GEC

25 kV ac Electric Locomotives

British Rail Class 87

GEC Traction Limited

Class 87 80-ton Bo Bo under delivery by BREL equipped by GEC Traction Limited to provide 3,750 kw continuous output. Adoption by BR of frame-suspended traction motors and Flexicoil secondary suspension

Bo-Bo 176 km/h 25 kV electric locomotive design for BR West Coast main line to Scotland

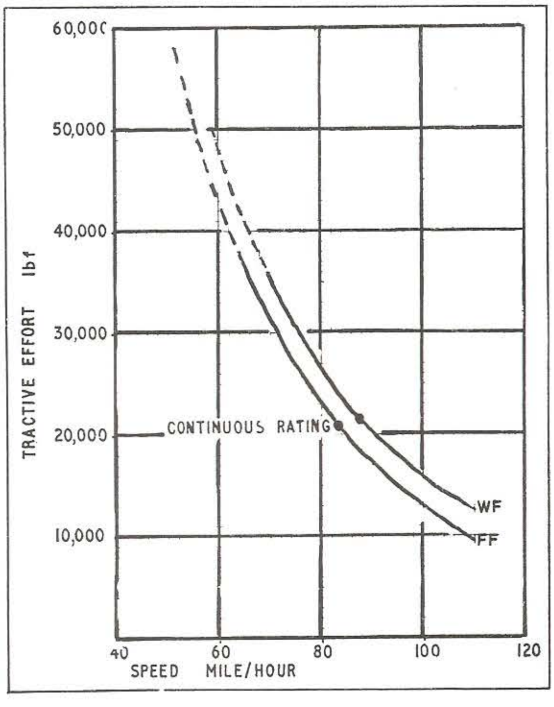
The latest and most powerful a c electric locomotives for British Rail are currently under construction at the Crewe Works of British Rail Engineering Limited, and the first of these entered service in July 1973. They will comprise a fleet of 35 units which will all be in service when the electrification of the BR West Coast main line to Glasgow is opened in May 1974. A further locomotive, number 36 in the class, will be equipped with thyristor control. The electrical equipment for all 36 locomotives is being supplied by GEC Traction Limited.

The Class 87 locomotives will provide motive power for the principal intercity passenger services from London to Birmingham, Manchester and Liverpool as well as to Glasgow. They are geared for 176 km/h operation though the line speed limits are at present being retained at 160km/h. These locomotives will be supplemented on the intercity services by fifty-two class 86 locomotives which are being modified and regeared for 176 km/h operation in readiness for the higher speed limits. These regeared locomotives are known as class 86/2. The remaining class 86/1 locomotives (together with classes 81-85) will be primarily used for freight service although they will retain their 160 km/h gearing.

The new locomotives have an improved performance characteristic at the high speed end as compared with earlier locomotives and a considerably improved continuous rating in the middle speed range for handling Freightliner trains over the difficult gradients north of Crewe. The continuous rating is 3,750 kW (5,000 hp) in weak field. In many other ways they are similar to the earlier locomotives being a Bo-Bo type and weighing 80 tons. External differences however include the incorporation of Flexicoil secondary -suspension, windscreen formed of two panels instead of three as on all earlier BR a c locomotives and the elimination of the train description indicator. Other changes include bogie-mounted traction motors to reduce the unsprung weight, the facility to work in multiple-unit pairs, the fitting of sanding gear and the ability to handle air brake trains only (earlier a.c. units were equipped to handle air- and vacuum-fitted trains).

The locomotive has a full-width cab each end connected by a through passage extending between and alongside the equipment which is arranged with the rectifier group, traction motor blowers and brake resistor mounted in each corner with the radiators, H.T. tap-changer H.T. bushing and main transformer located in the centre section. The cab front windows, in two sections only, are of Triplex safety-glass high-impact resistant screens, 21-mm thick, 950-mm X 660-mm incorporating HYV1Z colourless electric heating film, 320 W per screen, supplied at 110 V d c

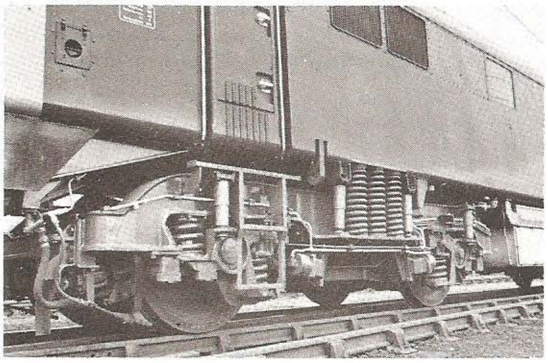
The whole half body-sides, cabs and underframe is a weld fabricated integrally-constructed assembly of steel plate and folded sections. The under-frame comprises a single longitudinal box section assembly made up of 8-mm longitudinal and lateral webs enclosed by 11-mm top and bottom plates. The upper section comprising the roof and upper body sides can be lifted off as a single assembly to provide maximum accessibility to equipment for major overhaul. It is a frame of 10 swg (3·215-mm) steel plate 'top hat' sections clothed in aluminium sheet. The transformer with tap changer, conservator, radiators, oil pump and pipe work can be lifted as one unit without the need to disconnect oil pipe joints. The roof has translucent panels to permit daylight entry. Auxiliary equipment is mounted mostly on the underside of the main frame and comprises main compressor, auxiliary compressor, battery and charger, weak-field resistor, rheostatic brake separate excitation equipment, air reservoirs and emergency battery isolating switch.



Tractive effort characteristics of BR 80-ton 3,750 kW a c locomotive

Reprinted from Rail Engineering International September 1973

Fully fabricated welded bogie assembly



Close up of the all-welded bogie and Flexicoil secondry suspension Koni dampers fitted to both primary and secondary suspension will be noted

The locomotive is mounted on 3,280-mm wheelbase, BP9 twin-axle bogies and no interconnecting linkage is fitted between them, the lines over which they travel at speed being free from sharp curves. Much attention has been given to unsprung weight and this has been reduced to only 2·6 tons per axle. The overall weight of the bogie is 18·1 tons fully assembled and without traction motors and their drive, 9·95 tons; a modest weight for the traction performance required. Solid-rolled 1,150-mm diameter monobloc wheels are fitted. As in the case of the Class 81 and 85, the Timkin taper-roller axleboxes are connected to the frame by 300-mm radius links held by Metalistik bushed pins locked solid in their respective attachment brackets. The journal centres are 2,050-mm.

Primary suspension is by 430-mm diameter vertical coil-springs placed fore and aft of the axlebox, one below and one above the axlebox centre line and pitched 300-mm about it. Secondary suspension is by Flexicoil groups referred to later. In the interest of weight saving, the 370-mm diameter axles are hollow-bored 120-mm. A standard welding technique using shrouded-arc and "J"-edge profile plate is used throughout for butt-joints where welding can be undertaken from one side only. This ensures good penetration through the plate without a tendency to burn the plate edge as can be the case with a single "V" chamfer. The steel used is BS 4360 (43A) quality.

Optimum strength/weight ratio design of the major sections was achieved by computer-analysis programmes developed by the Railway Technical Centre at Derby and consequently this 5,314-mm over headstock bogie has been designed to achieve a light-weight assembly with good stress distribution.

It is arranged with the nominal centre line of the king pin connection 60-mm below the axlebox centre line, the traction and braking forces being transmitted through the king pin. The side frames pass over the axleboxes and drop down only at the ends to connect up with the headstocks. The centre transome drops down to receive the kingpin-connection which comprises two placed laminated-rubber buffers, one fore and one aft, between which a steel bronze-bushed casting is sandwiched under a compression loading of about ten tons. The arrangement follows the principal of that fitted to the prototype modification of Class 86 locomotives equipped with Flexicoil secondary suspension. The initial transverse stiffness is low to build up a controlled resistance to side thrust but is high axially to take the traction loadings. The rotation of the bogie is through these buffers, the king-pin casting not being free to rotate within the casting. To facilitate assembly, this casting receiving the former is prior-assembled into the bogie. In the case of the prototype HST and 200 km/h modified Class 86, it was introduced attached to the kingpin post which necessitated the buffers being withheld clear in compression whilst the locomotive was lowered on to its bogies.

The secondary suspension is triple Flexicoil 640-mm high under compression assembly, the springs of which are pitched at 280-mm centres, have a nominal diameter of 225-mm and each set carries 11 tons, a quarter of the body weight of 44 tons. These obviously provide the torsional stiffness of the bogie when negotiating curves as well as controlling the general riding behaviour of the body. Koni dampers are fitted throughout the bogie; two working in conjunction with the Flexicoil secondary suspension set and one each side linking the kingpin with the bogie side frame. One is fitted also on the top of each of the axleboxes and attached to the bogie frame.

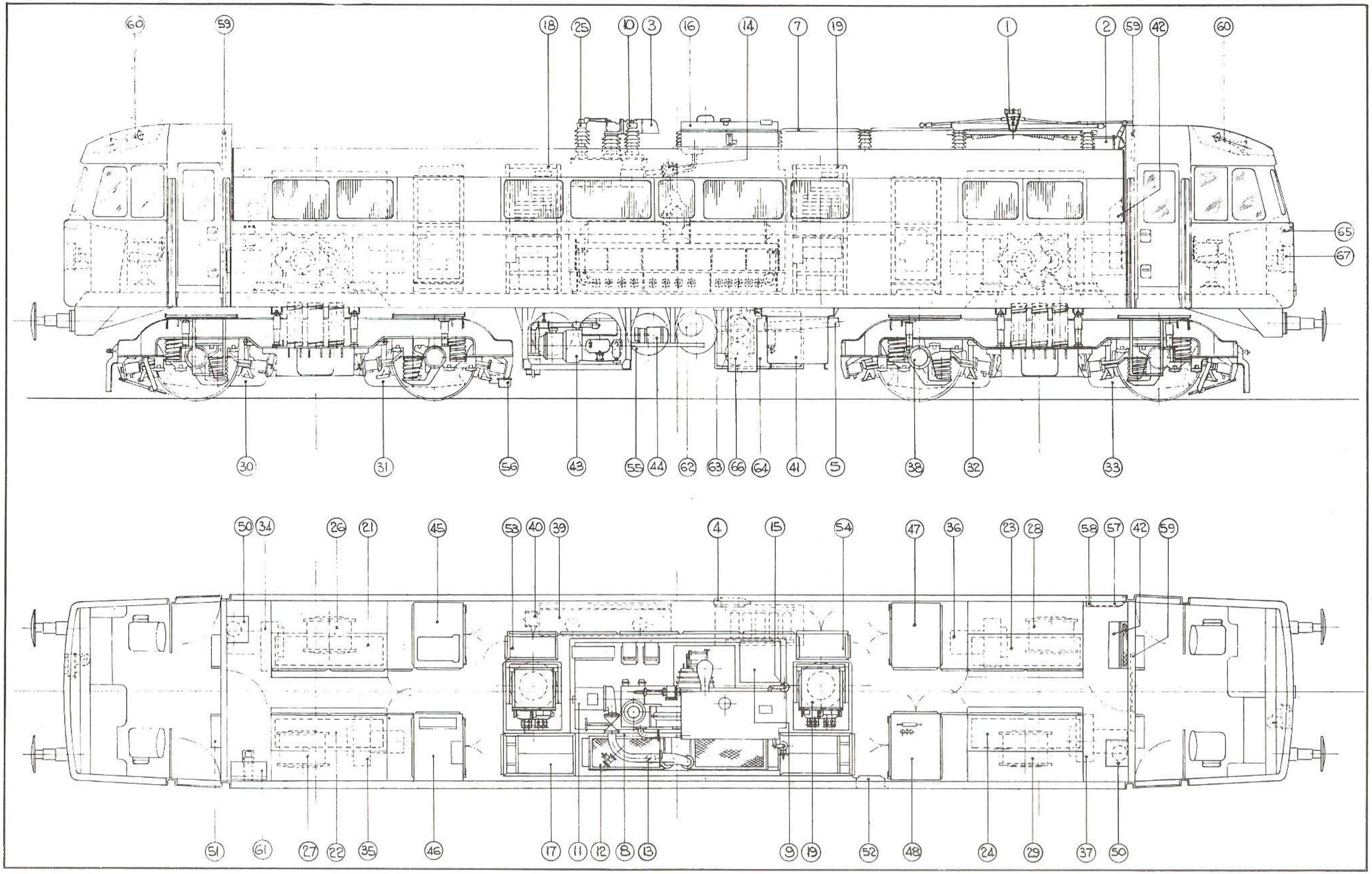
Eight Westinghouse air brake 6·5-in diameter cylinders are mounted, two to each wheel but not linked by a clasp-brake linkage. They are fitted outside, fed in pairs and operate through an internal lever which applies the brake force direct to the wheel brake-shoe. Each unit incorporates a combined slack adjuster. In addition, the four inner wheel-brake units on each bogie are fitted with hydraulic actuators which furnish the brake force for the Westinghouse electro-hydraulic stabling brake system with which the locomotives are fitted, the equipment of which provides electrical or manual control of its application and release.

Roof mounted electrical equipment

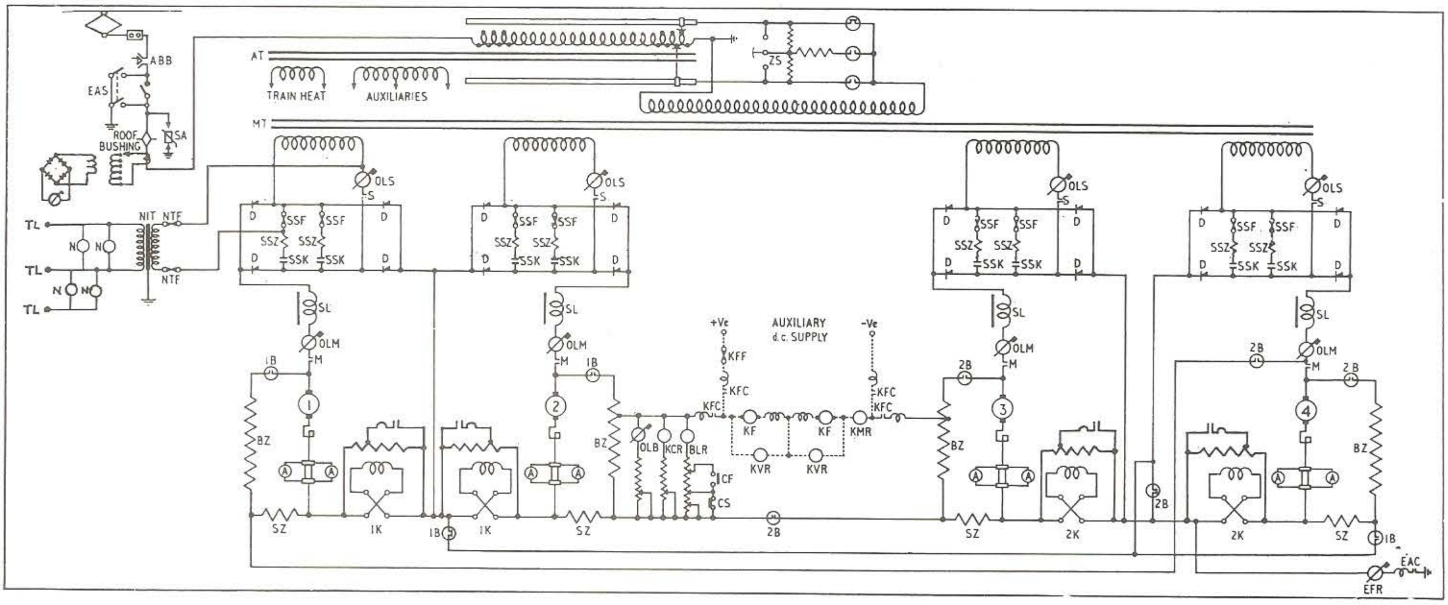
Current collection is by a single GEC cross-arm pantograph type 28 P7 A1 mounted immediately to the rear of cab No. 1. It is fitted with two copper-impregnated carbon rubbing strips and is designed for a static contract thrust of 20-lb. The system incorporates low-friction joints with PTFE-lined sleeve-bearings whilst the main journals have grease-packed ball-bearings. Auxiliary springing is provided in the pan head to allow for rapid response to irregularities in the contact wire caused by unevenness at section isolators, etc. The pantograph will lower automatically if the pan head becomes displaced or if a carbon strip becomes displaced. Controlled rate of rising is effected by an air motor which also causes the pantograph to drop quickly to within 12-in of its fully-closed position when it is being lowered. Other roof-mounted equipment includes the 250 MVA/25 kV circuit breakers, earthing switch and rheostatic brake exhaust outlet.

Six locomotives are to be equipped with GEC vacuum circuit breakers type NA27-B1 which incorporate two series-connected interrupters operating in a vacuum. Although the contact gap is only 9-mm a very rapid build

General arrangement of BR Class 87 80-ton Bo-Bo 25 kV express locomotive for 100 mile/h Inter-City services between Euston, Birmingham and Glasgow

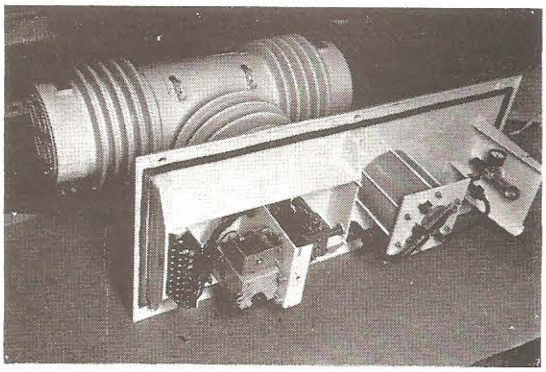


1. Pantograph
2. Pantograph air motor
3. Air-blast circuit breaker
4. Emergency air cylinder
5. Air drier
7. H.T. connections
8. Main transformer
9. H.T. tap-charger
10. Input bushing
11. Transformer oil pump
12. Transformer radiator
13. Oil flow indicator
14. Buchholz relay
15. Silica-Gel breather
16. Conservator
17. Shutters-radiator by-pass
18. Brake resister No. 1
19. Brake resister No. 2
21.—24. Main rectifiers No. 1—4
25. Surge divertor
26—29. Smoothing chokes Nos. 1—4
30.—33. Traction motor Nos. 1—4
34.—37. Traction motor blowers Nos. 1—4
38. Mileometer (right side)
39. Battery box
40. Battery box isolating switch and fu[illegible]x
41. Battery charger
42. Auxiliary compressor
43. Main compressor
44. Auxiliary compressor
45.—48. Control equipment frames Nos. 1—4
50. Boiling ring
51. Cab heater
52. Fuse panel-auxiliary
53.—54. Air equipment frames Nos. 1—2
55. Main air reservoir
56. A.W.S. receiver
57. A.W.S. junction box
58. A.W.S. static convertor
59. A.W.S. Change-end switch, horn and bell
60. Horns
61. Toilet
62. Reservoir (2) brake supply
64. Weak-field and rheostatic brake equipment
65. Multiple-unit jumper equipment
66. B.C.F. bottle-fixed fire-fighting equipment
67. Cab ventilating unit



Schematic diagram of main power circuits of Class 87 a c locomotive

A — *Ammeter*
ABB — *Air blast circuit breaker*
AT — *Auto transformer*
1B, 2B — *Power/brake change-over switch*
BZ — *Brake resistor*
CS — *Control camshaft—slow*
CF — *Control camshaft—fast*
D — *Rectifier diode group*
EAC — *Earth fault contactor*
EAS — *Earthing switch*
EFR — *Earth fault relay*
1K, 2K — *Reverser*
KCR1 — *Fan change-over relay*
KF — *Radiator fan motor*
KFC — *Radiator fan motor contactor*
KMR — *Radiator fan motor relay*
KVR — *Fan differential voltage relay*
M — *Motor contactor*
MT — *Main transformer*
NIT — *Potential transformer*
N — *Notch indicator*
NTF — *Notch transformer fuse*
OLB — *Brake overload relay*
OLM — *Motor overload relay*
OLP — *Primary overload relay*
OLS — *Secondary overload relay*
SSF — *Surge suppression fuse*
S — *Secondary contactor*
SA — *Surge arrester*
SSK — *Surge suppression capacitor*
SSZ — *Surge suppression resistor*
SL — *Smoothing inductor*
SZ — *Stabilising resistor*
SIT — *Saturable interposing transformer*
TL — *Train lines*
ZS — *Resistor changeover switch*



GEC roof-mounted vacuum circuit-breaker type NA 27-B1 with which six Class 87 BR locomotives are being fitted

up of dielectric strength is obtained and arc extinction is by rapid movement of anode spots during arcing. The interrupters are mounted horizontally and the operation is by rods connected to opposed air operated pistons supplied at 70 lb/in². The rated capacity is 600 A, the rupturing capacity is 250 MVA and a 2-second short-circuit of 12,000 A can be withstood. As a roof-mounted unit, the ambient range for which the design is suitable is 50° to –12°C. Vacuum circuit breakers of this type have been developed specially for railway service by GEC Traction. They are more compact than air-blast breakers and quicker in action, and other advantages include low first cost, low maintenance cost and high reliability.

Transformer and tapchanger

The transformer is electrically identical to that supplied for Class 86 except that because the Class 87 is a more powerful locomotive the total rating of the transformer is increased to 5,860 kVA, a rise of 20 per cent, and the train-heat winding load is also now up to 460 kVA to accommodate train air-conditioning requirements. The transformer consists of an auto-transformer which can be tapped at 38 positions by a high tension tapchanger controlled by the master-controller on the driver's desk.

The secondary-winding of the transformer is split into four parts; one part for each traction motor-rectifier smoothing-reactor group. Each of these circuits is self contained and in case of a fault can be isolated by the driver who can thus proceed on 75 per cent power; a separate winding is provided for the train heat and auxiliary winding. The auxiliary winding is centre tapped to provide 130-0-134 V for running auxiliary machines of the capacitor type.

The transformer is totally immersed in oil which is pump-circulated through cooling radiator. Also included in this circuit is a Buchholz relay which gives warning of gas accumulation in the transformer. The oil conservator accommodates changes in oil volume as the transformer warms up without allowing contact with the atmosphere which could allow ingress of moisture and consequent reduction of dielectric strength of the oil. All parts of the equipment which are oil filled can be removed from the locomotive together without the need to break the oil-circuit.

The transformer weight is 11,400 kg, a reduction of 1,000 kg compared with the Class 86 transformer, and has been effected by redesigning the container to reduce the oil volume, using a form-fitted cover, clamping the iron circuit and windings and using welded instead of bolted-on flanges. The oil cooling radiators are marginally increased in size to allow for the increased amount of heat generated at the higher rating. The transformer compartment is nominally a sealed area but a bleed of air is drawn from the locomotive body by the resistor fans and is allowed to pass through the compartment to scavenge it and prevent excessive accumulation of ionised gases and the possibility of flash-overs above the tapchanger contactors.

The high-tension tapchanger is a similar design to that successfully used on Class 86 and Class 82 locomotives but incorporates minor alterations to improve reliability still further. It consists of three parts:— a selector tank which contains the 38 fixed and two sliding contacts, a set of divert switches, and a drive mechanism which powers the sliders and operates the divert switches in sequence. Two sliders are used to ensure that one at least is carrying the load while the other can be moved off-load to another tapping position. Once this is done the load is transferred by divert switches to the slider in contact with the required tap and the other slider is thus disconnected from the load in order to move it off-tap. The sliders are moved along the slider bars by a roller-chain operated by a Geneva mechanism in the selector tank. The selector tank is in part of the oil circuit.

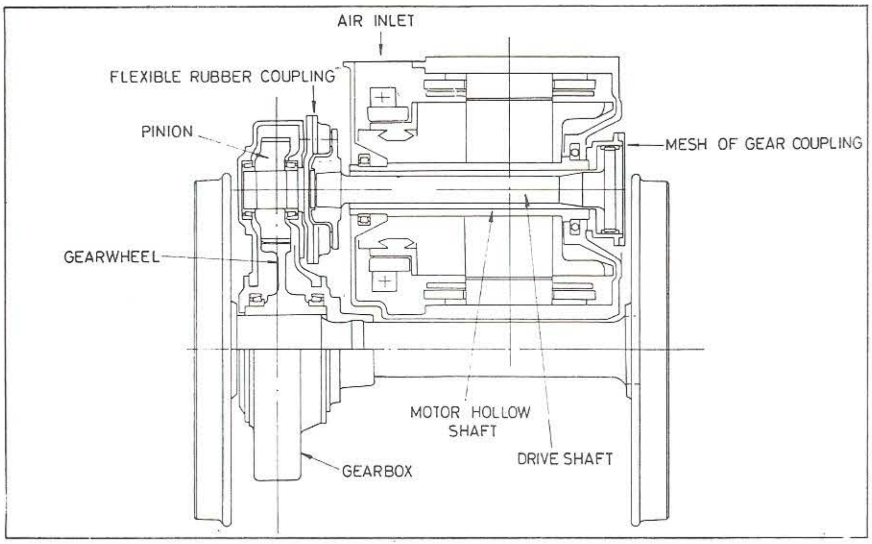
Low tension power circuit and rectifiers

The low-tension power circuits are divided into four separate but identical 'power-pack' groupings, each comprising: transformer secondary winding; bridge connected silicon rectifier assembly; smoothing inductor; traction motor. The grouping technique enables the whole of a circuit to be isolated by the driver without the need for a fault finding analysis if a component fault arises within one of the groups and the locomotive can then proceed on reduced power. Each of the four full-wave rectifier units supplies one traction motor and is cooled by the associated traction motor blower. Every full-wave bridge arm contains two parallel strings of two AEI type S.904 diodes rated at 1,860 A continuously and 1,340 V d c connected in series. Use of forward and reverse polarity pairs permits common heat-sink mounting and each diode is fitted with two parallel hole storage capacitors. Each rectifier unit incorporates a surge-suppression circuit mounted within the individual cubicle.

Each locomotive has four separate bridge rectifiers (one per motor). The rectifier cubicles have been designed to make use of the higher rated elements now available and to allow easier access for cleaning purposes. The improvement in rating is demonstrated because each rectifier now has only 16 cells whereas the Class 86 rectifiers had 96 cells. An auxiliary rectifier is used to feed d c auxiliary machines and is a completely self-contained unit. It consists of two elements connected in push-pull across the main trans former tertiary winding terminals.

Frame-mounted traction motors

The GEC Type G412AZ d c traction motors have been developed specially for the particular requirements of the BR West Coast main line. These machines are force-ventilated with a one-hour rating of 950 kW, 1,134 V, 885 A. The motor body is a steel fabrication with a partially laminated magnet frame to improve the commutation of the 100 Hz ripple. The motor armature is hollow and is coupled at one end, by a gear-type coupling, to a cardan shaft running through the armature to a resilient rubber-coupling, on the pinion. This allows the motor to be directly coupled to the bogie frame and considerably reduces the unsprung weight on the axles. The three-point suspension incorporates three conical rubber mountings, two on the nose and the third on an extension arm at the tail. The pinion and final drive spur gear



GEC G412 A2 frame-suspended traction motor, gearing and drive fitted to BR Class 87 and continuously rated at 860 kW

are contained in a cast-steel gearbox which is supported on the axle through taper roller-bearings and from the bogie by a rubber-bushed torque reaction link. The gear ratio is 73/32 and the bearings and gears are splash lubricated.

The G412AZ motors are four-pole, series-wound with interpoles and compensating windings. There is a permanent field-divert of 16 per cent with an operational divert of a further 23 per cent in a single stage, to give maximum utilisation of the locomotive performance over the speed range. For the purposes of rheostatic braking, the motor-fields are separately excited and each armature is connected to a resistor bank to dissipate the power.

The motor is of extremely robust design and incorporates many modern features to ensure long life with minimum maintenance. The armature winding is to Glass H standards with Kapton polyimide film insulation for both conductor and ground insulation. Glass banding is used to secure the conductors in the slots. The conductors are T.I.G. (Tungsten Inert Gas) welded to the commutator risers, which eliminates the danger of high resistance joints developing in the event of any abnormal conditions leading to above normal winding temperatures as can occur with soldered connections. The field windings are to class F standards with the series and compole coils through-bonded and bonded to their poles with epoxy resin. The through bonding gives extremely good thermal conductivity to the coils so that a very compact as well as robust field system results.

The robust design is maintained for the brushgear where the cast bronze brushholders are supported from the commutator chamber by large single mycalex insulated pins with P.T.F.E. sleeves to give easily cleaned creepage surfaces. A multiple spring system and three-part carbon brushes help to maintain good contact with the commutator. Two large openings in the commutator chamber give good access to brushes, brushgear and commutator for maintenance purposes.

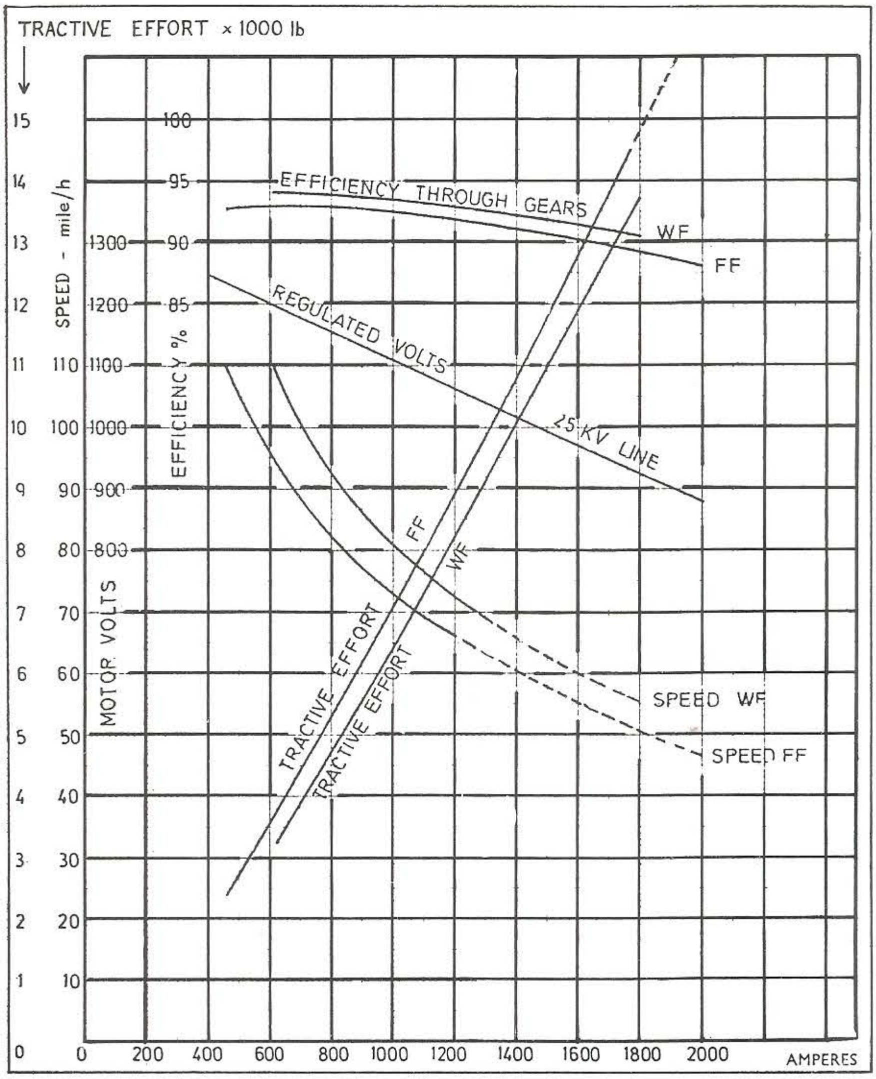
The frame is of fabricated construction and incorporates laminated bridges between main and commutating poles to assist commutation of the 100 Hz ripple current which is kept to approximately 30 per cent of the mean d.c. current at the continuous rating. The ripple is kept to this level by a smoothing reactor GEC Type SH152. The reactor is air cored with a Kapton insulated copper coil on an aluminium framework. The cooling air enters between the turns of the coil and leaves at both ends.

Combined rheostatic and air braking

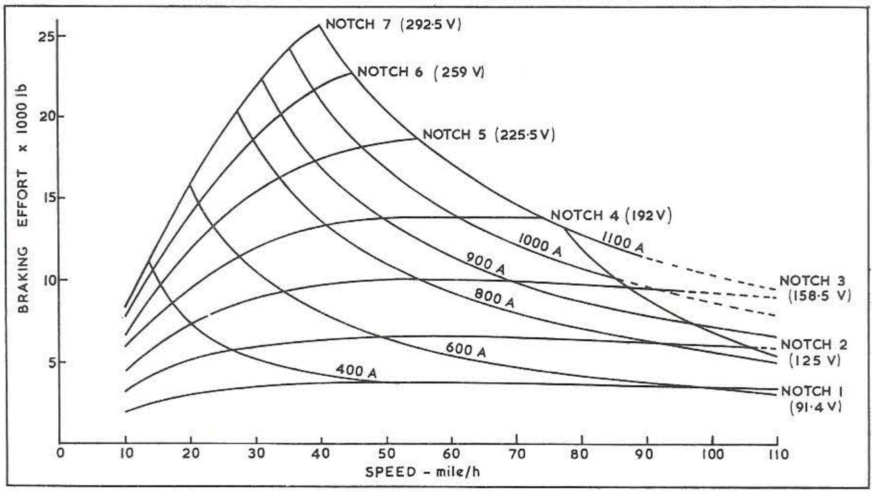
To provide a clean environment for the items of brake equipment e.p. relay and proportional valves, distributors etc., two cubicles have been provided. These are located near to the transformer and adjacent to the rheostatic brake resistance banks. The brake force is about 83 per cent of locomotive weight and may be achieved by rheostatic or air braking, or a combination of both. The driver's air-brake valve automatically brings in the former which can dissipate 2,000 kW and only at very slow speeds or in an emergency does the air brake on the locomotive supplement the rheostatic. If, however, there is any fault in the latter braking. equipment, the air brake is used exclusively.

The rheostatic brake has a separate field excitation, the control of which is by the high-tension tap-changer, thus eliminating the need for extra rheostatic brake control equipment. When rheostatic braking is in operation the motor fields are connected in series for separate excitation, the generated power being dissipated in a separate resistor connected across each armature. Compounding is achieved by virtue of resistors common to field and armature circuits which gives a desirable flattening of the brake effort/speed characteristic. Use of the high-tension tap changer and one of the rectifier bridges for excitation control eliminates the need for additional equipment.

The air brake equipment has been supplied by Westinghouse Brake & Signal Co. Ltd. It is a self-lapping automatic brake capable of graduable application and release under the regulation of brake pipe pressure which is in turn controlled by the driver's type M8AS automatic air brake valve at each driving position. Unlike other a.c. electric locomotives, the Class 87 locomotives are designed for hauling air braked trains only, but in the interests of standardisation many of the items of equipment are identical to those fitted to dual-braked locomotives equipped with both air and vacuum. In addition the locomotives are fitted with an anti-wheelslip brake which operates in conjunction with the automatic air brake and the rheostatic brake. The locomotive air brake may be operated independently of the train brake and the locomotive rheostatic brake, if required, by the straight air brake valve which is also fitted at each driving position. Compressed air for the locomotive and train is supplied from a Westinghouse type 3VC75 pipe ventilated two stage three cylinder motor driven air compressor with a swept volume of 75 ft/³min at a speed of 1,570 rev/min.



Traction motor characteristics of BR Class 87 equipped with GEC type G412 AZ motors geared for 176 km/h



Rheostatic braking characteristics of 80-ton 3,750 kW Class 87 BR a c locomotive

Control equipment and auxiliaries

The control equipment is housed in four equipment frames adjacent to each rectifier frame. The upper half of each equipment frame is sealed against dust and houses control and auxiliary equipment. The power equipment is housed in the lower half of each equipment frame, left open to ensure adequate ventilation.

One of the frameworks also contains the electronic module developed by BR for controlling wheel spin. This compares traction motor currents and contains a unique feature which provides automatic sensitivity adjustment to take account of varying machine tolerances. The equipment runs the tap-changers back if the current difference between any two motors is greater than a pre-set value. The speedometer and traction motor overspeed protection equipment are controlled by magnetic probes measuring gearwheel velocity.

The control is similar to that fitted to the Class 86 except that two locomotives can be operated in multiple and that a single-stage of field weakening is incorporated in the motor circuit. In multiple, fault indication is registered in the leading locomotive. Also, because the service requirements do not necessitate both running at full power simultaneously, full automatic synchronisation of tap-changers has not been provided. A notch-indicator for each individual locomotive is provided in each cab so that the driver is aware of the power being provided by the trailing locomotive. The two locomotives are linked by 36-way plugs and sockets which are deliberately chosen to be non-compatible with the other three types of jumper plugs and sockets on BR.

Towards each corner of the equipment compartment, a combined rectifier—inductor-cooling fan unit is located, the latter being situated immediately above the corresponding traction motor air-inlet ducting. Cooling air required for each of these four units is drawn through two bodyside louvres. To prevent the ingress of air borne foreign matter or water from entering the rectifier duct, a water separator comprising baffle plate and screen, is fitted between the louvres and the rear of the rectifier cubicle.

Cooling-air for the transformer oil radiator and the brake resistances is drawn through five body side louvres by two dual speed electrically driven radial flow fans, one at the base of each radiator stack. The air passes through the oil radiators on to the resistor stack and exhausted through self-acting roof mounted louvred outlets.

When rheostatic braking is in operation, the quantity of air required for cooling the brake resistors is far greater than can be drawn through the radiators or be delivered by the fans operating at normal speed. The speed of the fans is therefore increased, using generated Voltage from the braking effort, and shutters at each end of the radiators are opened, allowing the majority of air to by-pass the radiators. The air is exhausted as already described.

Driving cabs, vigilance system and fault indication

The driving cabs of the locomotives are similar to previous layouts but some changes have been made as a result of experience and developments. Forced ventilation has also been introduced to the cab design and the system automatically controls the cab temperature whilst ensuring changes of fresh air. Added driver comfort results from the provision of 'punkah' louvres fitted in the desk console. Trico-Folberth B.P.M. pneumatic windscreen wipers are fitted at the bottom of both windscreens and in order to meet modern requirements the motor has two speeds, automatic parking and a travelling water jet for washing purposes. A desk mounted combined control valve operated the complete cleaning system.

The Class 87 locomotives are fitted with a drivers vigilance system which basically comprises a two-position foot pedal incorporating an electric switch, audible signal device and relay unit. With the master controller in the driving position the pedal has to be kept depressed. After 60 seconds a continuous audible signal commences and if the pedal is not released and depressed to reset the system, an emergency brake application will occur after a further period of 5 to 7 seconds. The system can be reset at any time during the cycle convenient to the driver and to assist with operation of the driving controls, an alternative desk mounted hand switch is provided. Resetting the standard Automatic Warning System equipment in response to a cautionary signal aspect also resets the time cycle.

A general fault light on the driver's desk of each cab gives warning of all the above fault conditions plus transformer over-temperature alarm and battery charger failure. In the event of power circuit overload, four power circuit indicator lights on the top of No. 2 control equipment frame enable the driver to identify which circuit is faulty and isolate it before continuing at reduced power.

A thyristor-type battery charger is fitted. It is completely interchangeable with the magnestat -type battery charger in use on Class 86 and is identical to those fitted to the a.c. locomotives supplied by GEC for Pakistan Western Railways. It is powered from the outer taps of the tertiery winding (264V) and rated at 110V, 35A.

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BR Class 87 Bo-Bo 3,750 kW 25 kV a c express locomotive

Length over buffers ...	17,830 mm
Total wheelbase ...	13,159 mm
Bogie wheelbase ...	3,280 mm
Bogie centres ...	9,982 mm
Wheel diameter ...	1,150 mm
Service weight ...	80 tons
Axle load ...	20 tons
Maximum speed ...	176 km/h
Service speed ...	160 km/h
Continuous rating ...	3,750 kW
Starting tractive effort ...	58,000 lb
Continuous tractive effort ...	42,500 lb
Gear ratio ...	73/32
Rheostatic braking, maximum ...	25,700 lb