Electric locomotive equipment for the Manchester - Sheffield - Wath line British Railways

METROPOLITAN-VICKERS ELECTRICAL CO., LTD.
MANCHESTER 17 ENGLAND

Special Publication 7977/16

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Reprinted from an article by

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published in " The Metropolitan-Vickers Gazette " December 1954

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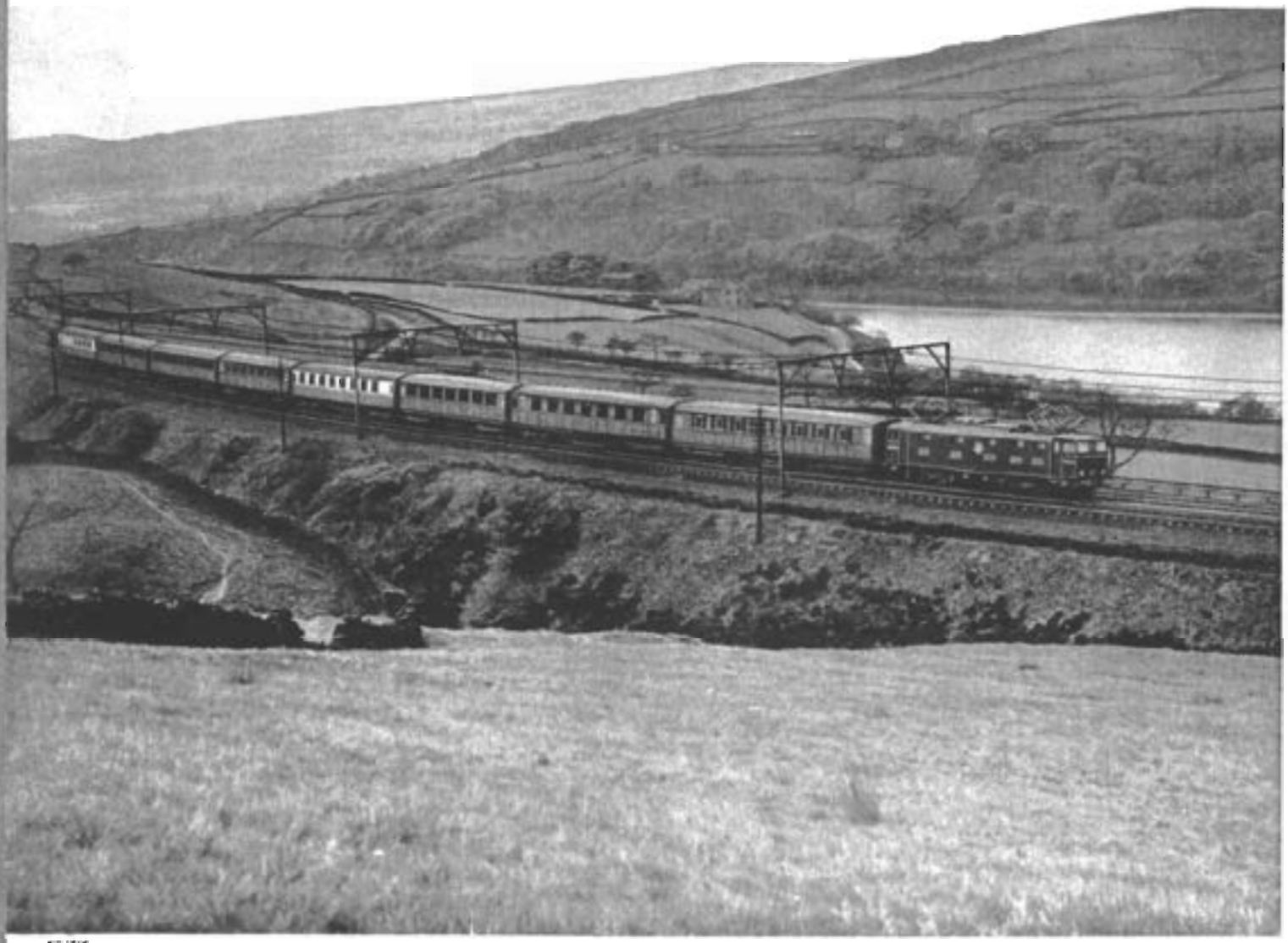

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Electric trains cross the Pennines

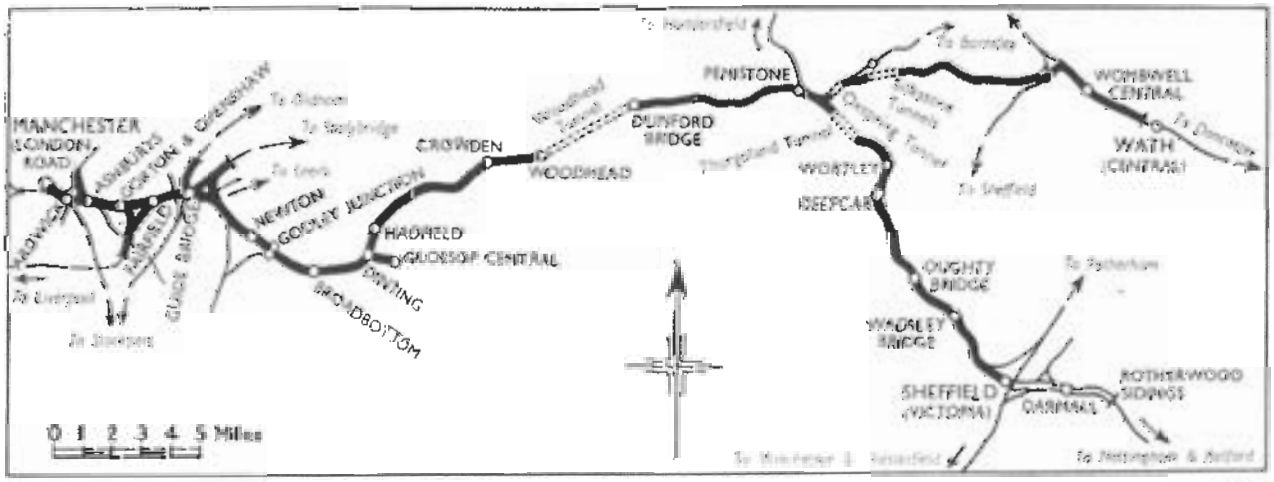
An 1868-hp locomotive hauling a passenger train near Hadfield. M-V supplied sixty-five electric locomotive equipments for passenger and freight service on the Manchester-Sheffield-Wath lines

Electric locomotive equipment for the Manchester - Sheffield - Wath line

THE Manchester-Sheffield-Wath section of British Railways, which came into virtually full electrical operation on September 20th, is the third large conversion using the recommended standard system of 1500 volts d.c. on an overhead wire and will be the first British main line to handle all traffic electrically. It carries a preponderance of freight traffic, mostly in the form of coal trains operating loaded from east to west, together with a moderate number of passenger trains, principally long distance corridor stock. For moving such traffic the locomotive is the only answer, and sixty-five mixed traffic electric locomotives are now in operation. A suburban passenger service is provided by eight three-coach multiple unit trains operating locally between Manchester and Glossop. The map (fig. 1) shows the lines that are electrically operated and the stages in which conversion has proceeded.

This stretch of line offers particular attractions to electrification. It carries a very dense traffic of the type indicated above, there being an average of seventy-five freight trains and fifteen passenger trains daily in each direction. The configuration of the line abounds in heavy grades and curves and has the well-known Woodhead tunnel, three miles long, at the summit; the profiles given in fig. 2 indicate the arduous nature of this section. The tunnel, which could admit only one train at a time under steam operation, and the comparatively slow operational speeds of the steam trains on the up grade towards it combined to create a bottleneck in the handling of traffic. With electrification however the higher running speeds have increased the traffic capacity of the tunnel, and the clear conditions of visibility mean that, when necessitated by increase in traffic, the present signalling allowing only one train on each track can be supplemented by intermediate signals, allowing two trains in each direction and increasing the tunnel capacity by at least 25%. (Incidentally a new tunnel was completed and put into operation simultaneously with the change from steam to electric operation; it lies in close proximity to the old twin tunnels, which could no longer be adequately maintained.) With electrification also freight train speeds up the grades towards the tunnel have increased to some 30 m.p.h. instead of 12-15 m.p.h., while passenger speeds show an appreciable improvement. Improved speeds on heavy climbs are an inherent characteristic of electric operation, owing to the overload capacity of electric motors.

The heavy up grades are of course followed by comparatively light loading conditions on the ensuing down grades, and here another valuable benefit is obtainable from electric traction, especially on freight trains, by the provision of regenerative braking. In steam operation, the wheel shoe brakes had to be continuously applied on the locomotive while negotiating the long down grades, and in consequence they became progressively less effective for stopping the train; it is not always realized that hot brake blocks can be less than half as effective as cold blocks in the braking of a train. With regeneration



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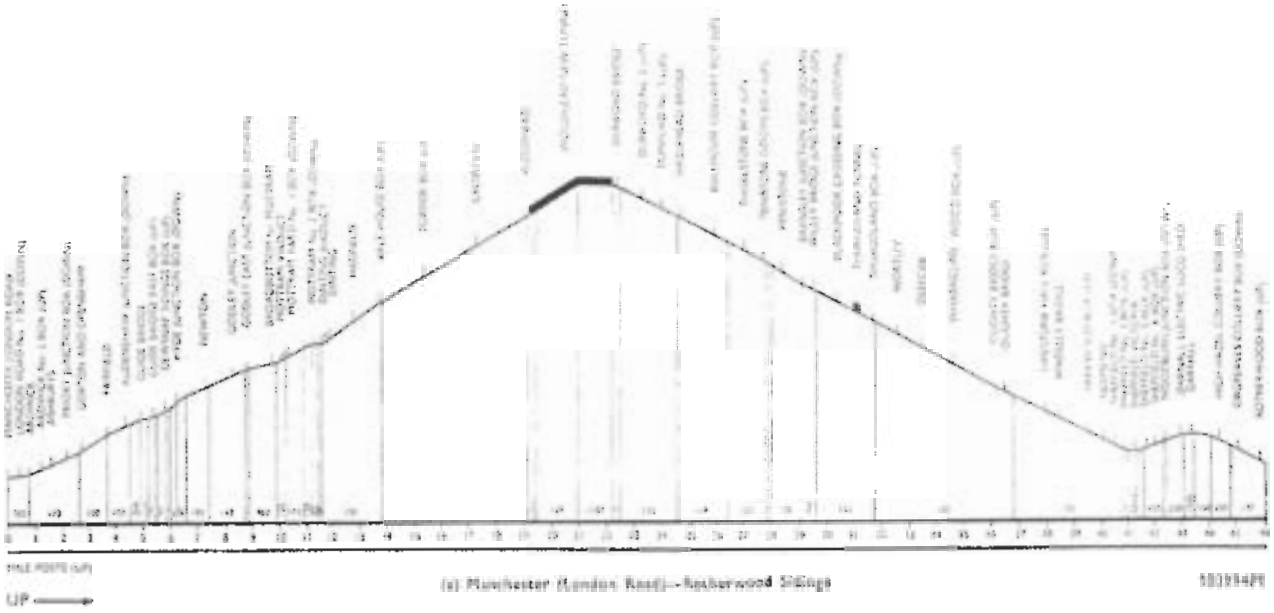
1—The Manchester-Sheffield-Wath electrified lines

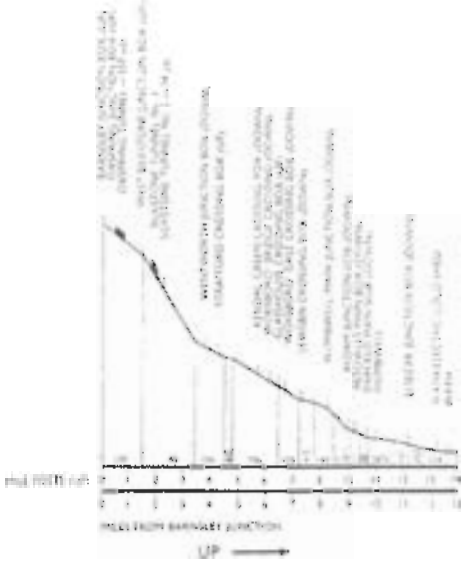


2—Simplified profile of the Manchester-Sheffield-Wath line

on the other hand the potential energy of the train is dissipated electrically, enabling appreciably higher speeds to be used with safety; maintenance is also very much reduced on brake blocks and rigging, amounting to quite an appreciable saving. A small additional benefit comes from the return of electrical energy to the line during regeneration; special devices ensure that any regenerated current that cannot be utilized by other locomotives is absorbed by resistances located at suitable points along the line.

The history of this electrification goes back to before 1936 when the preparation of tender specifications was begun, but with only one locomotive completed in 1941 further progress was halted by the war. Work was resumed in 1947, and in February 1952 freight working was put into operation on the first section of the line, from Wath to Dunford Bridge, with thirty locomotives. Further sections came into service successively, until on 14th June 1954 both freight and passenger services were hauled electrically through the new tunnel, the passenger services from Manchester terminating at Penistone and the freight services continuing through to Wath. The passenger service has now (September) been extended to Sheffield Victoria, and with the opening in January 1955 of the short section between Sheffield and Rotherwood sidings, where trains from the Nottinghamshire coalfields will change from steam to electric haulage, all freight traffic on the line will be operated electrically.

The electrical equipment for the locomotives—sixty-five in all—was manufactured and supplied by Metropolitan-Vickers. Fifty-eight locomotives have a Bo + Bo wheel arrangement, and seven are of the Co — Co type. The mechanical parts were undertaken by British Railways.



While both classes of locomotives will be used on the same passenger and freight services, it should be noted that the maximum speed in the case of the Bo + Bo class is 65 m.p.h., which is the highest speed for which the track is suitable. The Co — Co class, however, was built for 90 m.p.h. maximum in order that advantage could be taken of the higher speeds on any future electrifications; meantime, these locomotives in service will seldom use more than the first and second of their three motor combinations, these corresponding approximately in speed and horsepower with the first and second combinations on the Bo + Bo locomotives.

A Co - Co electric locomotive in service

British Railways photo 102164

The traffic handled ranges from local and express passenger trains of 250 to 350 tons weight and express and other goods trains of 450 to 600 tons to slow mineral trains of 700 tons or more. The performance of the Bo - Bo locomotive with various classes of load is shown in fig. 3. While all the Co - Co locomotives are fitted with electric boilers, only a few of the Bo - Bo class are so fitted ; in winter therefore, the former will tend to be kept mostly on passenger service.

All the locomotives are designed for operation by one man, and therefore incorporate such features as a 'dead man' foot treadle, which, six seconds after being released, cuts off power and applies air brakes on the locomotive and vacuum brakes (if fitted) on the train. However two-man operation is the rule, the second man attending to such duties as sighting signals from the off-side, coupling up to the train, changing coding lamps, and making contact with signal boxes when delayed.

Before describing the electrical equipment on these locomotives, the mechanical parts for the two types will be briefly reviewed. These were designed by British Railways at Doncaster and manufactured at their Gorton works near Manchester. Both classes are of the mixed traffic type, and the leading particulars are given in the table on this page.

The Bo + Bo locomotive bogies are connected to one another by an articulating joint at their inner ends, and their outer ends carry the headstocks with draw and buffing gear. All draw and buffing

LEADING PARTICULARS OF LOCOMOTIVES

	Bo + Bo class	Co — Co class
Number of locomotives	Fifty-eight	Seven
Weight in working order (total)	87 tons	101 tons
Length over buffers	50' 4"	60' 3"
Width over body	9' 0"	8' 10"
Height to top of pantograph—		
locked down	11' 9"	11' 9"
maximum working position	24' 0"	24' 0"
Wheel base	35' 0"	46' 6"
Wheel diameter	50"	43"
Line voltage (nominal)	1500 V	1500 V
Number of traction motors	Four	Six
Total horsepower on 1-hour rating (weak field) 1400 V	1800 hp	2760 hp
Current per motor on 1-hour rating (weak field) 1400 V	540 A	510 A
Maximum tractive effort (nominal)	45 000 lb	45 600 lb
Gear ratio	17:70	17:64
Maximum service speed	65 m.p.h.	90 m.p.h.
Number of motor combinations	Two	Three
Control voltage	50 V	50 V
Battery (nickel iron cadmium)	Thirty-three cells, 40 Ah	Thirty-three cells, 40 Ah
Motor generator output (supplying control circuits)	5 kW, 50 V	5 kW, 50 V
Motor generator output (supplying traction motor excitation)	15 kW, 45 V	9·6 kW, 45 V
Compressor displacement	18 ft³/min	18 ft³/min
Exhauster : capacity at release speed	132 ft³/min	132 ft³/min
Train heating boiler :		
rating	160 kW	360 kW
output	1000 lb/hr	1000 lb/hr
working pressure	65 lb/in²	65 lb/in²

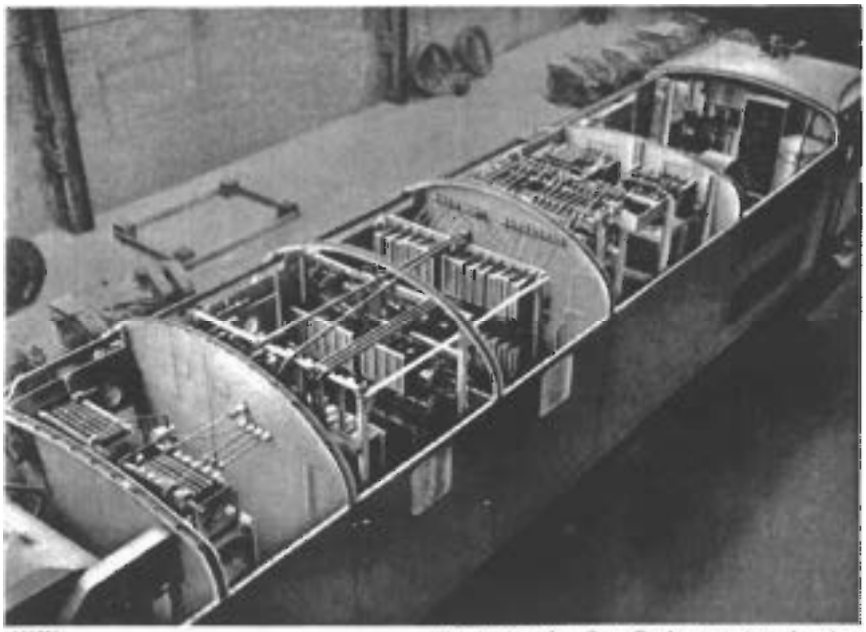
British Railways photo 102963

A 2760-hp six-axle Co–Co electric locomotive

shocks are therefore transmitted through the bogies. The body weight is taken on each bogie at four points, which are fitted with sliding pads; these are grouped in pairs at each side through semi-elliptical springs, the centre buckle of which transmits the weight to the bogie.

In the Co—Co locomotives, on the other hand, the bogies are not articulated, and the buffing and draw gear are fitted to the ends of the body. The body understructure is therefore made much more robust, and the suspension of body and underframe on the bogies is also different. The body weight is transmitted to the bogies through spring-mounted bolsters and swing links, a method of suspension providing much better riding, which is the more necessary for the higher maximum speeds for which this class of locomotive is designed. In addition the motor nose is suspended by a steel link having Silentbloc rubber mountings, and each motor also has a radial arm with Silentbloc bushes attached to the bogie side frame in order to minimize sideplay of the motor on the axle.

All the locomotives are provided with air brakes, and these can be worked either independently or in conjunction with the vacuum brake system fitted to passenger and express goods trains.



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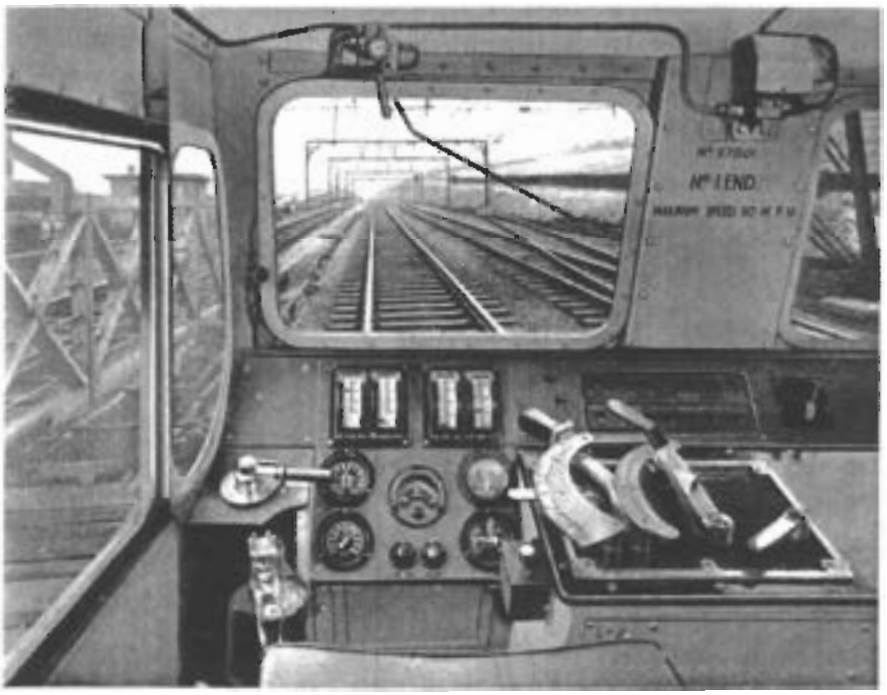
The body of a Co–Co locomotive showing the arrangement of electrical equipment

ELECTRICAL EQUIPMENT

The layout of the electrical equipment in the locomotives is similar for each class. The driving cabs at each end are connected by a side corridor; the intermediate space in the body is occupied by two open machinery compartments, one next to each cab, and a central portion divided into an h.t. compartment housing the switchgear and one or two (in the case of the Co—Co class) resistance compartments. Access to these compartments is through interlocked doors.

Control gear

The electrical equipment itself (with the exception of the main motors and some of the switchgear) is very similar on the two classes of locomotives, but much of the Bo+Bo equipment was manufactured before 1939, while the Co—Co equipments were designed and manufactured after the war and therefore incorporate some improvements. The main switchgear is of the electro-pneumatic type consisting of unit switches and drum-type grouped switches operated from master controllers. The switches and other items of equipment are housed in the h.t. compartment, in frames that are removable for easy installation or repair. The illustration on the previous page shows a Co—Co locomotive in course of erection; above is seen a driving cab showing the master controller and other items.



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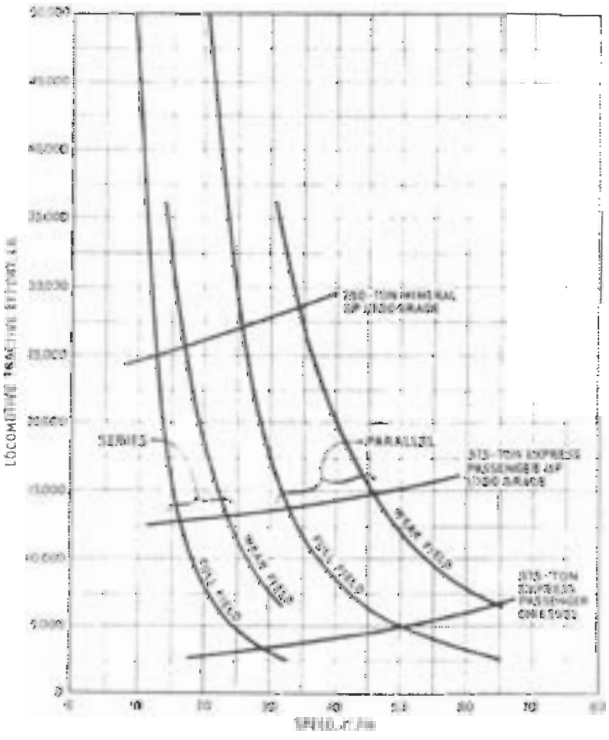
The driving cab of a Co—Co locomotive

The master controllers for the Co—Co locomotives have four handles: (i) a removable 'forward' and 'reverse' key; (ii) an accelerating lever for notching successively through all three motor combinations; (iii) a regenerative and weak field lever, which varies the amount of regeneration by altering the excitation of the traction motor fields and, moved in the opposite direction, enables three steps of weak field to be obtained on the motors while taking power; and (iv) a lever, on the extreme right of the controller, for selecting the motor combination in regeneration. All the levers are suitably interlocked to prevent improper use.

The controller on the Bo+Bo class has a somewhat different arrangement, there being a separate series and series-parallel lever, and the accelerating lever combining also the function of weakening the field during motoring.

The rate of notching is entirely in the hands of the driver. An unusually wide range of field weakening is provided in order to give a wide range of economical tractive effort and speed (fig. 3), thus enabling one type of locomotive to deal with the large variety of traffic already mentioned. The maximum locomotive availability is thus achieved, a feature that is of great importance on a comparatively short mileage such as is involved in this scheme.

To enable the maximum use to be made of the



3—Tractive effort—speed curve for Bo+Bo locomotive (1868-hp)

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A freight train drawn by a 1868 hp Bo + Bo locomotive near Barnsley Junction

British Railways photo 102966

available adhesion during acceleration the Bo+Bo locomotives are fitted with means for weakening the field of the leading motor on each bogie. This was especially necessary on this class of double-bogie locomotive with nose-suspended motors, since the maximum axle loads permissible for the track had already been adopted, and if full adhesion efficiency is to be obtained the alteration in axle load caused by the reactions of the motor torque and the drawbar pull must be counteracted. When the field of the leading motor on each bogie is weakened (by closing a weight transfer switch near the master controller) the effect is to reduce the tractive effort of these two motors to correspond with the reduced weight on their axles, which has been caused by the tilting action of the bogies during acceleration. Thus the locomotive as a whole is able to exert a higher tractive effort by notching at higher currents without producing wheel slip. The fact that the weight transfer switch has been closed is indicated by a green lamp, thus reminding the driver to revert to normal conditions as soon as the tractive effort can be reduced.

Traction motors

The traction motors are grouped together to give two combinations on the Bo + Bo locomotives and three on the Co – Co units, two combinations being available both for motoring and for regeneration. As shown in the power schematic diagram for the Bo + Bo locomotives (fig. 4) shunt transition is used from series to series-parallel.

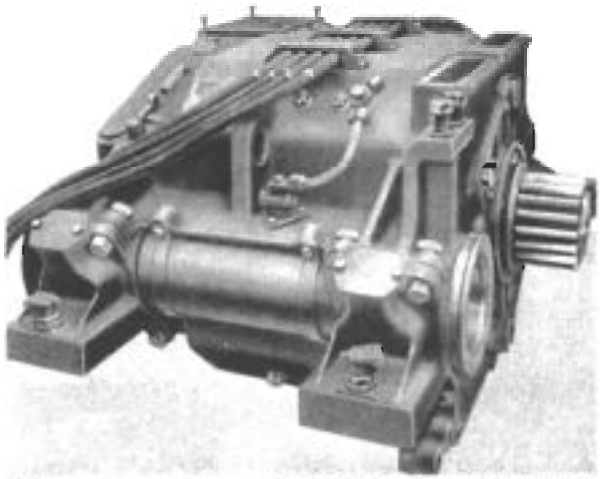
Regeneration is carried out by the well known separate exciter method using stability resistance. The resistances are of the self-ventilated heavy cast-iron grid type, housed in a separate well-ventilated compartment in the body; each bank can be easily disconnected and lifted out when required. These resistances have been specially designed for the very heavy duties imposed by the class of traffic, the heavy gradients, and the long periods of running at very low speeds during foggy weather—particularly on some stretches of the line provided with goods running loops working on the 'permissive' system.

All the traction motors are of the series-wound axle-hung forced ventilated type. They are four-pole machines, the armatures on Bo – Bo locomotives being of the two-circuit wave wound type, while those for the Co – Co class are of the four circuit-lap type with equipotential connections at the commutator end. Bakelite cambric slot wedges are used to keep the armature windings in position. The gears are of the single reduction straight spur type, the gear wheels being of rubber resilient type (except for some of the early Bo – Bo locomotives, which were provided with gear wheels incorporating resilience provided by a system of springs).

The wide range of field weakening provided on the Bo – Bo locomotives is obtained by the use of inductive shunts in series with tapped resistances. For the Co – Co class, field weakening is provided by field tappings combined with a small series resistance.

Auxiliary equipment

The auxiliary machines, which are identical on both classes of locomotive, include a 5-kW motor-



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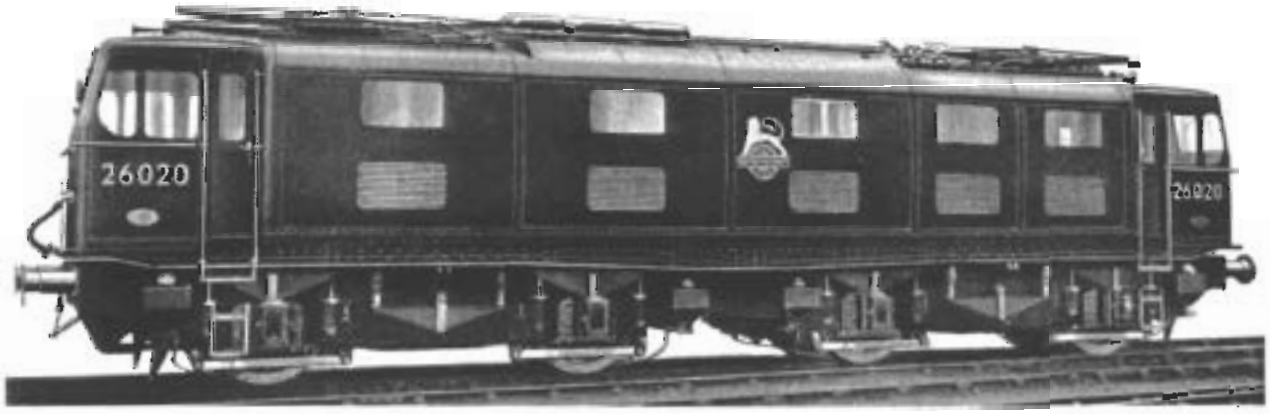
A 467-hp (1-hour rating) traction motor for a Bo + Bo locomotive



An 1868-hp four-axle Bo + Bo electric locomotive

British Railways photo 59765

generator set, which supplies the low tension current at 50 V for operating the control switches and charging the emergency battery, and a 35-kW m.g. set for the separate excitation of traction motor fields when regenerating. Each of these sets is coupled to a centrifugal fan, which provides forced ventilation to the traction motors. Other motor-driven auxiliaries are a two-cylinder reciprocating air compressor, which supplies compressed air for locomotive air brakes, electropneumatic switches, pantographs, horns, sanders, and window wipers, and a four-cylinder reciprocating exhauster, which provides for the vacuum brakes of the train.

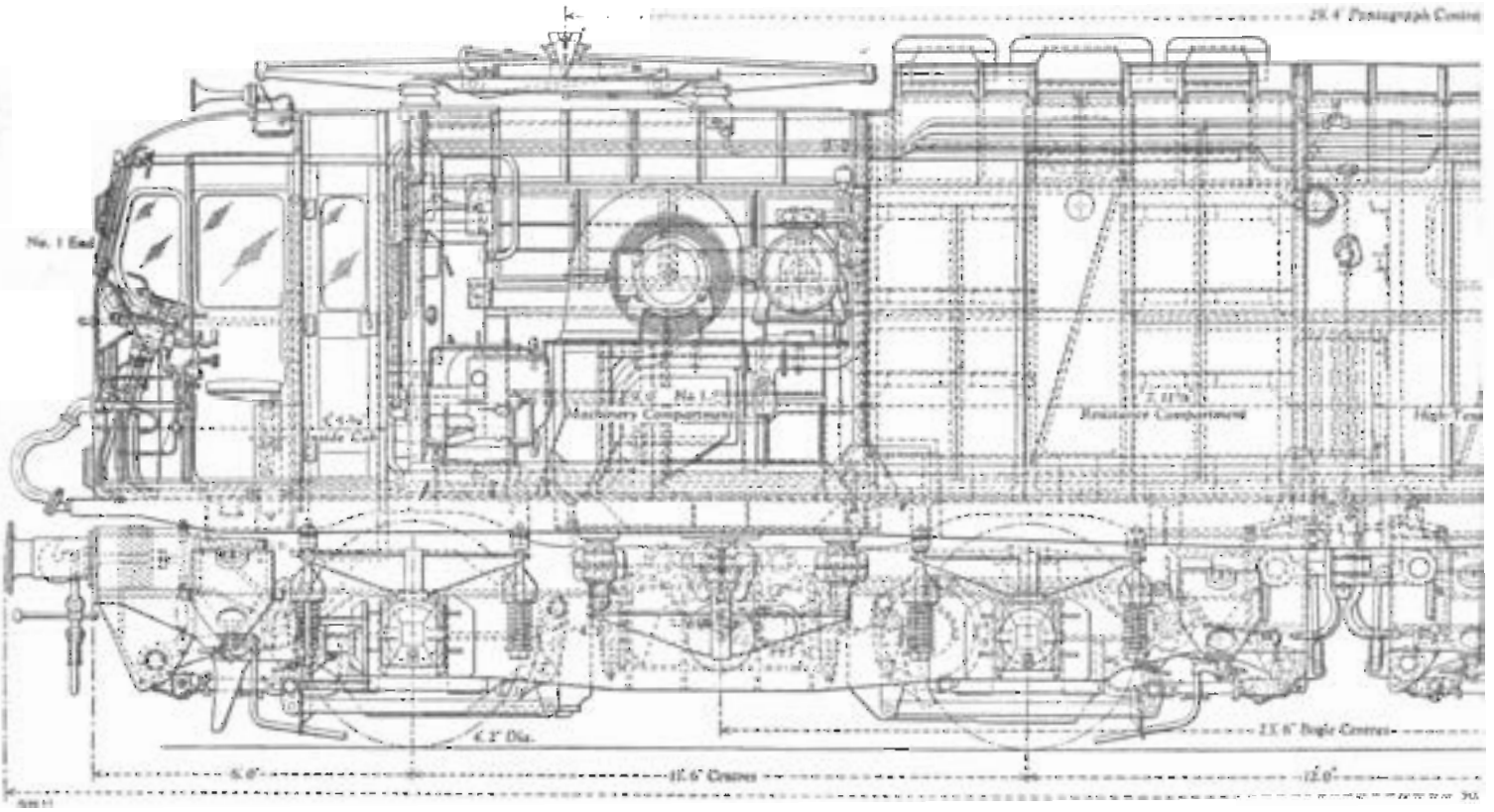
The electric boiler with which some of the locomotives are fitted has a rating of 1000 lb of steam per hour. It is fitted with 120 steel fire-tubes, each containing a Quarrzalite insulating tube, in which is housed a spiral heating element. Current is fed from the 1500-V supply to three separate electrical sections, each section being governed by a steam pressure switch. Fully automatic control is provided, together with all necessary protection. On those Bo + Bo locomotives not fitted with a boiler, an equivalent weight is provided in the form of a cast iron block, thus maintaining the same distribution of weight on the axles ; boilers can be readily fitted to these locomotives at a later date if required.

OPERATION

The locomotives on this electrification are normally used singly, except between Wath and Barnsley Junction (near Penistone). Only freight traffic operates over this part of the line, and many difficult conditions of working are encountered. For instance, up Wentworth Bank, which is a two-mile stretch of 1 in 40, the heavy trains have to be worked with both a train engine and a banking engine. Difficulties were experienced in the initial operation of these services—the first to be inaugurated—owing to the driver of the banking engine being often unaware of line conditions ahead. Audible signals are not always effective between locomotives on the same train, the track configuration forming a sound screen. However, with accumulated experience of the line conditions, coordination was gradually achieved by the drivers, and operation became satisfactory.

In the reverse direction, the 1 in 40 down grade is negotiated by using two locomotives, both at the head of the train, with regeneration. The ease and certainty with which this is accomplished under electric operation is in marked contrast with the conditions under steam : many of the wagon brakes had to be pinned down by hand at the top of the grade, the steam locomotive meanwhile pulling hard, and as these brakes heated up and so lost some of their braking power it became necessary for brakes to be applied on the locomotives also.

THIS NEW MAIN LINE ELECTRIFICATION, for which motive power is provided by the sixty-five locomotives equipped by the Company, resulted from the first in more efficient working of freight : for instance, the booked time to take heavy mineral trains across the Pennines from Wath to Mottram Yard has been reduced to 97 minutes from 162. The value of the scheme will undoubtedly grow with the increasing coal traffic from the Yorkshire and Nottinghamshire coalfields to Manchester and the north-west. Electrification has also provided faster and more frequent passenger services, reducing the express timing between Manchester and Sheffield from 70 to 56 minutes. Finally, the changeover from steam locomotives has revolutionized working conditions on a route notorious for its bad tunnels, and owing to the greater efficiency of central power stations it will save about 100 000 tons of coal a year.



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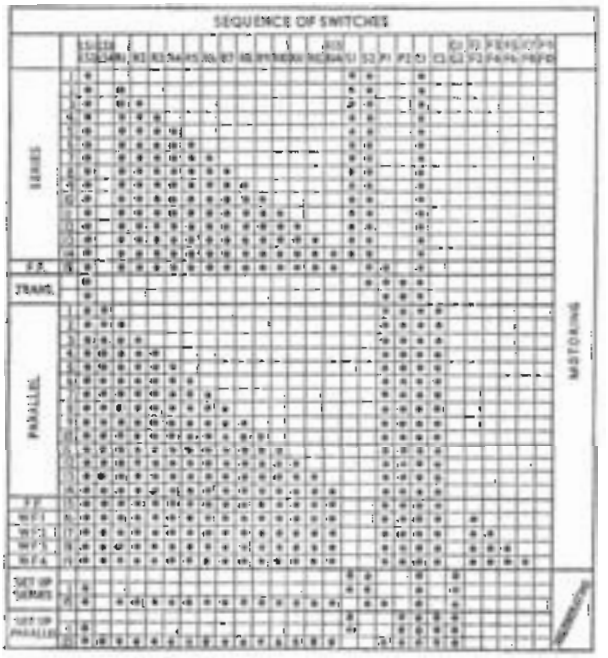
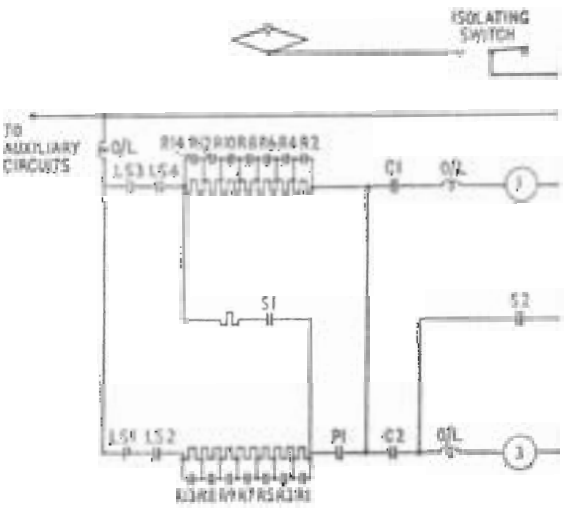
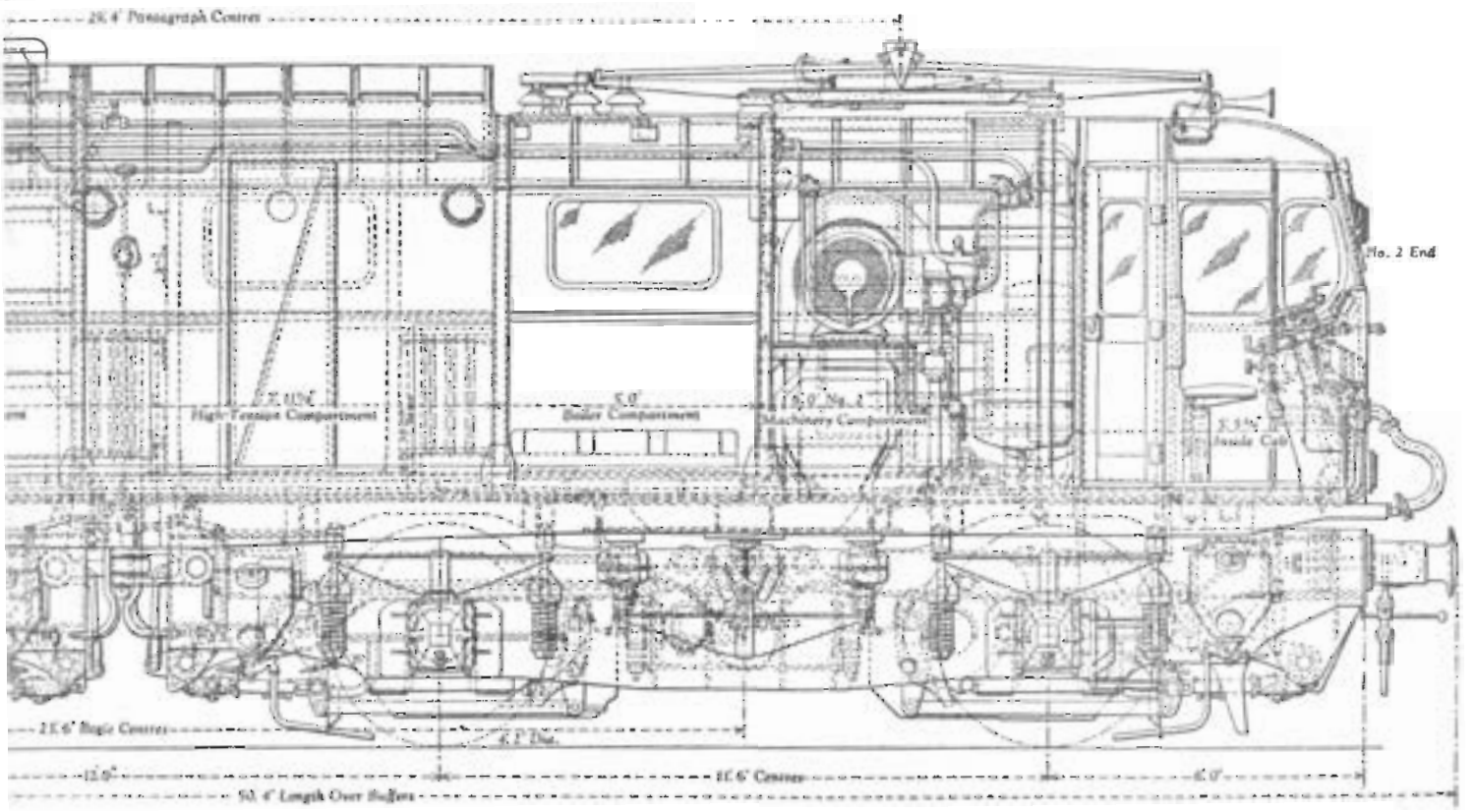
Longitudinal section of 1868-hp four-axle Bo + Bo





4—Power schematic diagram for Bo+Bo locomo



of 1868-hp four-axle Bo + Bo electric locomotive

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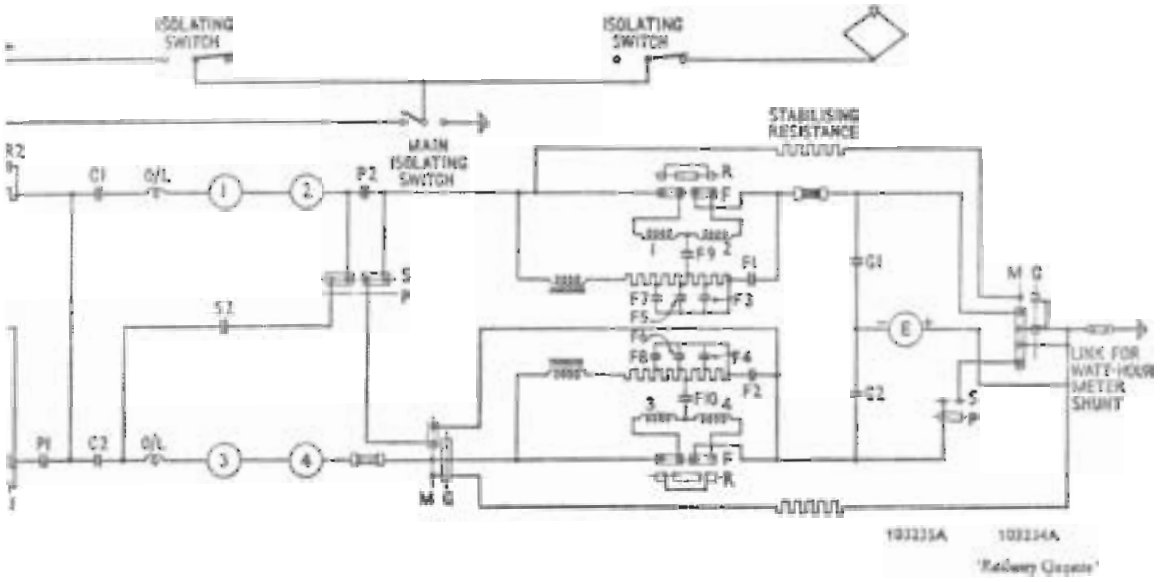

'Railway Gazette'

c diagram for Bo+Bo locomotive equipment

Printed by
The Arcadian Press Limited
London, England