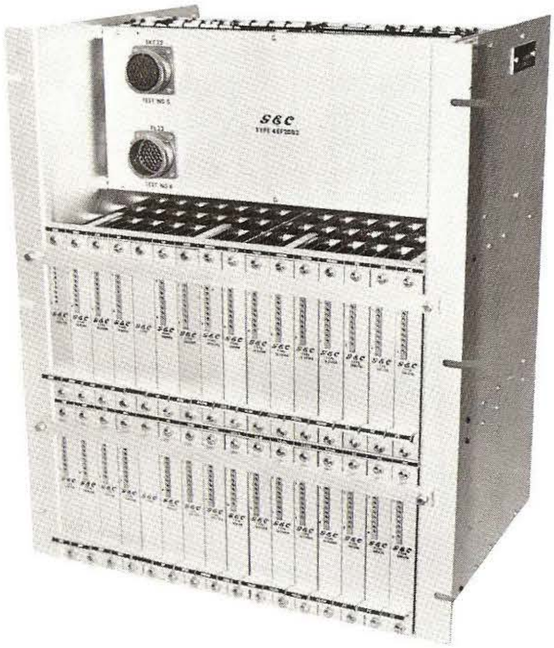


Fig. 9a. A rack of electronic modules showing locking arrangement

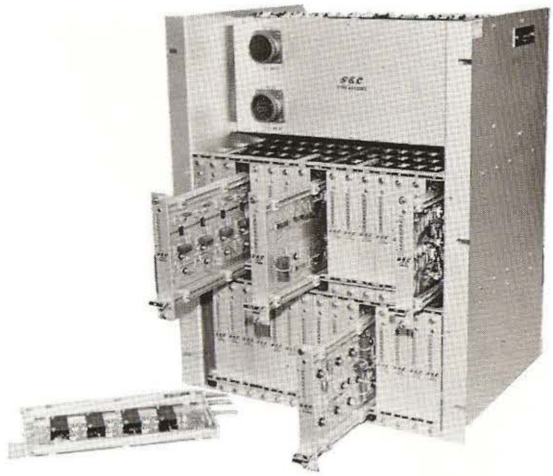
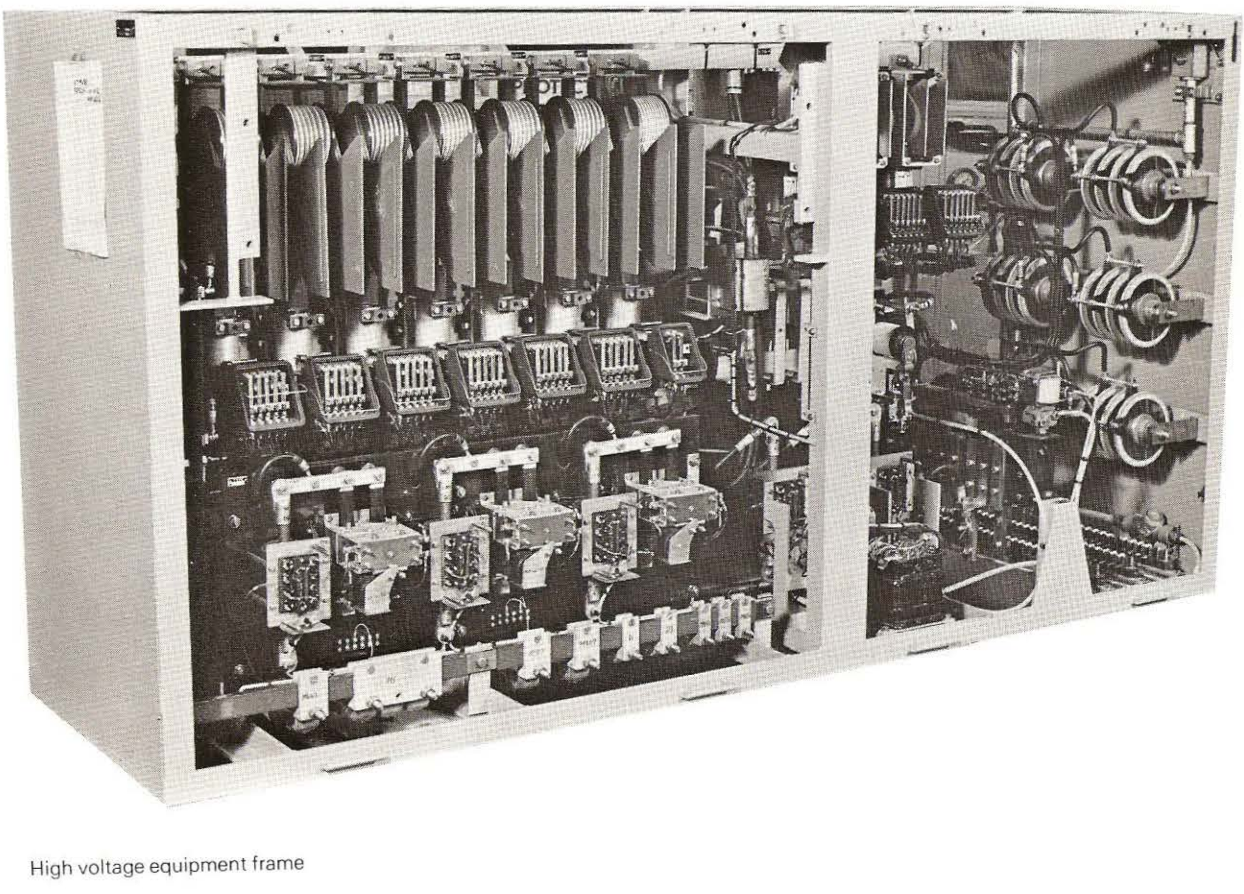
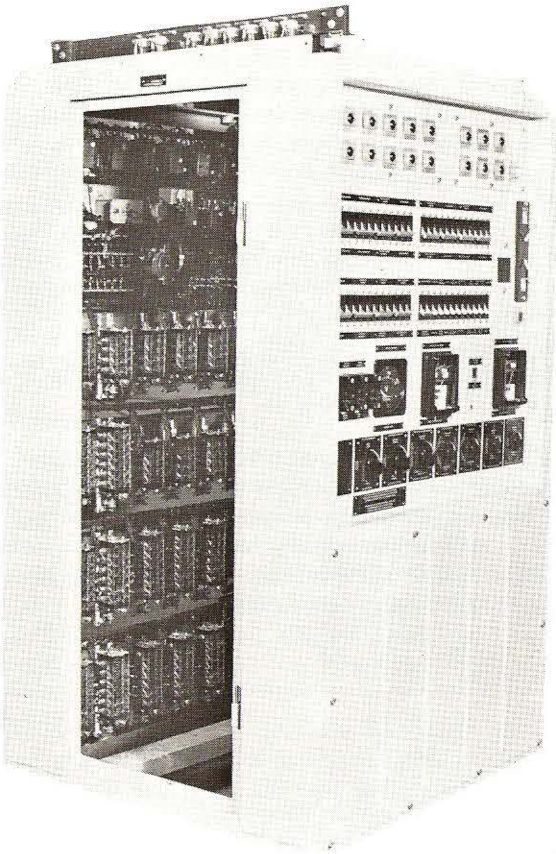


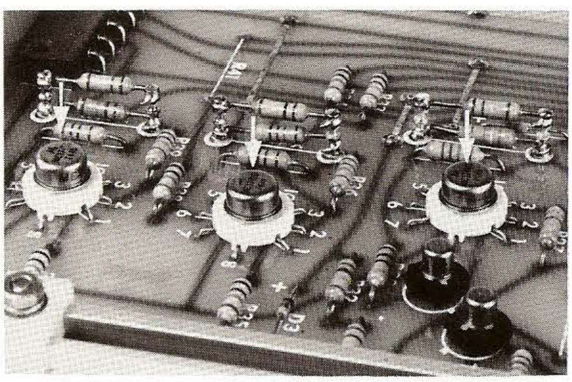
Fig. 9b. A rack of electronic modules some partly withdrawn



High voltage equipment frame



Low voltage equipment frame



Close up of turret pins on which calibrating resistances are mounted when on test

All the circuitry, including plugs and sockets, is mounted on the printed board with outgoing connections made at the rear of the card by means of a multi-way plug with gold plated pins. A similar, but smaller socket is mounted at the front of the card to allow access to monitoring points when the module is plugged into its mounting rack. No adjustable controls are fitted to the module, the calibration and all settings being made by fixed resistors soldered to turret pins. Polarising pins are fitted on the rear plate of each module to mate with appropriate holes in the mounting rack to ensure that they cannot be plugged in the wrong position.

Components are specially selected and are operated at currents and voltages below their rated capacity. The equipment is designed for a minimum life of twenty years and special attention has been paid to the mechanical design to ensure that no deterioration will result from vibration and shock.

Practical experience has shown that variable potentiometers can give trouble and they are no longer used except where essential such as wheel wear compensation. Modern electronic devices do not drift with age and once a module has bean accurately calibrated during manufacture, there is no need for further adjustment during its life.

The locomotives normally operate in multiple of three units, driven from the leading cab. An analogue signal is produced by the driver's controller, the position of which determines the magnitude of the signal, and this is used to determine the traction motor current and hence the tractive effort of the locomotive. If this analogue signal were passed directly down the train line there would inevitably be some attenuation due to resistance in the wires and jumper contacts and the trailing locomotives would operate at lower powers. To avoid this the analogue signal is first encoded into a pulse width modulated signal before passing down the train line to be decoded at each individual locomotive, to give the correct current and tractive effort demand.

All the essential electronic circuits to enable the driver to operate the locomotive, are duplicated and by changing the position of two plugs in the electronic cubicle the driver can cut out all non-essential circuits and change over to the second set of essential electronics.

Wheelslip

With separately excited motors, wheelslip is largely self correcting because of the exceedingly rapid torque fall-off, as speed rises with constant armature voltage. The time constants of the load sharing circuits have been deliberately made long in order that they will not have time to affect the torque of a slipping motor before it corrects itself.

As all additional safeguard, wheelslip detection and correction equipment is fitted to protect against prolonged wheelslip and multiple axle slip resulting from poor adhesion conditions. In this the speed of each axle is measured by an inductive probe, mounted in the gearbox, sensing the passage of the main gearwheel teeth.

Wheelslip is detected in two ways. Firstly by the detection of axle acceleration at a slightly higher level than the maximum that can be achieved in practice by a light locomotive accelerating at the maximum possible rate on dry track. Secondly, by comparing the speed difference between the slowest axle of the six and the other five.

In the case of slip on individual axles the only action taken on detection of wheelslip is to inhibit the action of the load sharing circuits to prevent field weakening of the slipping motor. The rapid fall-off of torque as the motor speed rises will then correct the wheelslip. When simultaneous slip is detected on all axles within a bogie power to that bogie is reduced until slip ceases and then is gradually re-applied.

A wheelslip indicating light warns the driver when wheelslip is present on any locomotive in the consist.

Mechanical Parts

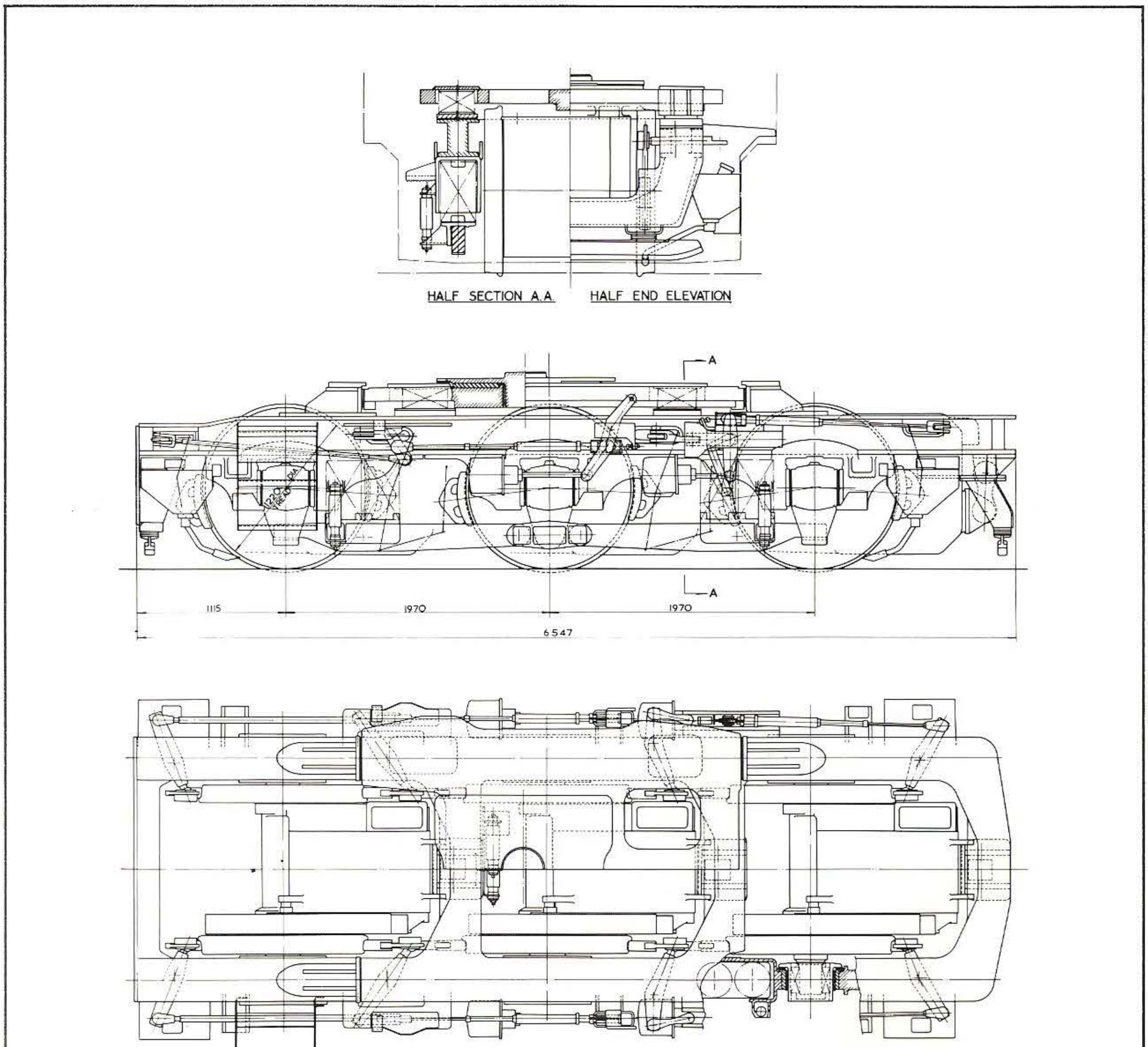
The locomotive underframe consists of two main longitudinal side members inter-connected by cross members at the bogie pivots, the equipment mountings and, at each end, by the buffer beams and drag boxes. The body sides are covered by steel panels welded to frame members and the roof is made up in five removable sections to enable equipment to be replaced if necessary. The bulkhead between the cab and the equipment compartment is sound insulated to reduce the noise level in the cab. The underframe, side frames, fixed roof members and bulkhead form a unit load-bearing structure.

Provision has been made for the superstructure to be lifted or jacked at four points adjacent to the bogie pivot centres. In addition, in order to facilitate re-railing, the locomotive can be lifted or jacked from one end, with the other end resting on its bogie.

Rubber cushioned draft gear is fitted together with central AAR type F interlocking couplers and a steel cowcatcher is provided at the cab end.

The bogie frame is a fabricated structure made from steel plate. The axleboxes are fitted with Timken AP bearings, Class CG, and the axlebox guides are steel castings, with manganese liners, secured to the bogie frame with fitted bolts. The frame is supported by coil springs on the equalising beams. The superstructure load is carried on a large flat centre pivot, the top half of which is spigotted and bolted to the underframe, whilst the bottom half is integral with the fabricated steel bolster. The bolster is supported on rubber units and is located by traction brackets on top of the bogie frame. Friction dampers are provided for the primary suspension with lateral friction dampers between the bolster and the bogie frame.

The rolled steel wheels are fitted with tyres and, because of the limited space available within the 1,067 mm gauge, the gearwheel is shrunk onto the roadwheel hub. Clasp brakes are provided for each wheel, actuated by 255 mm brake cylinders fitted with slack adjusters and four sandboxes are provided for each bogie.



Roof Equipment

The single GEC diamond frame pantograph is operated by a roof mounted air cylinder and piston driving an insulated push rod. Normally the air supply to operate it comes from the main reservoir but there is a small auxiliary compressor, driven from the battery, for use when the main reservoirs are empty. As a further back-up in case of emergency, there is a sealed, high pressure air bottle.

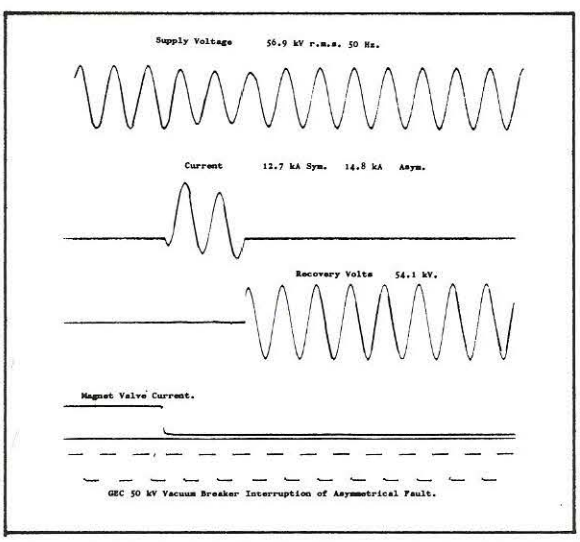
The primary protection is a vacuum circuit breaker, the design of which is based on a 25 kV breaker developed and built by GEC. The design has been used extensively by British Rail and has been introduced on a number of overseas railways.

The 25 kV breaker has two vacuum interrupters in series, operated by two opposed pistons which move apart when air is admitted, compressing springs and allowing the contacts to close. Releasing the air pressure allows the springs to expand and the contacts to part. The interrupters have a nominal voltage rating of 15 kV and 600 amperes, and two in series have a capability of 30 kV and an impulse voltage withstand of 170 kV.

GEC decided to use this breaker as the basis for a 50 kV design by using four bottles, arranged in two sets of two bottles. To meet the impulse level of 325 kV and a wet withstand voltage of 90 kV the insulation required considerable modification and the two types of breakers are shown. Of particular note is the rounded contour of the end caps and central housing to reduce voltage stresses, and the sharing capacitors needed for the higher voltage.

Each head incorporates a mechanism driving and insulated rod in the centre of the vertical insulator and connected in the base structure to an interlock which prevents closure of the breaker should a bottle fail to operate for any reason.

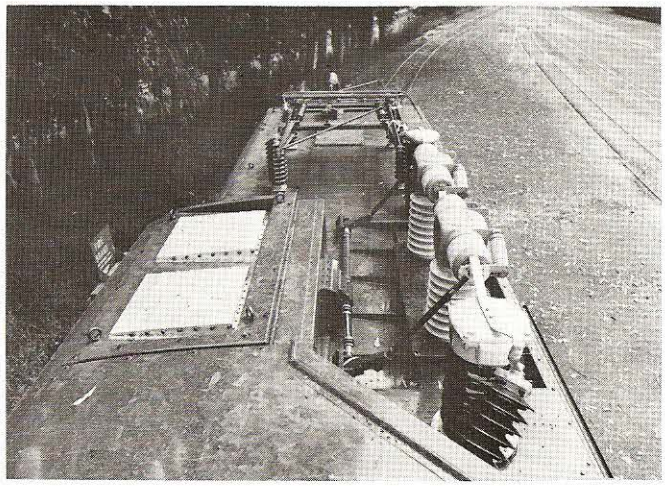
The advantages of the vacuum circuit breaker are the high insulating properties of a vacuum, the absence of exposed moving parts, failing safe in the event of losing air pressure, long contact life, and a separate air reservoir is not required due to the small air volume for operation. Opening of the breaker is achieved within five cycles, and it has been tested to 600 MVA at 55 kV. A typical trace is shown.

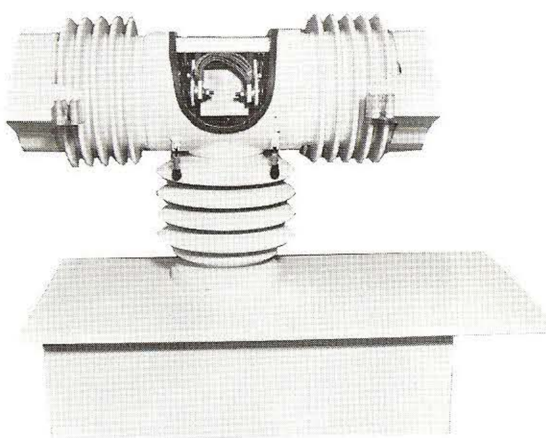


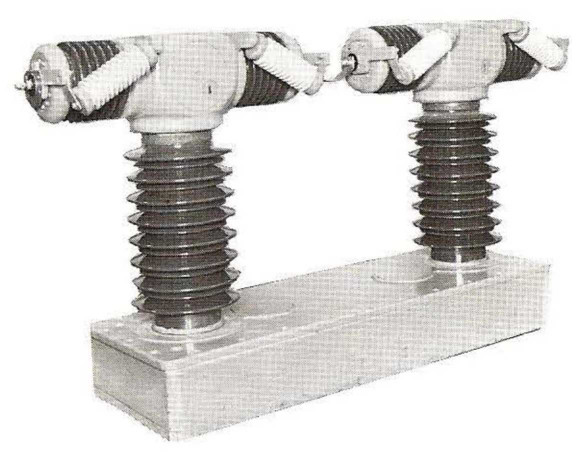
GEC 50 kV Vacuum Breaker Interruption of Asymmetrical Fault.

Earth switch contacts are fitted enabling the circuits to be made safe for maintenance and inspection. Controlled from inside the vehicle, a separate switch earths the H.V. system and operates a valve to prevent the pantograph from being raised.

A surge diverter connected to the transformer side of the vacuum circuit breaker is also mounted on the roof to protect the transformer against any lightning or switching surges on the line and is designed to cater for the high incidence of electrical storms in the area.







Transformer

The transformer is a hermetically sealed, forced oil and forced air cooled transformer built by GEC Power Transformers Ltd. at Stafford. It has a two limb core with two secondary windings on each limb. The high tension windings are located outside the secondary coils with the auxiliary windings above and below. The whole structure is rigidly clamped and braced to prevent any movement and is mounted in a welded steel tank.

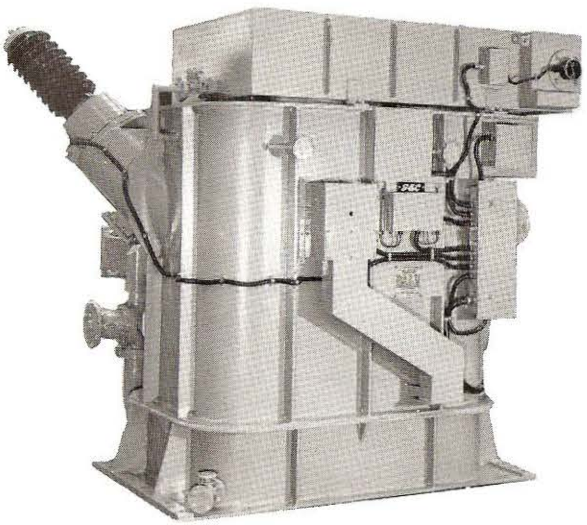
Oil to B.S.148 is circulated through the windings by a fully immersed pump and great care has been taken to ensure that the oil flow is directed over and through the windings to give uniform cooling. As the transformer is fully sealed, some space has to be left internally for expansion of the oil and for this purpose there is a separate expansion tank on top of the transformer and piped to it. This tank is divided into five compartments, each of which contains a sealed synthetic rubber bag filled with nitrogen. There is no gas in the transformer outside these bags, the space being completely filled with de-gassed transformer oil. The pressures inside the transformer are so arranged that the nitrogen bags are never in tension and they are designed to have a useful life as long as the transformer itself. The transformer is fitted with a pressure relief valve which operates in the event of an excessive build up of oil pressure in the tank.

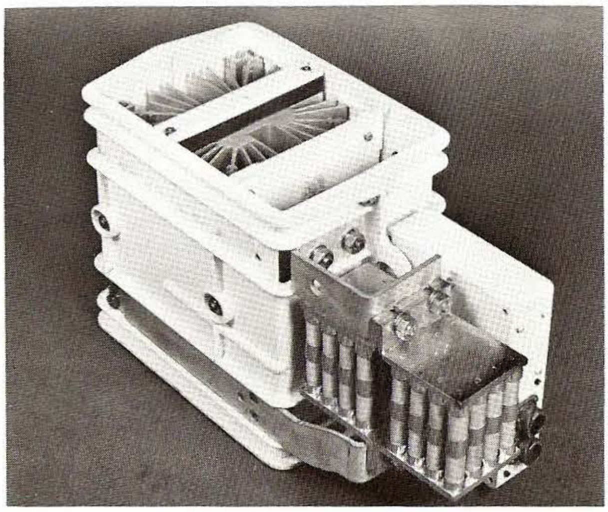
Rectifiers

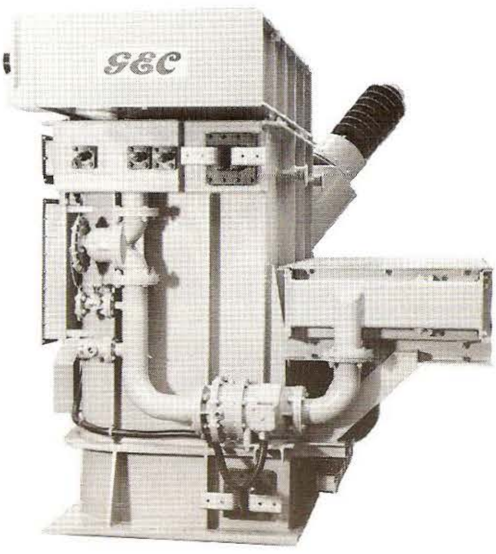
The single rectifier cubicle houses the four traction motor armature thyristor bridges, the six motor field bridges and the motor-alternator set thyristor bridge, together with their associated surge suppression circuits, chokes, fuses and indicators. The equipment is divided into two equal parts with access from the centre. Each armature bridge has two thyristor arms with three thyristors in parallel. The field bridges each have two arms with one thyristor and two arms with one diode.

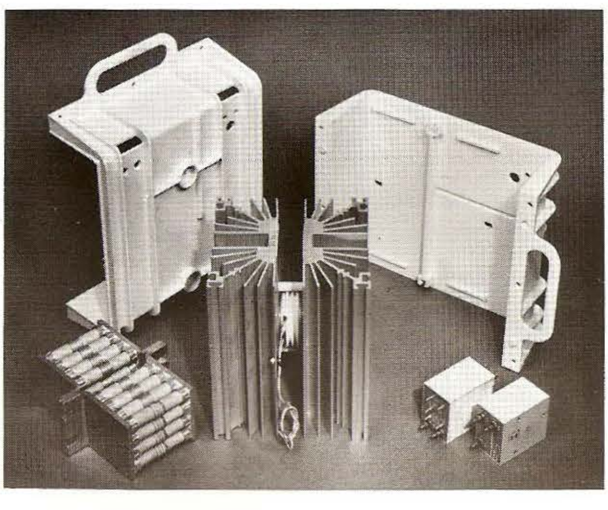
The semi-conductor devices are clamped to separate heat sinks with cooling fins which are mounted individually in separate glass fibre modules. Modules for the armature circuits contain one semi-conductor device clamped between two heat sinks whilst in the case of modules for the field circuits the devices are mounted on a single heat sink. Both thyristor and diode modules contain snubber circuits for transient voltage suppression, while the thyristor modules also include a firing transformer, choke and fuse for the thyristor in that module.

The modules are mounted in vertical columns and arranged for easy and rapid removal and replacement.









Traction Motors

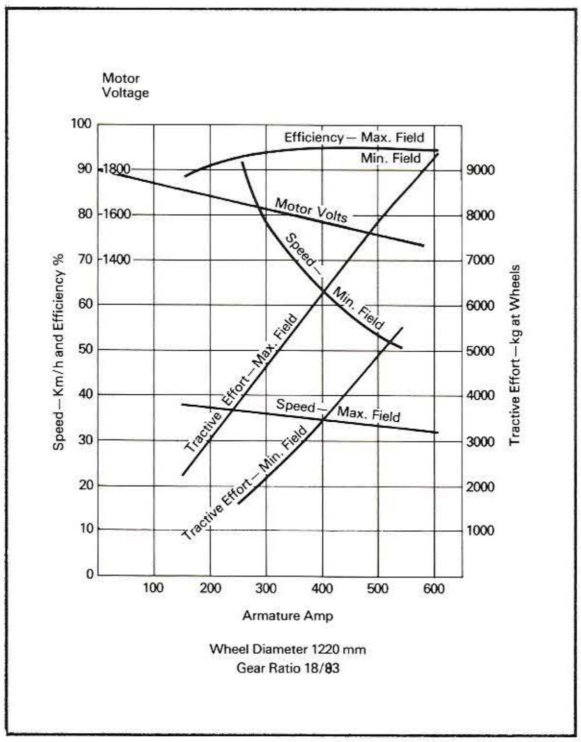
The G415AZ traction motor is a modified and uprated version of the GEC 283AY motor of which some 3,000 are in service on South African Railways in the 3,000 volt dc 6E1 class locomotives. It is a force ventilated pulsating current separately excited, four pole motor, axle hung on a roller bearing 'U-tube' suspension unit, driving the axle through a single reduction gear. Like its predecessor it is solidly built and has many features to ensure trouble-free operation and easy maintenance.

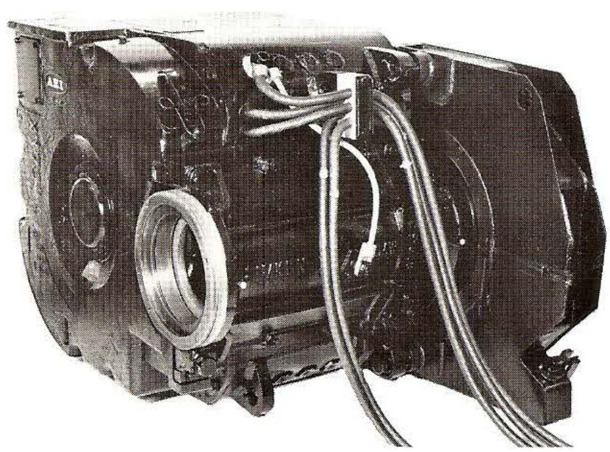
Apart from the separately excited fields, however, there are a number of other differences from the original 283 motors. For example:

- It is no longer necessary to insulate for 3,000 volts to earth as in the dc application, and this results in better cooling of the windings and allows a longer core.
- The pole and stator laminations are thinner and are insulated from one another in order to reduce the effects of the 100 Hz ripple.
- The distance between the gear centres is increased.

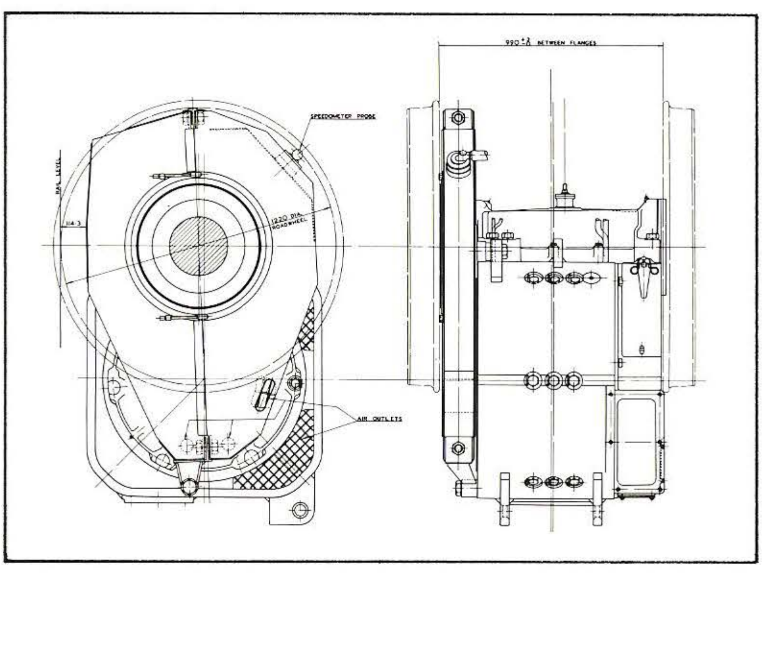
These changes collectively have resulted in a motor with an increased rating of 630 shaft kW.

Solid spur gearing is used, with the pinion shrunk on to a taper extension of the armature shaft and the gearwheel fitted to the roadwheel hub.





The 283AY traction motor (for 3000V dc applications) and the G415 (for the rectified 50 Hz supply of the 9E locomotives) are very similar externally but have significant internal electrical differences.



Auxiliaries

For simplicity of maintenance and reliability in operation, a three-phase auxiliary system is used, with all the auxiliary machines driven by three-phase induction motors except for the auxiliary compressors and the exhauster motors on six of the locomotives which run off the battery.

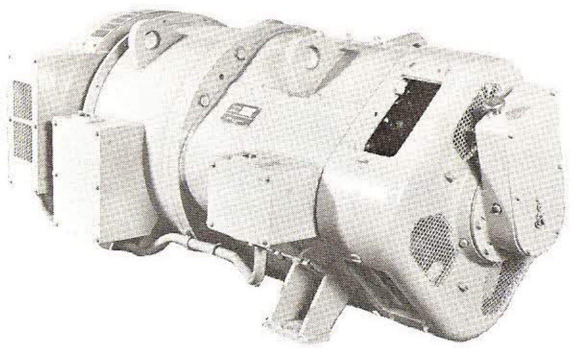
The supply is taken from a motor-alternator set with a continuous rated three-phase output of 125 kVA at 380 volts. The stationary motor and alternator components are housed in separate fabricated steel frames which are bolted and spigotted together, and the rotating components are mounted on a common shaft with a roller bearing at each end. The dc motor is a 585 volt four-pole machine with series and shunt excitation. The alternator is a four pole brushless design with an exciter supplying the fields through a rectifier bridge assembly mounted on the shaft.

The dc supply for the motor-alternator set is taken from a separate auxiliary winding on the transformer via a thyristor bridge rectifier and by controlling the dc output voltage of the thyristor bridge the speed of the set is maintained within 3 percent of the nominal 1,500 rev/min over the full range of load and line voltage.

The output voltage of the alternator is controlled at 380 volts ± 2½ percent over the full range by adjustment of the exciter field current by a static voltage regulator. A transformer/rectifier unit in the alternator line, injecting current into the exciter field, enables the large induction motors to be started up without causing the voltage to fall excessively.

All the various cooling fans, the main compressor and the transformer oil pump are driven by three-phase, cage wound, induction motors of standard industrial design modified for traction use.

A transformer and thyristor controlled rectifier bridge, connected to the main transformer auxiliary winding, gives a regulated 110 volt dc supply for the exhauster, control and battery charging.



Dynamic Brake Units

Each dynamic brake unit comprises nine resistance grids stacked on top of one another and force ventilated from below by an axial flow fan driven by a dc motor. The motor is connected across a section of the resistance for its power supply, and thus the speed of the fan and the cooling of the resistors varies with the load current.

The resistance grids are built in a square frame with a resistor element wound from continuous strips in a zig zag formation and fastened to the frame by steel pins. This method of construction allows free expansion of the strip without any strain being placed on the supports, as well as presenting all the resistor surface to the air-stream without excessive restriction on the air flow.

The resistor strip is non-corrodible chrome aluminium steel alloy which has a high specific resistance with a low temperature coefficient, allowing a fairly large cross section to be used giving good mechanical strength.

There are two dynamic brake units associated with each bogie and, in the braking mode, there are six resistance grids connected in series across each motor armature giving a total capacity of 1,053 kW per unit.

Vigilance Equipment

GEC vigilance equipment is fitted working on a time cycle which is adjustable between one and three minutes. It is reset by the operation of a safety pedal and failure to do this within the time cycle sounds an alarm and, if corrective action is not taken, applies the brakes.

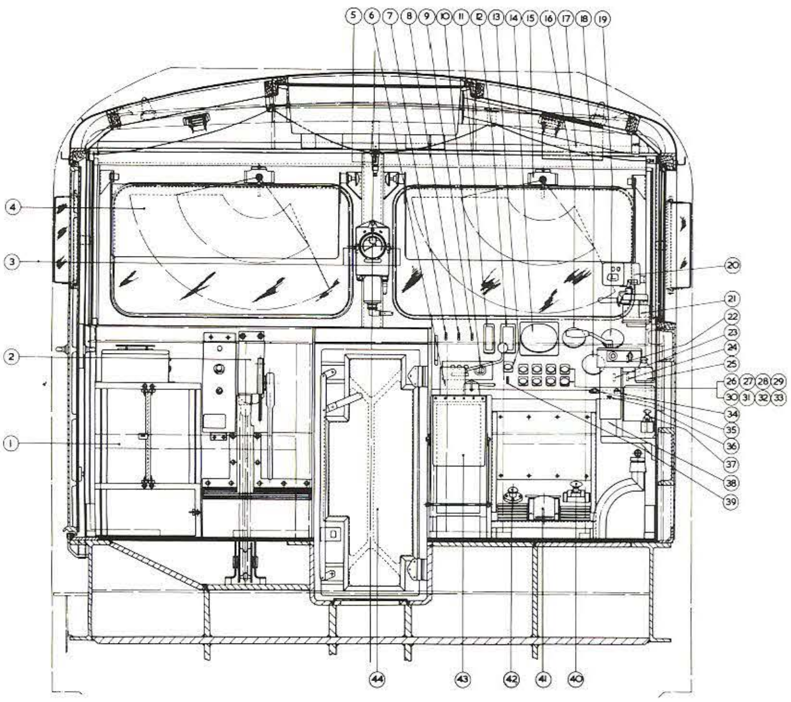
Data

Leading Dimensions

Wheel arrangement	Co-Co
Weight	168 tonne
Axle load	28 tonne
Gauge	1,065 mm
Length over buffer beams	20,120 mm
Height (pantograph down)	3,900 mm
Width	2,900 mm
Bogie Wheelbase	3,940 mm
Pivot Centres	12,700 mm
Wheel diameter (new)	1,220 mm

Ratings

Line voltage	55–25 kV
Maximum Speed	90 km/h
Maximum tractive effort	55,440 kg
Continuous tractive effort	39,040 kg
Speed at continuous tractive effort	34.5 km/h
Continuous output (UIC 614)	3,696 kW
Continuous output speed range	34.5–62 km/h
Dynamic brake effort at 16 percent adhesion	26,880 kg
Speed range for 26,880 kg dynamic brake effort	21.3–61 km/h



1. Assistant's Locker
2. Handbrake.
3. Twin jet windscreen washer.
4. Sun visor.
5. Horn valve.
6. Master controller.
7. Cab light switch – assistant's
8. Cab light switch – driver's.
9. Instrument light switch.
10. Control panel air conditioning.
11. Line voltmeter.
12. No. 1 and 4 motor ammeter.
13. Fault lights – test button.
14. Speedometer.
15. Windscreen wiper.
16. Duplex pressure gauge.
17. Off track radio shelf.
18. Duplex pressure gauge.
19. Duplex vacuum gauge.
20. Brake pipe flow indicator.
21. Independent brake valve D.F.2.
22. Tail light switch (No. 1 end).
23. Headlight switch (No.2 end).
24. Tail light switch (No.1 end).
25. Vigilance push button.
26. Indicator light – line.
27. Indicator light – vigilance trip.
28. Indicator light – fault.
29. Indicator light – wheelslip.
30. Push button – V.C.B. open.
31. Push button – V.C.B. close/reset.
32. Push button – pantograph up.
33. Push button – pantograph down.
34. Windscreen – intermittent wipe – control valve.
35. Wiper control valve.
36. Washer control valve.
37. Release valve – WTV 8/1.
38. Brake valve – D14A.
39. Headlight switch (No.1 end).
40. Sanding switch.
41. Vigilance pedal.
42. Horn valve.
43. Drivers drop table.
44. End door.

GEC ALSTHOM Transportation Projects Limited

P.O. Box 134, Manchester M60 1AH England
Telephone: 061 872 2431 Telex: 667152 Fax: 061 875 2131

GEC ALSTHOM

Publication GET/ELR1107A

039015GSP