It is exactly 20 years since the first tilting trains were developed by British Rail, following significant R&D work, along with pioneering trials with a gas turbine unit.

By the end of the 1970s, proposals to revitalise the network had been prepared and the infamous Advanced Passenger Train with its tilting coaches was already on test. Britain was not unique in developing body tilting mechanisms to allow trains to run at higher speed without massive investment in new, purpose-built lines. In the rest of Europe, investigations were proceeding with the technology. In 1979, BR spent some time in Germany advertising and promoting APT technology, although the techniques were more successfully adapted in Italy. Ironically, the successful development of the technology means that Pendolino will be put to work on the same routes travelled by the APT more than 20 years earlier. Throughout the world, the mimicking technology is being applied, in a market dominated by European manufacturers.

**TILTING TECHNOLOGY**

There have been two significant development arms for the technology, one driven by ABB, later Adtranz in Sweden, on the X2000 trains for SJ, with the other, of course, Fiat Ferroviaria in Italy. The principle attributes to rail transport of this technology are:

- Improved passenger travelling comfort
- High speeds on existing tracks
- Low investment costs and environmental impact
- Flexible operations
- Improved economics on operating expenditure

**X2000**

The X2000 that surfaced in the late 1979 was already on test. This four-coach train was the first in the world and the nickname ‘Pendolino’, adopted for the famous tilting railcar experiments, stuck. Work continued to improve the suspension and the tilting mechanisms, to reach the highest standards of safety and comfort. A decade later, in 1985, an order from Italian State Railways was received for 15 of the new ETR450 series trains.

**PENDOLINO**

The Italian connection has perhaps an even longer history, tracing its development back to the late 1960s. The first real steps forward were made in 1976, when the experimental ETR401 took to the rails. This four-coach train was the first in the world and the nickname ‘Pendolino’, adopted for the famous tilting railcar experiments. Work continued to improve the suspension and the tilting mechanisms, to reach the highest standards of safety and comfort. A decade later, in 1985, an order from Italian State Railways was received for 15 of the new ETR450 series trains.

**ETR450**

Eurail was, on the outside, a conventional fixed formation train, with two driving, power cars and seven intermediate trailers. The power cars were fitted with traction motors, while the body tilting mechanism was driven by a system of gyroscopes and accelerometers carried in the leading vehicles. The hydraulic actuators that provided the angular rotation were mounted within the bodyshell, reached from floor to roof level and connected to a lower mounted across the vehicle, under the floor. The vehicles' vertical and lateral secondary suspension was provided by 'integral flexible' springs.

January 1992 saw the arrival of the third generation of Pendolino in the shape of ETR460, with 10 three-car sets ordered by Italian State Railways (FS), for service on its 3kV dc network. The new Pendolino was built on the solid foundations established by its predecessors.

The heart of the new ETR460 and its active tilting mechanism is the bogie. The suspension includes two stages of horizontal and vertical suspension, together with anti-yaw dampers. Measurement of almost all aspects of suspension performance is carried out in real-time including yaw phenomena, depending on very sophisticated on-board computers.

Unlike the ETR450 series, the new Pendolino hydraulic actuators for the tilting mechanism are carried below floor level, just like the Swedish X2000 design. The only components of the tilting mechanism fixed to the body is the transverse locating beam, allowing the body and bogie manufacture to be undertaken separately. Four links connect the locating beam on the underside of the coach floor, with the tilting beam carried within the bogie. This also provides support for the upper ends of the secondary, flexicoil suspension, together with vertical and lateral dampers. The bogie to bogie forces are transmitted via a rocker arm mounted below the main tilting beam.

Supporting the weight of the overall vehicle, two groups of coil springs connect the axlebox with the bogie frame and provide the primary suspension. The secondary suspension consists of four pairs of coil springs that, in combination with the dampers, allow the bogie to move laterally and vertically.

This active suspension and tilting mechanism is controlled by a master computer, or microprocessor, mounted in the driving vehicle, taking input signals from sensors mounted on the leading bogie. The microprocessor calculates the centrifugal acceleration and, through slave microprocessors and pneumatic valves, instructs the hydraulic actuators fitted on each bogie to operate. The vehicle body is tilted at...
the appropriate angle according to speed and location on the track. In addition to this master-slave relationship, the slave units also perform localised control of the lateral suspension, together with the monitoring and control of the vehicle's anti-yaw dampers. All in all, a very sophisticated arrangement, providing for a smooth, comfortable ride for passengers at higher speeds on conventional tracks.

**INTERNATIONAL PROJECTS**

The success of this technology, in the 1990s has spawned a number of projects around the world, demonstrating the value of technology developments to the economics of railway operations. The principal activities are shown in the following list:

**Spain** – developed a tilting version of its famous Talgo articulated trains, with a passive or ‘natural tilting mechanism’, that has proved highly successful in Spain but has attracted little interest elsewhere. Prior to this, in the mid-1970s, Fiat had supplied a wide gauge version of the Pendolino being trialled at the time in Italy. Subsequently, it is planned to introduce yet another Pendolino variant, the IC2000 series on selected routes.

**Germany** – following the commercial approach to high-speed rail line, as promoted by French company, Germany has adopted tilting technology in the next generation of ICE trains, not surprisingly under the acronym ‘ICT’. In addition, Adtranz has provided another generation of regional diesel-electric railcars, the VT-611, using the technology developed for the X2000 trains in Sweden. These additional regional trains follow on from the successful trials with Pendolino technology on the VT-610 units. The first driving trailer of the ICT high-speed tilting train was unveiled to the public in the spring of 1998. This year, construction will begin on 43 of these tilting trains, joining the family of ICE trains providing high-speed services on the electrified main lines. The new ICT trains (32 seven-car sets and 11 five-car sets) will use the Pendolino active tilting system, similar in concept to the VT611 trains. For non-electrified lines, it is intended to introduce another variant of the VT611 trains.

**USA** – The American Flyer, for Amtrak’s Northeast Corridor is essentially an update of the Bombardier-built Light Rapid Comfortable introduced in both Canada and the USA in the early 1980s. The new units will be introduced this year, replacing Amtrak’s current Metroliner EMUs’ on this route between Boston and New York. The new trains will have a top speed of 160 km/h, bringing journey times down from 4 hrs 30 mins to 3 hrs. Alstom and Bombardier are supplying the trains, with Bombardier building on its previous experience with the LRC trains and supplying the active tilting technology.

**THE PENDOULINO ARE COMING**

Virgin Rail has placed a £1 billion order with Fiat-Ferroviaria/ALSTOM for the supply of 55 seven-car units, with Pendolino active suspension and Alstom electrical equipment. These new trains are for inter-city services west of the West Coast Main Line and are planned to enter service in the summer of 2001. The 320km/h trains are planned to reduce journey times by up to 30%.

**Another success for the ICT technology**

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