The second of a batch of ten locomotives for operating freight and passenger services over 1 in 33 gradients

NARROW-GAUGE LOCOMOTIVES OF GREAT HAULING CAPACITY

Ten 760-mm gauge units of 990 b.h.p. are engaged in heavy traffic on mountain line in Bulgaria

General Particulars of B.D.J. Locomotives

Rail gauge	760 mm
Axle layout	B-B
Wheel dia.	900 mm
Bogie wheelbase	1·90 m
Bogie pivot pitch	6·50 m
Frame length	11·47 m
Length overall	13·04 m
Maximum width	2·47 m
Overall height	3·52 m
Empty weight	44·5 *tonnes*
Service weight (2/3 supplies)	48·0 *tonnes*
Axleload	12·0 *tonnes*
Top speed	70 km/h
Starting/tractive effort	15,000 kg
Smallest curve	40 m
Fuel capacity	1,800 litres
Boiler water capacity	1,300 litres
Contin. rated t.e.	13,850 kg at 10 km/h
Engine output (site)	990 b.h.p.
Locomotive maker	Rheinstahl-Henschel
Engine type	Maybach Mercedes-Benz MB.820 Bb
Transmission type	Voith L.306 r
Cooling equipment make	Behr

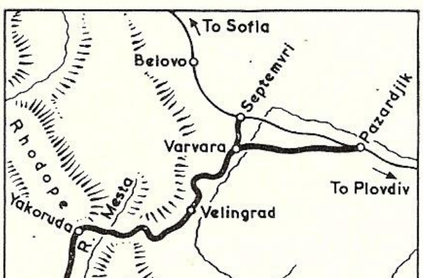
TEN DIESEL-HYDRAULIC locomotives of 1,100 b.h.p. (U.I.C.) and B-B axle layout are all now in traffic on the 760-mm gauge line of the Bulgarian State Railways extending south from the Sofia-Plovdiv main line at Septemvri, to near the Greek border, and are revolutionising the motive-power aspect.

This line is unusual among such narrow-gauge routes in that traffic is really heavy, and even before the arrival of diesel units the track was laid and ballasted to take 12-*tonne* axleloads, an unusually high value for this gauge.

Timber Traffic

There is intense traffic in timber northbound, and in constructional materials and other goods southward, and this is developing still further. Hitherto, 600-*tonne* freight trains have been hauled up the curved 3·0/3·3 per cent gradients by two 2-10-2T steam engines coupled chimney to chimney.

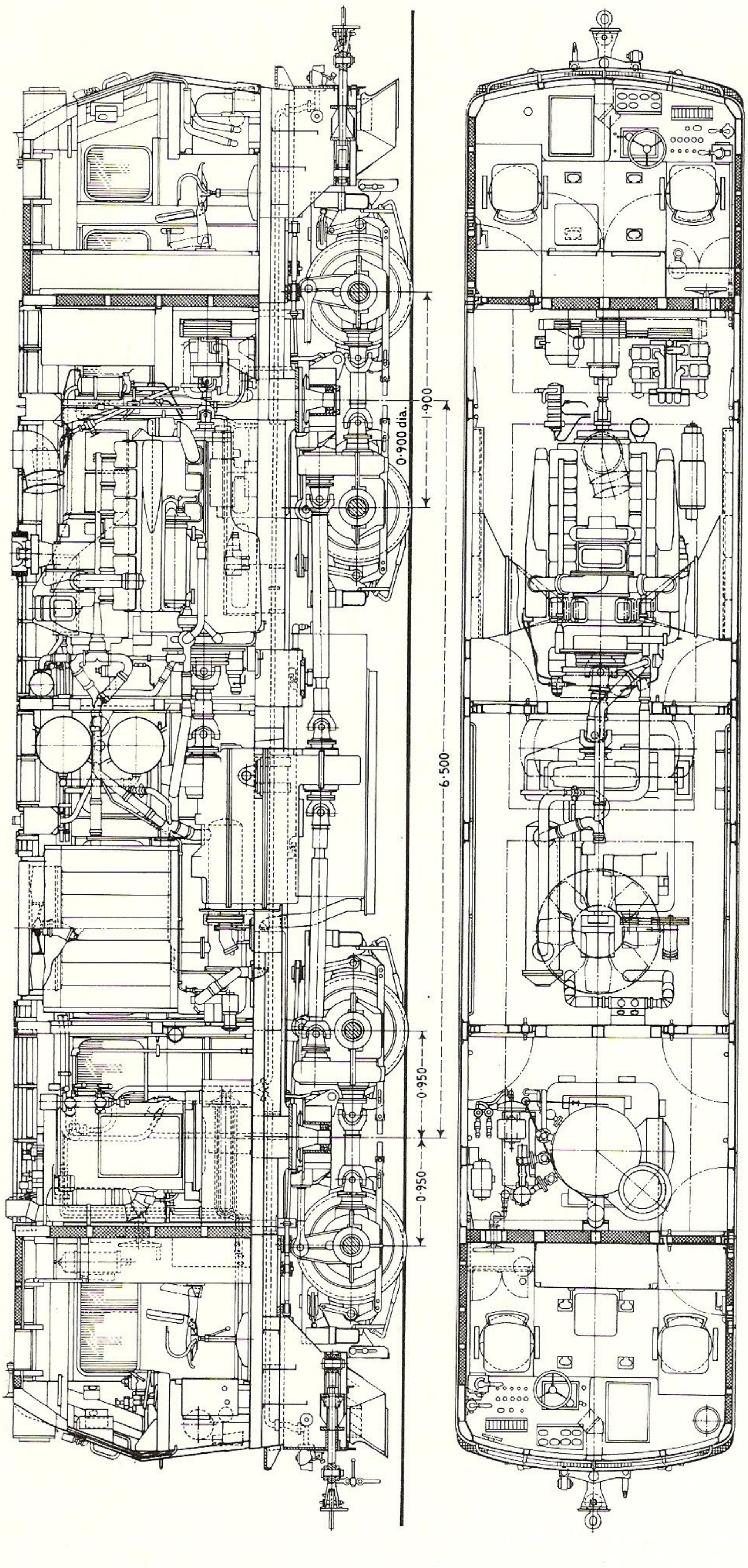
In the autumn of 1963 some trials were made with a standard Austrian 600 b.h.p. 32-*tonne* B-B diesel-hydraulic locomotive which showed the adhesion and low-speed pulling charactertistics of this type of power; but as the output and weight of this unit were far from what were needed for the line, the Bulgarian State Railways eventually placed in the autumn of 1964 an order with Rheinstahl-Henschel for ten much more powerful locomotives, designed and built specially up to the axleload which could be taken, and with as much power as could be put in.



Railway between Dobrinishté, Septemvri and Pazardjik

The result was a B-B of 48 *tonnes* weight with two-thirds supplies, an output of 1,100 b.h.p. (U.I.C.) and 990 b.h.p. (site), with a starting effort of 15,000 kg, and a continuous rated wheel-rim effort of 13,850 kg at 10 km/h, equivalent to 29 per cent adhesion at 14 per cent of top speed. This low weight includes train-heating equipment.

This was one of those cases where a high continuous rated effort was essential; and two of these locomotives in tandem can take a 600-*tonne* trailing load up curved 3·3 per cent gradients at 15 km/h without difficulty. Thus against the two 2-10-2T steam engines the two diesels with 96 *tonnes* of adhesion maintain a higher speed uphill than the 114 *tonnes* of steam locomotive weight, with more regular performance, and without the smoke nuisance in tunnels or the flange grinding on the sharp curves. The diesels can go round 40-m curves at low speed, which the ten-coupled steamers could not do.



The Septemvri-Dobrinishté line is 125 km in length, and, from its two junctions with the Sofia-Plovdiv main line at Sarambey and Pazardjik, crosses between the Rhodope and Rila mountains and ends at the foot of the Pirin mountains, attaining a summit level of 1,267 m. Temperature variation over the year is from 42 deg. C. to −38 deg. C., an extraordinary range, and one leading to special requirements in the cooling and allied systems.

Though freight service forms the majority of the duties, passenger trains must be hauled also; and as it was not desired to add special heating vans, as these could not be widely used because of the narrow gauge, it was necessary for the locomotives to have train-heating boilers. With these various considerations the empty weight of 44·5 *tonnes* for 1,100 b.h.p. U.I.C. is a notable result, representing 23 b.h.p. per *tonne*.

General particulars

In its general conception the locomotive is simply a 760-mm variation of the numerous metre and 3-ft 6-in gauge locomotives of 1,100 to 1,500 b.h.p. (U.I.C.) supplied by Henschel to Thailand, Spain and Togo; and the only constituents not thoroughly tried previously are those mechanical-portion details which had to be varied because of the narrow rail gauge and the restricted loading gauge (2·47 m maximum width and 3·52 m maximum height).

Equipment layout is conventional, with two cross partitions between the cab bulkheads giving three machine compartments, an engine room, a cooler room and a boiler compartment. In the last-named the boiler is mounted over a water tank, and there is a second water tank in the adjacent driving cabin. Balancing it in the other driving cabin is an electrical equipment cabinet. The main fuel tank is an integral part of the underframe and the fuel is stored on both sides between the bogies.

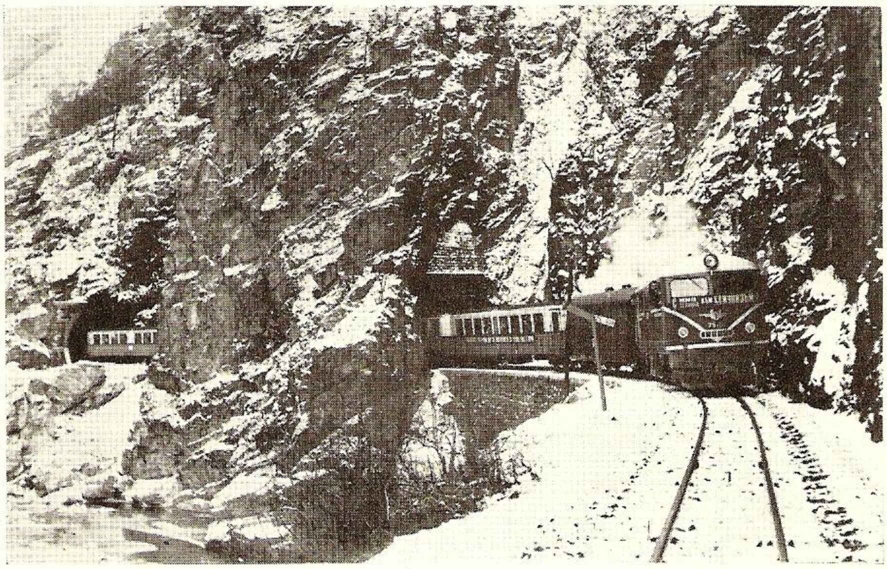
Technical considerations

Because of the restrictions imposed by rail gauge and loading gauge the wheels, bogie wheelbase and bogie pivot pitch are all smaller than in the metre-gauge locomotives mentioned previously, but the springing and cross supports have been proportioned to maintain the same easy-riding characteristics. In this case, special efforts could not be made to get a low position for the bogie pivot to ensure maximum practical use of the adhesion, but while the restricted dimensions would have made a pivot location below axle level impracticable the dimensions for coupler height, wheel diameter and pivot location could be well balanced out.

General arrangement of Henschel 760-mm gauge locomotive for Bulgarian State Railways (B.D.J.)

The arrangement of the cardan shaft connecting the two axles of a bogie is on axle centre line, and the bogie pivot is just above this. The roller-bearing axle-boxes are each supported by two helical springs on balancing beams below the axlebox and the body is supported well out at the sides by helical-spring groups on the centre-line of the pivot, and supplemented by hydraulic vibration dampers.

With the rail gauge of 760 mm, the axleboxes are on the transverse centres of the bogie-frame longitudinals, at a cross pitch of 1,350 mm, with the primary springs on the same centre lines; the body springs are at 1,850 mm lateral spacing. Total deflection of the combined primary and secondary suspension is equal to 2·44 mm per *tonne*.



Passenger train on 1 in 40 gradient near the Rhodope Mountains

Air system

Knorr straight and automatic air brakes with the KE distributor are fitted. There is a separate horizontal brake cylinder for each wheel, and this applies two blocks through clasp rigging, with a braking force equal to 100 per cent of the braked weight. The automatic brake is arranged to give up to 80 per cent braked weight on the train. The system also includes a passenger-goods change-over valve.

Air for the brake system, control system of engine and transmission, sanding and other details is furnished by a Knorr VV 450/150 four-cylinder compressor belt-driven off the main engine, and this has a capacity up to 2,800 litres/min to 10 atm. pressure. Air is stored in two main reservoirs of 250 litres capacity each.

Power group

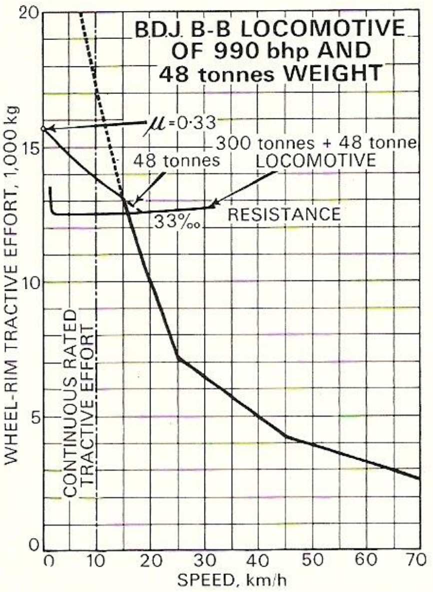
Power comes from a Maybach Mercedes-Benz MB.820Bb engine, a 12-cylinder 60-deg/V with pressure-charging but without charge-air cooling; and it is interesting to note that on the other side of the frontier, in Greece, the same unit has been making a steady 147,000 km a year for several years in powerful railcars.

In the Bulgarian locomotives, to suit the altitude of 1,270 m and a temperature of 23 degC at that height, the output has been set to 990 b.h.p. at 1,500 rev/min. With any higher temperature at that altitude the engine output is limited automatically by a charging-air limiting regulator.

U.I.C. rating

The U.I.C. rating of this engine, which has 175 mm × 205 mm cylinders, is 1,100 b.h.p. at 1,500 rev/min, corresponding to a b.m.p. of 11·25 kg/cm² and a piston speed of 10·2 m/sec; dry weight is 3,500 kg. This is one of the seven engine models which at the moment have the O.R.E. approval for installation in any standard locomotive.

Combustion air, and fresh air for engine-room ventilation, are drawn in through oil-wetted panel filters in the upper part of the side walls, and the former is led through trunking with flexible sections to the pressure charger. Exhaust is direct up through the roof,



Speed/tractive effort characteristic

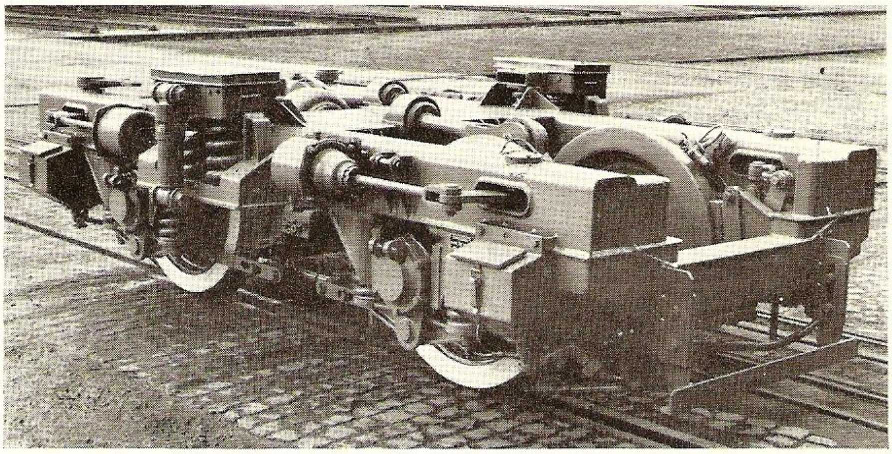
in two ducts. The engine is mounted on a raised subframe welded to the locomotive underframe, and is supported by four elastic mountings on the subframe.

Auxiliary drives from the free end of the engine are to the air compressor and a.c. generator, the drive going through a cardan shaft, elastic coupling and belts. The drive to the hydrostatic pump for the cooling-fan drive is by belts, which have to transmit up to 38 hp, but this belt-drive is taken off the primary shaft of the transmission.

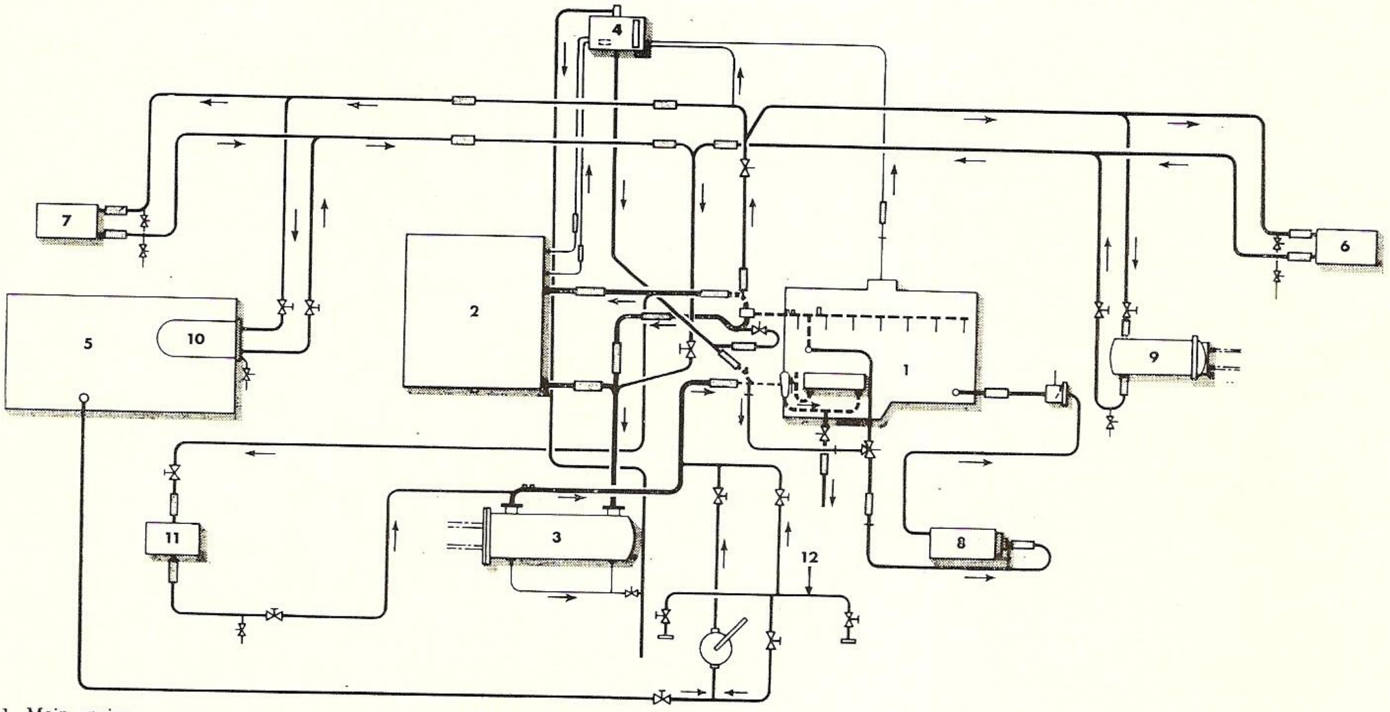
Cooling and heating

Cooling is by a Behr group with the customary high pressure hydrostatic motor for the fan, and with thermostatically controlled servo opening of shutters in the side walls and on the roof, and similar control of the fan-motor speed.

The radiators are in sloping banks within the cooler room and are supported elastically from the main strengthened longitudinal members of the roof structure. The passage-way down the locomotive interior is between the radiator banks and the vertical inlet grilles on the side walls. The main cooling-



Bogie with individual air-brake cylinders, flange lubricators and air-sanding gear



1. Main engine
2. Main cooler group
3. Transmission-oil heat-exchanger
4. Water header tank
5. Boiler water tank
6. Cab heater 1
7. Cab heater 2
8. Webasto pre-heater
9. Fuel heater
10. Water heater
11. Battery heater
12. Filling and emptying connection

Main and secondary circuit diagram of heating and cooling systems

water circuit includes the transmission-oil heat-exchanger.

Because of the stringent winter requirements, a comprehensive heating system is tied into the cooling system, and is based on a Webasto 180 WI oil-burning water heater. The layout is shown in the accompanying circuit diagram.

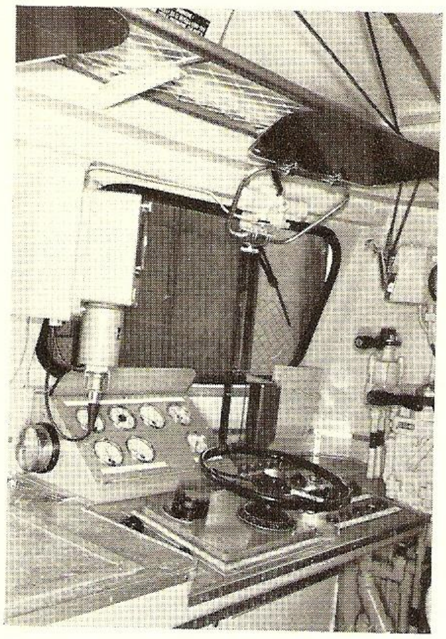
Automatic control

Automatic control arrangements are such that if the ambient temperature falls below 0 degC the fuel in the main tank is heated through the warm water coils within, the boiler water tank is heated to prevent any freeze-up and a current of heated air is blown over the battery cells, which are encased in a steel container slung from the underframe longitudinals below the bogie. By these means there can be no deposition of paraffin wax in the fuel which might clog the filters, and the full capacity of the battery is maintained to give a certain engine start in the cold.

Transmission

Main transmission element is a Voith L.306r block with three converters and in-built reversing gears; and converter automatic change-overs are at 25 and 45 km/h. The block is supported on the underframe more or less at mid-length, and from it cardan shafts go fore and aft to Henschel axle drives, so that all four axles are in one group and one or two axles cannot slip by themselves. Torque-reaction members are horizontal, from lugs above the axle-drive casing, and end in large rubber blocks bearing against the bogie centre transom. The electro-pneumatic control system has 16 notches, and is linked also with a Knorr axle-driven anti-slip anti-slide control.

Train-heating steam is provided by a Henschel quick-raising boiler of model HK.300, with a capacity of 300 kg/h and with full automatic regulation. This has a comparatively small water content and the normal pressure of 4·5 atm. can be raised in 15 min from a cold start. Diesel oil is the normal fuel. Control and supervisory apparatus for the heating boiler is in a separate cabinet in the boiler room, and actually attached to the boiler; and in the driving cabin apart from the switch for heating-on or heating-off, there is only a warning light, which illuminates on any boiler defect occurring. The 39-mm insulated train-heating pipe from the boiler is passed through the box-section longitudinals of the underframe.



Driving controls at right-hand side of cab

Electrical

Elements of the electrical system in the locomotive were determined to some extent by the desire of the Bulgarian State Railways to have an arrangement similar to that incorporated in existing diesel-hydraulic standard-gauge locomotives of 2,000 b.h.p., and so the equipment is laid out for 110-V storage-battery current and 135-V generator tension. The A.E.G. a.c. generator set has a continuous rating of 4·5 kW and runs at a top speed of 4,500 rev/min. This a.c. machine operates in conjunction with a silicon rectifier and full-electric voltage regulation. The storage battery is of the Austrian Jungfer make, as in the 2,000 b.h.p. locomotives, and has a capacity of 300 Ah at the 5-h rate of discharge.

Tests

Preliminary observations in Bulgaria show that these locomotives working solo are capable of hauling 280/300-*tonne* trailing loads at 15 km/h up 3·0 per cent gradients having uncompensated curves of 200 m radius, and of hauling 230-*tonne* trains over the same gradient and curves at 25 km/h. On level lines a 1,400-*tonne* train is hauled easily at the top permissible speed of 70 km/h. Delivery was on low-loading wagons by rail through Austria and Yugoslavia.

Load test in progress with the first Henschel B-B series 75-01 diesel-hydraulic

DIESEL EXPERIENCE ON 760-MM GAUGE LINE IN BULGARIA

Increasingly good results obtained with Henschel 1,100 hp diesel-hydraulics on the Septemwri-Dobriniste line since steam was withdrawn three years ago

DIPL.-ING. DIMITAR S. DEJANOV, *Traction Department, Railway Executive, Bulgarian State Railways*

REPLACEMENT OF CLASS 600^{76} steam locomotives by Class 75-00 diesel-hydraulic locomotives began early in 1966. These were placed in service as they arrived from the builders, Rheinstahl-Henschel, after being subjected to the official speed, brake and dynamometer trials which were conducted with a 760-mm gauge AB_4 test vehicle fitted out by the railway administration with the necessary equipment.

The tests with the first locomotive, No. 75-01, started on January 7, 1966, and ended with the last, No. 75-10, on March 31, 1966. These locomotives were described in THE RAILWAY GAZETTE of July 1, 1966, and Table I sets out on a gross tonne-km basis the steps in the steam-to-diesel conversion on the Septemwri-Dobriniste line over the five-months December 1965 to April 1966.

The changeover to diesel operation on the Septemwri-Dobriniste line was virtually complete by March, 1966, when 90 per cent of the tonne-km was achieved by diesel locomotives and railcars, and by July 1966 the majority of passenger trains were diesel hauled. The ten Class 75-00 diesel locomotives have therefore been able to replace the ten 13 Class 600^{76} steam locomotives for train running and the five railcars of Class 81-00 and 82-00; a total of 18 units in all.

Nevertheless these locomotives will not be sufficient to replace steam completely as some are still required for working a number of mixed trains and works trains on the Septemwri-Warwara-Pazardsjk line, and should there be a rise in goods traffic some steam locomotives would be needed at Bansko depot. Also, steam shunters are still used at Septemwri and Welingrad.

It is consequently still necessary to maintain and staff all the watering and servicing installations and further steam locomotives will be required to cover the prolonged inspection and overhaul periods of the diesels. From Table II it will be noted therefore that steam is still required to cover about 8 to 10 per cent of the traffic, primarily local requirements.

On the other hand, new locomotives will be required to handle the continual rise in goods traffic. The increase in gross tonne-km on the Septemwri-Dobriniste and Warwara-Pazardzjk line in 1965/66 compared with 1960 is apparent from Table III. Even over a period of no more than five years, the gross tonne-km on this line increased by about 30 per cent. This would have been even greater had it not been for the inadequate traction performance of the Class 600^{76} steam locomotives and the shortage of wagons.

Calculations have shown that if normal operation on the Septemwri-Dobriniste and Warwara-Pazardzjk line is to be carried out without steam locomotives another four to six Class 75-00 diesel locomotives and six Class 92-00 diesel shunting locomotives would be needed. The latter are required for shunting at Septemwri and Pazardzjk stations; shunting and tripping to serve Welingrad-South and Zwetuno, and the halts at Ostrez and Bistriza; shunting at Yakoruda Station and tripping to Belitza; shunting at Razlog and Bansko Stations and trip work on the Razlog-Dobriniste section, and one for stand-by to cover overhauls.

The changeover to diesel traction has cut traction costs considerably on this difficult mountain section. Table II shows the depot costs per 1,000 gross tonne-km for a period of six months in 1966 with diesels compared with the same period in 1965 under steam. Costs for the diesels were about 30 to 40 per cent lower than those of the steam and has contributed to the improvement in economic efficiency.

Depot costs

Table IV gives the depot costs per 1,000 gross tonne-km for steam and diesel locomotives for six months in 1965/1966 and for four months in 1967. The increase of the 1967 figures against 1965/66 for the steam locomotives is because they were mainly used for short distance local traffic, while the increase in the cost figures for diesel locomotives results from the fact that the 1967 values include the cost for the scheduled service overhaul which when new in 1966 was not yet due. Considering all factors which influence the costs for the traffic

Table I—Break-down of tonne—km during the five-month progressive changeover to diesel traction

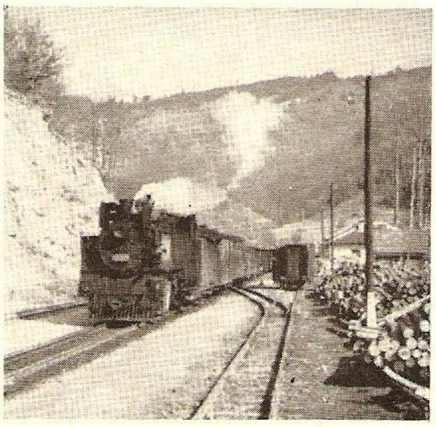
Traction	December 1965		January 1966		February 1966		March 1966		April 1966	
	Gross Tonne—km	Per cent	Gross tonne—km	Per cent	Gross tonne—km	Per cent	Gross tonne—km	Per cent	Gross tonne—km	Per cent
Steam locomotive	12,051,000	86·2	7,423,000	54·7	3,402,000	24·8	1,364,000	8·8	576,000	4·3
Railcar	1,922,000	13·8	1,784,000	13·1	1,568,000	11·4	1,428,000	9·3	1,605,000	11·9
Diesel locomotive	—	—	4,383,000	32·2	8,773,000	63·8	12,660,000	81·9	11,237,000	83·8
Total	13,973,000	100·0	13,590,000	100·0	13,743,000	100·0	15,452,000	100·0	13,418,000	100·0

on the Septemwri-Dobriniste line, the difference of 30 to 40 per cent quoted between steam and diesel traction can be taken as a reality.

The diesel locomotives have also improved passenger travel by eliminating smoke nuisance in the tunnels, and in 1966 two accelerated passenger trains were introduced which reduced the running time between Septemwri and Dobriniste by nearly an hour. The wagon turn-round time has been reduced also as set out in Table V, and this has tended to compensate the shortage of narrow-gauge goods wagons.

The Class 82-00 railcars no longer required have been transferred to the Tscherwen Brjag-Orjachovo section and have taken over the entire passenger traffic and reduced the journey time between Tscherwen Brjag and Orjachovo by two hours compared with the steam-hauled services which they have replaced.

From the outset, the results obtained by the introduction of diesel locomotives on the Septemwri-Dobriniste line have convincingly demonstrated the highly beneficial economic effect and high capacity of these locomotives. Nevertheless, if these new Class 75-00 locomotives are to be used to their best advantage it will be necessary to tackle certain further problems such as the acquisition of sufficient narrow-gauge passenger and goods vehicles and the increase in the maximum speed permissible for the track and rolling stock.



One of the last steam trains, hauled by series 600^{75} locomotive

The prototype of the new passenger coach for 760-mm gauge which was turned out of the nationalised A Jdanov wagon works at Drjanowo in 1967 has been tested in service and it is expected that 15 production units will be built this year.

There is still a shortage of goods wagons and the track and locomotives restrict wagons to a payload of 20, 25 and 30 tonnes. The time has come also to move away from plain bearings even with narrow-gauge wagons, and it is essential that all new narrow-gauge wagons are fitted with roller-bearings.

The permissible maximum speeds on the lines must be raised so that the passenger locomotives are used to their full advantage. The first task is to reduce the journey time from Septemwri to Dobriniste to 3½ hours, and it was hoped this might be solved by the end of 1967. It is practicable and does not present undue technical problems for the following sections to have the maximum speeds raised as follows:—

Septemwri-Warwara	60 km/h
Warwara-Dolene	30 km/h
Dolene-Kostandovo	35 km/h
Kostandovo-Welingrad-South	50 km/h
Welingrad-South—Sv. Petka	35 km/h
Sv. Petka—Awr. Kolibi	30 km/h
Awr. Kolibi-Tsch. Mesta	35 km/h
Tsch. Mesta-Beliza	60 km/h
Beliza-Raslog	50 km/h
Raslog-Dobriniste	65 km/h
Warwara-Pazardzjk	65 km/h

A few curves where the speed will have to be below that generally permitted for the line are being marked as special speed-restricted sections. The introduction of speed restriction warnings incorporating light-reflecting tape similar to road traffic signs would obviate the need for staff to light these up at night.

It is necessary also to improve the home signals by replacing them with dual-aspect signals and home signals with inadequate sighting distance would have to be supplemented by advance signals.

Because of the higher efficiency and greater tractive power of the diesel locomotives, the Septemwri-Dobriniste line could be extended as far as Gotze Deltschev. This would create a more stable flow of goods traffic as the area served would be extended over the entire Mesta Valley. The towns from Dobriniste to Gotze Delschev would have the benefit of reliable and rapid transport facilities throughout the year, and a longstanding demand on the part of the population of this area would be met.

The past has undoubtedly demonstrated the beneficial influence of the Septemwri-Dobriniste line on the economic and cultural development of the region it serves. In the Mesta Valley, new industrial plants are growing up, and fresh mineral deposits are being discovered. The economic importance of this region is therefore continually increasing and modernising the line with diesel traction has enabled it to accommodate the continually increasing goods traffic. Under mountain railway conditions there is no more effective and safer means of transport than a narrow-gauge railway operated by diesel locomotives.

Table II—Break-down of tonne-km since dieselisation

Traction	August 1967		September 1967		October 1967		November 1967	
	Gross tonne—km	Per cent	Gross tonne—km	Per cent	Gross tonne—km	Per cent	Gross tonne—km	Per cent
Steam locomotive..	1,645,000	11·1	1,025,000	7·6	1,105,000	8·1	809,000	5·5
Railcar	404,000	2·7	538,000	4·0	596,000	4·4	557,000	3·7
Diesel locomotive..	12,763,000	86·2	11,906,000	88·4	11,965,000	87·5	13,483,000	90·8
Total	14,812,000	100·0	13,469,000	100·0	13,666,000	100·0	14,849,000	100·0

Table III—Gross tonne-km for Septemwri-Dobriniste and Warwara-Pazardgjk lines

Year	Total gross tonne-km	Per cent compared to 1960
1960	128,637,000	100·0
1961	133,570,000	104·0
1962	134,932,000	105·0
1963	145,339,000	113·0
1964	158,723,000	123·5
1965	166,603,000	129·8

Table IV—Comparative costs between steam and diesel operation

	Steam locomotives		Diesel locomotives	
	1965		1966	
Month	Cost per 1,000 gross tonne-km Leva	Per cent	Cost per 1,000 gross tonne-km Leva	Per cent
April	10·254	100·0	6·676	65·2
May	9·924	100·0	6·774	67·8
June	9·714	100·0	6·860	70·6
July	9·015	100·0	6·313	70·0
August	9·889	100·0	6·730	68·1
September	9·495	100·0	6·624	59·4
	1967		1967	
August	13·687	100	7·536	55·7
September	14·184	100	7·705	54·3
October	17·089	100	7·447	43·5
November	18·958	100	8·144	43·0

Table V—Wagon turn round 1964-1966

Year	Average wagon round-trip in days	Per cent
1964	1·77	100·0
1965	1·78	100·5
1966 (9 months)	1·69	95·5