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EP20: An In-Depth Examination
RZD’s New Class EP20 Locomotives
The Russian electrified rail network has two voltage systems, 3 kV DC and 25 kV AC 50 Hz. With long distance passenger services taking a matter of days, rather than hours, between origin and destination, the time consumed changing locomotives at the voltage breaks (around 20 minutes or so) was considered trifling. But as overall journey times shrink, this factor has assumed relatively greater importance. There is now an endeavour to eliminate locomotive changes at the voltage breaks. For instance, on the run between Moskva and Sochi, somewhat over 1,900 km, there are two voltage breaks, and hence two changes of locomotive, with a corresponding increase in end-to-end journey time.

RZD decided that the best option was to order a large batch of dual-voltage locomotives. These are designated Class EP20, and are referred to as the fifth generation of the Russian electric locomotives with an AC traction. The first generation consists of those equipped with stepwise power regulation and with commutator DC traction motors. To the second generation belong locomotives with rectifiers based on silicon diodes. The third generation locomotives are those equipped with continuous power regulation, a recuperative brake and a system of automatic control. These components were installed in stages since 1963 until now, and this family includes Classes VL80, VL85 and VL65, the BYh and its derivatives, and the ZE5SK (Yermak) and its derivatives.

The fourth generation of locomotives came about with the arrival of non-commutator traction motors, starting in the 1970s. Such locomotives are fitted with asynchronous traction motors and thyristor based traction converters. Finally, the fifth generation locomotives are characterised by their IGBT traction converters, by having traction motors regulated in an individual mode, and by the microprocessor control and diagnostic systems installed.

During 2010/11 a new locomotive was developed for RZD by TRTrans (Tekhnologii Relsovogo Transporta, Rail Transport Technologies). This is a Moskva-based joint venture between Transmassholding (50 %) and Alstom (50 %), created under an agreement signed in early 2009. TRTrans’s branch for developing motive power projects is situated at Novocherkassk, was established in December 2010, and has six departments, for electric traction equipment, traction drives, control systems, bodyshells, bogies and mechanical integration. TRTrans has evolved over the past couple of years into a development centre for new electric locomotives within the TMH-Alstom consortium. It employs around 150 engineers, Alstom supplying teams from its engineers drawn from both parent companies, and its derivatives drawn from both parent companies, Alstom supplying teams from its factories in Belfort, Tarbes, Le Creusot, Omons and Villeurbanne in France and Charleroi in Belgium.

The result of this development procedure was the EP20, a dual-voltage express passenger locomotive. This made its public debut at EXPO 1520 in early September 2011, as shown in the photo on the adjacent page. It is RZD’s second dual-voltage batch-produced locomotive (the very first batch-built dual-voltage locomotive was the Class EP10, with asynchronous traction equipment, built by NEVZ together with Adtranz - see R 3/04, pp. 26 - 27). The EP20 was ordered by RZD in May 2010, with the first part of this batch to be delivered in readiness for the 2014 Winter Olympics in Sochi, and is designed to haul up to 24 carriages at 160 km/h or rakes of 17 at 200 km/h on straight and level track, compared with the existing Class EP1M’s capabilities - 19 carriages at 140 km/h.

The task to manufacture EP20 electric locomotives was assigned to NEVZ, which over the 75 years of its history has produced 65 types of electric locomotives, and in all about 16,000 machines. According to the technical specifications the new components and parts for the EP20 were ordered and manufactured. These comprise essentially the control system components, the protective and commutating equipment, the brake and mechanical components, control systems and the electrical components.

### EP20: Principal Technical Data

- **Axle Arrangement**: Bo’Bo’Bo’
- **Power Supply Voltages**: 3 kV DC/25 kV 50 Hz
- **Maximum Speed**: 200 km/h
- **Max. Rated Power**: 7,200 kW
- **Max. Tractive Effort**: 350 kN
- **Max. EDB Power - Recuperative**: 4,500 kW
- **Length Over Couplings**: 22,532 mm
- **Width (incl. handrails)**: 3,100 mm
- **Height Over Rail Top**: 5,100 mm (panograph lowered)
- **Distance Between Bogie Centres**: 6,765 mm
- **Bogie Wheelbase**: 2,900 mm
- **Wheel Diameter (new/worn)**: 1,280/1,200 mm
- **Minimum Curve Radius Negotiable**: 125 m
- **Weight**: 135 t
The front of the EP20’s cabs feature a new impact energy absorption structure, based on a smooth, multi-stage absorption of kinetic energy upon impact. The cab floor is in the height of 1,750 mm above rail top, and the impact on the crash element of the cab front is calculated to be 2,000 mm above rail top. The absorption of energy takes place at the expense of the deformation of the dedicated crash element installed in the front of the mainframe and the cab, resulting in a greatly reduced magnitude of longitudinal acceleration and, accordingly, of the force to which the crew and locomotive components are subjected.

The EP20’s Bodyshell

The EP20 is RZD’s very first Bo’Bo’Bo’ single-section passenger locomotive capable of operating at speeds of up to 200 km/h on both voltage systems in use in Russia. By way of comparison, the Class EP10 was designed for 160 km/h, while the only Russian locomotives designed for a top speed of 200 km/h were the two-section 3 kV DC Chs2500 machines. The Class EP20 incorporates up to 90 % of new technological features and components, and these are used in virtually all the locomotive’s systems - literally from the wheels to the pantograph. The use of a modular design for the cabs significantly improved the efficiency of the manufacturing procedure. The bodyshell incorporates impact-absorbing crash elements thus protecting the locomotive crew in the event of a head-on collision.

The bodyshell structure comprises the underframe, the sideways, five removable roof sections, and the driver’s cabs. The removable roof sections result in the machinery spaces being easily accessible from above throughout their whole length. At both ends of the bodyshells are automatic SA3 couplings. The deformation elements within the coupling suspension enable them to absorb impacts of up to 40 kJ without damage occurring to the locomotive’s bodyshell.

The modular cab meets the latest ergonomic and safety design requirements. All the cab windows are made of laminated safety glass, and the windscreen are electrically heated. LED headlights and tail lights are fitted, together with electric windscreen wipers and electrically heated rear-view mirrors intended for use in severe weather. The cab is enclosed in a steel-framed safety cage, with structural elements able to absorb an impact in the event of a collision. The cab modules are built by PKPP MDC (Designing and Construction Manufacturing Enterprise) of Dnipropetrovsk in Ukraine.

The cab incorporates multi-stage energy absorption elements in its frame and front section to protect train crews in the event of a head-on collision. The scenario for modelling and calculating the parameters for passive safety systems of this type were realised in collaboration with the VNIKTI research institute. The standard crash test of the cab end, with the locomotive travelling at a speed of 36 km/h, colliding with a loaded wagon weighing 80 t, and the system is designed to absorb at least 2 MJ of kinetic energy under such impacts, without exceeding the permitted longitudinal acceleration limit of 5 g inside the cab. At the same time, when the total deformation of the crash elements happens, there remains an undeformable area, offering sufficient space for the survival of the locomotive crew.

The bodyshell of the locomotive can withstand the following forces:

- a static end-on compressive force of 2,000 kN at the coupling level,
- a static end-on tractive force of 1,500 kN at the coupling level.

Snowploughs are fitted under the front end beams of the underframe and form part of the crash protection safety structure. The bottom edges of these ploughs can be set between 135 and 150 mm above rail top.

The cabs are equipped with a heating, ventilation and air conditioning system, designed to create a comfortable microclimate for the occupants, under all conceivable variations and extremes in weather and climate. The ergonomic design of the train crew is taken into consideration. Seat height, distance from console, armrest position, and backrest angle can all be adjusted. The armrests can be folded up if required. The driver is also able to programme the time when the heating or air conditioning can be switched on, thus ensuring maximum comfort levels in the cab when he starts work.

Materials which comply with the latest fire protection and environmental safety standards are used, and all the necessary internal and external equipment for the cabs are installed at PKPP MDC before they are mounted on the locomotives. Easy to use plugs and sockets on the rear bulkhead link in-cab apparatus with equipment situated within the bodyshell. Cab access is indirect, via the two exterior doors, one on each side of the bodyshell, situated behind the rear bulkhead of the cab.

The cabs are linked with the machinery compartments by a corridor running along the centreline of the locomotive. These compartments and cabinets house the traction and auxiliary components. Wiring and pipes for pneumatic functions are led through a special prefabricated duct directly beneath the corridor and accessed via hatches in the corridor floor. The central corridor in the machinery room provides convenient access to the installed power regulation blocks, modular cab, and the train protection systems.

The technical features incorporated in the EP20 will enable RZD and other potential operators to cut labour costs for maintenance by 20-fold. The intervals between heavy overhauls are substantially increased. For instance, the mid-life heavy overhaul is realised after 1 million km, instead of 600,000 km as with most older electrics. The service life is around 40 years, compared with 30 years for most electric locomotives in RZD’s fleet.

The type SM 806 sanitary module installed on the EP20. The cubic weighs 640 kg and it measures 1,100 mm long, 1,080 mm wide and 2,100 mm high. It is equipped with a washbasin, liquid soap dispenser, clothes hook, mirror, handrail, waste bin and paper holder.

Photo: PKPP MDC

The EP20 is the first Russian locomotive to be equipped with a computerised cab, featuring driver assistance, remote service diagnosis, remote control of the train crew, and the train protection systems.
equipment. This design concept permits the compact location of both the AC and DC equipment in the machinery room. This required a new blocking system for the high-voltage cubicles, this being solved using both electric circuits and mechanical keys.

A vacuum retention WC is provided in the machinery compartment, too. It is fitted in a special sanitary cubicle designed and manufactured by PKPP MDC in full compliance with sanitary norms. These cubicles are being delivered to NEVZ from Dnipropetrovsk fully equipped not only with the WC system (supplied by Evac), but also with the heating (2.5 kW) and ventilation devices and with an independent water supply system. There is a 60-litre fresh water tank and a 90-litre waste water tank.

Bogies

Each two-axle bogie is provided with helical coil primary suspension and flexi-coil secondary suspension. Flange lubricators reduce wheel wear. The mechanical braking system in the bogies consists of the Knorr-Bremse disc brakes, which include unsplit brake discs mounted on a wheel, the RZS disc brake units, and an additional shoe brake unit for cleaning the running surfaces of the wheels. The wheels are monobloc, and these in combination with the disc brakes and the modern lubrication system allow a 1 million km interval lifespan for the wheels before their tyres become fully worn. With wheels of the previous design used on RZD locomotives, the tyre lifespan was a mere 500,000 km.

The traction driveline within the bogie is suspended from the bogie frame and consists of a traction motor with a gearbox based on a Gealaf design, with the pinion shaft laid in two bearings in the gearbox casing, and the pinion shaft connected with the traction motor shaft by means of the coupling membrane. This arrangement is known in Russia as a third class traction motor, i. e. with the suspension of traction motors and gearboxes realised by a supporting frame (which means fully sprung). This configuration increases the durability of the bearing gears (in comparison with the free positioned pinion) and consequently increases the lifespan of the driveline. To reduce the bogie weight various techniques were used, including hollow axles and one-sided connecting rods for wheelset’s horizontal guiding, which result in a saving of 86 kg for each axle.

The longitudinal forces from the bogies to the bodyshell are transmitted via angled rods, which are on one side linked underneath each bogie at its central point and on the other joined to the bodyshell (see diagram, on p. 85). The vertical and transverse horizontal forces from the bodyshell are transmitted to the bogie frame by the Flexicoil springs (there are two pairs of cylindrical helical springs on each bogie). Each type and magnitude of a bodyshell roll is suppressed by vertically and horizontally positioned dampers: there are two horizontal and two anti-hunting hydraulic dampers on each bogie.

Each wheelset is fitted with flange lubrication jets, with automatic control of the air valve of the lubrication dispenser. Heated tubes from the sandboxes eject sand onto all the wheels. The volume of sand dispensed is controlled by the driver, and sand is fed onto the leading wheelset in the direction of travel in each bogie of the locomotive.

Henschel Antriebstechnik delivered a fully suspended axle drive, which weighs around 1,660 kg. The power transfer from the traction motor to the axle is realised by the gear units, in which the coupling between the motor and gearbox is created by a diaphragm coupling with overload protection, while that between the gearbox and axle is an elastic link. The ratio is 5.17 for a maximum speed of 200 km/h. The maximum speed of the traction motor is 3,750 rpm, and its maximum starting torque is 9,255 Nm.

Image and photo: Henschel

One of EP20-001’s bogies, which are of a new design.

In early February 2012 NEVZ completed EP20-002, which in comparison with 001 wears RZD’s new corporate livery. The locomotive is seen here on 17 February 2012.

EP20-001 on the VELNII/NEVZ test circuit at Novocherkassk on 26 January 2012.
**Electrical Equipment**

Key components, such as the traction and auxiliary converters, traction transformers and the high voltage protective equipment for the initial batch of locomotives, up to EP20-036, are being supplied by Alstom.

Four pantographs, produced by Alstefley, are fitted: two of Type AX 023 BU LT for DC and two of Type AX 024 BM LT for AC operation. The pantograph skirt width is 2,260 mm. A device is fitted to ensure that the pantograph can be lowered rapidly should the carbon current collection strip break. The next stage in the traction chain is formed by the safety earthing elements and switching devices.

Each Class EP20 locomotive is equipped with an ABB set composed of a traction transformer and inductances tank. The whole set is designed to operate under extremely low temperature conditions (-50 °C) and is connected by a common hydraulic circuit, resulting in a favourable weight/power ratio. This set is designed to operate under 25 kV 50 Hz and 3 kV DC electrification systems, with a maximum output power of 9,300 kVA for the transformer and 8,550 kW for the inductance. The transformer includes one primary winding, six traction windings and one heating winding.

The DC inductance tank includes six second harmonic reactors used in AC mode. The transformer and inductor containers have low temperature steel housings, and are of Class F insulation. They contain ester oil, and both have the following accessories: two oil pumps, two radiators, one oil level detector, two oil flow indicators, two thermostats with two switches each, four temperature sensors including converters, two overpressure valves, one air dryer, 31 low voltage DIN bushings and one Elastimod high voltage bushing.

A separate traction converter is provided for each bogie, containing two independent IGBT drives for the two traction motors. These combine a four-quadrant input converter, drive inverter and braking chopper. When the locomotive is running under 25 kV AC, each traction converter is supplied from the secondary winding of the traction transformer at 1,650 V. This voltage is rectified to a stabilised 3,000 V DC voltage for the DC link, which is connected to an autonomous voltage inverter. This converts the 3,000 V DC voltage into a three-phase variable maximum voltage of 2,183 V. When the locomotive is working on a 3 kV DC electrification network, this traction voltage is applied directly to the DC link through a diode input four-quadrant converter.

Applied control algorithms in the traction converters enable high tractive forces while maintaining a minimal loss of electric energy, this being supported by an individual axle power regulation. Also integrated in the control architecture are other important systems such as the wheel anti-slide protection system, the wheel flange lubrication device, and the ATP systems.
The three-phase asynchronous traction motors have squirrel-cage rotors. They are six-pole motors, of welded construction, frameless and air-cooled. For the rapid, trouble-free exchange of traction motors, the axle transmission box is designed with an oblique division. The cooling air for the traction motors is sucked in through a series of vents and exhausted downwards onto the track from the traction motor. The traction motors are fed from static converters of variable voltage and variable frequency, which form part of Alstom’s traction converter family. The motors work in parallel in each bogie, and are regulated in an individual control mode.

The auxiliary drives exploit their ability to regulate their power (and consumption) according to the load actually required, these being fed by Alstom’s auxiliary converter. Power is supplied from the DC link of the second and fifth branch of the traction converter and there are four outputs to enable redundancy in the event of faults. A modern electric power system protection unit is installed, working on a software basis observing specified parameters such as voltage, current, air pressure, temperature and suchlike. When the limiting values are reached, the endangered component is switched off. A great contribution to the efficiency of the locomotive is a temperature control system which permanently monitors the state of the traction motors, the axle boxes and the brake resistors.

The principal braking system is electrodynamic and recuperative. The priority braking is regenerative, but the locomotive has a 4,500 kW rheostatic brake for use in the absence of overhead line receptivity. The braking system includes an emergency air brake which is electro-pneumatically controlled. Creation of compressed air and its treatment take place in a pneumatic distributor. The compressed air is supplied by a Knorr-Bremse air supply unit consisting of two W270-T oil-free piston compressors with air dryers. The auxiliary air supply for the pantographs is provided by a V10-T compressor and a single-chamber air dryer. The air delivery rate is 1,840 l/min or 3,680 l/min at 9 bar depending on whether one or two compressors are activated by the compressor management. For the W270-T compressors a „cold start” at -50 °C is already standard which means that no preheating is required. The main compressed air reservoirs have a capacity of 1,020 litres, and are situated underneath the locomotive frame, between the second and third bogie.

The EP20s are „winterised” for operation in temperatures as low as -50 °C, with components suitable for extreme climatic conditions and preheating systems for their sensitive equipment, such as the electronic components. In addition, the main vacuum circuit breaker is powered electrically rather than using compressed air, to reduce start-up times in cold weather. The type of steel used in construction, and the strength it offers, the choice of wiring and cabling, the various types of rubber, and the oils and lubricants employed, are specially adapted for use in extreme conditions.

Testing

EP20-001 started its test runs in April 2011 on the VELNII institute’s test circuit at Novocherkassk (adjacent to the NEVZ factory). These runs focused on tuning up the software of all on-board systems. The locomotive then had a rest in early September, being presented at EXPO 2011 (see R 5/11, p. 41), being moved to Shcherbinka between 26 and 30 August in readiness for this event. The return journey to Novocherkassk took place between 10 and 20 September 2011, where the test runs on the VELNII circuit resumed on the 21st. Testing there was concluded on 14 February 2012. Later the same month EP20-001 returned to Shcherbinka, where it was subjected to dynamic performance trials, and realised the obligatory 5,000 km of trouble-free running, thus paving the way for authorisation testing.

In late April 2012 EP20-001 was dispatched to the test „polygon” formed by the Belorechenskaya to Maykop line not far from Sochi in Krasnodarskaya oblast. The machine returned to the VELNII base in June 2012, for the final phases of authorisation, which is expected to be granting in September 2012, thus giving EP20-001 type approval, and making it ready for handling over to RZD.


To accelerate the whole testing procedure a second prototype, EP20-002 was also built and involved in the test programme. Testing of this machine started in October 2011 in Novocherkassk, and as was the case with 001 first involved the tuning of on-board software. This phase lasted until January 2012. In March there followed a move to Shcherbinka. Various other tests were realised here, where the locomotive completed its obligatory 5,000 km of trouble-free running.

Since 11 May 2012 EP20-002 has been back in Novocherkassk, to be prepared by VELNII for test runs on the Belorechenskaya „polygon” line at speeds between 140 and 160 km/h. During these runs the influence of the
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locomotive on the infrastructure was also simultaneously measured, serving as groundwork for test running at speeds of between 200 and 220 km/h on the Oktyabrskaya doroga, between Moskva and St. Petersburg. These runs will be repeated in late August and early September 2012. Then EP20-002 will return to the VELNII test circuit for the final stages of authorisation testing, and it is expected that it too will receive type approval in September 2012.

Production

Batch construction of EP20s started in May 2012. During the remainder of this year three locomotives will be built (up to EP20-010), while during 2013 the remainder of the initial batch, numbered up to EP20-036, is to be built, and these machines will be used on passenger services linking Moskva with Sochi.

The manufacturing of the Class EP20 prototype has allowed NEVZ to test a new, modular assembly procedure. Also new to the factory’s assembly technology was the installation of the third class traction motors, and such-like. Alstom’s factories at Tbilisi and Belfort are providing the high voltage electrical equipment (traction and auxiliary converters, main circuit breakers and the main transformer), and the control systems for the traction drives for the first 36 EP20s. The other components (including the bogies) are produced by TMH. Starting in the fourth quarter of 2012, the bogies will be manufactured at Bryansk mashinostroitelny zavod (BMZ), since a new bogie production line for TMH-built locomotives has been installed here (the bogies for EP20-001 and 002 were NEVZ products).

From EP20-037 onwards, the French components delivered from Alstom’s Tbilisi and Belfort works, namely the traction drives (electric equipment and traction motors) will be manufactured by a second joint venture, called RailComp. Under an agreement signed in 2009 between Alstom and TMH, this company was scheduled to be founded before the end of 2011, but it was in fact founded in April 2012. The first RailComp factory, which will also be situated within the NEVZ complex, will also produce traction drives for the 2ES20, and other locomotive types, starting in 2014. The assembly of EP20s will then continue at NEVZ until 2020, the latter establishment gradually benefiting from the joint progress made on the project.

A New Locomotive Family

The EP20 is intended to form the basis for a family of asynchronous locomotives for passenger and freight duties, deployed across the entire Russian network. It is anticipated that between 75 and 80 % of the components will be common to all members of the new TMH family of passenger and freight electric locomotives. The second of these envisaged is the two-section Class 2ES4, a Bo’Bo’ + Bo’Bo’ sister of the Class 2ESS, and a prototype of this is scheduled for construction in or around 2014. This diagram also shows the other variants envisaged.

Aleksy Parkhomenko, Yelena Beregovaya, NEVZ
Jarmir Pernicka

Diagrams and photos, unless otherwise cited, by TMH

ZSSK’s Class 381 In The Vysoké Tatry

On 24 and 25 July 2012 ZSSK’s 381.001 (type 109 E2) realised a series of haulage tests using scheduled ZSSK CARGO freights. The objective was to see how the locomotive coped on the difficult main line which runs from east to west through the gap between the Vysoké Tatry and Nízke Tatry mountain ranges, between Poprad and Liptovský Mikuláš, focusing on the gruelling ascents and the summit at Štrba, where four uphill runs were made. With the first freight 381.001 acted as a rear-end banker, and on the other three it was coupled in front of the train locomotive. The new locomotive independently managed to start a trailing freight load of 1,549 t on a gradient of 15 ‰ (the steepest part of the line), developing a tractive effort of 277 kN. Here we see 381.001 with two-section ZSSK CARGO’s electric 131.033/034, just beyond Štrba station, starting on the downhill run to Spišská Nová Ves, on 24 July 2012.

The test runs were not requested by the Austrian rail administration body URZD, but were realised by the manufacturer, ŠKODA, for its own benefit. At present ŠKODA currently has all the documentation necessary to evaluate the results of tests and to eventually grant the Class 381 authorisation for operation in Slovakia.

Tomáš Kuchta
Photo: Martin Ciprian