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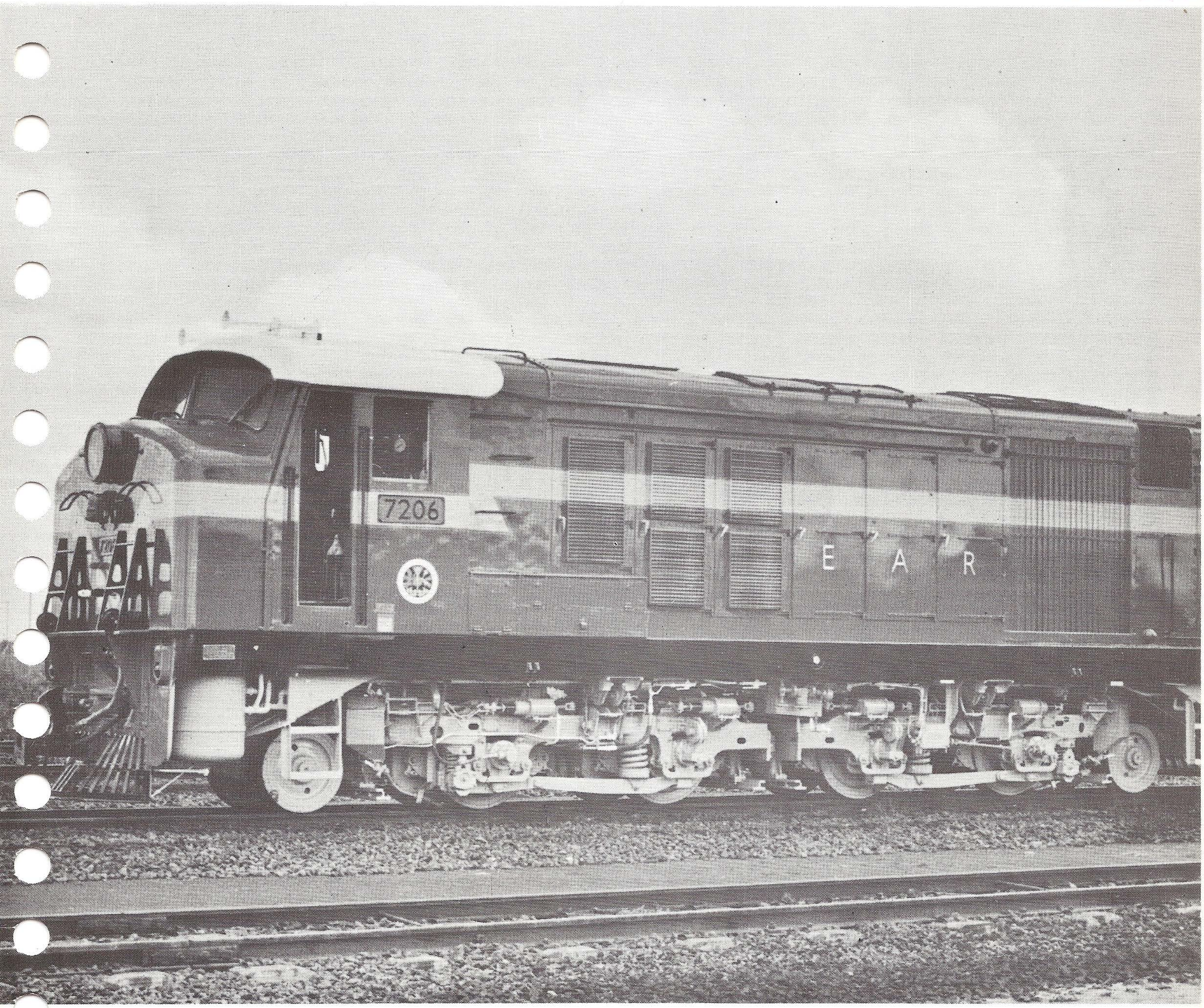

1 Bo-Bo1 DIESEL ELECTRIC LOCOMOTIVES FOR EAST AFRICA

GEC Traction Limited

ENGLISH ELECTRIC | AEI

DIESEL ELECTRICS FOR LIGHT MAIN AND BRANCH LINE WORKING IN EAST AFRICA

Delivery by English Electric of ten 1,350 hp 91 Class Locomotives to East African Railways & Harbours

THE East African Railways & Harbours Administration ordered in 1958 its first ten main-line diesel locomotives of 1,875 hp with six motored axles and unmotored guiding axles in the outer ends of the main bogies. Following service experience and tests further locomotives were ordered in 1962, 1965 and 1966 to a total of 44, and the last of these 90 Class locomotives are now in course of construction and delivery.

They are engaged on heavy main-line passenger and freight duties in Kenya and Uganda between Mombasa, Nairobi, Kisumu and Kampala, and more recently have appeared in Tanzania on the Dar-es-Salaam to Morogoro main line.

The main features of their design were suitability for operation over a wide range of altitudes and ambient temperatures, and a bogie design giving particularly good hauling ability and low lateral forces at the rail head while being suitable for 60 lb/yd rail. These qualities have been demonstrated over the seven years of their service through their low maintenance requirements and from rail stress tests carried out by the EAR & H. Development work on successive orders has enabled their performance to be maintained over the full range of altitude in East Africa from sea level to over 9,000 ft.

Following the satisfactory introduction of this main-line diesel power, it was decided to dieselise some sections of the railway system completely so as to eliminate the provision of expensive steam locomotive servicing installations. At the same time a new class of locomotive was required for that part of the East African railway system laid down in rail of 50 lb/yd or less in weight. This mileage, which is extensive, includes long main lines with light traffic and branch lines.

A feature of some sections of these lightly laid lines is the tight curves which range down to 350-ft radius. It is of interest to note that one line, the Nanyuki branch, has 63½ miles of curves, making up 48 per cent of the total length. These curves include 8 miles of 350 to 441-ft radius curves, 27 miles of 573 to 716 ft radius curves, and 5½ miles between 716 and 955 ft radius.

Considerable lengths of gradients at 1·5 and 2·2 per cent occur on this type of line, and the locomotives are suitable for maximum gradients of 3·5 per cent, compensated for curvature. In addition to an altitude range between sea level and 9,136 ft the climatic conditions were specified as including ambient variations between 30 and 100 deg F and humidities between 9 and 100 per cent.

As these light lines do not carry the dense traffic associated with main-line operation their construction can be simplified, nevertheless this places a premium on bogie design to minimise lateral loads on the rail head if track maintenance and wear is to be kept as low as possible. This was one of the main requirements in the railway's specification when quotations were requested. At the same time the specified train weight of 450 to 500 long tons ascending a 1·5 per cent compensated gradient at 17 mile/h called for good adhesion qualities in the bogie design.

Dynamic braking

The dynamic brake has become well established on the East African Railways with the 90 Class locomotives, on which it has gained the confidence of the drivers and reduced brake-wear and maintenance very considerably. The control of trains down the rather steeper gradients met on some of the light lines required good dynamic braking.

A further duty envisaged for this class of locomotive is that of handling pick-up freight trains. This requirement, together with the lack of locomotive turning facilities at the ends of some branch lines, required a driving position for each direction of travel.

Against this background the East African Railways issued its enquiry for light diesel locomotives in 1965. Some latitude was permitted to manufacturers regarding bogie design and wheel arrangement to seek the best bogie for the hauling duty which would also give low lateral railhead forces. Manufacturers were thus able to offer six-motor equipments with Co-Co bogie arrangements, four-motor equipments with rigid three-axle bogies, four-motor equipments with bogies incorporating guiding axles at their outer ends, and six-motor equipments with guiding axles similar to the 90 Class.

After due consideration of all these possibilities the EAR & H decided to order the four-motor equipment with outer guiding axles (Fig. 1). This 1+Bo-Bo+1 design gives satisfactory hauling ability with four 12-ton driving axles while being markedly superior to the Co-Co arrangements as regards lateral forces. The six-motor 8-axle equipment was ruled out on the grounds of expense and undue complication against the duties for which the locomotive was required, although it was capable of high tractive efforts with low rail stresses.

The design put forward by the English Electric Co. Ltd. was ordered early in 1966 because of its excellent hauling capabilities, coupled with low rail forces and general similarity with the existing locomotives. Additionally, considerable interchangeability and maintenance similarities held out promise of economy of operation, together with the minimum of re-training of maintenance and driving personnel.

The bogie design is of particular interest in this locomotive. The main bogie

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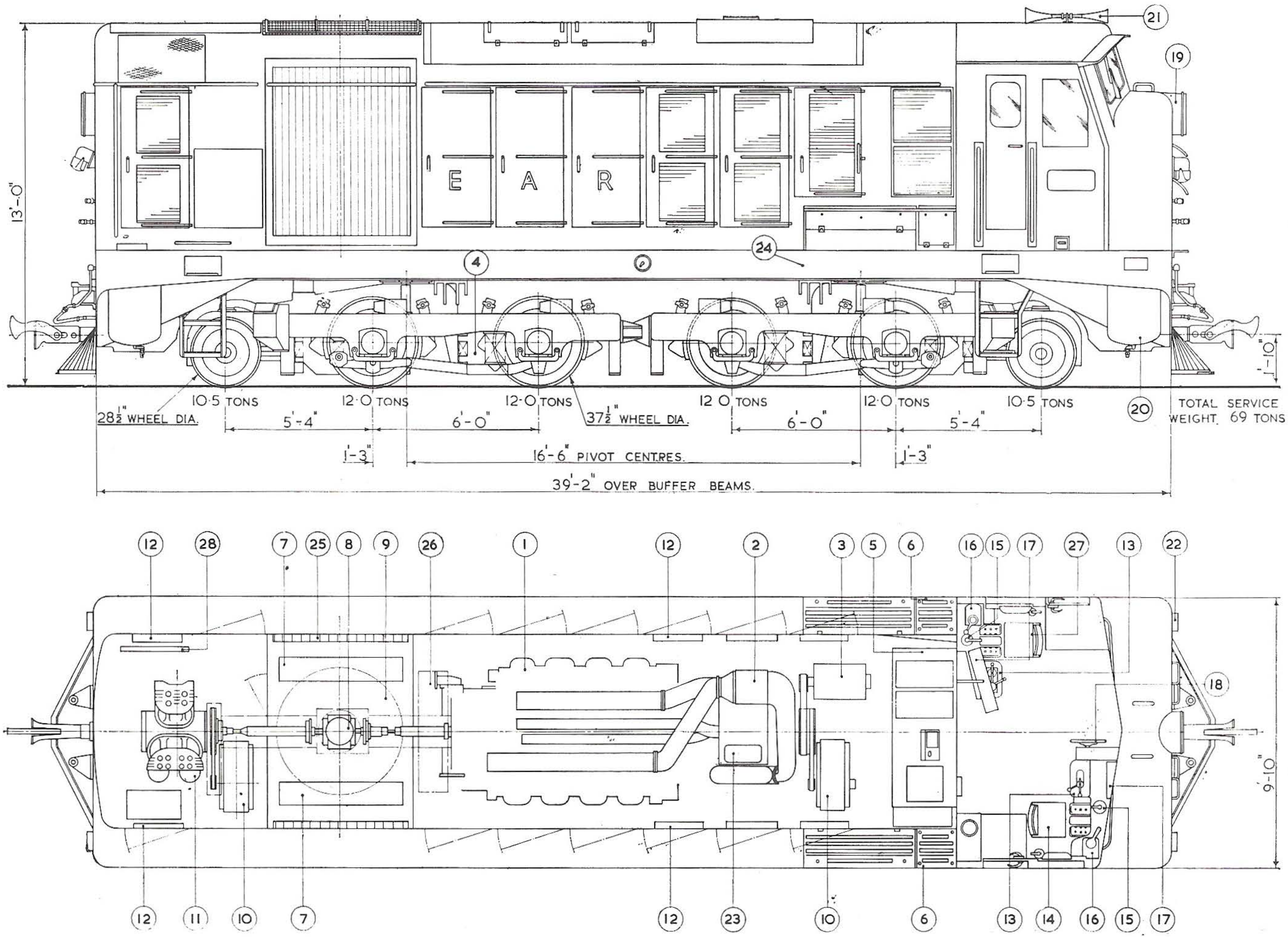


1. Engine 8 CSVT
2. Main generator EE 819
3. Auxiliary generator EE 755
4. Traction motor EE 537
5. Control frame
6. Batteries of 92 Ah capacity
7. Radiator panel
8. Radiator fan gearbox
9. Radiator fan
10. Traction motor blower KB 15
11. Compressor 4C200
12. Filters
13. Master controller
14. Forward driving seat
15. Straight air brake
16. Automatic air brake
17. Instrument panel
18. Handbrake
19. Headlights
20. Air reservoir
21. Horn
22. Marker lights
23. Engine air intake
24. Fuel in 660-gal underframe tank
25. Radiator shutters
26. Water header tank
27. Reverse driving seat
28. Compartment intercooler

General arrangement of English Electric locomotive for East African Railways & Harbours

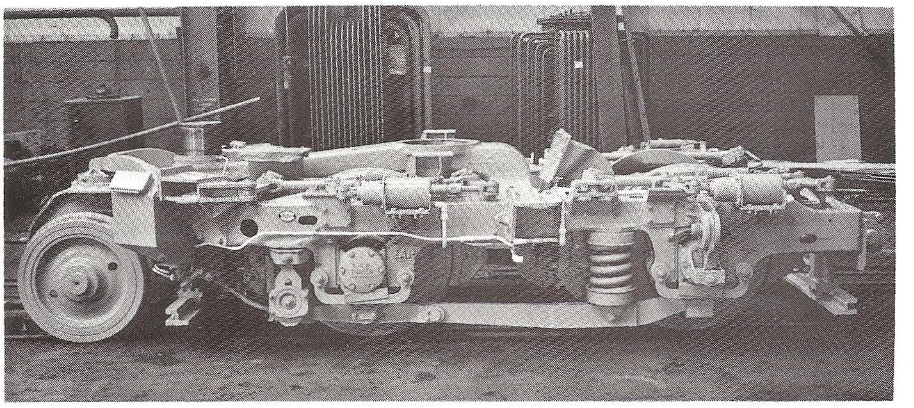


Fig. 1. 1+Bo bogie showing equalising system

frame is a steel casting and carries axlebox guides for the two driving axles together with a location at its outer end for the guiding axle. The superstructure is carried on each bogie by a large-diameter resiliently mounted centre pivot located between the motor axles, and a spring-loaded support located forward of the leading motor on the locomotive longitudinal centre line. Two anti-roll stops are located on the bogie side castings. Tractive effort is transmitted horizontally through manganese steel surfaces. This method of support allows the main bogie to accommodate itself to track undulations.

Axlebox guides in the main frame are fitted with removable manganese steel liners, which are oil lubricated; horn clips are accurately located by ring dowels and secured by through bolts. Fully equalised suspension is provided between driving and guiding axles, and nests of helical coil springs support the bogie frame on equalising beams between the driving axles and pony axle. These beams are supported beneath the axleboxes.

The beams between the pony axle and the leading motor axle are pin-jointed to the main bogie frame extension in a manner similar to the 90 Class locomotives One end of these equalising beams connects to one end of the first motored axle short equalising beam, and the other end is supported on the top side of the pony axle coil spring nests.

The pony axle is carried in a cannon box of robust cast steel construction. A liner is fitted on its upper surface, which carries the helical coil spring seat. Four widely spaced radial-links run from the cannon box to the main bogie frame to control the pivoting of the guiding axle, and provision is made for free movement of the pony axle both vertically and radially. Ahead of the cannon box is the spring unit providing lateral control of the pony axle. This spring control unit is bolted to the main bogie frame extension. Provision is made for lifting and jacking the bogie.

An inter-bogie spring control is arranged between the inner headstocks of the main bogies which, together with the lateral spring at the guiding axle and with the geometry arranged by the radial links between the pony axle and the main bogie frame, result in low flange forces as the locomotive passes through curves.

This design is the latest in a series by English Electric for railways in Africa where the main bogie has a guiding axle to reduce rail stresses in curves. Although based on the design and test results for the 90 Class bogie, it incorporates features which simplify manufacture and maintenance.

The EAR & H bogie is fitted with two EE537 traction motors which are both axle-hung with their nose suspension towards the pony axle. This disposition of traction motors, together with the complete equalisation of driving and guiding axles, results in very low weight transfer from the driving axles. There are four brake cylinders per bogie, arranged in a manner similar to the 90 Class bogie and incorporating clasp brakes.

The driving wheel diameter is 37½ in and that of the guiding wheel is 28½ in; these are identical with the previous class of diesel locomotive and are interchangeable.

Charge-cooled engine

The engine of the 91 Class locomotive is the English Electric Type 8CSVT with eight cylinders pressure-charged and charged-air cooled, developing 1,240 bhp. (site) at 850 rev/min. It incorporates the same components associated with English Electric 10-in bore 12-in stroke engines as in the 90 Class. The standard temperature and pressure rating is 1,350 bhp. at 850 rev/min. Brake mean effective pressure, at the s.t.p. continuous rating, is 168 lb/in^2 and at the site rating is 153·7 lb/in^2. Both ratings are at a piston speed of 1,700 ft/min. Charge cooling is provided by a single English Electric/Napier Type HP210 turbo-blower matched to the engine requirements for the full range of altitudes in East Africa. This matching was based on extensive tests carried out with a fully instrumented 12CSVT engine on a 90 Class locomotive.

Maximum tractive effort is 40,000 lb, and the continuous rating is 32,000 lb at 10·9 mile/h.

A Woodward governor with pressure bias load control and fuel limiting is fitted. Engine power is controlled through the governor by varying air pressure at the driver's master controller. In turn the governor adjusts the loading on the engine through a hydraulically operated regulator which varies the main generator field and hence its output. The combined effect of these arrangements is to give continuously variable control of the engine from the driving position while arranging that the engine operates in the most economical manner and cannot be overloaded. This system is closely similar to that on the 90 Class locomotives.

Twin radiators are supplied by Spiral Tube & Components Co. Ltd. and are arranged for two separate water cooling circuits. One cools the water from the engine jackets and the other from the charge inter-coolers and the oil cooler. Pumps are fitted for each circuit.

Radiator cooling air is provided by a 60-in diameter fan running at 1,100 rev/min driven via a right-angle gearbox from the free end of the engine.

The main generator is the English Electric Type EE819 continuously rated at 1,200 A and 670 V d.c. at 850 rev/min. This six-pole machine has Class H insulation generally, and has a separately excited main field with a series field used only for engine starting. The generator armature is bolted solidly to the end of the crankshaft and is supported additionally by a single bearing in the main

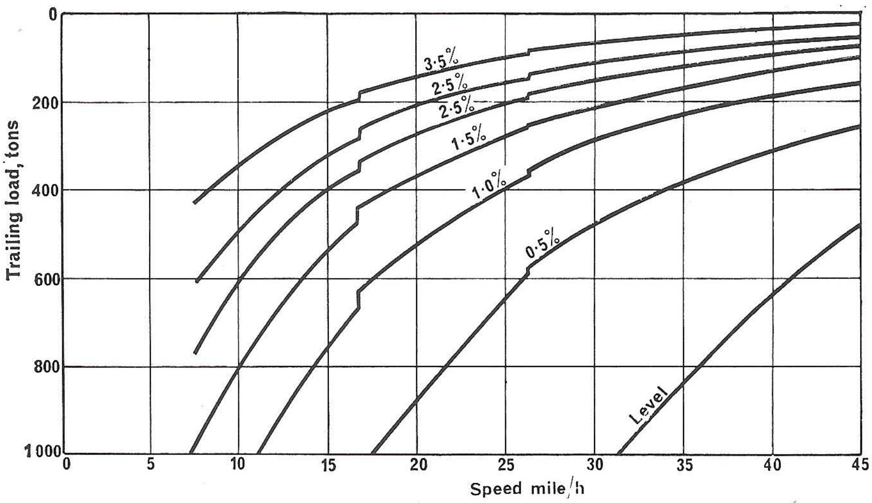


Fig. 2. Performance curves of locomotive

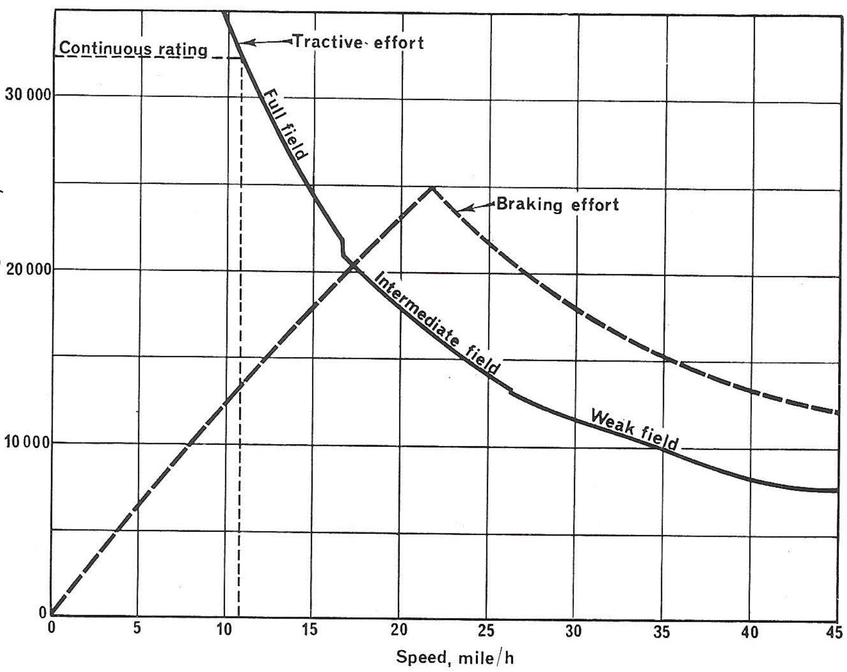
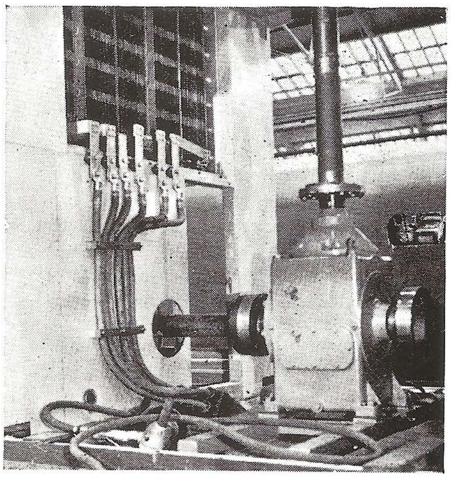
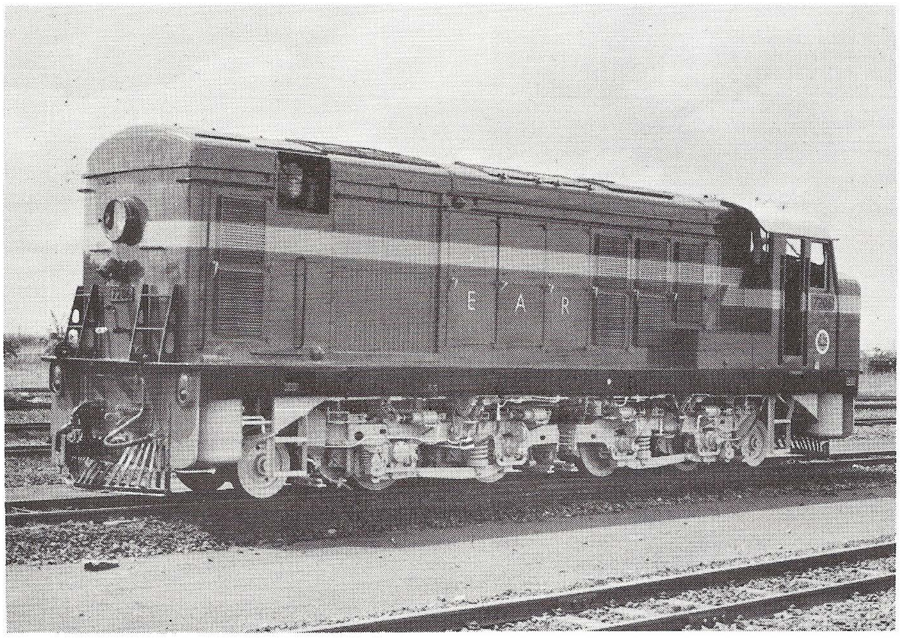


Fig. 3. Capacity of dynamic braking system



Dynamic braking resistance in radiator compartment bulkhead



View from bonnet end.

frame. It is cooled by a fan on the flywheel using filtered air which is discharged through the floor of the superstructure.

The generator supplies the traction motors, which are interchangeable with the motors on the 90 Class locomotives, and are arranged in two series strings in parallel. Output conditions of the generator are arranged to match the power called for by the driver, and when full excitation has been reached the load regulating unit controlled by the governor initiates two stages of field weakening on the traction motors. The locomotive performance curves are shown in Fig. 2.

Wheel slip detection is provided by sensitive relays which compare voltages across the two armatures in a string, and also by a current balance relay which compares currents in the two parallel circuits. Protection is provided by running back the load regulator.

Type EE537 traction motors are four-pole nose-suspended machines driving through straight spur reduction gearing; they have Class H insulation throughout and have a continuous rating of 600 A at 350 V and 490 rev/min. They are ventilated using filtered air from two Keith Blackman belt-driven centrifugal fans.

A dynamic brake installation of 1,000 kW is mounted at the end of the engine bonnet of the locomotive. It has two resistors of "Expanded" metal arranged one across each pair of traction motor armatures, and these are cooled by the radiator fan. For dynamic braking a series of shutters is arranged to reduce the air flow through the main radiator compartment, while others introduce an air flow through the dynamic brake resistor frame. When reverting to power operation the air flow through the resistors is closed off by shutters and normal flow is restored to the main radiators. Control of the dynamic braking is the same as for the 90 Class; the driver's controller is moved through the "off" position to three dynamic brake positions "increase," "lap," or "decrease." The capacity of this dynamic braking system (Fig. 3) provides a safe margin for controlling all trains that can be anticipated for these locomotives on steep descending grades.

The locomotive is equipped with Westinghouse Brake & Signal equipment for automatic train air brake and independent locomotive air brake. The locomotive brake is interlocked with the dynamic brake so that both cannot be applied simultaneously. Compressed air is supplied by a Westinghouse 4C200 compressor driven by an extension shaft from the radiator fan gearbox.

The locomotive service weight at 69 tons including a medium speed diesel engine is fairly light and required careful attention to detail design. This low weight has been achieved using orthodox construction without recourse to stressed skin methods. The underframe is an all-welded structure fabricated from rolled steel sections and plates with the two main longitudinal members forming the main fuel tanks. The ends of the underframe slope down to meet the drag boxes, thus providing a very strong structure against buffing loads. The floor is sealed to prevent leakage of oil on to the bogies and is provided with facilities for draining off spillages.

The short nose in front of the cab contains items of air equipment, and beyond the cab the engine-room contains additionally the control equipment frame, one traction motor blower and the auxiliary generator. The next compartment contains the radiator system, and the end compartment the second traction motor blower, main compressor and dynamic brake resistor frame.

All cooling air for machines and engine supplies on the locomotive is filtered using elements standardised by East African Railways. These filters are arranged in the doors on the bonnet sides providing access to the engine room through which air for the traction motor blower, auxiliary generator, main generator and engine passes. Air for the second traction motor blower and the compressor passes through similar filters in the doors providing access to the end of the bonnet structure. Engine air is drawn from the engine room through secondary filters on the turbo-charger inlets. Air is exhausted through the bonnet roof.

The driver's cab is arranged with a standard 90 Class type driver's position for movement with the cab leading. A second fully equipped driving position is arranged on the opposite side of the cab for driving with the bonnet leading.

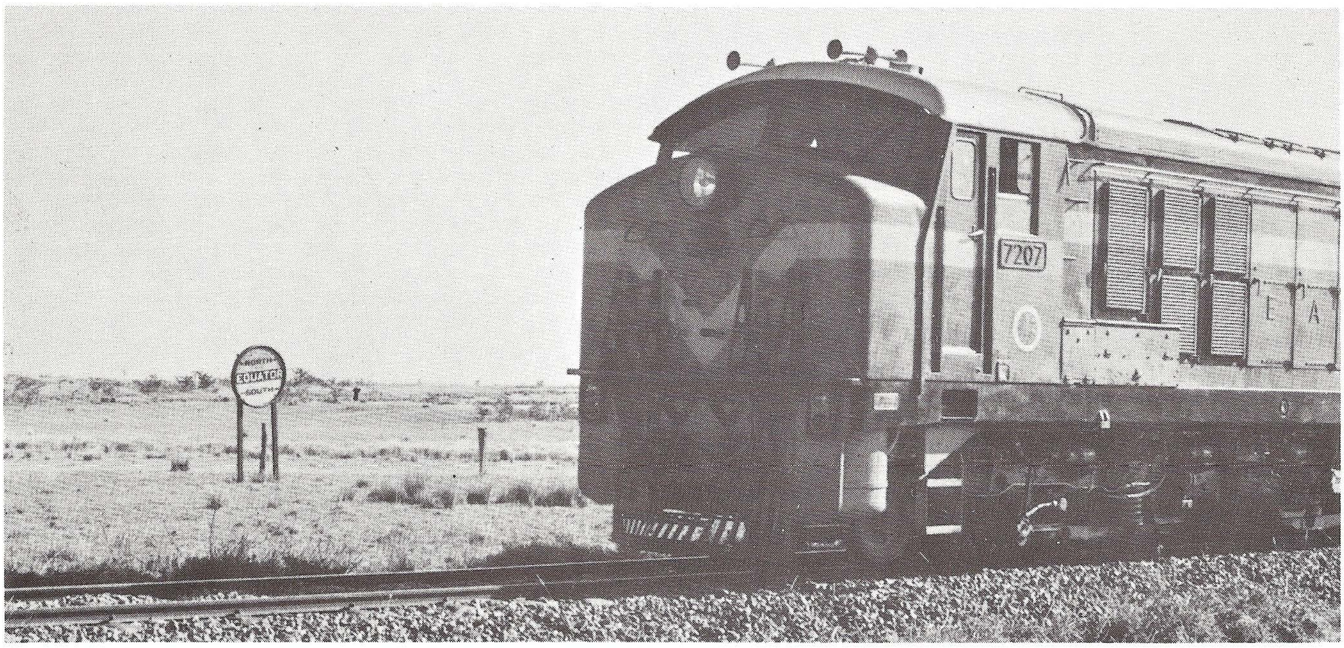
An auxiliary generator, belt-driven from an extension of the main generator shaft, provides supplies for heating, lighting, control, fuel transfer pump and battery charging. This generator, English Electric Type EE755, is rated at 90 A, 110 V d.c. Engine starting is by main generator and series field supplied from an Exide lead-acid battery.

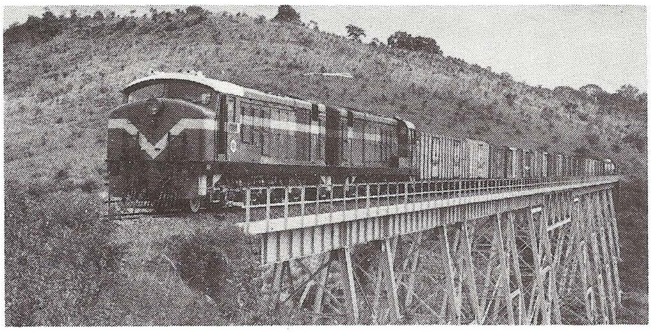
The locomotives have been arranged for multiple unit operation with others in the same class, or with 90 Class locomotives. Up to three locomotives can be operated in this manner.

The first locomotive was despatched from the English Electric Works at Newton-le-Willows in November and enters service in East Africa this month. It is expected that initially the locomotives will be based on the Makadara Maintenance Depot in Nairobi, and they will operate in western Kenya.

Principal suppliers for the 91 class locomotives

British Timken	Main bogie axlebox details and cannon box components
Usines Emile Henricot S.A.	Cast steel bogie frames
Westinghouse Brake & Signal Co., Ltd.	Brake systems
Locker Industries Limited	Air filter panels
Pyrene Co. Ltd.	CO_2 fire extinguisher equipment
J. Stone & Co. (Deptford) Ltd.	Lighting
Spiral Tube & Components Co. Ltd.	Radiator equipment
Marston Radiators Limited	Radiator shutter units
Thos. Turton	Silicon manganese steel coil springs
K & L. Steelfounders & Engineers Limited ..	Pony truck slides Jacking brackets Control gear brackets Axle box bodies Brake box shoes Traction motor frame castings
Trico-Folberth Limited	Windscreen washer and wiper equipment
Specialloid	Pistons
Bryce Berger Limited ..	Injection equipment
Serck Radiators Limited	Radiators
Vokes Limited	Lubricating oil filters





The original ten locomotives were designated 91 class but as a result of a general reclassification on EAR they were subsequently renumbered as the 71 class.

A further 10 locomotives, the 72 class, were supplied in 1972. The principal equipment, performance and layout were unchanged but a number of detailed changes were introduced at EAR's request, in some cases for evaluation purposes, The principal changes were:-

i. an electrically driven dynamic brake blower tapped across the braking resistance replacing a mechanical arrangement with pneumatically controlled shutters.

ii. a hydrostatically driven radiator fan replacing a mechanical drive.

iii. an electrically driven compressor, instead of mechanical drive.

iv. a larger auxilliary generator to cope with the increased load.

v. driver comfort improved by the installation of a filtered drinking water supply and a toilet–the latter required substantial rearrangement of the brake equipment and pipework in the nose.

vi. externally end lifting lugs were added and extra protection added to reduce damage following collisions with wild life.

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