# GEC


# 3000 VOLT dc ELECTRIC LOCOMOTIVES FOR SOUTH AFRICA

## Classes 6E & 6EI

## GEC Traction Limited

**Class 6E and 6E1 reached 300 mark in August as build-up of a 500 strong fleet proceeds embracing a South-African designed 87.5 tonne Bo-Bo for SAR 3000V d.c. network incorporating GEC Traction electrical equipment. This Union Carriage build is a design product of the company in co-operation with GEC and includes regenerative braking**

# Four-axle 2,500 kW 3-ft 6-ins gauge South African Railways electric locomotives of high performance

Since 1968 South African Railways has ordered a total of 500 Class 6E and 6El Bo-Bo 3,000 V d.c. electric locomotives and the 300th was commissioned on August 17. These are the most powerful four-axle 3,000 V d.c. locomotives operating on 1,067-mm gauge track and each is currently running some 120,000 km annually. The fleet km accumulation is thus some 36 million km per year but is rising rapidly with eight or nine further locomotives entering service each month.

The 6E and 6El locomotives are electrically almost identical but there are mechanical differences as far as the bogie is concerned. Whilst this article is primarily concerned with the Class 6E1 because it is the more numerous series, differences between them and the Class 6E will be mentioned where they are of particular interest. Both Classes are of South-African manufacture, the builder is Union Carriage & Wagon Co. Ltd., Nigel, and all incorporate electrical equipment designed and supplied by GEC Traction Limited, and made in this company's works located in Great Britain and the Republic of South Africa.

They were the first main-line electric locomotives to be designed in South Africa, the work was carried out by Union Carriage in co-operation with GEC Traction Limited, and follow a long tradition of association by both manufacturers with SAR. GEC Traction and its predecessors have equipped all the electric locomotives running on SAR and have in fact supplied the majority of them complete before the establishment of indigenous manufacture by Union Carriage in 1962. Furthermore the first 555 locos supplied by this South African builder were to GEC Traction's 5E1 design. The latest generation of 6E and 6E1 locomotives are a logical development of the 5E1 and are built to the same overall dimensions, but there is a considerable increase in performance both as regards actual rating and flexibility of operation. Table I gives brief details of all the electric locomotives supplied by the two Companies to SAR and Fig. 1 illustrates both the build up of the fleet and the improvement in specific rating.

*South African Railways Class 6E1 electric locomotive of 2,500 kW*

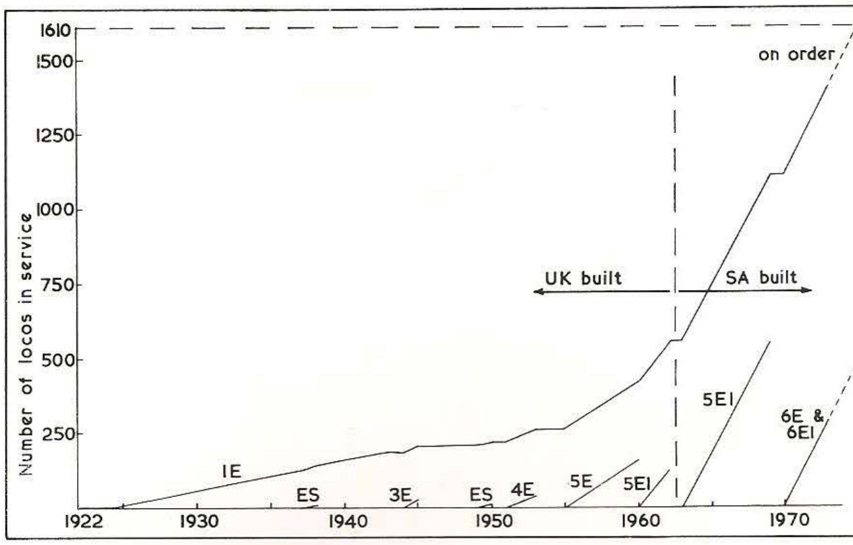



**Fig. 1.** *Growth of the South African Railways electric locomotive fleet showing also the increase in specific power*

## General description

The 6E1 (and 6E) locomotives are twin cab, full-width body Bo-Bo types weighing 87·5 tonnes and rated at 2,500 kW (one-hour) at sea level. They can operate in multiple up to six locomotives of the same class. Locomotive braking is air and regenerative and they can handle both air and vacuum-braked trains.

They operate under a wide variety of severe climatic and electrical conditions. The highest temperature specified is 40°C and this is frequently encountered, together with serious dust storms, some containing iron particles. Minimum temperatures can be -10°C and the relative humidity can be as high as 85 per cent. Locomotives operating between Johannesburg and Durban pass through a region of frequent electrical storms where lightning strikes of the overhead are common, thus necessitating a surge resistance level in the insulation much higher than is usual on 3,000-V systems. This run, together with that out of Cape Town, takes the locomotives from sea level up to a maximum of 1,980-m and this requires special attention to the electrical-equipment ventilation to take account of the more rarified atmosphere at high altitudes. All locomotives may operate in any or all of these areas.

**Table 1. Main line SAR 3,000 V d.c. electric locomotives supplied or equipped by GEC Traction Limited**

| *SAR Class* | *No. supplied, or on order* | *Date* | *Rating, continuous kW* | *Axle arrangement* | *Supplied by GEC Traction* |
|---|---|---|---|---|---|
| 1E | 172 | 1922-42 | 900 | Bo-Bo | Complete |
| ES | 12 | 1937 | 900 | Bo-Bo | Motors |
| 3E | 28 | 1944 | 2,000 | Co-Co | Complete |
| ES | 10 | 1949 | 900 | Bo-Bo | Complete |
| 4E | 40 | 1951 | 2,300 | 1Co-Co1 | Electrical equipment |
| 5E | 160 | 1954-56 | 1,500 | Bo-Bo | Complete |
| 5E1 | 135 | 1957 | 1,700 | Bo-Bo | Complete |
| 5E1 | 555 | 1962-65 | 1,700 | Bo-Bo | Electrical equipment |
| 6E | 80 | 1968 | 2,250 | Bo-Bo | Electrical equipment |
| 6E1 | 420 | 1968-72 | 2,250 | Bo-Bo | Electrical equipment |

## Performance

The mean tractive effort during the resistance notching portion of the acceleration is 312 kN. Very wide operating flexibility is obtained over the remainder of the speed range by having nine stages of field weakening is parallel (10 in series). In regenerative brake the retardation at maximum speed of 115 km/h is 83 kN whilst the maximum retardation is 284 kN at 29 km/h. The specified emergency starting duty requires each locomotive to make two consecutive starts on steep grades without overheating. Accelerating and braking performance is shown in Figs. 2 and 3 respectively.

The very high accelerating tractive effort available in the resistance notches calls for a true adhesion factor (after weight-transfer compensation) of 36·4 per cent. Such levels of adhesion are commonly attainable in some areas of South Africa but even so it is vital to reduce the current swings on each notch to the lowest practical value. Because these locomotives were originally intended to work in multiple with existing 5E and 5E1 locomotives it was not possible to alter the number of main master controller notches but three vernier notches were added between the main notches. These vernier notches are introduced by a separate vernier controller handle adjacent to the main power handle, and provide a total of 67 notches in series and 63 in parallel (instead of 19 and 18 respectively). The main power and vernier

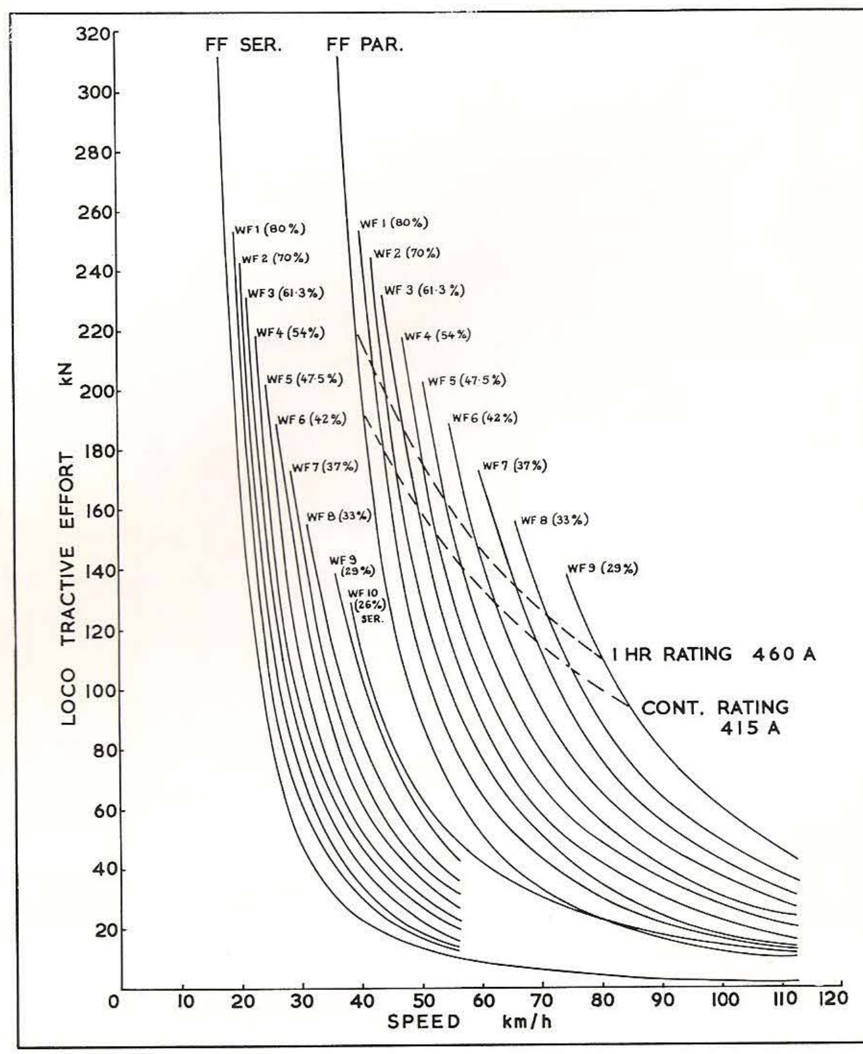



**Fig. 2.** *Performance curve of SAR Bo-Bo 87·5 tonne 6E1 electric locomotive*

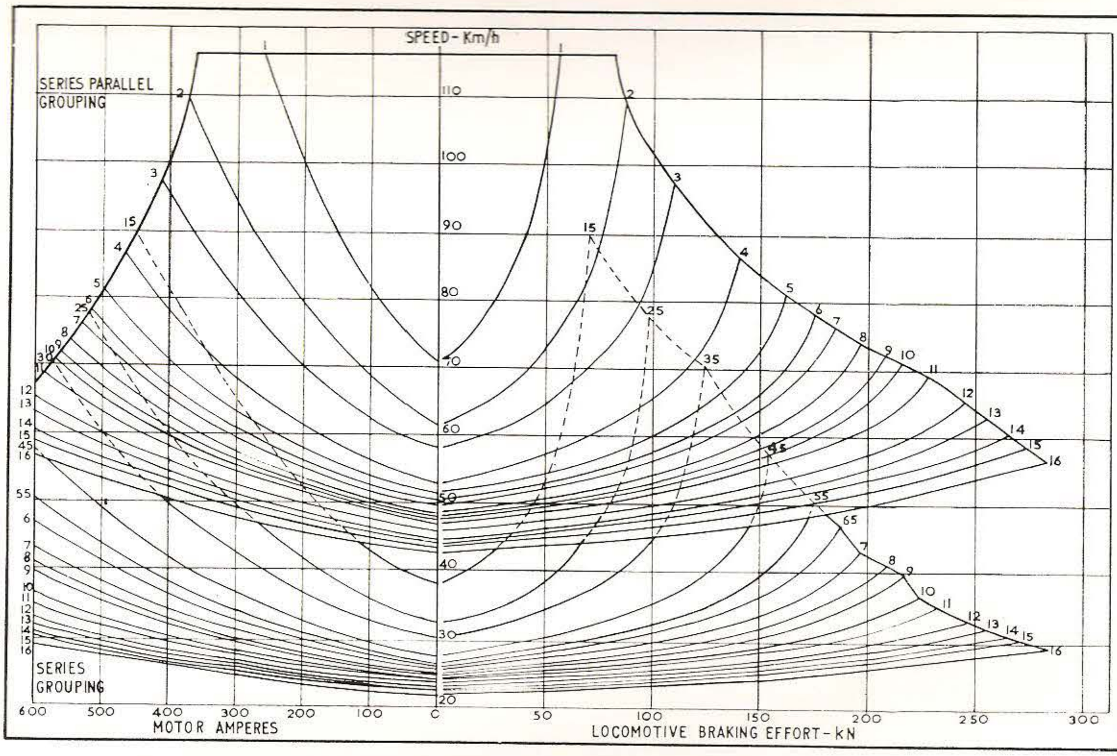
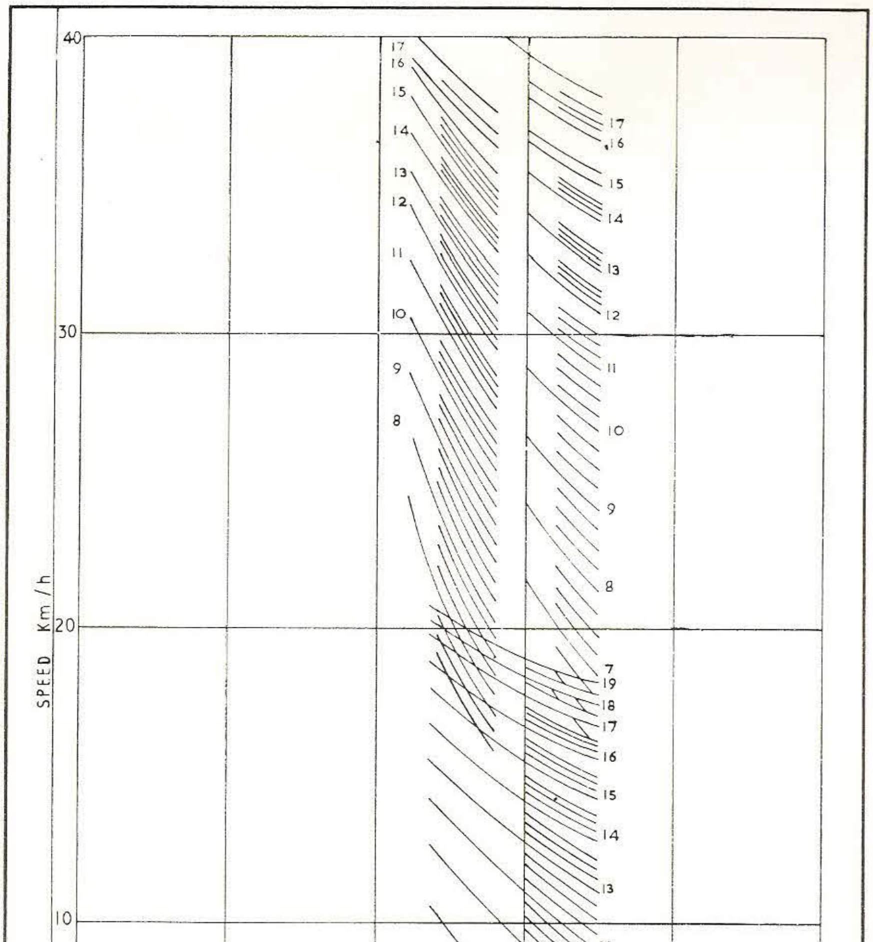



**Fig. 3.** *Regenerative brake performance of 6E1 3,000 V d.c. electric*

**Fig. 4.** *Vernier notching curve*




notches are shown in Fig. 4 which very clearly also illustrates the "soft" starting notches.

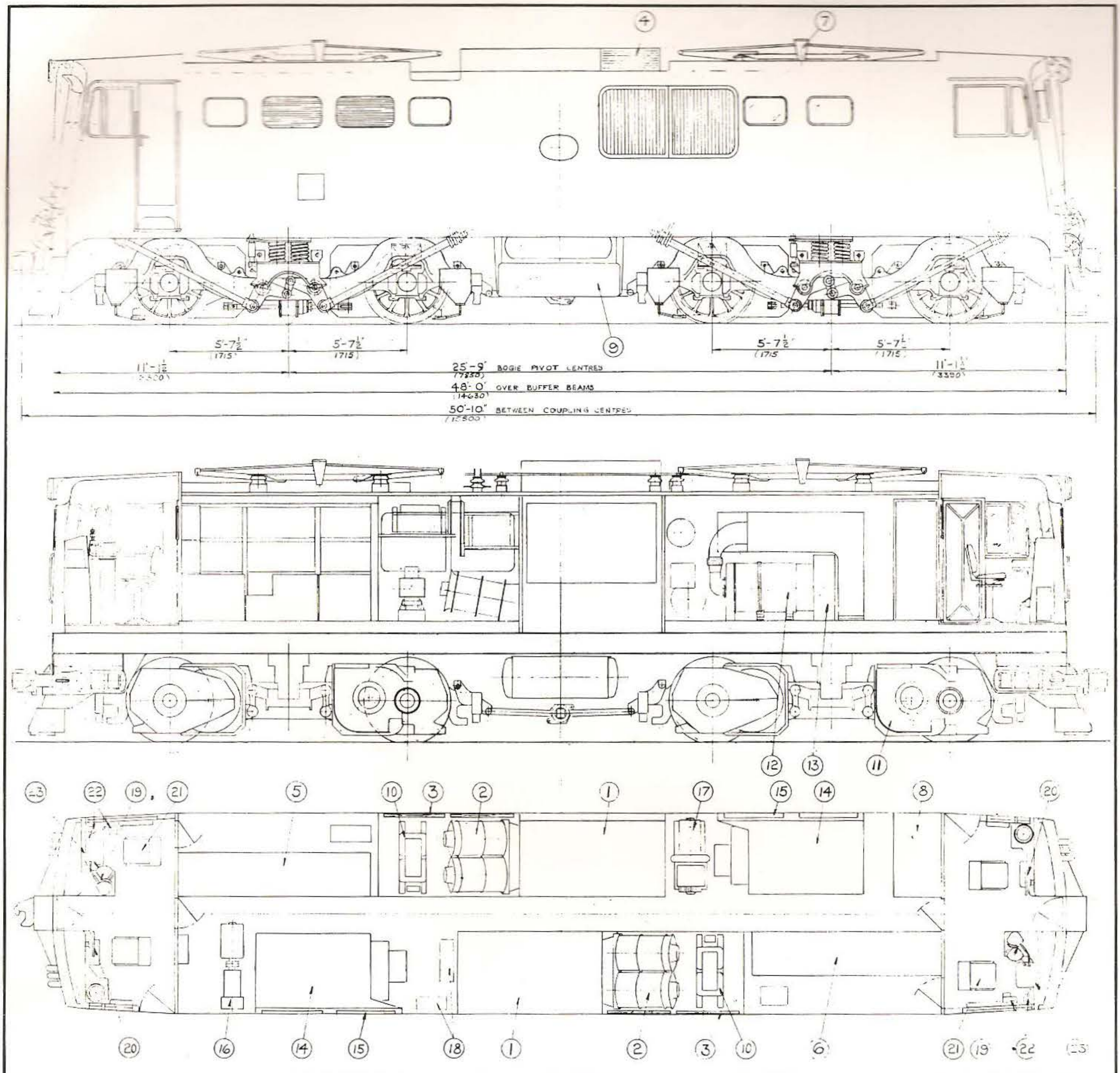
**Interchangeability and metrication**

The South African Republic Authorities hold very strong views on all these subjects. SAR obviously requires components on a contract to be interchangeable. However there has already been five contracts for these locomotives in a period of about five years and each contract has included detail improvements resulting from service experience. These have also been incorporated retrospectively in the earlier locomotives and furthermore it was required that whenever possible items of the 6E1 generation should be interchangeable with the earlier 5E1 locos (and even the 5E's) if not detrimental to the required considerable improvement in performance. Nevertheless, the challenge to provide maximum interchangeability has been met to a remarkable degree.

SAR policy on metrication was to some extent guided by South African national policy. This policy was adopted after the first 300 6E and 6E1 locomotives had been ordered and has had to implemented without upsetting the fundamental requirement of maintaining interchangeability throughout the fleet. A compromise was essential and this has been done by generally metricating fixings and fastenings so that main components in either units are interchangeable but not all the small details.

**Manufacture and general layout**

The superstructures for these locomotives are manufactured locally from locally produced steel and the bogie frames are of cast-steel, machined locally also. Manufacture of the electrical propulsion equipment is split between the British Factories of GEC Traction at Manchester, Preston and Sheffield and GEC (South Africa) factories at Knights and Benoni. Power and control cable is obtained from African Cables, a company, in which GEC has a large

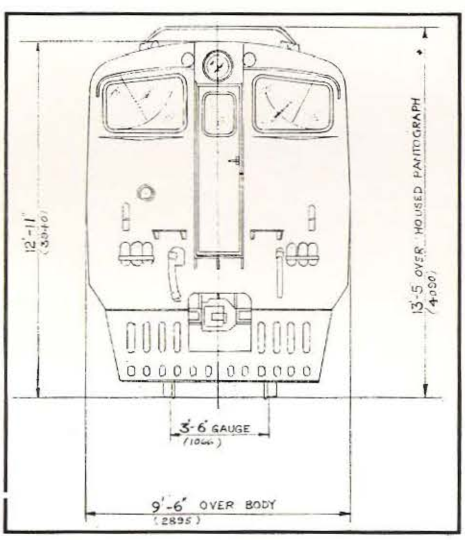



share holding, whilst filters which were originally obtained from Locker-Airmaze in Britain are now manufactured by its South African subsidiary.

The general arrangement is illustrated in Fig. 5 from which it will be seen that the equipment layout is generally symmetrical between the two cab bulkheads with two HT equipment groups diagonally opposite and the two resistance compartments in the centre of the locomotive. The two motor/alternator supply/exciter sets are located opposite the HT compartments beneath the intertial filters.

Normal access to the cab is from a door at the left hand side by the assistant's seat. There is an additional door above the centre coupler for access to adjacent locos in multiple. The drivers seat is on the right side of the cab with electric controls on his left side and air/vacuum controls on his right side. Instruments are located in front of the driver with line voltmeters, ammeters and brake gauges prominently

**Fig. 5.** *General arrangement of SAR Class 6E1 Bo-Bo 87·5 tonne electric locomotive for 3-ft 6-in 3,000 V d.c. network*




1. *Resistance compartment*
2. *Resistance blowers*
3. *Air inlet louvres-resistance compartment*
4. *Air outlet louvres-resistance compartment*
5. *No. 1 H.T. switch group frame*
6. *No. 2 H.T. switch group frame*
7. *Pantograph*
8. *L.T. equipment*
9. *Battery*
10. *Inductive diverts*
11. *Traction motor*
12. *M.A. set*
13. *T.M. blower*
14. *Inertia air filters and duct*
15. *T.M. air inlet louvres*
16. *Air compressor*
17. *Exhauster*
18. *Air equipment*
19. *Master controller*
20. *Handbrake*
21. *Seat*
22. *Brake valves*
23. *Instrument panel*

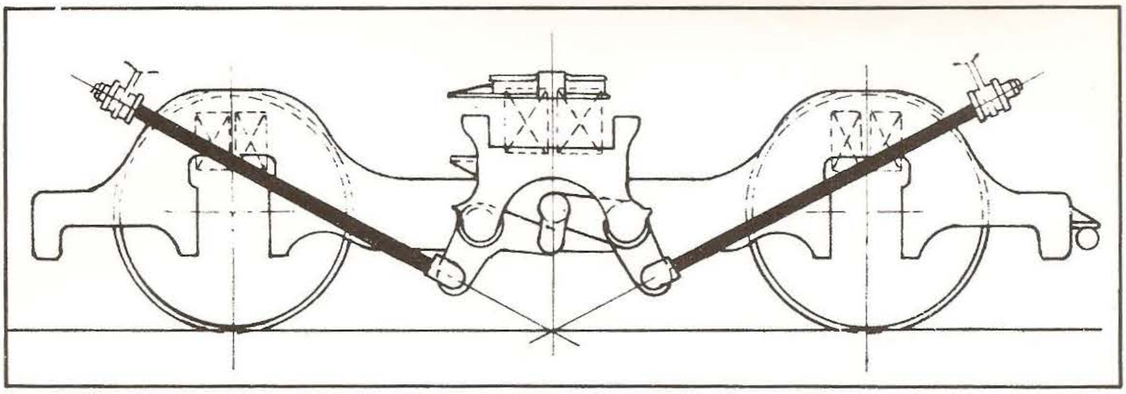


**Fig. 6.** *Bogie arrangement of SAR 6E1 showing inclined links*

displayed. The hand brake wheel is located in front of the assistant seat. There are air operated windscreen wipers for both drivers and assistants. Two 500-W foot-heaters in each cab are connected to the locomotive's 110-V auxiliary supply.

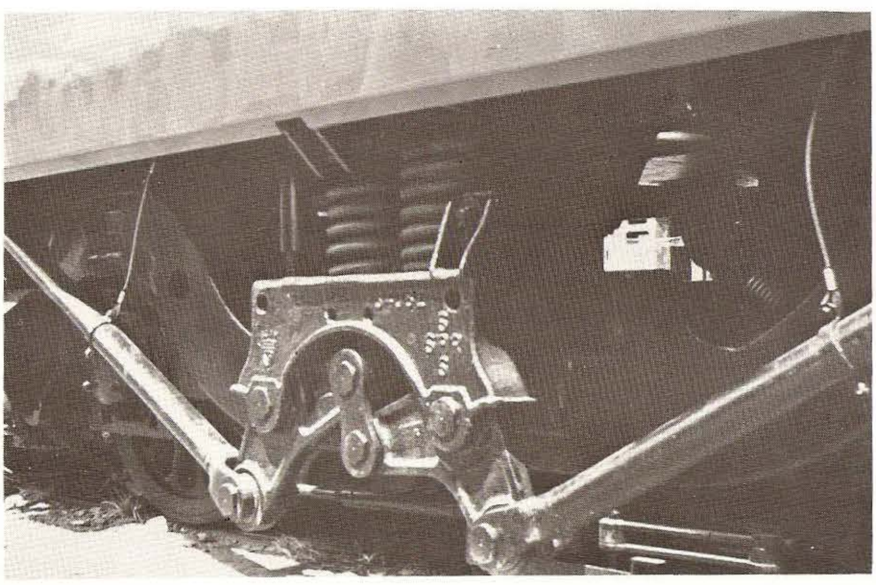
Behind the driver's seat, at both ends of the locomotive, an interlocked door gives access to one of the two HT compartments. Access to these compartments is also obtained through panels in the corridor wall which are also interlocked to prevent entry unless the pantograph is down and the HT equipment earthed. Through the door in the centre of the No. 1 rear partition the air compressor stands on the floor on the right. On the rear partition wall are mounted the pantograph selector cocks and the traction motor cut-out switch.

Above the compressor is the rack on which the inter-locomotive jumper cables are carried when not in use. Opposite the compressor, across the corridor, are the two hand-operated motor-alternator circuit breakers, with their handles let into the wall of the No. 1 HT compartment. Further down the corridor adjacent to the compressor is the exciter motor-alternator set and coupled blowers with the traction motor inertial, self-cleaning filters situated above it. Removable panels allow access to the filters.

The two compressed air equipment frames occupy the space between the exciter motor-alternator blower set and the No. 2 resistance compartment. Across the corridor from the air equipment frames is the No. 1 resistance fan compartment which is ventilated with unfiltered air by means of two identical adjustable pitch aerofoil fans. The two resistance compartments are either side of the corridor in the middle of the locomotive. At the far end of No. 2 resistance compartments are its two ventilating fans similar and in a similar compartment to that of No. 1 resistance fans, separating the resistance compartments from No. 2 high-tension compartment.

Opposite No. 2 resistance-fan compartment is the vacuum exhauster, snifter, strainer and check valve unit and the vacuum emergency application valve. Mounted above the exhauster is the pantograph reservoir. The supply motor-alternator blower set with the traction motor inertial filter above it, is placed diagonally opposite the No. 1 set, while the low-tension cupboard occupies a position against the No. 2 cab rear partition diagonally opposite the compressor. A space between the low-tension cupboard and the traction motor inertial filter ducting allows access to the LT cupboard. Removable panels in the corridor and in the back of No. 2 cab allow access to other parts of the low-tension cupboard. Any item of equipment which is too large to be removed through any of the doorways may be withdrawn through removable sections of the roof or body.

*Class 6E1 electric locomotive showing close-up of inclined links.*



**Weight transfer compensation**

The cast steel two axle bogies are designed to have minimum weight transfer characteristics. The 6E1 bogies incorporated inclined traction links which, by producing the effect of a virtual pivot centre at rail height, eliminate weight transfer within the bogie itself. Weight transfer between bogies is compensated for by arranging for the traction motor in the leading bogie (regardless of the direction of travel) to operate with less tractive effort than the trailing bogies. This is done by operating the leading bogie in the third stage of field-weakening and the trailing bogie in full field when in "series" combination, whilst in "parallel" the leading motors are in full field and the trailing motors in the first stage of field weakening. A current sensitive relay automatically introduces this electric weight transfer compensation whenever the total tractive effort exceeds 186 kN.

The main difference between the 6E and 6E1 locomotives is their bogies and the method weight transfer is compensated within the bogie. The 6E's do not have the inclined links but instead apply vertical forces to the bogie

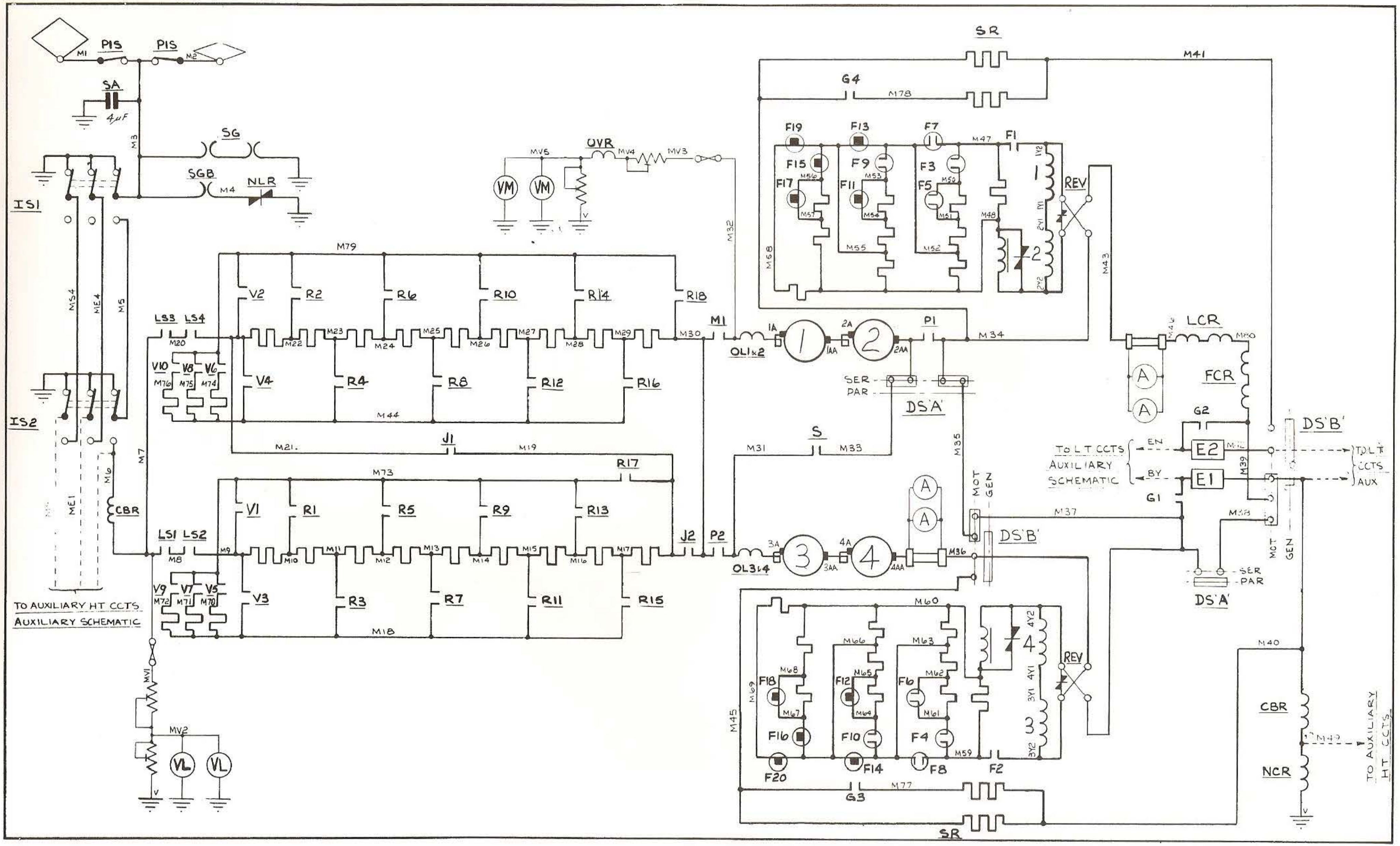
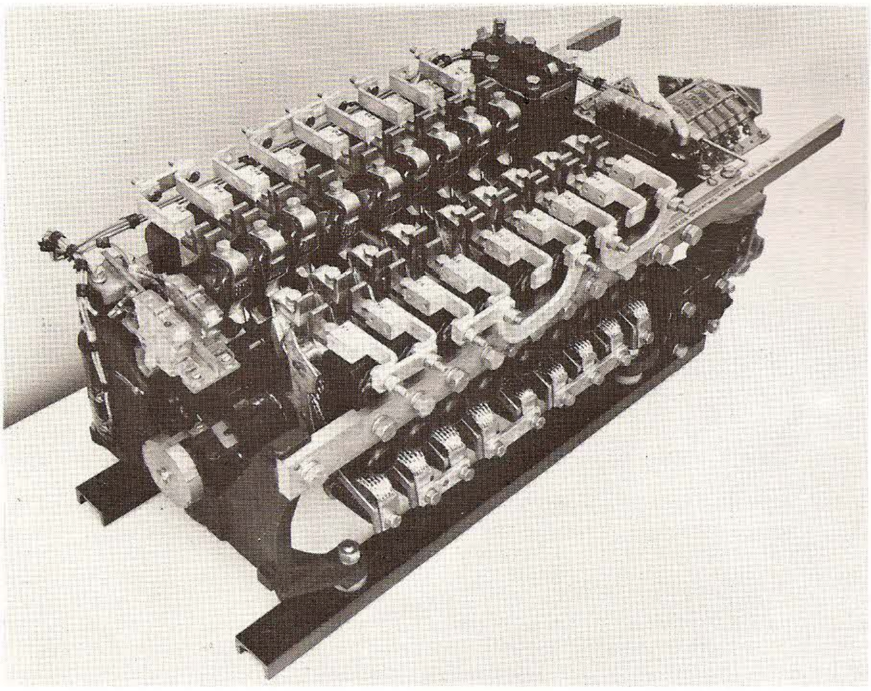



**Fig. 7.** *Power schematic of SAR Class 6E1 3,000 V d.c. electric locomotive*



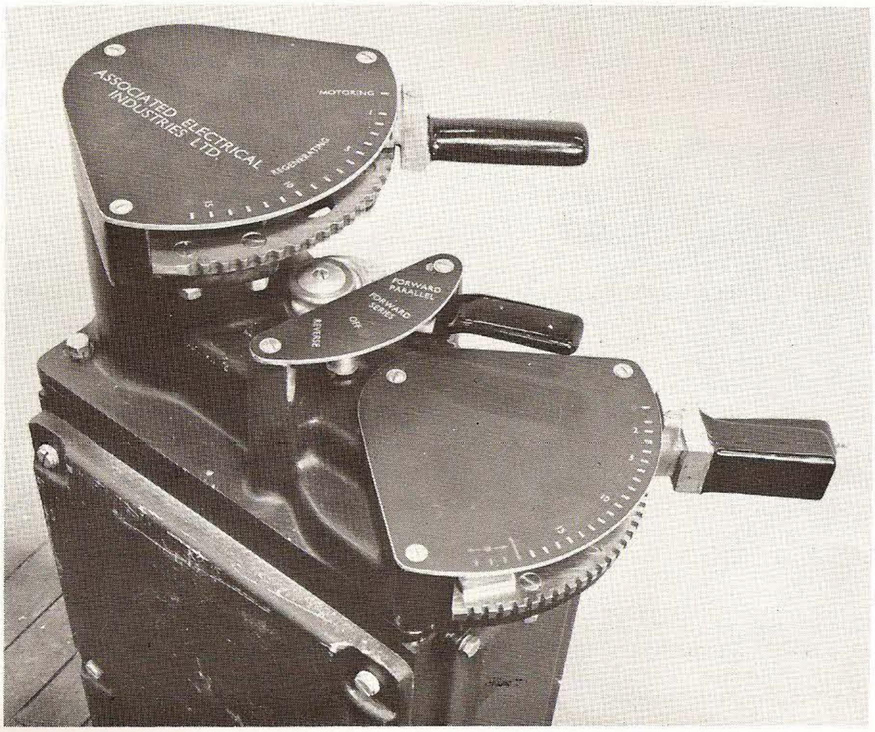
*Camshaft used for weak-field notching on SAR 6E1 locomotives*

headstocks by air bellows so as to physically over-ride the weight transfer forces. This feature was fitted to the 80 6E locomotives supplied mainly in 1970 but all subsequent 420 locomotives ordered have been 6E1 type with inclined links.

**Electrical equipment and control system**

The electrical equipment is designed to withstand the frequent and severe surges which result from lightning strikes to the overhead supply in spite of the protection of line to earth capacitors at close intervals on the overhead itself. Every effort has been made to limit the magnitude of these surges within the locomotive itself, by the fitting of a line to earth capacitor and a double arc horn on the roof remote from all other apparatus, and an auxiliary spark gap associated with a non-linear "Metrosil" resistor inside the loco body. This auxiliary spark gap is set to flash over at approximately 8·5 kV d.c., and this on a nominal 3-kV system. To cope with these severe conditions all electrical clearances and creepage distances are greater than specified by the various British Standard and IEC specifications.

*Master controller of Class 6E1 showing clearly the regenerative braking control handle at the top of the group*




Control of the traction motors is by means of electro pneumatic unit switches. The four motors are in two pairs of two motors connected permanantly in series, and the pairs may be connected in series (for starting) or parallel. Transition from series to parallel is by the "short circuit" method in which a part of the main resistance is re-inserted after which half the motors are short circuited before being reconnected to the line. This method has the advantage of retaining some of the tractive effort on half the motors.

The nine stages of weak field (10 in series) are obtained by connecting varying values of resistance across the motor fields in conjunction with an inductive divert. The first stage of weak field is by an EP contactor but the remaining stages are obtained by contactors controlled by an air engine driven camshaft (a high-voltage to earth version of that fitted to all theLondon Transport 3,043 power cars). A field control (notching) relay monitors the motors current and picks up to prevent a further weak-field stage being taken when to do so would result in an undesirably high current. It has a small differential and drops out when it is safe to take the next notch.

"Overload protection" is provided by overload relays operating in conjunction with two line switches in series and some of the resistance contactors. When an overload occurs the resistance contactors open first, thus reducing the current, before it is finally ruptured by the line switches. A "current-balance" relay provides further protection if the current at the positive end of the circuit exceeds that at the negative end.

"Over voltage" relays protect against excess regenerated voltage if the line becomes non-receptive, and a "no volt" relay protects against sudden re-application of line voltage after a line voltage failure.

A motor cut out switch enables the driver to isolate a pair of motors in the event of a motor failure.

**Driving procedure and regenerative braking**

For normal motoring the "reverse" key is placed in the "series" position after which the main handle is moved notch by notch until all the resistance sections are out of circuit and the full field series connection is reached. If accelerating close to the limits of adhesion the driver will also use his "vernier" controller which provides him with three vernier notches between each main notch except 1-2 and 2-3. The vernier controller is located to the rear of the master controller and is spring-loaded to return to the off position. On reaching full-field series the main handle can be moved into the weak-field zone to obtain any of the multiple stages of field-weakening.

To accelerate further the "reverse" key is moved to "parallel" and the main handle moved quickly back to notch 1 when transition takes place. The driver then notches up as he did in the series connection. In weak-field there are three positions marked "Down", "Hold" and "Up". These control movement of the weak field camshaft (under the over riding control of the notching relay).

To obtain regenerative braking the "reverse" key is moved to the selected combination and the regen brake handle moved until the motor voltage equals the line voltage, as indicated by two adjacent voltmeters. The main handle is then moved to the full field position thus short circuiting most of the main resistance; what is left in circuit ensures correct and stable operation with other 6E1 locos in multiple. The regenerative-brake handle is then moved to vary the degree of excitation to the exciter set and the amount of braking effort is thus generated.

The anti-slip brake may be applied by the driver at any time by means of buttons located at every driving position. The feature is trainlined for simultaneous operation on all locomotives in multiple and provides a light air brake application.

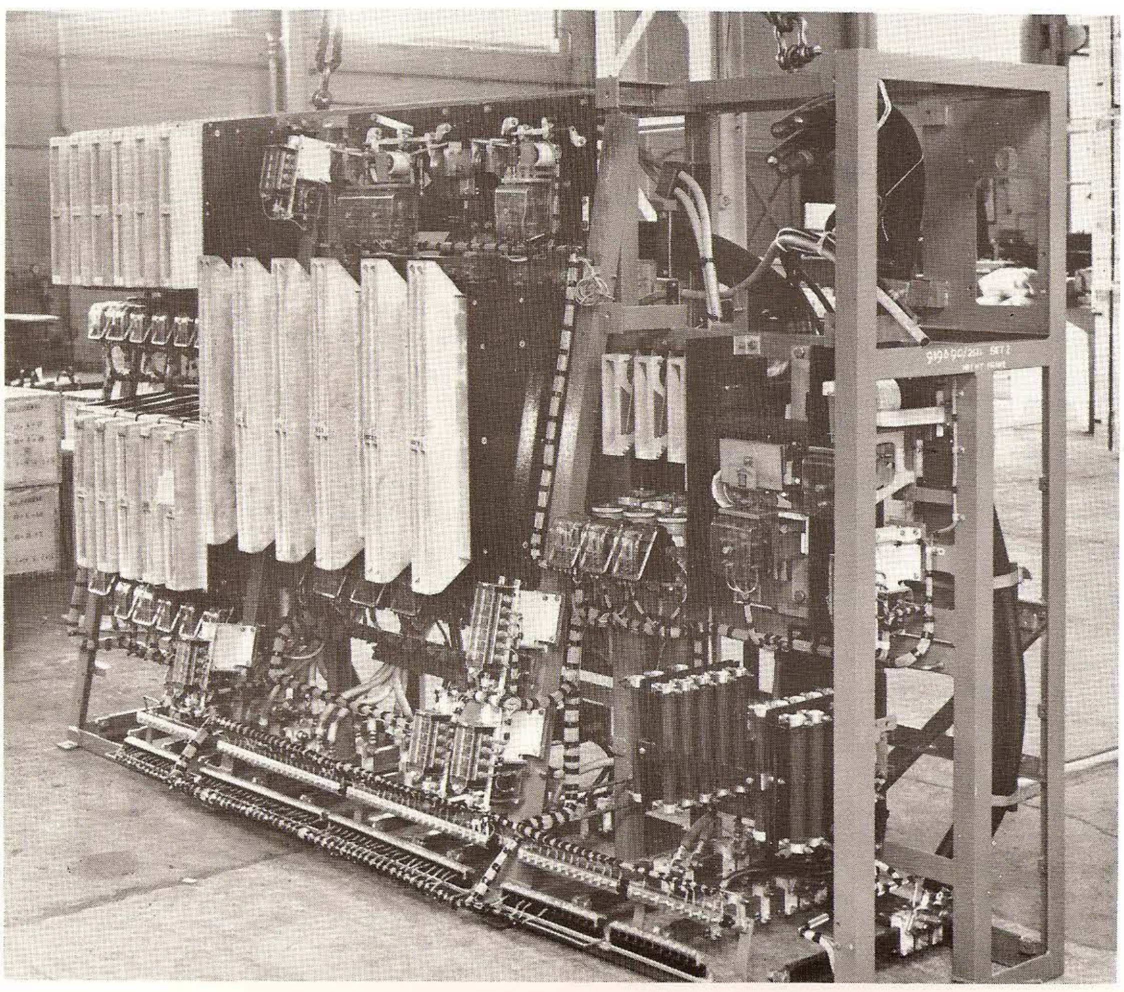
**HT Control Equipment**

The HT control equipment is housed in two compartments. The only access to each is by a single door which is interlocked mechanically with the main HT isolating switch and hence the pantograph air supply. The arrangement is such that the doors cannot be unlocked until the isolating switch is fully home in the earth position and the isolating switch cannot be reclosed until the HT compartment doors have been reclosed. Access to the main resistances is by means of hinged covers which cannot be opened until the isolating switch is fully earthed.

The master controller "reverse" key unlocks the HT compartment door. The required time delay between lowering the pantograph by the main isolating switch and operation of the earthing switch is obtained by the relative position of the two items. It is necessary to move from the cab into the corridor and close the cab corridor-door before the earthing switch can be thrown.

There are two line switches in each motor leg, type 13PC. They have large arc chutes capable of handling any overload rupturing duties that may occur as well as normal switch-off duties. The motor combination and resistance switches are type 14PC, whilst those for the field circuits and braking connections are heavy current type 22PC. Both mating surfaces are solid silver but knuckling action is such that the rupturing takes place at the toe which is a copper contact, thus avoiding burning of the silver. The vernier contactors operate with only a low voltage across their tips so they only have a small arc chute although insulation to earth is for the full 3,000 V.

There are two single-pan type pantographs per locomotive, type 14P11 with a pan head 203-mm wide and 2,032-mm long. There are four copper strips per pantograph. All pantographs are designed to be fitted with lubrication of the contact strips and hence the overhead line but it is SAR practice to fit only a portion



*GEC Traction HT-equipment frame fitted to SAR Class 6E1 locomotives* of each fleet ordered. The lubrication is obtained by pumping caster oil to each outer wearing strip. The pans are designed to accept small irregularities of the contact wire and the pan is pivotted at a point such that the leading and trailing strips share contact pressure very nearly equally. The main bearings are ball type and other frame bearings consist of stainless steel sleeves and phosphor bronze hinge pins, grease lubricated. The pantographs are raised by springs arranged so that pressure is almost constant over the full working range (Fig. 8) and lowered by a pull-down spring which overrides the balance springs. Raising and lowering is pneumatic, lowering being rapid at first and gentle as the pantographs reaches the stop. Each pantograph is provided with an isolating switch which is operated by a link stick, normally carried in the corridor.

Resistances are located in two compartments on opposite sides of the corridor, each ventilated by two electrically-driven blowers. The blowers operate at full speed only during resistance notching and at reduced speed, to cut down noise and power demand at all other times. All the blowers are normally connected to the exciter set. The exciter has two 55-V output circuits and one blower in each compartment is connected to each circuit. In the event of a blower failure it can be shut down and the locomotive will still be able to make a normal start although it will be necessary to wait some time before a second start can be made. This applies also if the exciter set fails, in which case all four blower motors are connected in series across the supply set.

### LT control equipment

The auxiliary voltage is 110 V d.c. It is obtained by rectifying the output of the motor-alternator supply set and voltage control is by a type 20RG static voltage regulator. Lead-acid batteries were installed in the earlier locomotives (Exide type 6XMZ5M rated at 46 Ah) but later versions have had alkaline batteries (30 AH) both at 5-hour rate. A rectifier prevents reverse current flow if the motor-alternator voltage is less than that of the battery.

The LT contactors are generally electro-magnetic type (whereas the HT contactors are electro-pneumatic). There are two types, the larger 15EC controlling the LT machines whilst the smaller 10EC controls excitation of the regenerative motor-alternator exciter-set and various other parts of the control circuit.

Interlocks are fully protected against the ingress of dust and unauthorised interference and can be sealed if necessary. Contacts are silver thus requiring minimum maintenance — six months interval is normal. When adjustment or replacement is required it is easily carried out as access is from the front of the main equipment. The magnet valves on all the EP devices including unit switches, reversers, etc. are all identical which greatly facilitates spares holdings.

Three sets of inter-locomotive control-couplers are provided giving a total of 81 train lines. Three sockets are located at each side of each cab and a loose set of three jumper-cables is carried in each locomotive. The receptacles are located at solebar height so that insertion or withdrawal of plugs can be done by a man standing on the ground.

### The Type S equipment

This is an electronic equipment developed to give a speed signal of greater accuracy than that available from the usual electrical or mechanical tachometers. It operates on the principle of counting pulses generated when a toothed-wheel passes a magnetic-probe. Subsequent development has given rise to the availability of a variety of speed dependant functions such as speed indication, distance counting, wheel slip, vigilance and overall vehicle control systems.

For the 6E1 locomotives, the equipment provides fast wheel-slip detection, overspeed protection, speed indication and distance counting. Signals are obtained from magnetic probes mounted on each of the four gear-cases using the main gear-wheel teeth to provide the pulses. All four signals are processed in a common electronic control box which in addition to carrying out the wheel-slip detection and over-

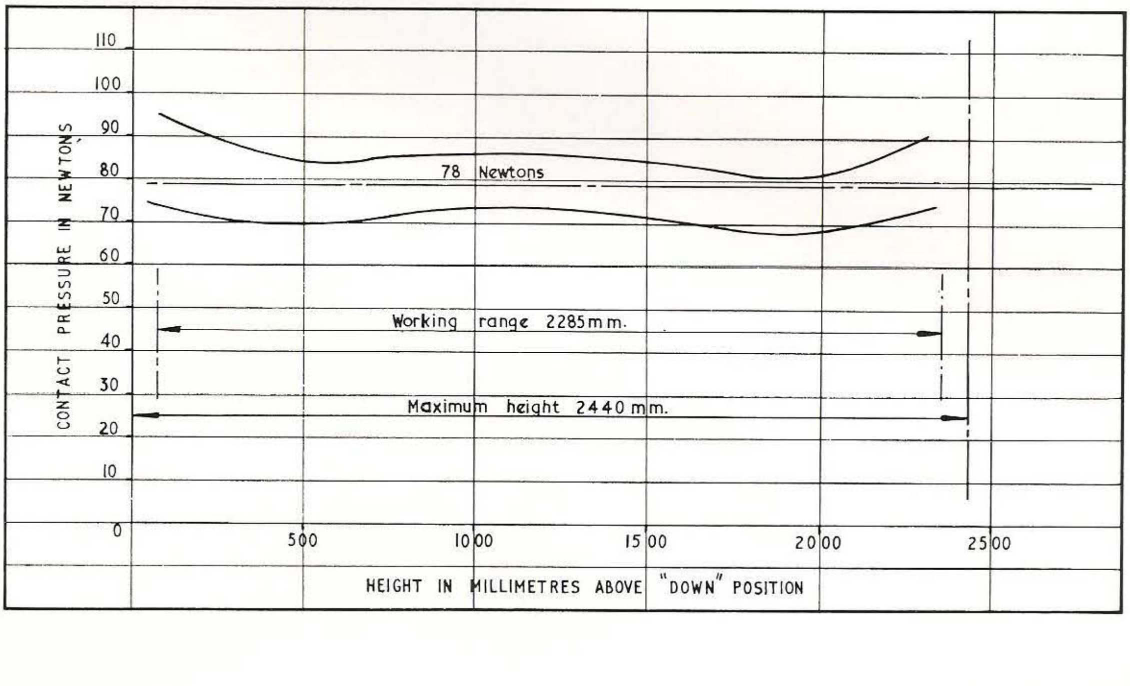



**Fig. 8.** *Pantograph height/pressure curve of 6E1 locomotive*

speed protection, transmits a speed signal to each cab and records locomotive distance travelled on a counter attached to the control box.

Differential wheel-slip indication is given whenever the speed signal from any two axles differ by some 12 km/h (allowance being made for differing wheel diameters and tolerance within the equipment). A rapid breakaway of any one or all of the four axles is detected by a "rate of acceleration" or "spin" circuit set, at 5·0 m/sec². This apparently high setting is to prevent transient operation due to buffing shocks. Both of these circuits emit a signal arranged to sound the wheel-slip buzzers and illuminate the wheel-slip lights on the driven locomotives when working in multiple whilst the anti-slipbrake is applied to the slipping locomotive only.

In order to cater for failure to correct the slipping condition, an overspeed protection circuit is fitted. This is set to trip at 10 per cent above the maximum permitted locomotive speed, at which point all power is removed from the motors, thus eliminating the risk of burst armatures.

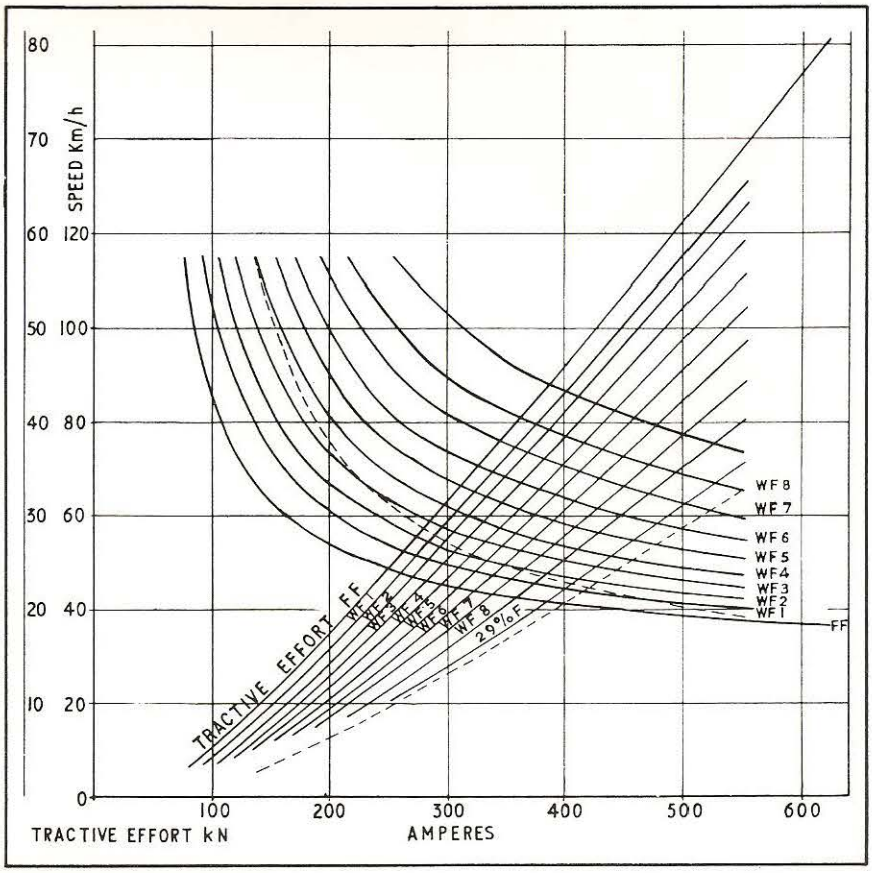



**Fig. 9.** *Traction motor characteristics of 6E1 115 km/h electric locomotive*

**Axle-hung traction motors**

There are four traction motors per locomotive, type AEI 283. The original machines were the AZ version but current production is of the metricated AY version. They are nose suspended, axle-hung non-compensated machines rated at 460A, 1450v, 624kW, 835hp, 644 rev/min, 1-hour full-field at sea level.

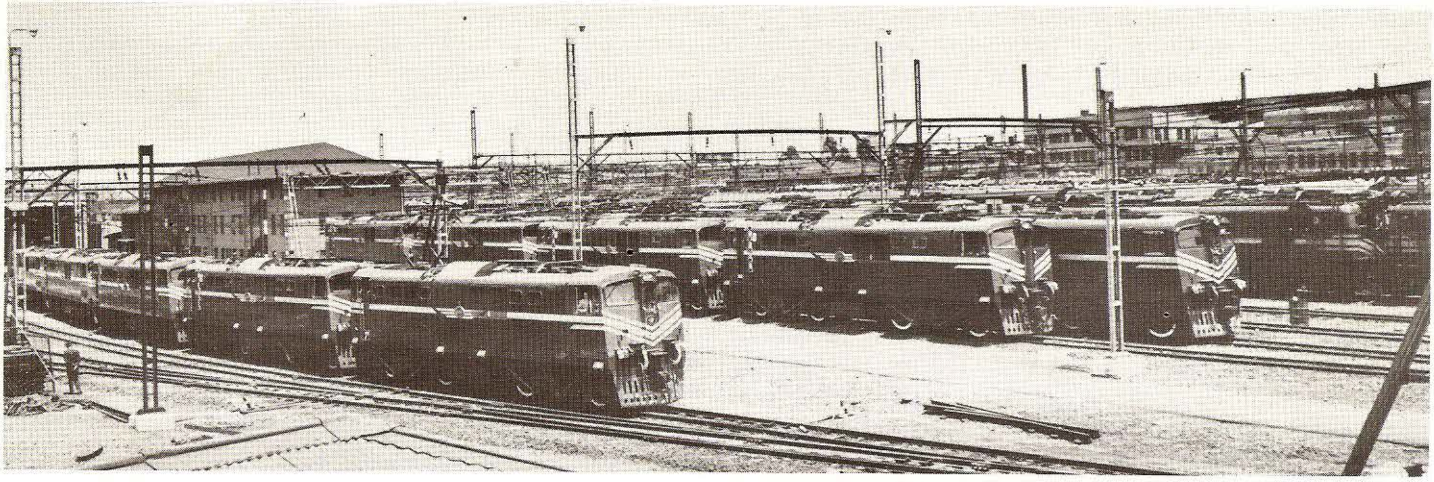
Earlier traction motors on SAR had shown progressive improvement over the years and it was felt that the AEI 281 motor, as fitted to the 5E1 locomotive, represented the limit of development of that type of machine without changing the basic design quite radically, because reactance voltages and voltages between commutator segments had reached limiting values. The substantial increase in performance of the 283 motors was achieved by using a lap winding which extended the commutating capacity of the motor by halving the current in each coil compared with a wave winding and also, having more commutator bars, reduced the volts/bar as well as taking advantage of the inherently better commutating performance of the equalised lap winding as compared with an equivalent wave winding. The high performance characteristic required at starting necessitated an increase in flux and consequent increase in magnetic section. Hence special attention was paid to weight savings.

The magnet frame illustrates weight saving techniques. Most magnet frames are of cast construction and to be able to guarantee that the minimum section will always be available, it invariably happens that excess material is used. In this case the magnet frame was fabricated from steel plate with the result that the minimum section could be guaranteed with a very small top tolerance. A portion of the flux is carried in a laminated circuit, welded to the inside of the frame, to improve the response of the flux to sudden increases in current after momentary interruptions. The commutator chamber is cast and bolted to the frame.

In common with all recent locomotive motors supplied to the SAR over the last 10 years the AEI 283 motor is carried on the axle by roller-suspension bearings. Although these have been extensively used for many years on standard gauge motors it is believed that the 3,400 roller-suspension units in service on the SAR are the only examples of this type in fleet use on high power narrow gauge locomotives and multiple unit stock. The difficulty in using a roller-suspension bearing is that it is large in diameter and short in length, whereas the sleeve bearing equivalent is smaller in diameter but longer. Thus, whereas a sleeve bearing can be accommodated within the main body of the motor, the roller bearing must of necessity come outside it. In the case of the SAR locomotives room has been found for the roller-bearings by making the centre of the resilient gear-wheel integral with the locomotive wheel centre.

Previous SAR roller bearings have been of the split tube type but it was felt that a design of improved strength was required to cater for the very high power of this application. The U-tube design was therefore supplied. This GEC Traction design was first applied to British Railway class 86 25-kV a.c. locomotives, which travel some 21 million km per year, much of it at 160 km/h. The bearings are mounted in a single piece casting which consists of 2 bearing-housings joined by a "U" shaped section which surrounds the axle. The unit is bolted direct to the motor frame but is electrically insulated from it to prevent return current passing through the bearings.

The increased rating of these motors was made possible by the development of improved insulation systems. Kapton polyimide film is



*Braamfontein locomotive depot in Johannesburg, South Africa, with a number of SAR Class 6E1 locomotives in the foreground*

used for slot and conductor insulation as its use permits a greater cross section of copper to be fitted into a given slot size; in this case some 16 per cent more Because the overall motor dimensions were fixed by outside parameters it was necessary to reduce the space available for the poles in order to make space available for the thicker magnetic section. This was achieved by using an epoxy resin integrated mica system to bond the poles and coils together. The complete field system is only insulated for class F temperature rises and yet, because of the improved thermal conductivity, heat losses as high as previous machines with class H insulation but non-bonded coils can be allowed without exceeding the class F temperature limits.

The very high grade insulation systems means that high currents and overloads can be accepted without necessarily damaging the windings but such circumstances might well cause problems with conventional soldered joints between the armature conductors and the commutator risers. This has been overcome by using Tungsten Inert Gas (TIG) welding which can withstand severe overloads without damage.

Round-wire equalisers are fitted which experience shows gives a better mechanical construction than strip. They are located at the commutator end which service experience has proved to be preferable to the pinion end as it can be secured better and longer creepage distances are available. There is also less inductance in the equalising circuits.

Brushgear insulators are mica glass mouldings covered with PTFE sleeves. There are two full width brushes per box and four independant springs per box in order to exert pressure equally. Pigtails are fitted as experience has shown that current passing between the brush and brush-guide caused slight burning without them when operating at high brush current density.

**Motor-alternator and LT driven equipment**

There are two identical motor-alternater sets normally connected with one as a low tension supply set and the other as an exciter but if the supply set fails then the exciter can be reconnected to act as an emergency supply set. The duty of the exciter is appreciably greater than that of the supply set so all machines are tested as exciters. A traction motor blower is over hung from the alternator and at the motor end there is a small blower for scavanging the inertial filters (which are located above each MA set).

The motor is a 2-pole machine with a continuous sea level rating of 70.5 kW. The three phase claw type alternator has 2 output circuits which are connected in series for the supply set and in parallel for the exciter. All outputs are immediately rectified by silicon rectifiers. The alternator is rated at 44 kW; the large difference between the rating of the two machines being accounted for by the fan load.

Compressors, exhausters and resistance fans are all driven by LT motors. Different brake machines have been supplied for different contracts as follows:

| *Locomotives* | *Compressors* | *Motors* | *Exhauster* | *Motors* |
|---|---|---|---|---|
| Original | Knorr Bremse VV230/180N-1 | AEG | Reavall 17S | AEI AY28 |
| Later | Westinghouse 3VC75 | Integral | Northey 300RE FM Mk 10 | Westinghouse |
| Latest | Westinghouse 3VC75 | Integral | Reavall 17S | AEI AY28 |

AEI type 602BW motors have been used throughout for the resistance blowers.

**Table II. Leading particulars of Classes 6E and 6E1**

| | |
|---|---|
| Wheel arrangement | Bo-Bo |
| Maximum service speed | 115 km/h |
| Weight in working order (total) | 87·5 tonnes |
| Weight of 6E1 body | 41·7 tonnes |
| Weight of 6E body | 41·1 tonnes |
| Weight of 6E1 bogie | 22·9 tonnes |
| Weight of 6E bogie | 23·2 tonnes |
| Length between coupler centres | 15·50 m |
| Length over buffer beams | 14·65 m |
| Height over cab | 3·940 m |
| Width over body panels | 2·895 m |
| Bogie wheelbase | 3·430 m |
| Bogie centres | 7·850 m |
| Wheel diameter | 1,220 mm |
| Coupler height | 890 mm |
| Minimum radius track curve | 84 m |
| Traction motors | Four, axle-hung |
| Gearwheel | Resilient spur |
| Gear ratio | 18·67 |
| Locomotive brakes | Air and regenerative |
| Train brakes | Vacuum or air |

**GEC Traction Ltd.,**
Trafford Park, Manchester M17 1PR
Telephone: 061 872 2431. Telex: 667152. Cables: Assocelect Manchester.