Double-stack under the wires

RESEARCH A test programme has confirmed the feasibility of operating electrically-hauled double-stack container trains, leading to Indian Railways' decision to wire the Western Dedicated Freight Corridor at 25 kV 50 Hz.

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Tests with a loaded train were carried out during July 2008.

Indian Railways has decided to forge ahead with the development of two Dedicated Freight Corridors (RG 6.08 p383). Work on the Eastern Corridor began on February 10, and a start on the Western Corridor is expected shortly.

The Eastern Corridor will consist of a double-track line over the 866 km from Sonnagar on the East Central Railway to Dadri on the North Central Railway, plus a single-track line over the 412 km from Khurja to Ludhiana on the Northern Railway. Traffic will consist mainly of bulk goods such as coal from the eastern coalfields destined for power stations in the north and west, together with finished steel products, food grains, cement, fertilisers, and limestone from western India bound for steel plants in the east.

The Western Corridor will have 1 483 km of double track from Jawahar Lal Nehru Port Trust to Dadri via Vadodara, Ahmedabad, Palanpur, Phulera and Rewari. In addition, a 32 km single track connection from Pirthala Junction near Asaoti on the Delhi – Mathura line to Tughlakabad is planned, and there will also be a connection with the Eastern Corridor at Dadri. Much of the traffic on the Western Corridor will be ISO containers from JNPT and Mumbai port in Maharashtra and the ports of Pipavav, Mundra and Kandla in Gujarat destined for terminals in northern India, especially Tughlakabad, Dadri and Dandharikalan. Whereas just 690 000 TEUs were carried over conventional lines from these ports in 2005-06, IR is forecasting that 6·2 million TEUs will be moved over the Western Corridor in 2021-22.

The expected levels of traffic in both corridors suggested that both routes should be electrified, as this means fewer locomotives per train, faster acceleration and higher speeds for optimum line capacity. In strategic terms electrification helps to reduce dependence on imported oil. There is also the prospect of earning carbon credits from regenerated power under the Kyoto Protocol — IR already has an extensive electrified network, which totalled approximately 19 000 route-km on March 31 2009. With around 1 000 route-km a year being wired, IR expects to have 20 000 route-km electrified by 2010.

By far the most efficient way of moving large numbers of containers is to carry them in double-stack configuration, which has an excellent track record in North America. On the face of it, double-stack operation is not compatible with existing electrification as IR's standard contact wire height of 5 500 mm above rail top is too low for double-stack operation. IR therefore decided to experiment with a high contact wire to ascertain whether sufficient clearance could be achieved.

Table I. High-rise overhead line equipment for IR's Dedicated Freight Corridors

Contact wire height *mm*	7 450
Catenary wire height *mm*	8 650
Fabricated mast type	K-175, K-200, K-250
Mast height *mm*	10 850
Minimum implantation* *mm*	2 800
Presag *mm*	50
Maximum span length *m*	63
Contact wire tension *kN*	1 000
Catenary wire tension *kN*	1 000
Tension length *m*	1 500
Stagger on tangent track *mm*	150
Stagger on curved track *mm*	250

* Implantation is the horizontal distance from the nearest face of the traction mast to the centre line of the track.

Design parameters

When Chinese Railways decided to introduce double-stack container trains in 2004, it opted to carry the stacked containers on well wagons so that they could be more easily accommodated under overhead wires. In contrast, IR chose to stack the containers on conventional flat wagons as this method makes better use of train length. This meant that the contact wire had to be well above the standard height, and IR designed an OHLE system to fit within a dynamic envelope 7 100 mm high and 3 660 mm wide.

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Studies into the design of overhead line equipment and high-reach pantographs were carried out, culminating in a decision to place the contact wire at a height of 7 450 mm above the top of the rail (Table I).

As feeder traffic will access the corridors from conventional electrified lines, a critical feature was the transition zone between the standard electrification and the 'high-rise' overhead line equipment. Of particular concern was the gradient of the contact wire in the transition area, which was fixed at 10 mm/m. This was chosen so that locomotives could draw current smoothly and without contact loss.

Many of the electrification components were common to standard OHLE on conventional lines such as the three-pulley modified groove auto-tensioning devices, insulators, tubes and other fittings. Special components for the higher OHLE included guy rods 2 m longer than normal, a longer length of wire rope for auto-tensioning and different fasteners for clamps. The design team also had to ensure that the foundations were satisfactory for the higher masts, while the design of the portal structure had to be modified. Maintenance equipment too had to be specially designed with longer ladders, for example.

RDSO's modified Netra overhead line test car awaits the next test trip in Tomka yard. The special mounting for the pantograph is clearly visible on the roof.

Test track

The Central Organisation for Railway Electrification in Allahabad was given the job of developing a trial section of high-rise OHLE, and the chosen location was between Jakhapura and Daiteri on the East Coast Railway. The work was completed in just 125 days — an extraordinary achievement as it was scheduled during the rainy season and trains from Banspani to Jakhapura were being diverted as a result of disruption on the Kharagpur – Balasore section of the South Eastern Railway. Possession time was also very limited, even during the trials.

To monitor the condition of OHLE, IR uses a recording car known as Netra (Network of Electrification, Testing & Recording Apparatus) which was developed by RDSO. This vehicle can measure contact wire height, stagger, line voltage, hard spots and calculate the percentage contact loss to assess current collection performance.

As built, the Netra car was not able to record parameters for the high-rise OHLE as the maximum reach of the vehicle's pantograph was only 6 450 mm. It was therefore modified for the programme of trials, although this was not a simple task.

The instrumentation system, including the optic fibre communication cable for transfer of data from the roof to a control panel inside the car, had to be dismantled and a structure designed to raise the pantograph mounting by 1 100 mm, bearing in mind that the structure would be subject to strong oscillations when the locomotive was travelling at speed. The pantograph then had to be refitted, and the OFC cable carrying the rod and voltage divider tube had to be installed on an elevated platform, along with all the instrumentation. This work was done at Kanpur depot. Once the modified equipment was in place and static tests carried out, it had to be dismantled for the trip from Kanpur to Jakhapura as it infringed the space occupied by standard OHLE. At Jakhapura the car was taken to Tomka marshalling yard for reassembly of the high-rise test equipment.

High-reach pantograph

The high-reach pantograph had to be able to collect current on both high-rise and standard OHLE. RDSO prepared a design in August 2007 for a high-reach pantograph for AC locomotives, and two pantographs were procured from Stone India Ltd after carrying out tests which included wind tunnel trials at the Department of Aerospace Engineering & Indian Institute of Science in Bangalore. The design met international standard IEC-60494-1.

The most important feature of the pantograph is its raising and lowering mechanism which uses air-powered actuators and a pneumatic control panel, an arrangement which obviates the need for a spring or servo motor. The design helps to ensure good dynamic behaviour during current collection and stable operation at either the standard height or in the high-reach position. Thanks to the smaller number of components, the pantograph is more reliable and maintenance-friendly than conventional sprung pantograph designs.

Right from the start, development of the pantograph posed a number of challenges. These included ensuring that the dimensions of the mountings allowed pantographs to be exchanged. Working pressure, upthrust at various heights, and the geometry of the pan and contact strip also had to permit interchangeability. Keeping the lateral play within specified limits at the maximum height and ensuring stability of operation at different heights were key issues, as was ensuring smooth current collection and satisfactory dynamic behaviour of the pantograph at the maximum height. At the same time the weight of the pantograph had to be kept as low as possible, despite an increase in size.

Trials

Tests were initially conducted with a pair of WAG-7 locomotives and later with empty and loaded trains on July 7-8 2008. The locomotive fitted with

Work in progress on installation of high-rise overhead line equipment on the test section between Jakhapura and Tomka.

the high-reach pantograph made four successful runs from Jakhapura station, where standard OHLE is in use, to Tomka station, where the high-rise OHLE is installed. A distance of 21·9 km was covered under 7450 mm high OHLE, and the transition between standard and high-rise OHLE was negotiated successfully on every trip. Current collection was smooth and almost without arcing on both the transition and high wire sections.

Current collection performance was monitored with the help of Olivir-G software. A continuous record of the runs showed that there were no significant sparks up to a speed of 70 km/h, the maximum permitted on the test section.

From the recordings made using the Netra car on the trial runs it was also observed that the contact:loss ratio was 3·17%. This value falls well within the permissible value of 20% adopted on Japanese Railways and on Indian Railways, where it is around 5%. The Netra car did not detect any other abnormalities.

No irregularity in current collection was observed during tests with the locomotives operating by themselves, nor with empty or loaded trains. The tests confirmed that the high-reach pantograph worked satisfactorily under both the existing and 7 450 mm OHLE, so validating the design for operation in the Dedicated Freight Corridors. On the basis of these tests IR decided in August 2008 to electrify the Western Corridor at 25 kV 50 Hz.

Two WAG-7 locomotives were fitted with high-reach pantographs for the trials.

Table II. Technical features of high-reach pantograph

Designation	Omniversal Intelli
Mounting	Four-point
Distance between mountings *mm*	807 x 1 160
Rated current A	600
Power supply	25 kV 50 Hz
Static upthrust *kg*	6·5 to 8·5
Weight (without insulator) *kg*	198
Maximum reach above rail level *mm*	7 700
Working range *mm*	100 to 3 500
Maximum folded height *mm*	326 ± 5
Collector strips	Metallised carbon
Pan width *mm*	1 800 ± 5
Pan length *mm*	400 ± 5
Total length *mm*	3 285
Minimum pressure to raise *kg/cm²*	5·6
Minimum pressure to lower *kg/cm²*	3·6
Maximum permissible pressure *kg/cm²*	10
Raising time (3 500 mm) *sec*	14
Lowering time (3 500 mm) *sec*	12
Resistance between carrier and power take-off *mΩ*	1·8