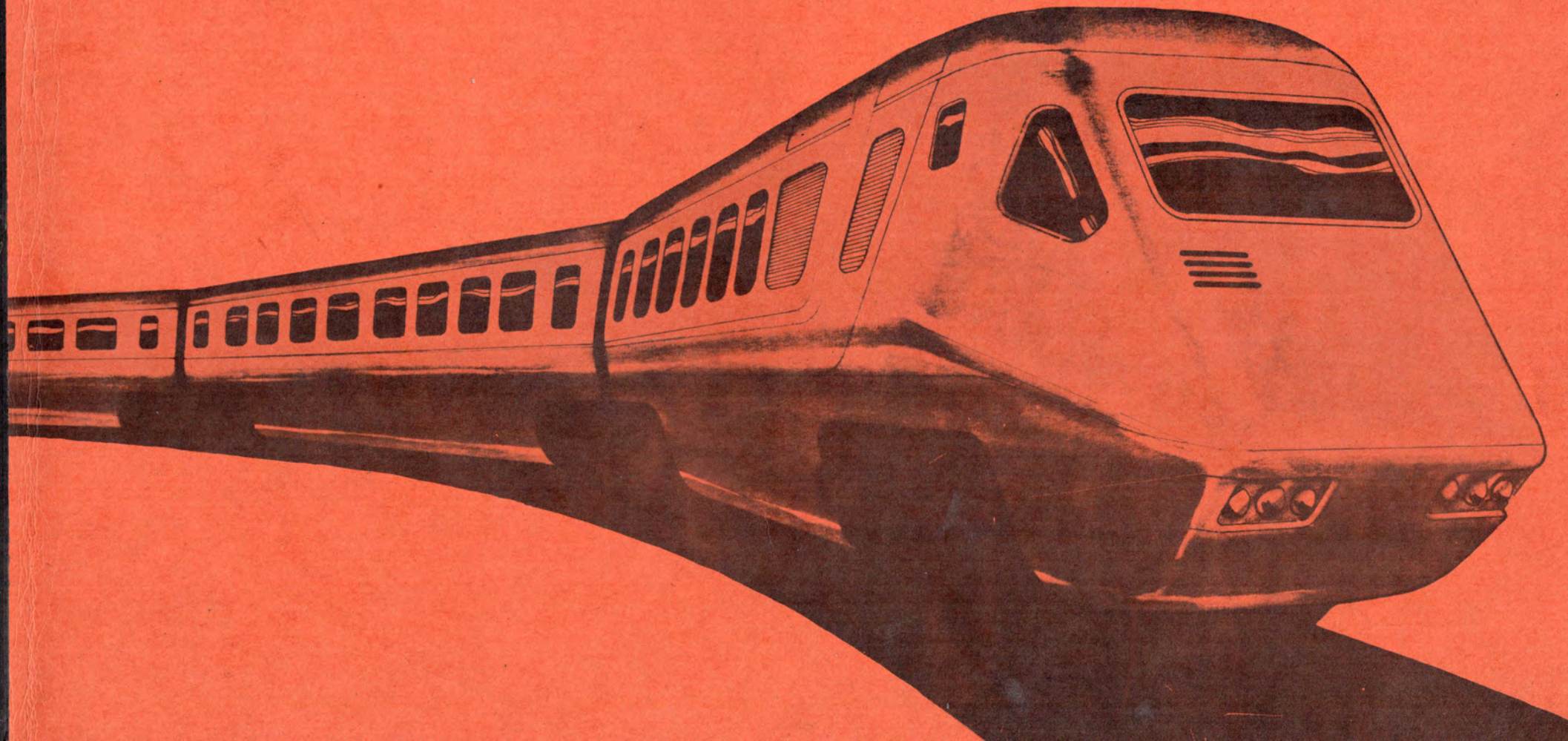
Advanced Passenger Train



Advanced Passenger Train

The forerunners of the two fleets of trains designed to boost British Rail's Inter-City traffic. On the left the prototype of the 125 mile/h. (200 km/h) diesel powered High Speed Trains. On the right the experimental 155 mile/h (250 km/h) Advanced Passenger Train.

Faster Trains–Commercial Rewards

Many factors help to attract more passengers to rail. Better coaches, more frequent services, brighter stations, improved catering – these are some of the most obvious, and steadily changing pattern throughout British Rail shows that they are not being overlooked. But market research and analysis of service characteristics and traffic trends show that the most significant factor is speed and the shorter journey times that it brings.

There are limits to the extent to which British Rail can improve train speeds with the existing locomotives and coaches which are operating at the maximum speed possible within their design limitations.

In planning for the development of its Inter-City services, British Rail rejected the prohibitively expensive choice of building a totally new railway in favour of adapting the existing railway to give better journey times with new rolling stock.

One European approach to higher speed has been the development of the Trans-Europe Express (TEE) network of all first-class trains available to a limited number of passengers on payment of a supplement.

British Rail decided that money for replacement and improvement should not be spent on a few special trains, but should instead be used in such a way as to provide improvements in speed and comfort for all customers on its main services. The replacement of locomotives and coaches on railways is a continuous process and within the next 5-10 years the process, together with expenditure on track and signalling, will require considerable capital investment.

Instead of replacing like with like, therefore, British Rail engineers have embarked on a major programme to get the maximum value for money out of the investment.

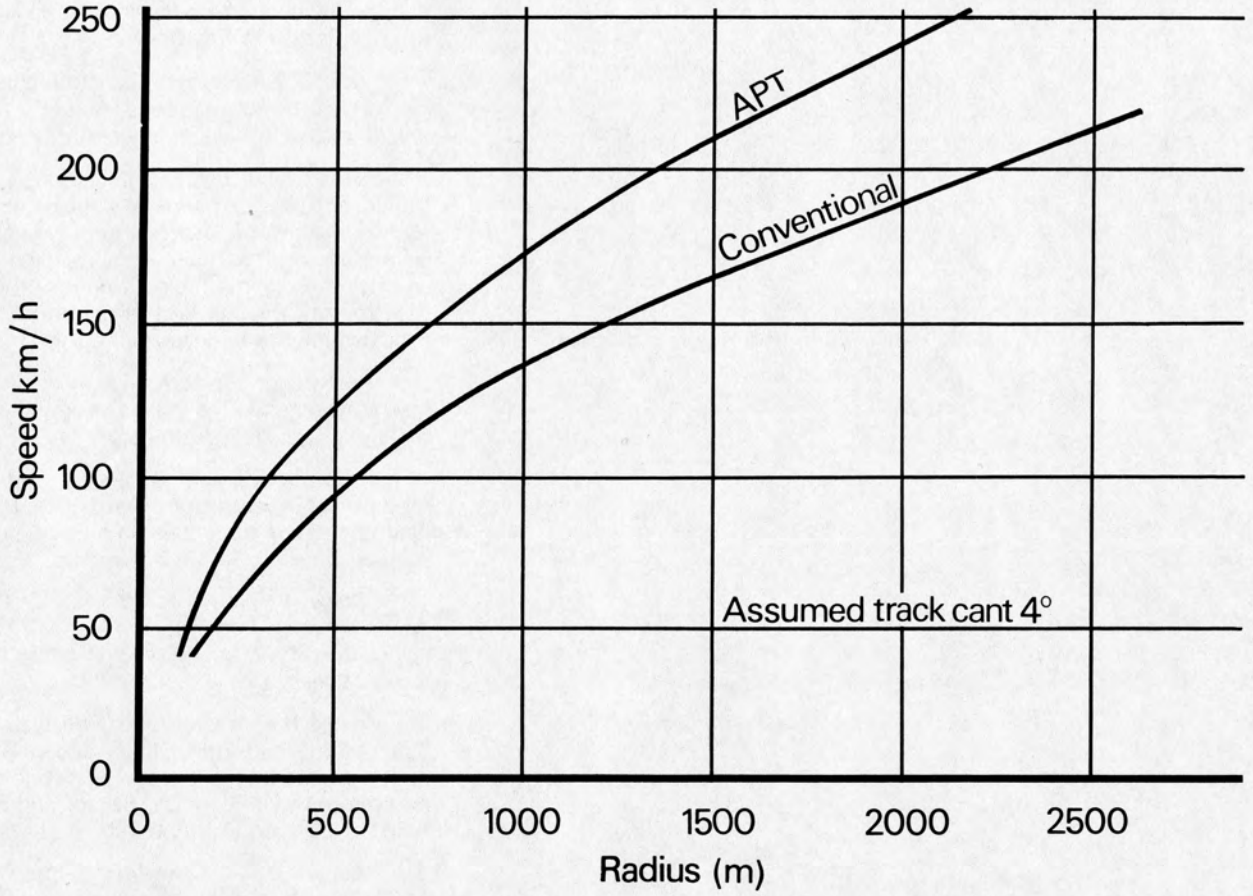
The development of a new kind of train is a long process – it can take over 10 years from first concept to full commercial service. That is why there are three clear-cut stages in the plan for reducing Inter-City journey times.

Stage 1 – now complete, was the electrification of the main rail artery between London, Birmingham, Manchester, Liverpool and Glasgow, using the 25kV overhead system and 100 mile/h (160 km/h) electric locomotives.

Stage II – is the current programme introducing the diesel-powered 126 mile/h (200 km/h) High Speed Train (HST). This high performance multiple unit train is already operating the world's fastest daily diesel train services between London, Bristol and South Wales. More trains are being built for London to Edinburgh and London to the West of England.

Stage III – is the introduction of the Advanced Passenger Train (APT) which represents a major technical advance. The higher average speeds of the APTs come largely from better performance on curves without the need for expensive track re-alignment. With a top speed capability of 155 mile/h (250 km/h), the trains will run initially at 125 mile/h (200 km/h) between London and Glasgow.

APT speed improvement through curves



APT–The Objectives.

The APT project is designed to be a cost effective solution to the problem of providing fast inter-urban transport on existing tracks.

The average speeds of conventional trains are determined largely by speed restrictions due to curves and only modest gains can be made for a speed capability above 100 mile/h (160 km/h) on all except the straightest routes. Roughly 50% of BR's major routes is made up of curves and of these about 50% are relatively sharp.

The major objective of APT, therefore, is to raise operating speeds round curves by typically 20-40%, so enabling a high maximum speed of up to 155 mile/h (250 km/h) to also result in a high average speed. Passenger comfort is maintained round curves by tilting the coach bodies inwards by up to 9°.

Other major objectives are low energy consumption, low noise generation, acceptable maintenance costs, and a similar total cost per seat-kilometre as present day trains.

Performance

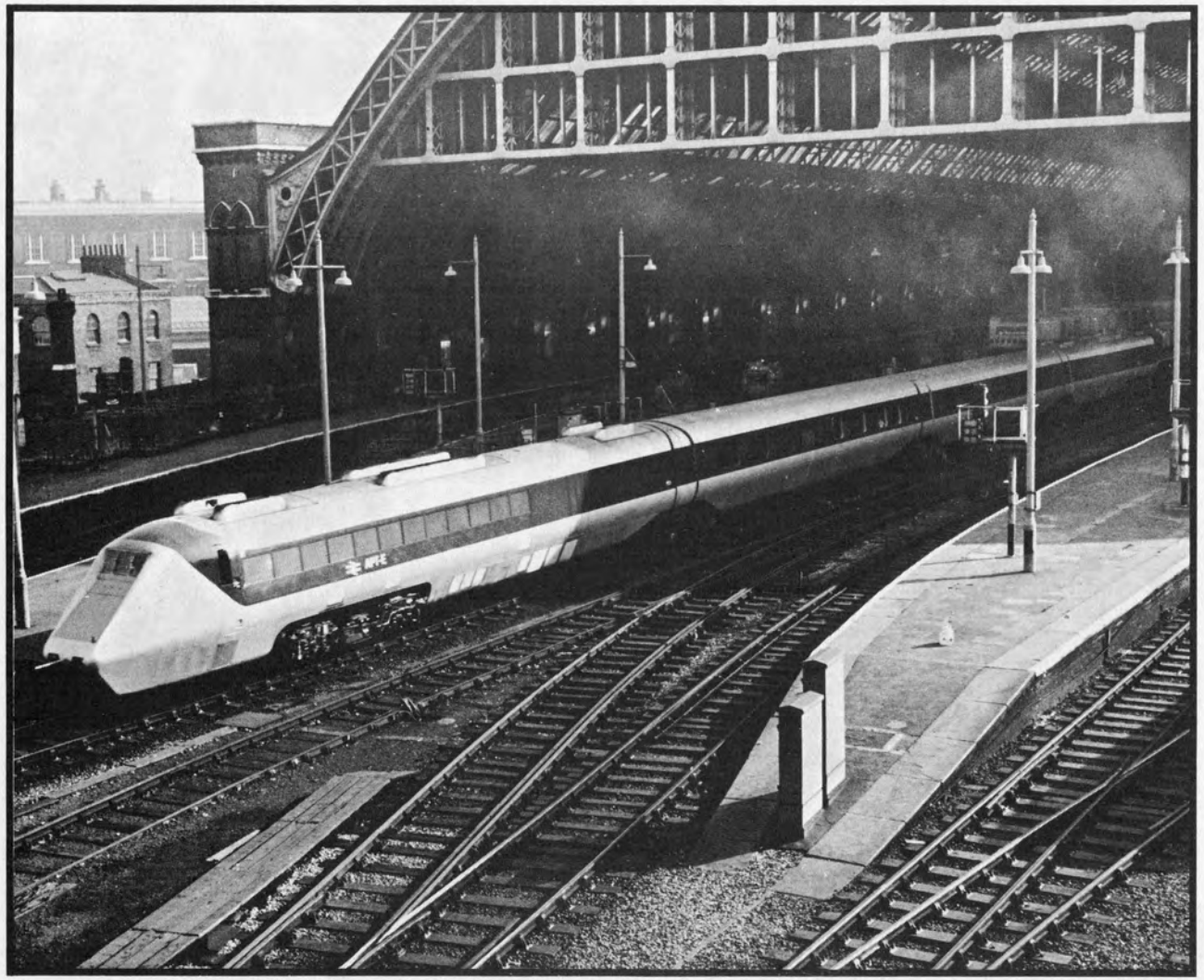
At high speeds, the major source of train resistance is aerodynamic drag, which increases as speed-squared. Consequently, the energy and power used in traction tend to rise rapidly as operating speeds are increased.

Although train weight has only a small effect on energy consumption at constant speed on level track, its effects are important when climbing hills and during accelerating and braking. Train weight influences particularly the number of powered axles, and hence the amount of power equipment required for operation at acceptable adhesion levels.

For economic performance, therefore, a streamlined low-drag profile has been adopted for APT, together with lightweight construction. Since the effect of acceleration rate on Inter-City journey times is of secondary importance, only sufficient power is installed to give a train balancing speed on level track about 5% above the maximum operating speed.

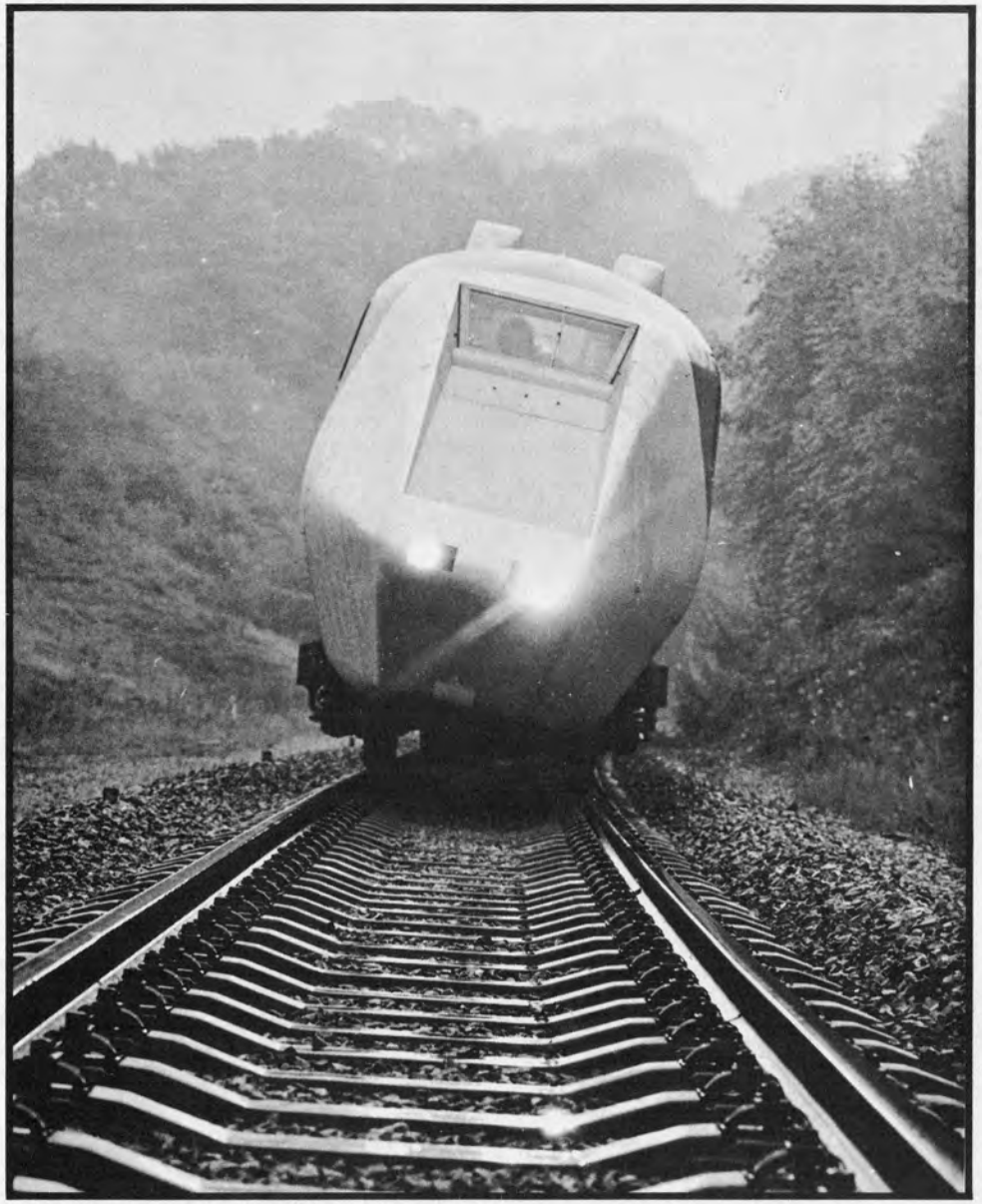
The low aerodynamic drag of APT results from its nose and tail shape, its reduced cross-section, including lower roof height, and its general surface smoothness. Further drag, weight, and cost reductions are achieved by using an articulated formation with bogies shared between coaches.

The braking system for APT is designed to stop the train within existing signalling distances. Hydrokinetic (water turbine) brakes are used to meet the arduous braking duty, being capable of dealing with very high levels of energy and power dissipation.



The experimental APT at London's St Pancras Station

Theory into Practice



APT-E demonstrating its tilting action

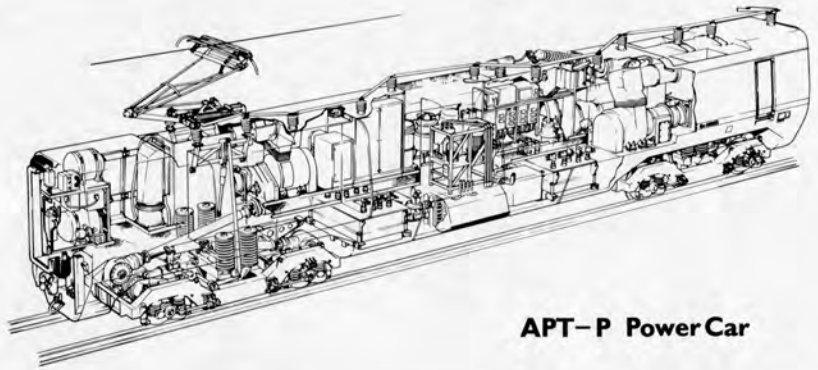
The APT makes the biggest single step in improved performance yet attempted by a railway. The project originated in 1967 as a by-product of fundamental research into the dynamic behavious of railway vehicles.

The new understandings of the interactions between vehicle and track that were developed enabled the technical potential of railways to be re-appraised and the economic feasibility of passenger travel at higher average speeds recognised.

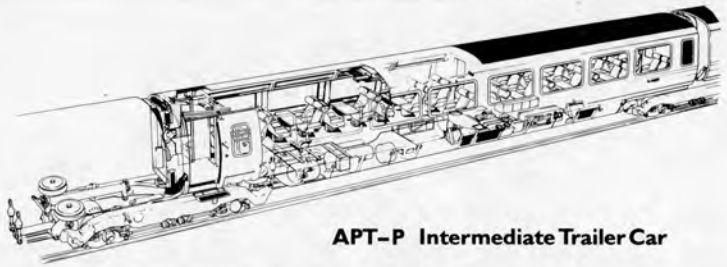
The APT concept required an extensive research and development phase prior to commercial exploitation. Extensive laboratory development was supported by the building of an experimental train, APT-E. It was towards the end of an extensive test programme that APT-E demonstrated its unique capabilities on 30 October, 1975 when it ran from London to Leicester, a distance of 99 miles (160 km), in 58 minutes. This, with a recovery allowance, represents an APT service time of 1 hour 02 minutes. The fastest scheduled trains are timed to cover the distance in 1 hour 24 minutes, an average speed of 70.7 miles/h (114 km/h) so that APT-E reduced the journey time by over a quarter, maintaining an average speed of just over 100 mile/h (160 km/h). Because this is a route with a number of major speed restricted curves the improved performance was mainly due to the higher curving speeds of APT.

On other occasions APT demonstrated its high speed capability on straight track reaching a speed of 152 mile/h (244 km/h).

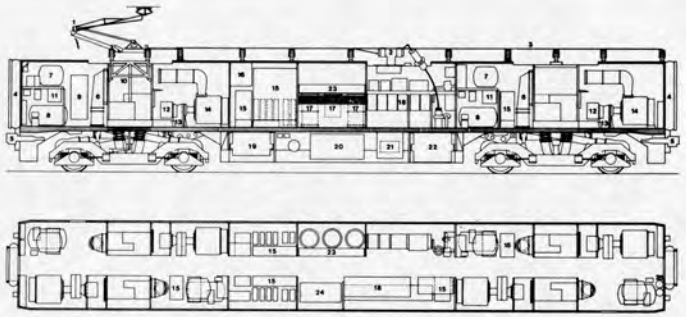
The project has now moved from the experimental stage with British Railways Board authorising the building of three pre-production prototype electrically-propelled passenger carrying APTs.



APT–P Power Car



APT–P Intermediate Trailer Car



1 PANTOGRAPH.
2 CIRCUIT BREAKER.
3 H.T. BUS-BAR.
4 GANGWAY CONNECTION.
5 DRAWBAR.
6 HYDROKINETIC BRAKE RADIATOR & FAN.
7 HYDROKINETIC BRAKE AIR RESERVOIR.
8 HYDROKINETIC BRAKE WATER RESERVOIR.
9 DOOR.
10 PANTOGRAPH ANTI-TILT MECHANISM.
11 HYDROKINETIC BRAKE CONTROLS.
12 HYDROKINETIC BRAKE.
13 TRANSMISSION GEARBOX.
14 TRACTION MOTOR & BLOWER.
15 ELECTRIC CONTROL EQUIPMENT.
16 AIR COMPRESSOR
17 COOLING FAN FOR TRANSFORMER,CHOKE, THYRISTOR & TILT SYSTEMS.
18 THYRISTOR CONVERTORS.
19 CHOKE.
20 RADIATORS FOR TRANSFORMER,CHOKE, THYRISTORS & TILT SYSTEMS.
21 THYRISTOR COOLANT TANK & PUMP.
22 TRANSFORMER.
23 BATTERIES.
24 TILT SYSTEM CONTROL PACK.
25 FIRE EXTINGUISHER GAS BOTTLES.

General arrangement of power car

Power Car

The APT-P power cars are lightweight steel semi-monocoque structures with deep side skirts.

Each power car is carried on two four-wheel bogies and contains thyristor electrical control equipment feeding four 750 kW body mounted traction motors. The motors drive the axles via a body mounted gearbox, cardan shaft and lightweight final-drive reduction gearbox. Each powered axle is hydrokinetically braked, the brake being fitted to the body mounted gearbox in the mechanical drive to the axle.

Power cars are equipped with anti-tilt mechanisms to ensure that the pantograph remains level as the body tilts.

Each power car weighs 69 tonne.

Trailer Cars

Trailer cars are arranged in identical rakes each side of the power cars. Three basic types of vehicle are required not only for low total train mass, but also for acceptable axle loads, especially on articulated axles. To meet the mass targets, APT trailer car bodyshells are constructed in aluminium alloy, giving a 40% weight saving over conventional steel coaches.

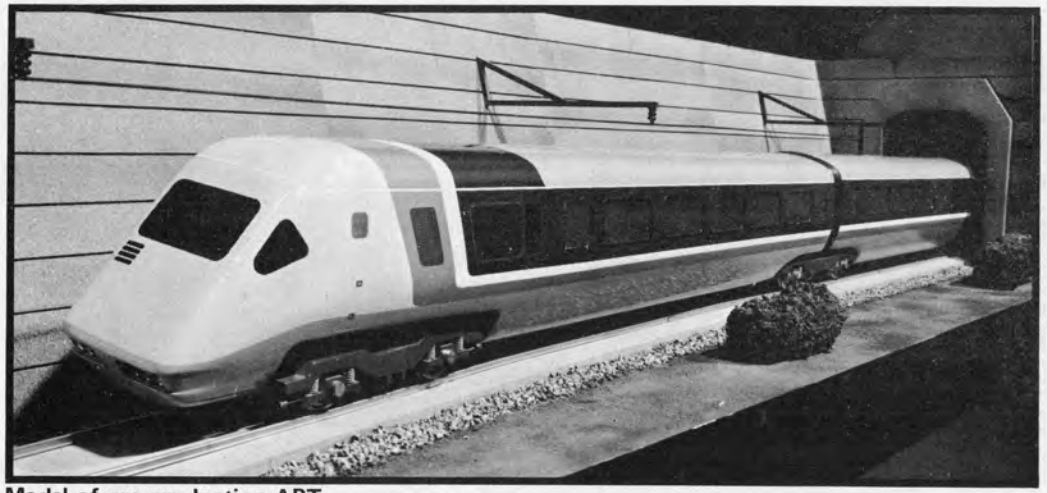
The vehicle structures are designed to meet the UIC loading specifications for main line coaches, including the 200 tonne proof buffing load. The dominant design criterion tends to be stiffness rather than strength, as high flexural natural frequencies are essential for good ride quality at high speed.

Passenger doors are of the power-operated sliding-plug type with a rectractable step. By having only two wide doors per vehicle located in diagonally opposite corners, it has been possible to accommodate 72 second class seats or 47 first class seats at standard pitch within a 21m vehicle length.

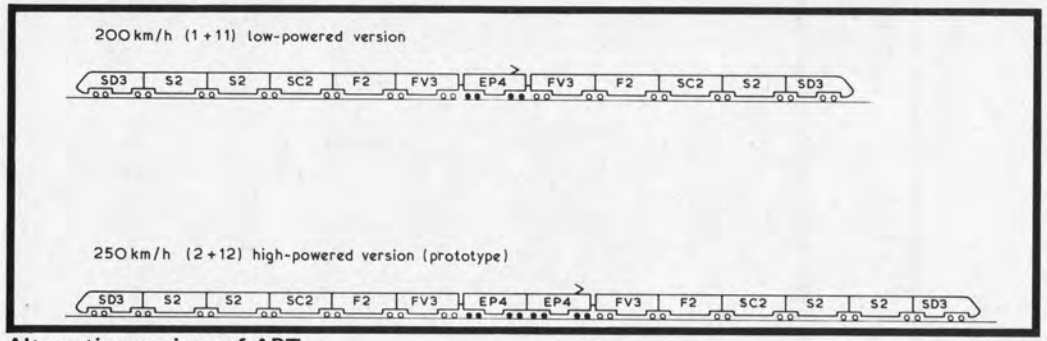
Internal fittings such as seats, luggage racks and trim panels are modular and easily replaceable. Similarly, air conditioning, tilt control and brake control units are installed in the vehicle underbelly as pre-commissioned, readily-removable packs.

Substantial weight savings have been achieved by developing a chemical toilet, lightweight seats, and a low-energy air-conditioning system. This system uses a low fresh air charge and a high (80%) re-circulatory flow, de-odorised by carbon filters. The small intake and exhaust areas are sealed on entry to tunnels to protect passengers from transient pressures.

Pre-Production APTs



Model of pre-production APT



Alternative versions of APT

The 25 kV electric pre-production train (APT-P) comprised two rakes of articulated trailer cars between which are positioned one or two power cars. Each trailer rake consists of a number of two-axle intermediate cars and two three-axle end cars. Each power car has four axles. Power cars and trailer rakes are easily uncoupled from each other in order to satisfy operating and maintenance requirements.

The train can be formed into alternative versions. The 125 mile/h (200 km/h) (1+11) low-powered version, with 11 trailer cars, represents the longest train that can be hauled by a single power car. The 155 mile/h (250 km/h (2+12) high-powered version, with 14 vehicles total, is the longest train which can be accommodated within the existing platform lengths.

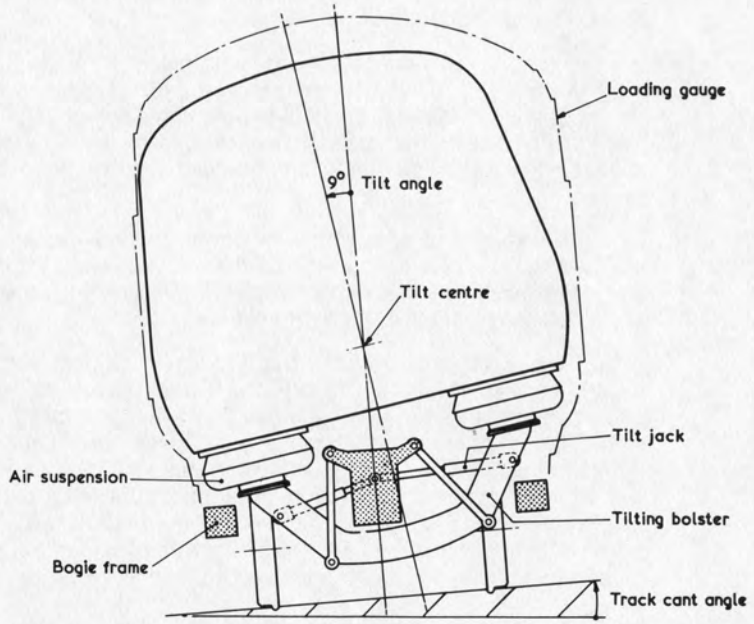
The train configuration, with power cars positioned in the middle, has been adopted so that current can be collected satisfactorily, using only one pantograph, and so that excessive suspension buckling forces can be avoided when pushing with two power cars.

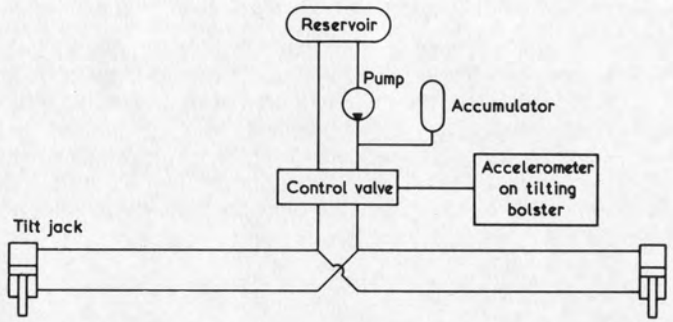
Communication between the two trailer rakes is normally available to staff only, via a corridor through the power car. Passengers are permitted access only in emergencies and when escorted by a member of staff. To minimise this disadvantage, each rake of trailer cars is self-contained, incorporating both first and second class accommodation and catering facilities. First class accommodation is in the middle of the train and second class towards the ends, the division being marked by the intermediate catering car. The catering unit provides full meals for first class passengers in their seats and a buffet service for all passengers.

Coach Tilting

APT vehicles tilt by up to 9° on curves. The requirement to stay within the BR loading gauge leads to their characteristic shape.

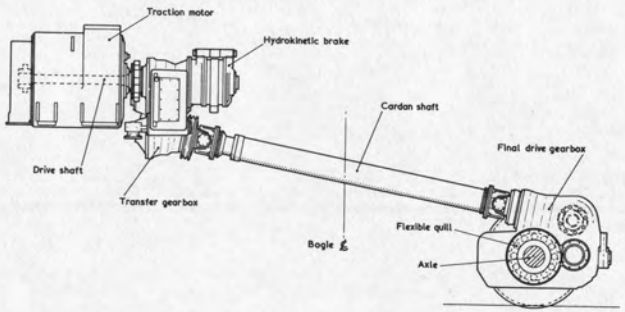
Each vehicle is tilted individually by hydraulic jacks mounted within the bogies. Power for the jacks is provided by a hydraulic power pack mounted below the vehicle floor. Tilting is controlled by an electronic box that measures the lateral acceleration of the bolster. This measurement is made by a "spirit level" accelerometer in which the position of the bubble is sensed by electrical connections. The tilt system design permits the vehicle body to adopt an upright position in the event of hydraulic system failure.



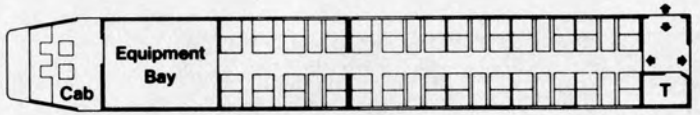


Arrangement of APT-P vehicle tilt suspension and simplified diagram of control system

First Power Car

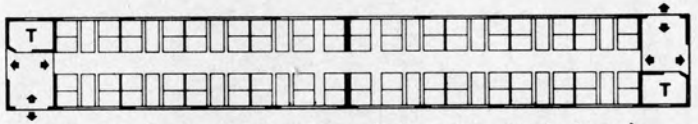


APT-P mechanical transmission



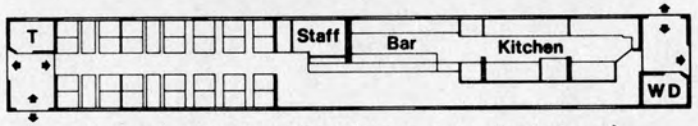
SD3

Driving Trailer Car (52 seats, 2nd class).



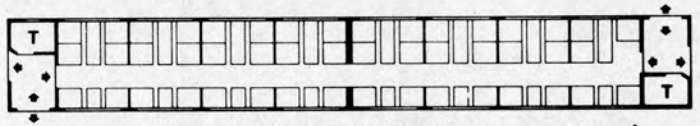
S2

Intermediate Trailer Car (72 seats, 2nd class).



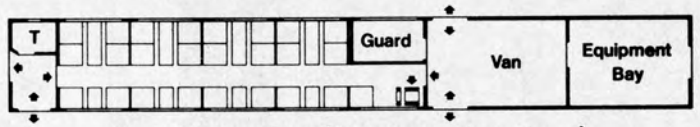
SC2

Catering Trailer Car (28 seats, 2nd class).



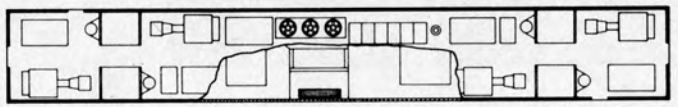
F2

Intermediate Trailer Car (47 seats, 1st class).



FV3

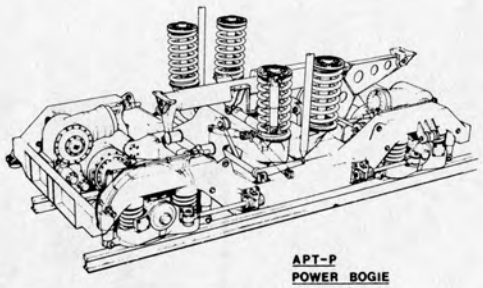
Van Trailer Car (25 seats, 1st class).



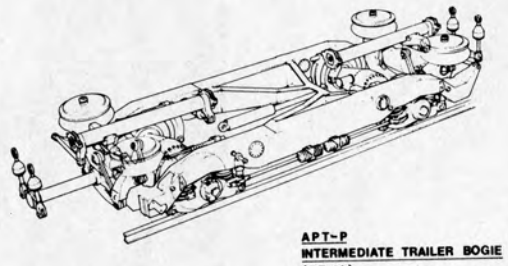
EP4

Power Car.

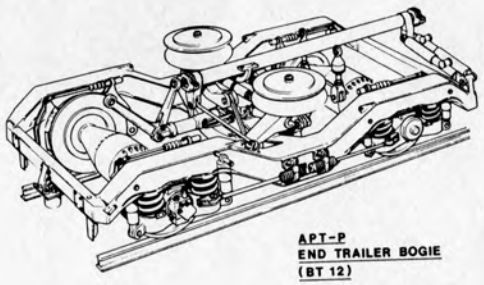
Layout of APT-P vehicles



APT-P
POWER BOGIE
(BP 17a)

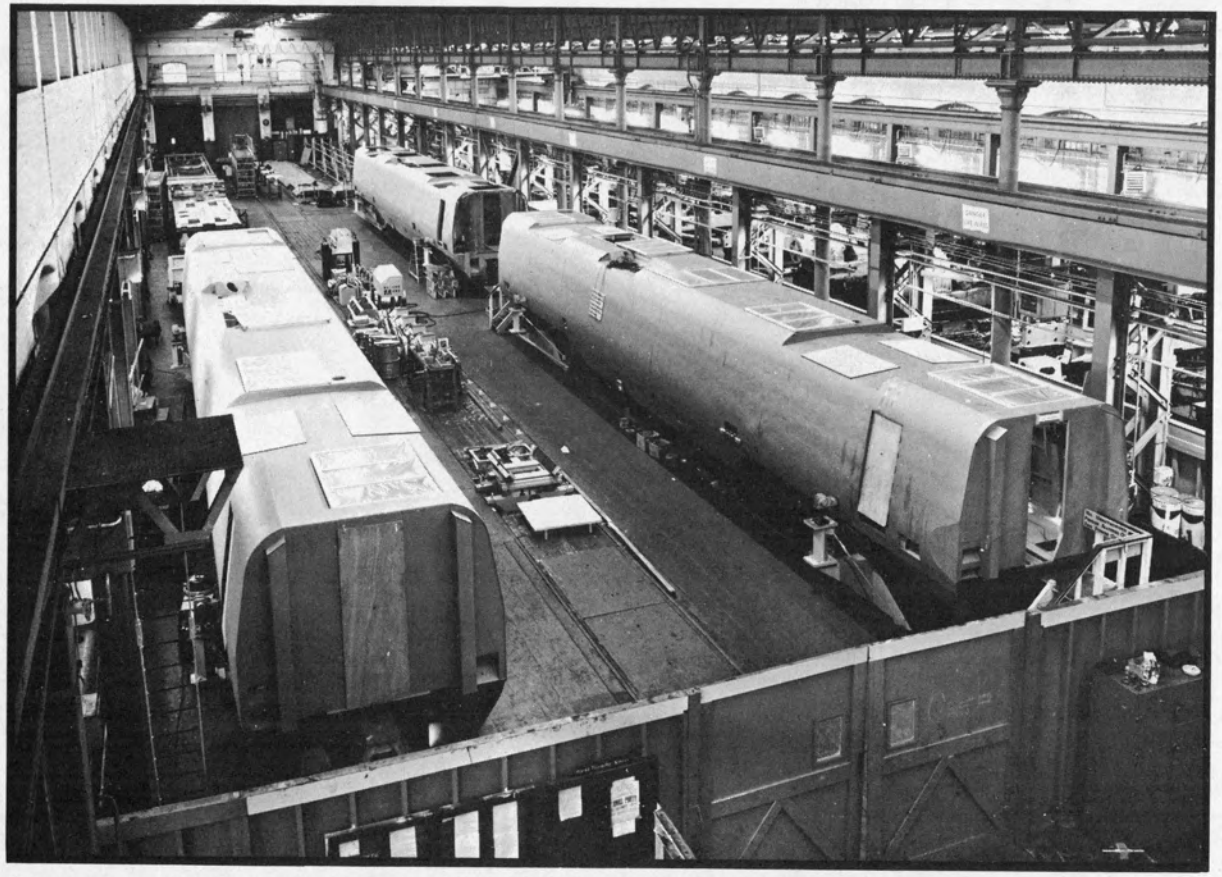


APT-P
INTERMEDIATE TRAILER BOGIE
(BT 11)



APT-P
END TRAILER BOGIE
(BT 12)

Diagrams of APT-P bogies



Power car construction at the Locomotive Works of British Rail Engineering Limited

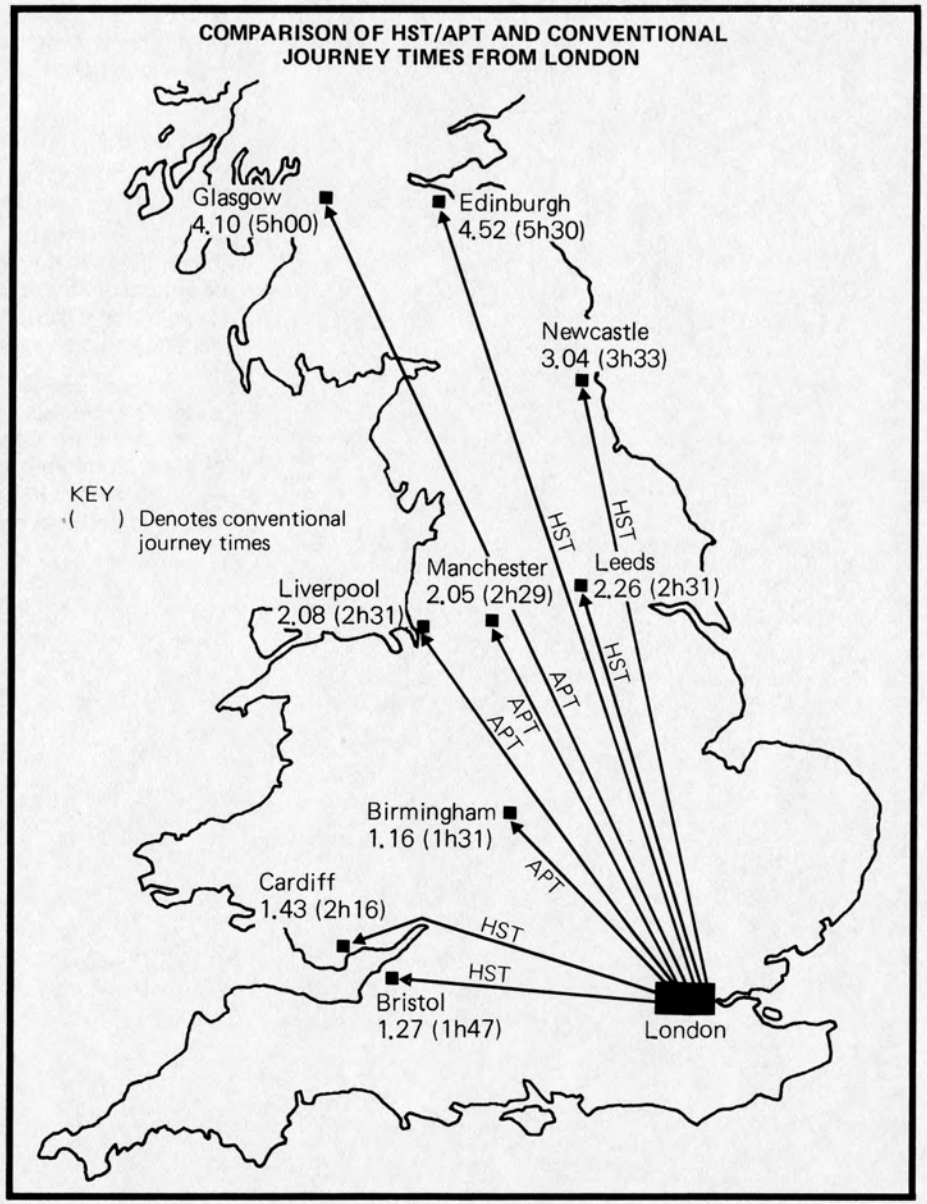
Building Advanced Passenger Trains

The manufacture of the Advanced Passenger Train pre-production prototypes is being undertaken by British Rail Engineering Limited – the wholly owned subsidiary of British Railways Board that controls B.R's 13 main workshops.

The Company's two works at Derby have undertaken the project, the Locomotive Works manufacturing the six power cars together with all of the bogies, whilst the Litchurch Lane Works is building the trailer vehicles.

In order to produce this new generation of passenger trains, many of the traditional skills and techniques inherent in railway engineering had to be updated. In particular, the unconventional designs of the aluminium trailer vehicle structures have meant that BREL has had to develop new welding and assembly techniques.

After overcoming the initial unfamiliarity of working with this material a number of important advances have been made. Possibly the most significant of these has been the proving that fully automatic welding of wide aluminium extrusions, is both practical and reliable, and that the body structure can be fabricated in two main assemblies – lower body and roof – joined together by window pillars.


COMPARISON OF HST/APT AND CONVENTIONAL JOURNEY TIMES FROM LONDON
Glasgow
4.10 (5h00)
Edinburgh
4.52 (5h30)
Newcastle
3.04 (3h33)
KEY
( ) Denotes conventional journey times
Manchester
2.05 (2h29)
Leeds
2.26 (2h31)
Liverpool
2.08 (2h31)
HST
HST
HST
APT
APT
APT
Birmingham
1.16 (1h31)
Cardiff
1.43 (2h16)
HST
HST
Bristol
1.27 (1h47)
London

The APT Programme

Authority to build three passenger carrying pre-production prototype trains was given in October 1974.

The first vehicle to be delivered was one of the six 4,000 hp (3MW) power cars which emerged from the Derby Locomotive Works of British Rail Engineering Limited in June, 1977. This vehicle started a period of main line test running in the autumn of 1977.

Early in 1978, the first test runs of a power car and three APT trailer cars will take place to be followed soon afterwards by the appearance of the first fully-formed APT which will act as an engineering test train to be used initially for testing and commissioning purposes between Glasgow and Carlisle.

Later in 1978, driver training runs will start with a second APT-P and when the equipment has been proved and sufficient crews trained, an APT-P will be substituted for one of the standard 100 mile/h (160 km/h) London to Glasgow trains in daily passenger service.

In 1979, a second such substitution will be made and then later in the year both trains will run to scheduled 125 mile/h (200 km/h) timings between London and Glasgow.

During this period, the Board will be seeking Government approval for the construction of the first fleet of production APTs to run between London and Glasgow.

In the longer term, plans will be prepared for the building of diesel engined APTs in order that the advantages of APT performance can be brought to non-electrified routes.