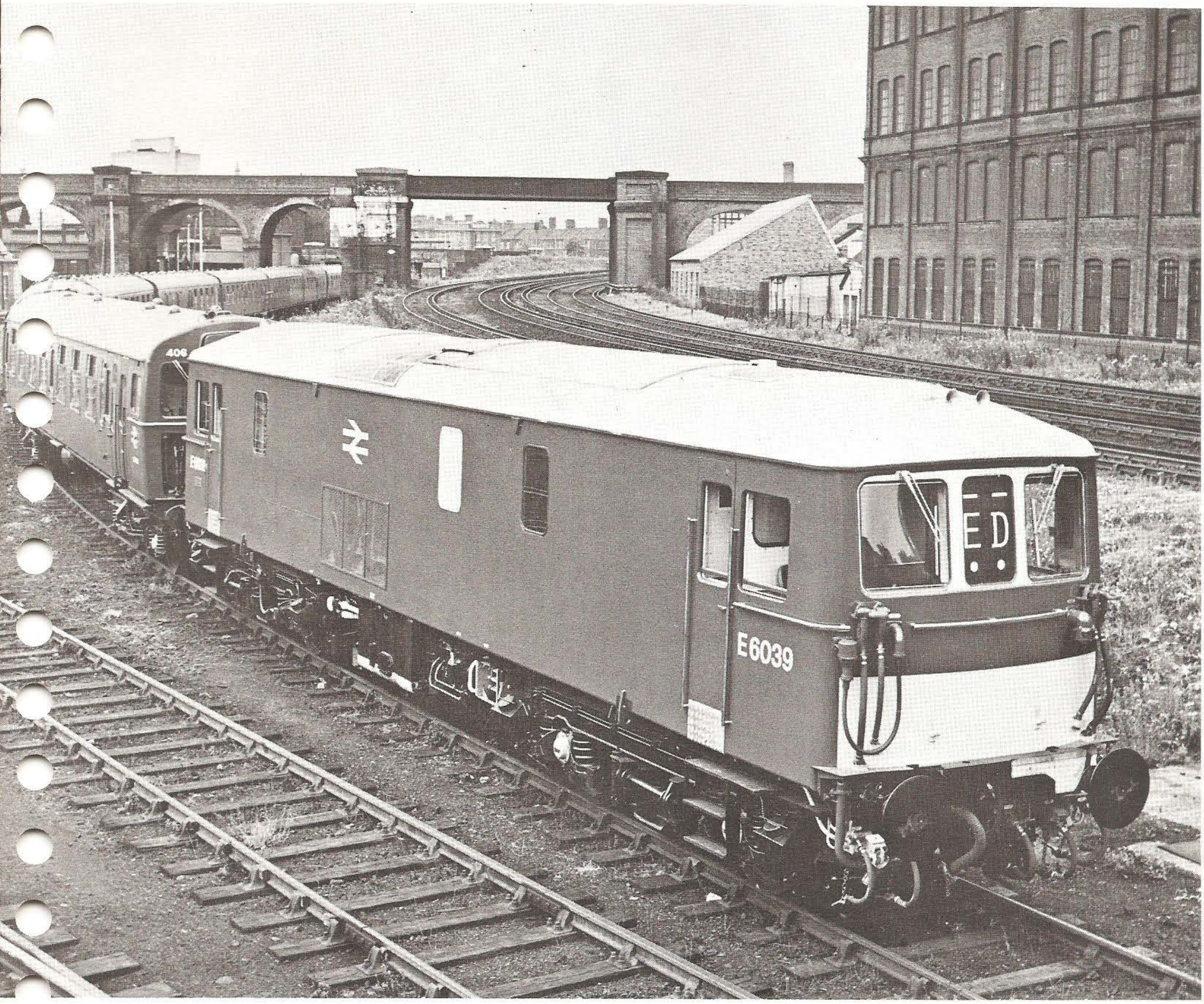
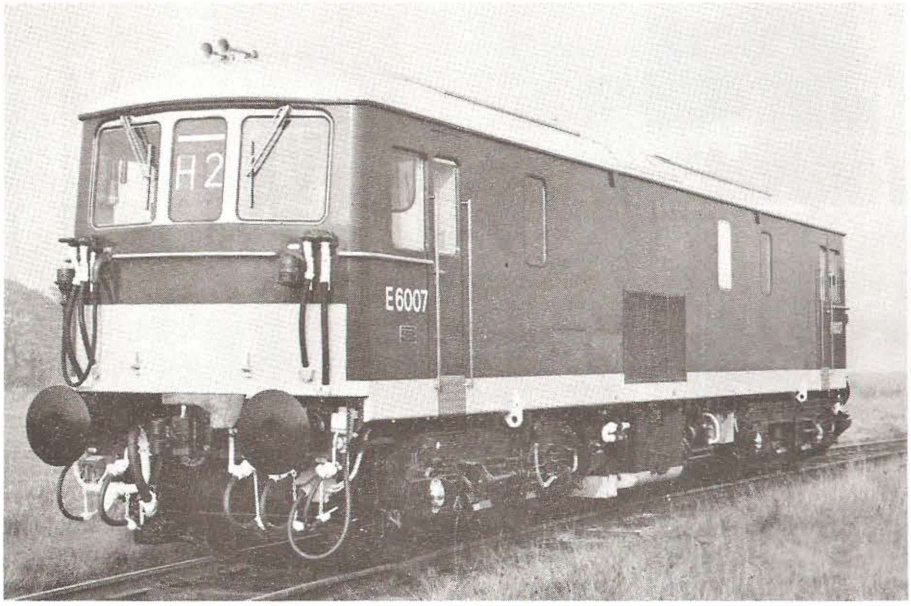
GEC



ELECTRO DIESEL LOCOMOTIVES

GEC Traction Limited

ENGLISH ELECTRIC | AEI



This page left: Type JB electro-diesel locomotive No. E6007.

Facing page centre left: No. E6021 operating on diesel power in a marshalling yard.

Facing page centre right: The usefulness of an electro-diesel's "amphibian" capabilities are seen in this view of No. E6043 testing newly-laid conductor rail between Southampton and Lymington Junction near Redbridge on January 5.
Photo by J. H. Bird

Facing page bottom: Loco No. 6014 approaches Brentford Central with a freight train.
Photo by B. Stephenson

EE Electro-diesel locomotives for British Rail SR

E. K. ERRINGTON

THE English Electric Co. has recently completed a British Rail order for 43 1,600/600 h.p. electro-diesel locomotives. The order was placed as part of the programme to eliminate steam traction on the Southern Region and also as part of the Bournemouth electrification scheme. Delivery of these locomotives commenced in November, 1965

The design of the power equipment was carried out by The English Electric Co. to the requirements of the CM&EE, Southern Region and the mechanical parts were designed by the BRB's Mechanical Engineer (Design), Brighton. The 43 locomotives, Nos. E6007-49, are designated Type JB to distinguish them from the six prototype locomotives, Nos. E6001-6, which are known as Type JA. They have been built at The English Electric Co's works at Newton-Le-Willows, where the diesel engines were also manufactured; the electrical equipment was produced at the company's Preston works.

The design of the Type JB locomotives generally follows that of the six prototype Type JA units, which were built in 1962. As electric locomotives, each is a 1,600 h.p. unit operating on the 675V d.c. third-rail system. Over non-electrified lines—or over electrified lines from which current has been shut off—the electro-diesel can work as a 600 h.p. diesel-electric locomotive, powered by an English Electric Type 4 SRKT diesel engine.

Versatility in m.u. operation

The locomotives have been designed so that they can operate in multiple with other electro-diesel locomotives, diesel-electric locomotives and with multiple-unit electric trains. They can be controlled from a remote driver's cab whether functioning as a diesel or an electric unit; if required the diesel engine can be started from a remote driving position. The changeover from electric to diesel power and *vice versa* can be made at any time and does not involve stopping the train.

When operating as a diesel-electric, each locomotive has sufficient power to cover all shunting work and to work trains over "dead" sections of line at reasonable speeds. The locomotives are capable of performing the same type of duty as the Southern Region's Type 3 1,550 h.p. diesel-electric locomotives, which involves haulage of freight trains loading up to 700 tons and passenger trains of up to 10 coaches on a ruling gradient of 1 in 70. The performance of the electro-diesel is superior to that of the Type 3 in the lower speed range, where more power is available for acceleration, but at over 75 m.p.h. the power of the diesel-electric exceeds that of the electro-diesel.

Component layout

As the accompanying diagram shows, the body of the electro-diesel is divided by a central bulkhead; the diesel power equipment is installed in the compartment towards No. 1 end and the electrical control equipment at No. 2 end. The buffer beam at No. 2 end is thicker than that at No. 1 end to provide additional weight and thus equalise the wheel loading.

The electrical control equipment compartment has a central corridor with control frames on either side. There is access to these control frames from front and rear. The starting resistances, which are adjacent to the central bulkhead, are located on each side of the central corridor. The resistance frames compartments are open to the atmosphere to provide maximum cooling. Stainless steel tie rods are used to hold the insulated, edge-wound, strip-type resistance units. The batteries are housed in boxes between one control frame and the body side, and the inductive shunts are similarly located on the opposite side of the locomotive. The space between the control frames and No. 2 cab bulkhead is occupied by the brake equipment frame and one of the two traction motor blowers. A difference between this design and that of the Type JA locomotives is that the air to the traction motor blowers is now ducted direct from the atmosphere through filters and not taken from the compartment.

The engine generator set is installed with the generator nearest to the central bulkhead. A load regulator is also adjacent to this bulkhead. The cooling unit and the second traction motor blower are mounted between the free end of the engine and the No. 1 cab bulkhead. The exhaust silencer is fitted in a recess in the roof immediately above the traction generator.

Equipment mounted on the underside of the underframe includes two fuel tanks, air compressor, auxiliary motor-generator set, two exhausters, main reservoir and auxiliary and control reservoirs.

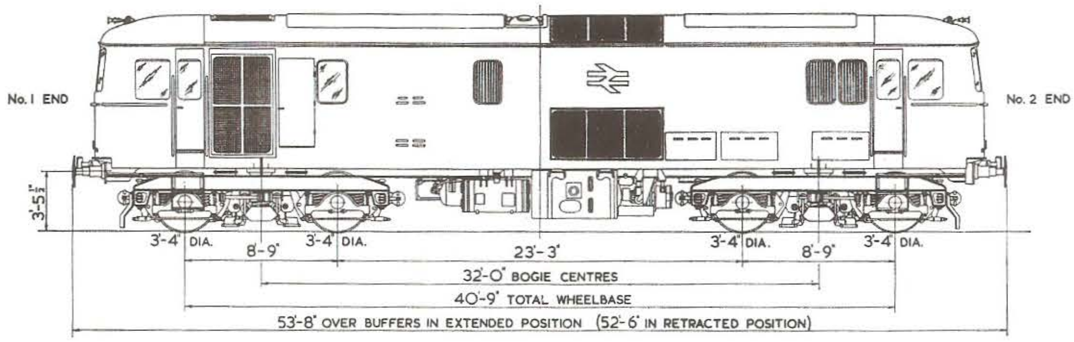
Electrical control system

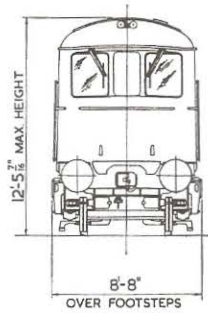
The master controllers, brake controllers, instruments and switches are housed in a full-width, prefabricated driver's desk. The desk incorporates two separate and fully equipped driving positions, to the left and right hand, at each end of the locomotive.

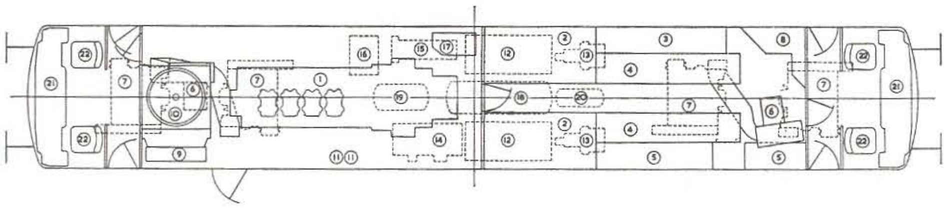
Rheostatic control, with two motor groupings plus a wide range of motor field control, is used. The large number of notches in each motor grouping restricts changes in tractive effort during notching to the minimum, thereby reducing the tendency to wheelslip during acceleration. The driver's master controller has two main power handles, one for electric operation and one for diesel. Each handle has two "off" positions, namely "lock off" and "off"; to select one of the two forms of power, the relevant handle selected is moved from the "lock off" to the "off" position. The controls are interlocked with the current collector-shoe operating mechanism to ensure that the shoes are always in the raised position when the locomotive is operating on diesel power.

There are 20 camshaft-controlled resistance notches in series (two parallel pairs of motors in series) and 10 in parallel (four motors in parallel). There are also four weak field notches in series and in parallel controlled by a separate camshaft giving,

Reprinted from Modern Railways March 1967





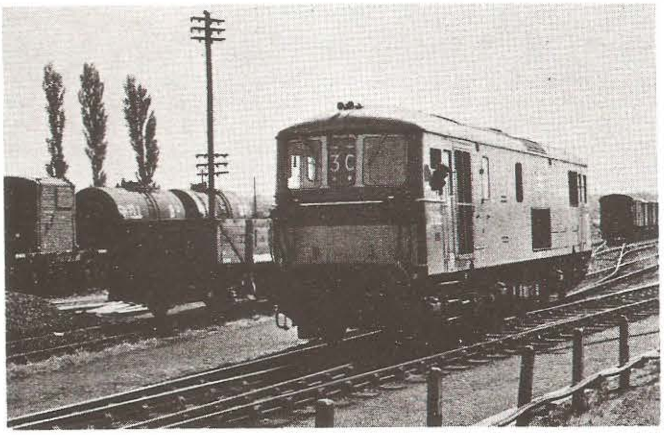


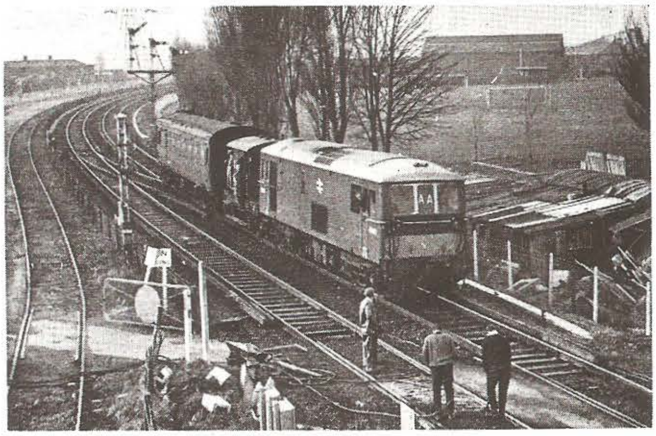
KEY

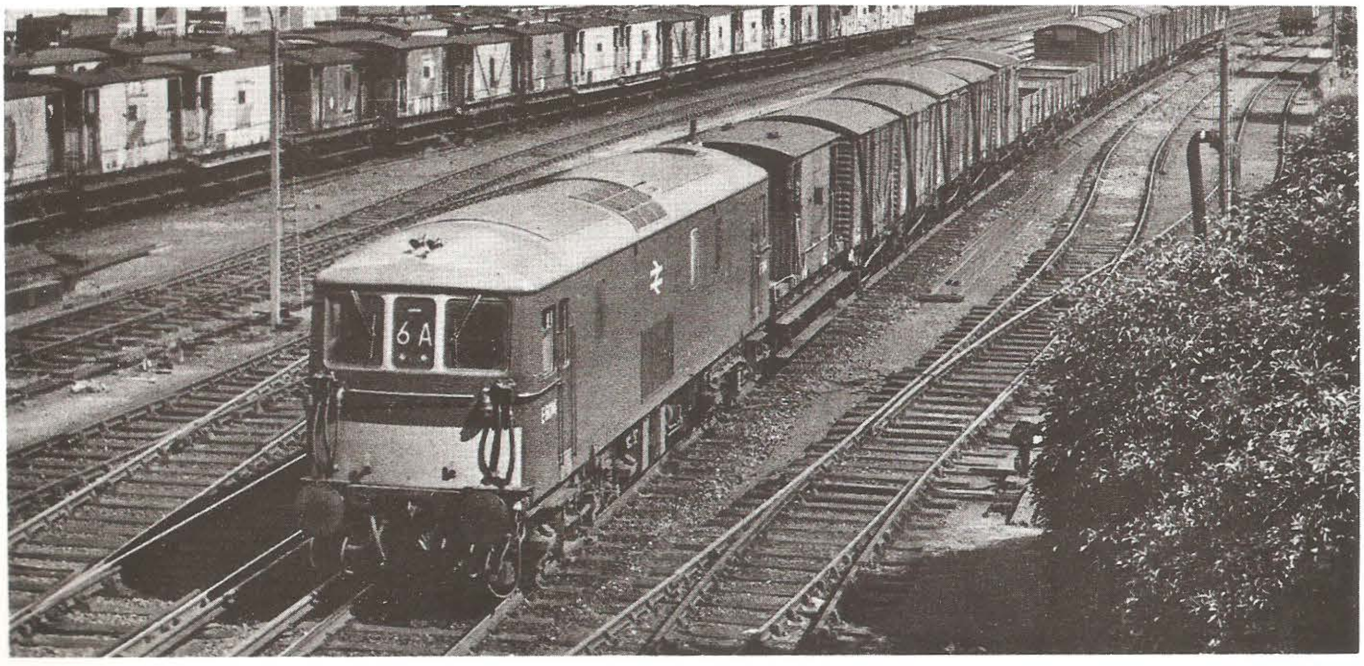
1 Engine and generator
2 Starting resistances
3 Inductive shunts
4 Control frames
5 Batteries
6 Traction motor blowers
7 Traction motors
8 Valve stand
9 Radiator
10 Fan
11 CO_2 cylinders
12 Fuel tanks
13 Exhausters
14 Motor generator set
15 Compressor
16 Resistance frames
17 Load regulator
18 Main reservoir
19 Auxiliary reservoir
20 Control reservoir
21 Driver's desks
22 Driver's seats

LEADING PARTICULARS

Gauge	4' 8½"
Wheel arrangement ...	Bo-Bo
Maximum service speed	90 m.p.h.
Power rating—1hr ...	1,600 h.p. electric 600 h.p. diesel
Tractive effort (nominal maximum)	42,000 lb. at 25% adhesion
Tractive effort (1hr FF)	18,600 lb.
Nominal supply voltage	675V d.c.
Weight in W.O. ...	75 tons
Length over buffers ...	53' 8"
Width over footsteps	8' 8"
Overall height ...	12' 5 7/16" max
Bogie pivot centres ...	32' 0"
Bogie wheelbase ...	8' 9"
Wheel diameter ...	3' 4"







with the full field notches, a total of 10 economical running notches. The power circuit is a conventional series/parallel, parallel combination with bridge transition. Relays located in the power circuit provide overload, earth fault and wheelslip protection.

Traction motors and auxiliaries

Each of the four traction motors is a four-pole machine with a 1hr rating of 395 h.p., 1,010 r.p.m. 675V, 475A; they are of the nose-suspended, axle-hung type with roller suspension bearings. The ratio of the spur reduction gears is 19:61, which gives the locomotive a permissible top speed of 100 m.p.h. when the motor speed is 2,770 r.p.m. Traction motor cooling air is provided by two motor blower sets; each blower is driven by a motor with a rating of 5.75 h.p. at 2,550 r.p.m.

The motor generator set which supplies the auxiliaries is rated at 24kW at 1,210 r.p.m. This motor generator set functions when the locomotive is on electric operation and provides a 110V d.c. auxiliary supply, this voltage being controlled by a carbon pile regulator. An electrical feed is provided for train heating when the locomotives are on electric operation, but no heating supply is available from the engine generator set.

Diesel power unit

The engine generator set is basically the same as that used in the Southern Region's diesel-electric multiple-units and in the original six prototype electro-diesel locomotives. The engine is an English Electric Type 4SRKT turbo-charged type, whose 1hr rating is 600 b.h.p. at 850 r.p.m.

Speed control is continuous and is provided by the governor over the speed range of 450-850 r.p.m. There is full torque control with automatic transition and traction motor field weakening. The oil and water cooler comprises a single side-mounted panel, and the fan, which is mounted in the roof, is driven by an electric motor. The coolant temperature is maintained between 160 and 180 deg. F. by a thermostat which controls the radiator fan motor.

The main generator, which is a single-bearing machine, is directly coupled to the diesel engine and has a continuous rating of 387kW, 850 r.p.m. 430V, 900A. The auxiliary generator, which is over-hung from the main generator shaft, has a continuous rating at maximum governed speed of 35kW, 850 r.p.m. 110V, 320A. This machine supplies all auxiliaries when the locomotive is operated on diesel power. The complete diesel engine generator set is three-point mounted and is arranged for removal through the area of the detachable roof section.

Four driving positions

Resin-bonded glass fibre mouldings are used for the cab roofs, cab doors and the drivers' desks. As already mentioned, each cab has two complete driving positions, making four in all, each with a set of controllers, brake valves, instruments and push-buttons. Fully adjustable seats are provided for the driver and his assistant. There are two deadman's pedals at each position, one for operation when sitting and the other when standing.

Underframe and body

The cab is of double skin construction and is fully insulated, the double skin of the roof being filled with plastic foam. Glass fibre mat is used to pack the cavity of the cab rear bulkhead. Plastic panels line the cab and screens are fitted behind the driving and assistant's seats to form a vestibule between the cab entrance doors. Electric gold film demisters are incorporated in the windscreens and two windscreen wipers are fitted to each cab.

The underframe is fabricated from rolled steel joists, plates and channel section solebars. The drag boxes are made up of fabricated plate box structures. The buffing and drawgear are fitted with drophead buffer couplers and the sprung rubbing-plate of the Pullman vestibule for operation with multiple-unit electric stock. Retractable buffers of the Oleo-pneumatic type can be extended or retracted as required and rotated through 90 deg. to lock in position.

The body sides are fabricated in the form of Warren girders and are covered on the outside by 14 SWG sheet steel. At floor level the body width is the maximum permitted by the Hastings line gauge, and the sides slope at the top to conform to the multiple-unit stock dimensions. Removable translucent panels are fitted in the roof to permit the removal of equipment. Aluminium sheet is used to line the body sides and partitions in the engine compartment, and aluminium tread plate is used on the floors.

Bogie design

The bogies are similar to those fitted to the Type JA prototype locomotive, except that at the corners, castings are used instead of a fabrication. These bogies on the 43 Type JB locomotives are interchangeable with those on the AJ e.m.u. motor coaches for the Bournemouth electrification scheme. The bogie frame is a one-piece welded fabrication of broad flange beams and the headstocks, which carry the brakes cylinders, are of channel section. The wing-type axleboxes which house roller bearings have cylindrical guides. The pads on which the body rests on the bolster have spherical seatings, lined with non-metallic material.

The secondary springing consists of one nest of coil springs at each end of the bolster resting on the spring plank, which is suspended from the bogie frame by vertical swing links with knife edge pivots. The secondary springs are located to provide roll stability with the soft springing and lateral bolster movement is limited by rubber buffers. Damping of the primary suspension is by spring-loaded friction pads and of the secondary suspension by hydraulic dampers. Lateral damping of the bolster is also by hydraulic dampers.

The shoe gear is arranged to retract the shoe clear of the loading gauge when the locomotive is running on non-electrified track. Each bogie has four shoe arms, each carrying one shoe. The arms are pivoted on Silentbloc Frustacon mountings to restrain the movement of the arm and to cushion any shocks from irregularities in the live rail. Springs hold the retracted arms in position. The shoes are brought into contact with the live rail by an opposed piston air cylinder. The vertical movements are then controlled by the Frustacon mountings.

Straight air and automatic braking is fitted on the locomotive and the control equipment is suitable for trains with air brakes, vacuum or the electro-pneumatic brakes on the multiple-unit electric stock. The Type JB locomotives, unlike the original six locomotives, are fitted with slack adjusters and have large single brake blocks instead of small double blocks.

Photo by J. H. Bird

ELECTRIC LOCOMOTIVES CONVERTED TO ELECTRO-DIESEL UNITS

Ten 2,500 hp 750 V d.c. electrics built for the Southern Region in 1958 have been extensively modified to enable them to work over non-electrified docks and sidings

ABOUT TEN YEARS AGO 24 electric locomotives were built at Doncaster Works for use on the Southern Region's 750 V d.c. third rail system. These locomotives were rated at 2,500 hp, and incorporated a motor-generator booster set with a flywheel which could store enough energy to carry the locomotive across gaps in the conductor rails. A pantograph was used to collect power in sidings, which were wired for this purpose at the same voltage as the third rail. A description of these locomotives appeared in our issue of February 13, 1959.

The booster set comprised a mechanically coupled motor and generator, the motor being fed from the line and the generator arranged to buck or boost the supply to the traction motors. Control was by camshaft controlling resistance in series with the field of the booster generator.

In 1965 discussions took place between, the Southern Region CM&EE and the English Electric Co. Ltd. to determine the most suitable type of electro-diesel locomotive to fill the requirements for a higher power than that of the 1,600/600 hp electro-diesel locomotives then being built by English Electric, of which 43 have been supplied. It was ultimately decided that the best arrangement would be for 10 of the 2,500 hp electric locomotives to be modified to 2,500/650 hp electro-diesel locomotives.

When it became necessary to re-design the existing locomotives to take an additional engine-generator set, hard thinking and considerable work was necessary to solve the weight and space problem. The Paxman Ventura 6YJXL diesel engine was selected, which gave a good power/weight ratio and also had the advantage of being a type which was already in service on British Railways. Its high speed also ensured that the traction generator would be small and light.

Integral blowers

Having settled this aspect it was then necessary to consider how space could be provided in the locomotive for the additional unit. On the existing locomotives the booster set also had a flywheel and an auxiliary generator, and the traction motor blower was a separate motor-driven machine. It was decided to dispense with this separate machine and the fly-wheel on the booster set, and re-build each booster set with two integral traction motor blowers which would also cool the booster set, thus reducing weight and gaining space. Each blower is mounted in-board of its parent machine, and the coupling for the booster set is located between the two blowers. It was also considered that weight would be saved by making the radiator unit and the silencer unit as integral roof sections.

On the 1,600/600 hp electro-diesel locomotives the engine generator set is used to control the performance of the locomotives by generator voltage control within the engine power curve as on diesel-electrics, there being dual control systems on the locomotive.

In this new design the engine generator set simply replaces the third rail supply when the locomotive is working in non-electrified areas such as Southampton Docks. There is only one control system on the locomotive, which is able to take account of the limited power capacity of the engine.

Static control

During the early stages of the design thought was given to the possibility of using static control of the booster generator field in place of the resistance camshaft. It was decided that this was a feature which had many advantages and the improvement in control likely to be achieved warranted its inclusion in the design.

The method of control selected by English Electric was one involving a closed loop system. This system allows the driver to select any desired value of accelerating current which is maintained automatically up to the limit of performance. Logic circuits control the selection of weak field and the return to full field.

As obtaining a variable d.c. supply by controlled rectifiers requires an a.c. supply, the existing auxiliary generator was converted to a three-phase alternator, with a static automatic voltage regulator maintaining the phase voltage constant.

Increased tractive effort

One improvement which this type of equipment gives over normal rheostatic d.c. locomotive control is that it is possible to achieve increased tractive effort for any given adhesion condition. It also gives fine control of tractive effort on starting when working on diesel power. Normally the driver has to keep the mean tractive effort well below the rail adhesion limit to ensure that peak tractive efforts do not exceed this limit. With constant current control the driver is able to keep the locomotive very close to the limit of adhesion. Improved wheelslip control is also a very important feature.

With the constant current control the booster generator output is regulated in such a way that the maximum current of any traction motor does not exceed

Reprinted from Railway Gazette 17th May 1968

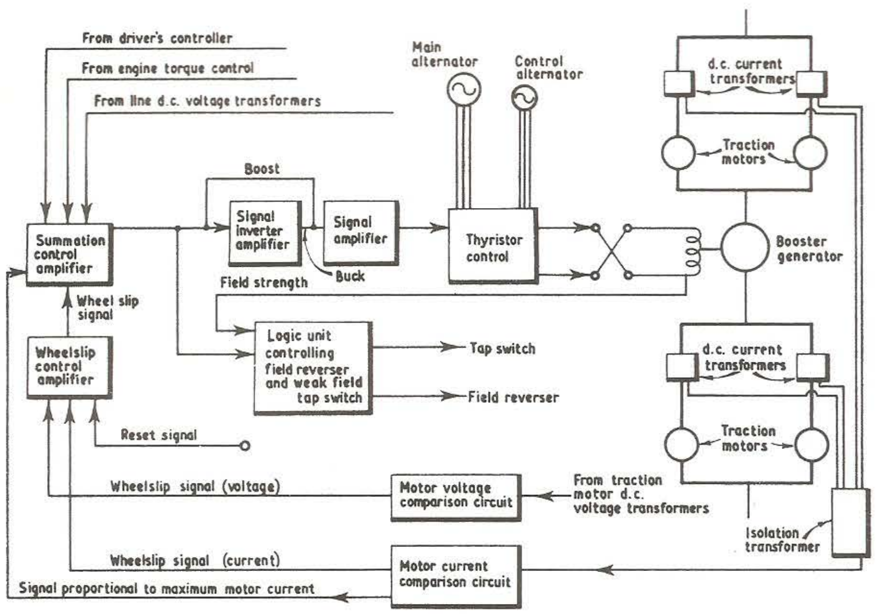


Fig. 1. Traction control schematic for electric and diesel operation

the selected value. Even when one motor starts slipping, the voltage across that group of motors cannot increase because the current in the non-slipping motors is not allowed to increase. Recovery of power is automatically controlled and is also extremely rapid.

The use of static equipment reduces the number of moving, and hence wearable, parts. This will reduce the need for examination of components and will reduce maintenance costs.

The arrangement of the traction motors is the same as that on the existing locomotives; series/parallel with the booster set generator armature in the equaliser link.

Initially the booster generator field is at a maximum and the generated voltage opposes the line (full buck). A low voltage is thus applied to the traction motors at starting. When the generator field excitation is reduced the generator volts fall, thus allowing the voltage across the traction motors to rise until, with zero excitation (no buck, no boost) the generator volts are almost zero and the voltage across each traction motor is approximately half line volts.

Reversal of the generator field current and an increase in excitation brings the output of the booster generator up to full boost. With the generator output assisting the line volts at full boost the voltage across each traction motor is approximately equal to line volts.

Control of the booster field is by a signal from the driver's controller which is fed through control amplifiers to a thyristor amplifier (Fig. 1). This provides phase angle control of the thyristors in a three-phase bridge rectifying alternating current supplied from the alternator coupled to the end of the booster set.

The firing angle of the thyristors is altered by the magnitude of the signal from the control amplifiers. The driver's controller provides a signal proportional to the angular position of the controller handle. When the locomotive is working independently infinitely variable control is possible, but notches are provided on the controller so that each locomotive may multiple with an identical locomotive, a 1,600/600 hp electro-diesel, various types of multiple-unit train, or a Type 3 diesel-electric.

Two constant voltage notches are provided for coupling up and shunting. In addition, three further notches are provided suitably spaced over the operating range of the controller handle. They correspond to series, parallel and weak field positions on the multiple unit stock (2, 3 and 4 positions on later equipment). These three notches control the progression of the static equipment; in position 2 the equipment will go into no-buck no-boost, in 3 full-boost full-field, and in 4 weak-field.

Theory of control

The closed loop system of control is used in that a signal proportional to the output (known as re-set signal) is fed back and compared with the applied signal (known as the setting signal). If there is an error between the two signals then this modifies the output. If there is no error then the circuit is giving the output called for; no error exists and so no further control is given.

When the driver's controller is moved to a given position the signal from this is compared with other signals. First, it is compared with the feed-back which is proportional to the current drawn by the traction motors. This signal is derived from d.c. current transformers and isolation transformers. Secondly it is compared with the feed-back representing wheelslip, if any. Thirdly, if the locomotive is using the diesel engine as its prime source of power, then the signal from the driver's controller is also compared with the feed-back from the diesel engine to determine whether the engine is overloaded.

If there is a difference between the controller signal and the sum of the three re-setting signals, the error signal is fed to the control amplifiers and the thyristor amplifier, the thyristor firing angle is modified, and thus the booster generator field current is altered. This in turn alters the traction motor current, the feed-back signals and hence the original error is reduced.

Ostensibly constant current and tractive effort is maintained. The booster generator field reverser is thrown when the logic unit detects a small increase in error at the no-buck no-boost setting.

Should the locomotive continue to accelerate after full boost condition has been reached then the difference between the driver's controller setting and the current feed-back signal will increase as the traction motor current falls, the traction motors following the constant voltage characteristic. This increasing difference (the error) will cause the output of the control amplifier to increase, and when this output reaches a predetermined voltage the logic unit will operate the field tap switch to introduce weak field. Current in weak field will then be controlled at approximately the previous full field value until the weak field characteristic is reached.

Wheelslip

Should wheelslip occur either with a single motor or a pair of motors, the outputs from the appropriate d.c. current and voltage transformers combine together with a fixed bias voltage at a control amplifier. This amplifier has a transfer characteristic such that when wheelslip begins traction motor current and hence tractive effort is quickly reduced to about 50 per cent of the pre-slip value, and slowly reduced still further if slip persists. After this tractive effort is allowed to rise by 50 per cent of the reduction, and then after a short time to the original value. This effects precise and automatic control of current which will maintain the tractive effort at a value just below the maximum which adhesion will permit.

Control equipment

The control equipment is housed in two control frames. No. 1 frame houses the usual control equipment consisting of line-breakers, reversers, relays and so on, and also the current limiter which is necessary for the protection of the shunt characteristic booster motor against traction supply transients.

No. 2 frame also contains normal control equipment, but in addition it houses the static equipment at one end in readily accessible and removable trays, each of which is fitted with a test socket. These test sockets are associated with a test instrument which is available for use by maintenance staff and is designed to avoid the need for specialised electronic training. The procedure for testing the static equipment is to apply the test plug to each socket in turn, checking readings against those recorded from test data. Should any particular tray not give its prescribed output that tray is pulled out and replaced.

Diesel engines

The Paxman Ventura 6YJXL diesel engine has a continuous rating of 650 b.h.p. at 1.500 rev/min. This engine has six cylinders arranged in a Vee form. It is a four-cycle direct injection pressure charged engine which has been specially developed for rail traction; 57 Ventura engines were supplied for Type 1 diesel-hydraulic locomotives built at Swindon Works, and a further 20 have been supplied to the Scottish Region for use on Type 2 locomotives as part of the BR re-engining programme.

The engine crankcase is a high grade iron casting which has been fully stress relieved. The forged steel crankshaft is located by a combined locating and journal bearing and the crank pins are hollow to reduce weight. A viscous torsional damper is bolted to the flange at the free end of the crankshaft. Fork and blade connecting rods have been used in Paxman designs for over 25 years and this engine is no exception to this well tried feature. The aluminium alloy oil-cooled pistons are each fitted with three compression and two oil control rings. The top pressure ring is fitted in an Alfin bonded cast iron ring grooved insert.

Single unit cylinder heads are fully interchangeable and each head houses two inlet and two exhaust valves seating on replaceable inserts. Wet liners include hard chrome plated bores, together with external chromium plating for waterside protection. Monobloc injection pumps, one element per cylinder, are grouped one on each side of the engine housing and the Regulateurs Europa governor is driven from the engine camshaft by gearing and is located at the drive end of the engine. The engine is fitted with a single Napier exhaust-gas driven water cooled turbo-charger located at the free end of the engine.

Booster set

The booster set comprises a motor coupled to a generator with a traction motor blower fan mounted on each machine, each blower providing air to two traction motors after passing through one half of the booster set. The main alternator, which is mounted at one end of the booster set, supplies a.c. for all auxiliaries and for the d.c. voltage and current transformers. A control alternator which provides an entirely independent three-phase a.c. supply for the thyristor firing circuits. At the opposite end of the machine is an overspeed trip.

E6012 after conversion. The retractable shoegear can be clearly seen.

Radiator

The radiator unit is roof mounted and comprises two cooling sections with a centrally-mounted motor driven fan. The fan is driven by an EE766 motor and is switched by a water temperature thermostat.

The original four EE532/A traction motors are used on these locomotives. They are six-pole machines each having a one-hour rating of 638 hp at 675 V.

Mechanical parts

The bodywork of the original electric locomotives was not intended to take any main stresses and was of comparatively light and simple construction. In view of the increased weight of equipment in these new locomotives it was necessary for the body sides to be stressed, and this was accomplished by the use of Warren girder framework with out-riggers to support the curved side skin. Modifications to the mechanical parts were carried out at Crewe Works to the requirements of the Director of Design at Brighton.

Over the equipment portion of the mechanical parts, apart from the radiator and silencer roof sections, the roof sections are formed in translucent glass fibre allowing natural light into all parts of the equipment compartment.

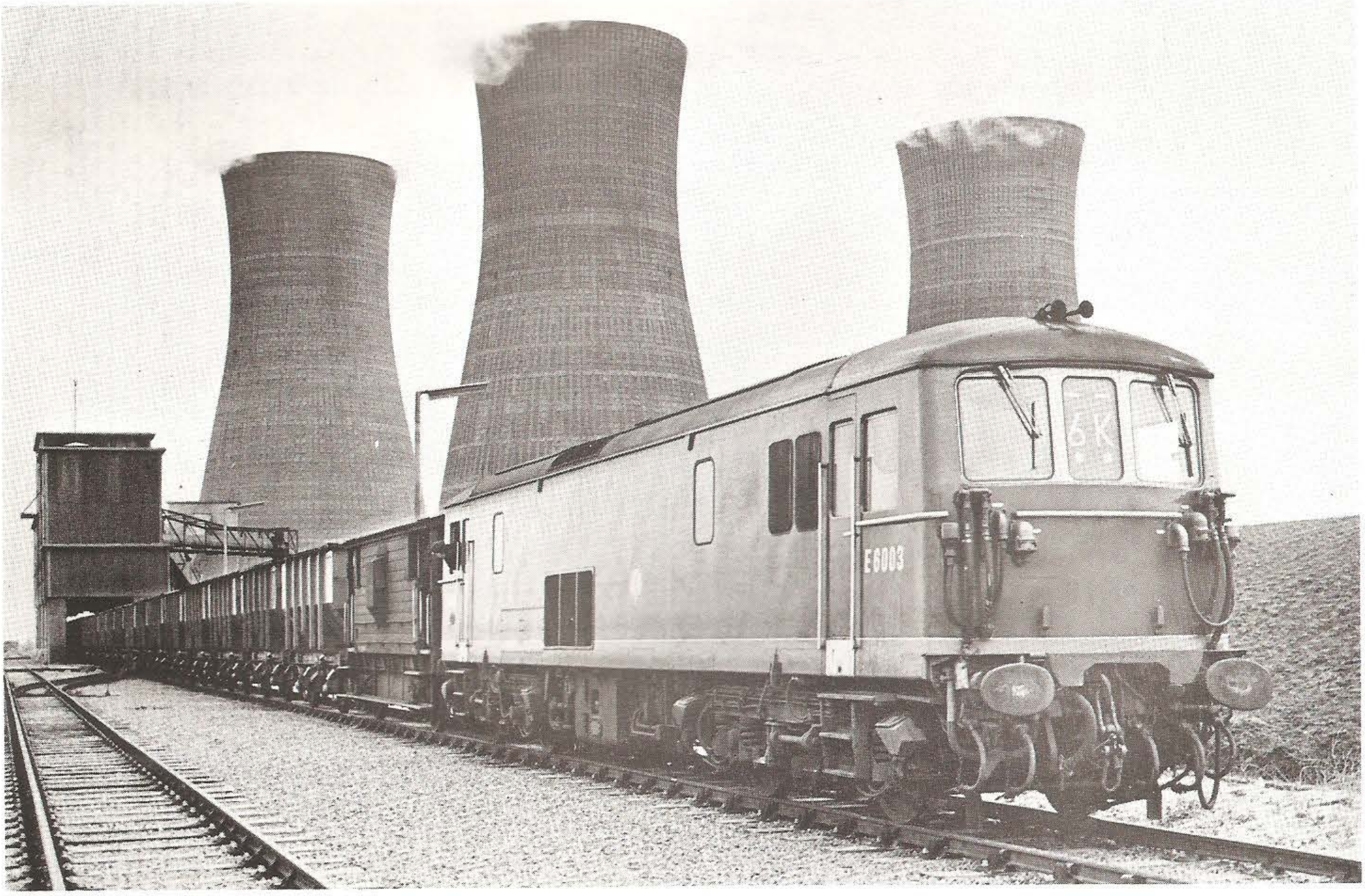
Each cab has two driving positions, each having an air brake controller and a single power controller which is used for operating either on electric or diesel power.

Air ducting

To provide the maximum access to equipment the air ducting within the equipment compartment is kept to one side.

Ducting from the booster set to the traction motors and also the air intake to the booster set and the air intake to the engine is kept to one side of the locomotive.

The bogies are basically the same as those used on the original locomotives. There are differences in that the secondary suspension is now in the form of laminated springs instead of helical springs. Retractable shoe gear has been fitted and this has required a difference in the layout of the shoe beams and the fitting of retraction gear on each side of the spring plank.



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

GET/ELR 1101 *Printed in England*