ADVANCED PASSENGER TRAIN

A PERSONAL STORY

BY JULIAN MARSHALL

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The author’s website??

The eBook “APT Derailed” by Julian Marshall gives more detailed technical information.
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A project management case study

Was the APT a misconception?

or did it fail due to internal misconceptions?

JULIAN MARSHALL

PROTOTYPE TILT SYSTEM DESIGNER

Photograph: The author's electric scale model of the prototype of the Advanced Passenger Train.

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PREFACE

In December 1981, British Rail (BR) put its Advanced Passenger Train (APT) into public service. Those who had authorised the Launch of the Prototype Train were surprised when they found that their Train provided passengers with a bad ride. As a result the hope of developing fleets of low cost and fast inter-city tilting trains was abandoned.

This book was written as a personal story, from a designer's point of view. The author worked with enthusiasm on this project for a decade, always hoping for a good outcome. David N Clough who had worked as an engineer on the APT wrote "The untold story" and Hugh Williams, who was APT-E train Supervisor, wrote "APT A promise unfulfilled". These stories of the same event were viewed from their own point of view and they have been helpful to the author in writing his account. The Train was also ridiculedfor many reasons and there was a history that led up to the event.

The achievements of the Prototype Train delighted the author. He remembers years of waking up in the morning thinking that he had just the right job for him, with good colleagues working together to achieve a large social benefit. However, this book focusses more on how it turned into a disaster.

The author thanks many people and to those who helped him to write this book.

Julian Marshall

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INTRODUCTION

From 1948, the "big four" railways were nationalised to form a unified British Railways. During, the1950s diesel and electric rolling stock were deployed, but by 1955 rail revenue had fallen and the network ceased to be profitable. Much of the transport business was being superseded by motorways and other public highways. Many people thought that, unless there were major technical improvements ahead for railway transport, this industry would decline as the canals had done. By 1963 Dr Beeching started to reduce the loss making railway businesses.

In 1964, Japan's Shinkansen line demonstrated that its special high speed passenger trains could operate at 130 mph on nearly straight track. Regular maintenance of the tyre profile together with a subtle improvement to the design of the suspension, prevented hunting. However, the cost per passenger-mile was high and to replicate this technology in Britain it was considered to be beyond anything that the British public would support by taxes.

In 1965, British Railways was renamed as "British Rail" and a brilliant corporate identity was created. This re-branding was a substantial success. BR had made a good change and it was being implemented well, indicating that there might be a re-birth of railways about to happen.

To increase BR's ability to make improvements, the Railway Technical Centre was built at Derby. The he application of technology was needed to improve its commercial competitiveness. Many passengers, including the author, had experienced being shaken from side to side in carriages when suspensions were hunting. When the railhead shape formed a rut in the wheel, the guidance tended to become unstable at speed. As the tyre profile became worn then the slower would be the speed at which hunting set in. The conventional ways to prevent hunting had been for the train to go even slower and to re-profile the wheels. Both of these were expensive.

BR's Research organisation had developed a theory that explained the Japanese achievement. By about 1965, this theoretical understanding was ready to (a) reduce maintenance costs (by spreading the wear evenly over the tyre profile) and (b) gain guidance on curves (without the high wearing screaming occurring on curves). If both these design features were to be incorporated into a suspension design, then journey times could be substantially reduced and railway operations become more economical. If engineers could make suitable suspensions in practice, then this design improvement might bring a renaissance for railways around the world for decades to come.

If this large technical improvement was going to happen in Britain, then other preparations would be needed for it to be demonstrated as a success. The Research organisation had been building up the sort of competence and computing power that would be vital to designing a new generation of trains. For example, BR needed the ability to predict dynamic performance from suspension drawings, ahead of the design drawings being issued for manufacture, so as to reduce the uncertainty about its ride quality and about its running costs. In addition, BR needed a bespoke laboratory that could explore the dynamic behaviour of parts of trains and a private track for testing even before commissioning the train on the operational railways.

BR proposed to design a new High Speed Train (HST) for the main line routes which could emulate the Japanese success in a lower cost solution for our existing tracks. To compete with the cost of motoring, the HST's running cost needed to be no more than 0.3 pence per seat/kilometre. In addition, it needed to be quicker than previous services to attract passengers away from using motorways. It was not until 1965, following bad accidents in foggy conditions, that the motorways became limited. The opportunity time for drivers to see warning signs and come to a stop was shortened in foggy conditions. The whole motorway network was limited to 70 mph. This reduced time applies to both roads and railways. It was hoped that the HST train, at speeds of 100 mph and possibly up to125 mph, would be able to cope with the reduced opportunity period for seeing the warning signs of danger.

Railways have speed restrictions on its curves, and the lateral ride comfort would deteriorate in proportion to the amount of overspeed beyond the set line speeds. Any substantial reduction of journey times on BR's many curvaceous routes was possible either by making highly expensive straighter routes, orby developing innovative tilting trains to operate on the existing curvaceous track.

The Birth of a Revolutionary Train

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New trains were needed to operate at much faster speeds to be competitive with the new motorways and they needed to work on existing routes without any upgrade such as a higher standard of smoothness of the tracks. Britain and BR invested in the Advanced Passenger Train (APT) Project. The concept originated in the Research organisation. There were three large engineering uncertainties, tilt, brake and suspensions and there were many other innovative advances, which all needed to work, before the date for the birth.

Conventional train's had limited line speeds on the curves, both to prevent the trains overturning and for passenger comfort. Drivers would learn the fixed speed restrictions for each route before being allow to drive on the route and, also, learn the temporary ones day by day. By 1970, the need to go faster round curves using tilt had been internationally recognised. When the author asked he was told that there had been a number of attempts at doing so, but at that time there was no example of tilt being satisfactorily accomplished. He was told that the British tilt system would go about 20% above the existing speed limits on curves by tilting up to 9 degrees.

Until people had experienced this amount of tilt, it was uncertain how they would react. While on straight track, the lateral ride must not deteriorate if the tilt is turned on. Tilt should make the lateral ride better than the conventional trains going at their slower speed, on the same straight track. At this time it was unknown whether it was possible, or if it was really necessary, to achieve this ride performance improvement. When on curves, the ride should be as comfortable as for straight track, including achieving zero unbalance. The tilt should be accurate while the train was transitioning from straight to going on to round curves. At this time it was unknown whether it was possible, or if it was really necessary, as there was no experience to established how accurate it needed to be achieved in practice. It was imagined that the ride should be comfortable enough for passengers, whether they are seated or walking along corridors, in all these situations.

The second substantial design challenge was brakes. Railway signals had been laid out to operate close to the conventional train's stopping distance, with just a small distance as a safety margin. It was known that if a conventional train had over sped when it was approaching a warning signal, then the wheels might slide along the rails (wearing flats on the tyres), and also the train might pass the final signal at danger (so putting the train at danger of collision). The author was told that the new train should be able to pass warning signal at 50% faster, than had been permitted for the existing trains. It was uncertain whether there was adequate adhesion for this retardation, and whether the adhesion was there for, both braking and tilt at the same time. No train had used anywhere near this level of adhesion in practice. Multiple disc brakes mounted on the axles would be so massive that the cost of aligning the track to keep it smooth would be significantly increased. The drag caused by picking up, and pumping the cooling air, would be a significant cost. TheProject decided to use the low cost light weight hydrokinetic within the axle. This type of brake system had never before been used before on railways. The author had heard of and admired William Froude who had innovated this type of water brake. Froude used it as a dynamometer to absorb and measure the power of large naval engines. In 1837, Froude had worked for Brunel and he developed an empirical method for setting out the route that joins straight track to curved (constant radius) track, with which the new tilt system had to accommodate.

The third challenge was obvious, as it was ride comfort. If a conventional train went faster than normal, then the ride comfort would deteriorate and passengers might not tolerate it. It was uncertain whether trains it was possible that suspensions could be designed to ride better than the existing trains, especially when the new train had to operate at 20% to 50% higher speeds over the same track as the conventional trains had been using. High speed ride comfort had been achieved for regular services internationally but only with straighter routes and on smoother track. This time it had to be achieved by better design of the suspensions only.

The fourth challenge was simple and was a response to the commercial needs in Britain. The running cost had to be substantially reduced to be less than 0.2 pence per seat/kilometre. It would have been a highly ambiguous target to achieve these commercial savings with trains operating at the the same timetables. To save running cost and reduce journey times would more than double the uncertainties. For example, this meant that the new train should use no more energy than a conventional train for the same journey while still reducing the journey times by 20%.

In November 1970 the author had entered BR, and the Project, at the bottom level when an Experimental train was being built. To be selected to take part in such an exciting challenge would be exciting.

The opportunity for the Project was there to make a huge impact on BR’s future, on railway transport in Britain, on engineering exports and so Britain’s balance of trade.

CHAPTER 1 THE PROJECT

Working towards a Fleet of new trains

In the November 1980 (see figure 1) the Chief Executive of BR justified investing in a fleet of trains. His text was made available to the staff through Railnews, BR's official monthly newspaper,. Those in authority had recognised it was as too much to expect that a fleet of trains could be designed and get it right first time. A Project was needed to make it possible.

There were many new features and each had many uncertainties and each needed to have been worked out and tested before the designer could know that the feature would work. It may have seemed like throwing many sided dice with a number on each side and hoping that every one of them turned up "6" on the first or even the second throw of the dices. This Project had multi-disciplinary complicated interdependencies, so it was decided that there would be three steps to making a fleet. It might be wise to base moving from on from step one to step two, and then to step three only when the product had been proved safe and fit for the next step. During each step, development might need improvements, to make the product free from uncertainties, before starting the next step. It was hoped that the three step process would lead eventually to achieving fleets of competitive trains which fully complied with the specified requirements and was suitable for BR to use for many decades to come.

The Project needed to build BR's confidence, to embed trust and to create a bank of achievements and of competent staff. This was necessary to deliver a high quality fleet of trains, free from design faults.

Step 1 **Experimental train**

The Experimental train (see top photograph of (figure 2) was created from within BR's Research organisation. It was ambitious and seen by the public as similar to the Concorde project. There was cause for concern as some of these technical projects in Britain had ended in failure.

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The Experimental train fired peoples' imagination. There were many uncertainties which could one at a time be addressed by the Experimental train. For example, it was hoped that the train might demonstrate that the ride at its speed was comparable to the normal level of comfort. The train was needed to test whether it was possible to stop from these high speeds at high rates of deceleration. It might be directed to demonstrate its braking performance, over the whole range of weathers, such as in early morning dew and over types of leaf fall. Lessons were expected to be learnt and made available for the next step.

When the author joined the Project, it had built up a substantial supporting organisation with many highly qualified staff and a large computer power and advanced laboratory available. If the leadership go the politics right, then the technology and these assets were expected to have been carried forward to the benefit of the next step.

Step 2 **Prototype train**

Second step, a Prototype Train (see bottom photograph of figure 2) would establish all the standards and specifications which were applicable to the design of the fleet. Some core features of the Prototype had to be created from scratch, such as ways to reduce the chance of overspeeding and the Train overturning on curves.

An assessment of the value of the Prototype's launch right being a success and if, things went wrong, the cost of failing at the last moment, would reveal how critical it was to get the best staff working on the job and how vital it was to get the most important decisions right from the top people.

Step 3 **A Fleet of trains**

Thirdly, fleets of trains would be required.

The sequence of the events is shown in the "chronology".

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The Train had to be low cost, substantially reduced journey time together with added no infrastructure costs. It was also hoped that the new fleets of trains would be of good quality. Quality was especially important for complicated advanced technical projects.

Managing Quality

Manufacturers had launched a new car in the 1960's, knowing that it had to work properly. It was no good buying a car that appeared to be good, if the one you received from the production line would have many faults. Customers, who wanted certainty in what they purchased, soon learnt to refer to feedback ratings about quality, such as to the J.D. Power customer satisfaction rating. By 1970, the management techniques round the engineering world were evolving ways to actively manage uncertainties, and achieve improvements in quality. It was notable that those at the top of large British industries were internationally behind others in finding how to direct resources to deliver suitable quality.

Rather like serious accidents, there are usually many causes, which have come together and contribute to result in an occasional unwanted faults, which cause failure. Sometimes those at the top were ignorant of some of the hazards to success. Where uncertainties are exposed in the author's engineering experience, then the right directions could be given to overcome the causes of faults happening.

The aircraft industry was ahead of the railway industry, but even then there were times when things went wrong. In 1971 when the APT Project was in the experiment stage and planning for the next step, Rolls Royce faced financial ruin due to late unexpected high costs of development of a new engine design. Both the APT and the RB 211 engine originated in Derby and about the same time. The engine's non-conformance problem was so bad that it became international news. After the Prototype had been designed and before it was commissioned, the author used to represent the Project to various organisations and people in the audiences would ask about the risks. The author had no role in managing the APT Project and its risks, but due his innovative designs and his engineering experience , he was asked by Rolls Royce Ltd to give some lectures to their engine designers. So he shared experience about managing the risk in designing innovative products.

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In theory, those directing the project, working with the managers, should make sure that they have (and understood) a list of the uncertainties and decisions should take them into account when planning the project and setting the budget. Where there may be complicated interdependencies, any one of the hazard being overlooked, might jeopardise the whole project. When the list is fully completed, then a plan can show how to reduce both the chance of things going wrong and the severity of the consequences of having gone wrong. Tests should be undertaken to demonstrate that the uncertainty has been overcome at earliest opportunity.

In practice, things in the APT Project were not organised in line with the above theory. Four examples are given:

i) Vertical ride comfort: There was uncertainty about the new train's ability to achieve a good ride. It was known that for more than a century and in many countries, designers had tried to make trains ride as comfortable as they could, but there was still some discomfort. In general it is hard to guide a carriage above a railway track and keep it central to it, without also making the carriage vibrate as it travels along the track. Realistically, many experienced railway people would think the chance of the new train having an outstandingly good ride comfort first time would be low. Wisely in an attempt to reduce uncertainty, the scientists and mathematicians had used the large BR computer to predict the ride comfort. Based on draft suspension designs, the scientists using the computer had the ability to predict whether the new suspension would be a good enough.

In 1972 when the Experimental train, as shown in the top photograph in figure 3, first ran the actual vertical ride turned out to be substantially worse than conventional passenger trains.

The author took a liberty and enquired from one of the scientists, why the computer model had failed to show that the vertical ride would be poor. The scientist informed the author that the model had not included the inertial effects of the suspension's swinging arm links. To reduce the uncertainties the suspension's isolation performance could have been laboratory tested before fitting it to the Experimental train or when it ran. This could have revealed the fault in the design and also the fault in the computer model. In the hassle and the political confusion at the time, the computer model was left unmanaged.

The Prototype suspension (see bottom photograph in figure 3) was started to be designed in 1973. It was again based on the spring stiffnesses and damper rates and so on for the suspension, coming from the Research organisation and its computer model. A result the passenger ride comfort was poor. It was not compared to the ride comfort standard nor a conventional carriage's performance.

ii) Short fat screws: On each Train, there was about 1,000 short fat screws clamping the two parts of the axles together,. Each of the screws could loosen inside their blind tapped holes. Those at the top must have recognised it as a warning sign. However no change was made to the design before the Launch. A useful definition of safety is that it's safe when there is no reasonable alternative and no practical things that could make it safer. Due to these screws coming loose the Train was less safe than it could have been.

iii) Safety warning sign: There was uncertainty about going faster than normal because the train would be closer to the overturning speed than for conventional trains. One of the most important safety warning signs was the removal of the tilt function in the event that the Train went too fast round curves. The Commissioning Team experienced it, but appeared to have overlooked its full meaning. It was again overlooked during the Launch and because the Train was not slowed down for the upright carriages, the passengers suffered bad ride.

It was a general matter of judgement to decide whether to get the faults remedied by development so as to bring the product up standard, or whether to put off doing development work further in favour of putting the Train into public service. Those making these important decisions might not understood the uncertainties. In practice this became out of keeping with the theory of quality.

iv) Poor quality practice included spreading misconceptions: About 12 months before the Launch, BR staff were informed by the BR house newspaper that the Prototype Train had been a success. In November 1980 edition of the Railnews, the Chief Mechanical and Electrical Engineer (CM&EE) expressed his view: "*APT is a prime example of the collaboration between the Research [organisation] and the CM&EE departments, and a tribute to all concerned. I am confident that the* *squadron service will fulfil customer expectations and keep BR in the forefront of high quality inner-city travel*." The same edition of this staff newspaper recorded that "*The development and intensive testing programme had proved the major technical features of the APT. No problems have arisen which would invalidate the technical correctness of the train. Those that have been encountered have been resolved and vehicles are being rectified*."

This information coming from someone, who was presumed to know about the Train, would have been good news to the thousands of staff that read the paper, and also for those, who were in the hierarchy above him. However, to the author, his opinion aided mis-conceptions to grow.

CHAPTER 2 THE FATEFUL DAY

Contents

1. *Preface*

On this day there was one of the largest staged demonstration of incompetence. BR wanted to display to the public that it was capable of improving the railways. How did it happen? That morning did they know what they were doing and what would be the result? Did in-fighting destroy the future? This chapter gives some answers.

2. *Preparation for the Launch*

Before the Launch, Sir Peter Parker, BR's chairman had expressed his confidence in the Train being ready and its value for money (see figure 4) as he had understood it in November 1980. The commission led people to continue to expect that the Train would have a running cost of <u>0.2 pence per seat km</u> which was substantially below the HST at 0.3 pence per seat km, and the capital cost was about 0.2 pence which was similar to the HST and this was much better than the conventional trains. It was time to unite to protect the commercial benefits which were easy to imagine. The first step should have been review the progress on the work to overcome the uncertainties.

From the start of the Project, there had been some uncertainty about delivering and this was allowed to continue to be a live question right up to the Launch. The most striking success for the Train had been before the Commissioning Team became anxious. It was when the Prototype Tain demonstrated its ride comfort to passengers who were made up from the Project's staff and their families. The tilt system had rotated each carriage in turn giving seated passengers a feeling of being "perfectly balanced" at all times. It started from Crewe station and travelled on the West Coast Main Line. Passengers observed that nothing spilt from filled cups standing on the table tops. Passengers enjoyed being tilted. It was special and the first of its kind in the world. The author and his family came away thinking that if this was what the public were going to experience they would be delighted.

The Commissioning Team went on to take a further 12 months. Then there were preparations the Prototype Train which needed to be completed for the Launch on 7th December 1981.

BR chose to stake its reputation on the line at the Launch. If it worked well it would be a glorious boost for railways and demonstrate that the industry was fit to adapt for the future. The Launch might demonstrate that this new Prototype Train was the icon of BR's ability and that BR was ready to compete with the motorways between cities.

3. Check on the fitness to operate

During 1980 and 81, the Commissioning Team tested the Prototype Train and should have been able to demonstrate where confidence in the Train was justified. It was engineering practice to determine whether everything complied to relevant standards and specifications before Launch. If the Launch was undertaken before the commissioning had demonstrated that the Train met the standards and specification, then those in authority had have taken it on themselves to be responsible for anything that turned out unsatisfactory on the day.

Test are only done where the outcome in uncertain. The work of commissioning is to test where there is uncertainty, and enable development work to be done to gain compliance where necessary. This is illustrate by four examples:

a. Brakes: Conventional trains and the Prototype Train must stop within the existing signalling system, whilst having started to brake from their different speeds. They had to achieve this with a suitable margin for safety.

   The Prototype's brake system had technical specifications established before doing the designs. It had to stop from the higher speeds and at about the twice the deceleration of the conventional trains. There was uncertainty about the availability of adhesion between rail and wheel both in magnitude and length and deterioration of poor adhesion. While writing the brake system specifications for himself to adopt, the author noticed that the Prototype brake had to cope with a much larger amount of traction power and more frequent stopping, than had the Experimental brake. If the design had been upgraded for thermal capacity and thermal cooling straight from the Experimental brake system design, then both system's weight, and the system's space of the Prototype brake system would been double that of the Experimental brake system. The author was told that these increases were not acceptable for the Prototype Train. By making substantial innovative changes to the way the brake system worked, this onerous braking duty was achieved without any increase in weight and space. When it came to commissioning, this innovative feature of the new brake system should have been carefully investigated and understood. During commissioning the brake dragging failure modes should have been commissioned and this should have included exploring the new component failures of the innovative parts of the new design of the system, such as the floating ball valve. That should have included testing failures that might resulted in brakes self-destructing, both in the hydrokinetic and the friction brakes. Those in authority could have checked what was being done about brakes dragging. Naturally the Train should not go into public services with brakes, where there was uncertainty, such as being less reliable than the conventional brakes. For example, if there were brakes dragging then the commissioning could have informed those in authority about the non-compliance and demanded that development work be done in the bespoke Research laboratory to overcome the problem.

b. The Prototype's ride comfort: The conventional and the Prototype Train were specified to provide comfortable ride each their difference speeds. The Commissioning Team was required to test the Prototype Train at its design speed of 150 mph. The Boocock ride comfort standard specified an average weighted accelerations less than 0.2 meters per seconds squared laterally and less than 0.3 vertically.

   A bespoke portable instrument called a Jacobmeter (see figure 5) had been designed for measuring the ride comfort and was available. When commissioning began, this meter had already been tested on local service trains and was made available for the Commissioning Team.

The Jacobmeter was intended by the author to be used when:

- measuring the average the ride comfort over the length of the journey between London and Glasgow both vertically and laterally. If this had been carried out by the

Commissioning Team then ride comfort could have been compared to the Boocock standard.

- determining locations where there was any rough track which resulted in the ride being below the normally experienced and so should indicate where track needed to have been maintained to bring it up to normal. If this had been carried out during commissioning, then the track roughness at every location could have been known and compared to the average ride comfort to direct the maintenance appropriately.

- determining whether the Prototype Train was more comfortable than the existing train services on the same track at their different speeds. If this had been done then the chance of failure at the Launch would have been reduced.

- determining the ride comfort in a variety of failure modes, including when carriages were automatically locked upright by tripping the SWS.

- shortly before taking the decision to launch the Train, and when the Train was in public service.

Those checking before deciding when to Launch the Train could have asked if the ride comfort complied to the standard. If they did not know what the ride comfort was, it hampered their ability to understand the last moment proposal to make a change, and it hampered their ability to set the date on the launch.

c. Energy consumption: Temporarily during 1973, the speed limit on motorways had been reduced to 50 mph. The normally, one saves energy by going slower, for example the 5% slower would be expected to save not 5% but 10% of the energy and so CO_2 pollution and reduce fuel consumption. The "Railnews Special Souvenir Extra" from November 1980 records that the Prototype Train uses one-third less energy at 125 mph than a diesel HST at the same speed. Staff were told that if the Prototype Train had its top speed reduced from 150 to 125 mph, then it could still save an hour on the journey time and use less electrical energy than a conventional train each at its own slower line speeds. The decision was made that the advisory speed (see figure 6), which was continuously shown in the cabin, would be limited to125 mph. It was uncertain that this could be consistently achieved.

d. When the Launch date 7th December 1981 came close, it would have been expected that those in authority would have assured themselves that their Prototype Train had demonstrated compliance to all the standards and specifications. These decision makers might have had a running check list of what had complied and what remained to be developed to meet the requirements. Any remaining tests and non-compliance should have been had been brought to their attention in authority. Without this account, it hampered their ability to control the commissioning and to understand the consequence of ending commissioning early.

5. Check on safety

There were many safety aspects, but here the risk of the train overturning is described, but there were other safety risks which needed special attention before the Launch. The main feature of this new Train was tilt. The main consideration, when designing it, was safety, and top of the list must have been the chance of the Train overturning on a curve.

Managing the risk of overturning: The new Train was planned to go round curves at speeds which were closer to the speed at which a train would overturn. The chance of overturning should not have been higher than for conventional trains at their line speed. The consequence of overturning at high speed might be larger than at lower speeds, but there were migrating measures such as the carriage body structure of the new train design. Both the expected chance and the expected size of the arm and damage of an overturn event at high speed were consider in designing the Train and many decision were made to reduce the likelihood and mitigate the consequences.

Basic: When starting the design, there had been uncertainty as to whether the designers could come up with suffi cient ways that would make sure that the Prototype Train was less likely to overturn than was the case for conventional train. The Safety Warning System became fundament to the Project. Only if this Train was demonstrated to be safer than the conventional trains with regard to overturning risk, should the Train have been tilted in public services.

All those in BR from the bottom of the hierarchy and up to the top should have been united to reduce the chance of the Train overturning. It was important that all staff involve with the Project from top to bottom were aware of risks and the safety barriers. The Safety Warning System that was the main barrier to reduce the chance of the train overturning. The condition at which the Prototype Train would overturn (see figure 7) was the same as conventional trains, namely at 26 degrees of unbalance.

Multi layered checks*:* The Prototype's Train's Safety Warning System (SWS) included the following three stage approach:

(a) The first stage was to provide the driver with a continuous indication of the advisory speed, built into the cabin desk in front of him. This system was called the C-APT. It was a substantial improvement on the conventional trains which relied on drivers having learnt the route and then following pre-establish speed limits by memory. Both the conventional and the new trains relied on the drivers obeying the speed limit to prevent trains overturning on curves. The people considering putting the Train into public service might have checked that a zero margin for over speeding for the Train was properly established by asking some relevant staff before the Train was to be shown off at the Launch.

(b) The Train was provided with a second stage safety barrier. It monitored severe over-speed events. This second barrier detected the level of unbalance (see appendix 2). The passengers would feel unbalanced when any over-speeding occurred, due to centrifugal force. The greater the amount of overspeed, then the greater would be the unbalance. A spirit level device was used to detect this unbalance in each carriage and, whenever the bubble on the device moved too far away from the centre, a safety warning was tripped. The trip was designed so that it would trip and turn the carriage's tilt system off. The designer of the prototype tilt system set the standard at which the trip would occur. Those making the check before deciding to authorise the Launch might have asked relevant staff if the SWS had tripped at 30% above the advisory speed on curves, that is equivalent to 9 degree of cant deficiency. For example with rounded numbers, where a curve was conventionally taken at 80mph and the Prototype Train would be advised to take it at 100 mph, then when the Train was driven at 130 mph or more, the Safety Warning System (SWS) should trip. This trip warned that the Prototype Train had been too close to the overturning speed. Both conventional and tilting trains could be expected to overturn if this curve had been taken at 150 mph.

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(c) The third stage is a ratchet device. The ratchet was designed to lock its carriage in the upright position, when the second stage SWS had tripped, and to keep the carriage upright for the rest of the day, as a tell-tale-signal. Those making the checks might make sure that such event would be treated in a similar procedure as for a signal having been passed at danger. Once tripped, the Train should have been driven at the conventional trains' line speed for the rest of the day.
The designers recognised that if over speeding had inadvertently occurred, perhaps more than say once in 40 years, then the train's computer aid that controlled the advisory speed might be developed so that it automatically reduced the Train's speed to the conventional trains' line speed for the rest of the day if there had been a SWS trip.

Until these three features had been commissioned in the state that the Train would be at the Launch and demonstrated to work properly, the Train should not be considered as safe as it should have been before public services. The SWS's reliability should have been demonstrated as being more reliable than the Automatic Warning System for signals passed at danger.

Commissioning should have demonstrated that the SWS was compliant and made sure that all the safety procedures were proven and established the satisfaction of Her Majesty's Inspector of Railways. During commissioning there had been a number of trippings with carriages uprighting plus bad riding.

Those making those final checks on the Train, and the Consultants doing their review, might have asked about managing the chance of the Train overturning and found that the Commissioning Team lacked an adequate training and so understanding of how close they had come to overturning the Train on curves.

When it came to using the Train it was hazardous to severely over-speeding on a curve by 30% beyond the advisory speed as indicated by the SWS. The situation might have been made more hazardous, if those in charge were ill prepared for being that close to overturning the Train. Any attempt at commissioning the SWS should have involved Her Majesty's Inspector of Railways before attempting it. Those making the checks before the Launch might have asked the staff if they had been made aware of the potential consequences and the special temporary precautions before the SWS had tripped. It seems obvious, in retrospect, that there should have been no occasion when the staff were not pre-warned when the overspeed was going to be tripped. Those reviewing the

Train to check the chance of it overturning might have asked about the number of times it had come so close that it tripped the warning system.

At the end of commissioning the SWS there was a perverse consequence arising from commissioning the SWS. The drivers became familiar with the Train's ability to substantially over-speed around curves and also to continue at high speed. During commissioning the SWS, staff riding in these uprighted carriages experienced the bad ride. This was how the Commissioning Team came to ask for a ratchet device to lock carriages upright. This familiarity should have been addressed by those in-charge to make sure severe over speeding ceased. If those, who were checking the new Project manager preparedness, had understood this aspect then they might check whether he understood this perverse implication and also the way that with his Experiment, it could, increase the unbalance and so increase the likelihood of the SWS tripping unless he took action to prevent it.

In preparing for the Launch, the on-board staff should have been trained to use the emergency alarm whenever a SWS had tripped carriages upright. If ever this chaotic situation had arisen and not been reported to those in authority properly, then it might have grown into a misconception. In retrospect the author speculates that due to the prevailing culture, instead of the bad news being communicated to those higher up in the hierarchy, the news of this bad ride may have spread to staff in the Research organisation a few months before the Launch. It might have been turned into an opportunity in the competitive power struggle before the Launch.

During the first day of the Launch passenger suffer bad ride comfort. The Train did not have the Jacobmeter present measuring the ride.

At the time BR did not reveal that they knew this information and nor did reveal that they were doing an experiment to overcomer travel sickness. In reality the only way known, when it was being designed, to make carriages ride badly on a journey was to have made the Train severely over speed, and then in addition for the Train to continue without slowing down to conventional line speed. The way to prevent bad riding in uprighted carriages during a journey was to prevent unbalance in the carriages.

There was no mention of the increased risk of the Train overturning as indicated by the bad ride, nor of the safety systems involved. In the month or so coming up to the Launch the people making high level decisions would have known that the consequences of a train over turning at high speed on curve were similar to a train in collision. The Train would have about 70 passengers in a number of carriages when out was launched. The way to prevent overturning was to prevent severe over speeding.

6. *The last moment change of direction*

A couple of months or so before the day of the Launch, a major change to the direction of the Project was made. It was not until the Launch that the consequences to the Project was felt. There were four consequences:

- Dr Boocock, the Project Manager, was replaced by a new man from BR's Research organisation who promoted concerns about travel sickness.
- The author was sent on a long residential training course without knowing when the Train would be launched. He was not involved in the Experiment nor the Launch.
- This new man recently had revealed his desire to test his hypothesis about travel sickness with an Experiment. He wanted to demonstrate that it could prevent travel sickness
- The Launch of the Prototype Train became an opportunity for this Experiment.

A last moment change is not something that would be normal. It sometimes signals a desperation with the current situation. Something might have happened that damages trust. In the prevailing culture, it might have been relatively easy to create a misconception and lead people to imagine that the Prototype Train had suddenly been found out. It might have been said that if it went into public service in the state that it was in, then passengers might feel travel sick. With the past history, it might have been suggested that the bad ride had been covered up. Having created the fear, the desire to overcome it might lead into claiming to know how to overcome the travel sickness. It is the author's experience that when people delight in thinking about the glories of a possible success and spinoff benefits, they might refraining from considering what might happen if it went wrong. When encouraging others to go along with them, many heroes have adopted this style of behaviour and get rid of any potential opposition.

If the top level support for the existing people had been considered cautiously, they might have asked for a demonstration of travel sickness, then they might have found that it could not be repeated in normal operation or they might have learnt that the bad ride could only occur when the Train had been severely overspeeding round a curve and the SWS had been overlooked. Before believing this new man's story, it might have been wise to ask for a joint technical report on the suggested bad ride from those who had designed the systems and another from those who had experienced the bad ride. If such a report was done properly, it have passed bad news upwards. On reading it they might well have learnt enough to know that the proposed Experiment was inappropriate. Such a report should have revealed how the SWS would rightly trip and it could result in bad ride. May be in practice, there was no such demonstration and no such report written or may be it was covered up. The author was not asked to contribute, but it is possible that he might have been quoted.

Those considerations were not tested. Adopting this Experiment might have been adopted because of frustration with the Commissioning Team's anxiety and their inability in complete their work even after months of work. It was not caused by the Project overshooting of the budget. According to the Railnews dated November 1980 *"The Project cost of three Prototype trains complete was £32.5 million which was 26% below the original authorised investment for the Project."* BR's turnover was around £1million per day.

The decision to change the direction was made. Following the change of direction of the Project, the communication and co-operation between the Experimenter, who became the new manager of the Project, the operational manager, the Chief Mechanical and Electrical Engineer (the CM&EE) and Her Majesty's Inspector of Railways, became crucial to ensuring safety. At any time, one of these senior people could have discovered that the Experiment would introduce unbalance in carriages. Possibly there might have someone who knew that this unbalance would have been detected by the SWS, which would trip and make carriages become locked upright. On learning this information, the potential consequences could have been envisaged and then the Experiment might have been stopped.

Revised on Thursday, 7 May 2020

7. The change was a prime hazard

In preparation many issues may have been reviewed in preparation for the Launch. At the last moment a major change of direction had been made and these sort of things are notorious for increasing risks of failure. It might have been treated like a prime hazard. However checking it might have felt like doubting their own judgement. The change of direction may have been thought by the decision makers to be necessary to prevent passengers suffering from travel sickness. However they might have been wise to check whether there were spin off problems and then it might have raised the following questions in the corporate mind:

1) Had those now directing the Project made sure that all the uncertainties surrounding the Train's safety and fitness for public services had been properly addressed?

2) Had the justification been adequate to believe that the change of direction that came with an experimental sound? Was the remedy was necessary to overcome the travel sickness problem which he had recently discovered?

3) Had the Experimenter experienced the problem that he described and been able to demonstrate the tendency to feel travel sick on the Prototype to substantiate his claim? Had any of those making the decision to change direction, travelled on the Train and investigated it?

4) Had the Experimenter been authorised to do his Experiment by the right people such as Her Majesty's Inspector of Railways, or anyone else with proven competence in tilt and the safety systems in support of tilt?

5) Had the Train been commissioned in the condition that it was to be presented to the public and found to be safe?

6) Did those, who authorised the Experimenter, know that there were risks in his appointment and his Experiment? Had the Experimenter, who became a new project manager in-charge of the Launch, been fully informed at the handover of the Project? In particular was he made aware of the special safety features of the Train? Was someone responsible for oversight of this handover?

7) Did the CM&EE and the Experimenter know that there was a SWS and how it should function as a barrier to the Train overturning?

1) Was there a record that showed due consideration and special measures made to reduce the chance of the SWS tripping and to better reduce the possible consequences of the Experiment at the Launch?

2) Had the drivers, passengers been fully informed about the potential to trip the SWS and the procedure to follow when it had tripped?

3) Had training, for reacting to the Safety Warning System (SWS) tripping, been given to the staff, enabling them to know when to use the train emergency system?

8) Who knew about the Experiment at the time of the Launch? Did the press know about the risk of travel sickness that had been spoken about within BR and about the Experiment to reduce travel sickness before the Launch or had it been planned to do so after the Launch?

9) Had the new Project Manager told the drivers that they should drive no faster than the advisory speed and warned them, that a consequence of the Experiment the SWS would trip at lower overspeed than it had ever done before?

10) Had passengers and the staff been warned just before they boarded the Train, that if the ride was bad then it was indicating that their journey was less safe than was normal? Were passengers and staff told to raise the alarm, if the ride was bad?

11) Was there the right expertise available to decide whether to cancel the Experiment, in the event that the SWS tripped?

12) Was there sufficient expertise available to learn lessons from the first day of the Experiment? In the event of carriages coming back to the depot locked upright, had the staff been informed that it might have resulted from the Experiment? Did they know to inspect for carriage being locked up? Did they know to report incidents of carriages being upright to Her Majesty's Inspector of Railways? Did they know what actions they should take as a remedy before letting the Train leave for public services next day?

13) In the preparation, had the elite people who had promoted this Experiment been lined up for personal praise, ready for the Launch's success? Had preparations been made to blame someone, in the event that there had been bad ride?

However, in retrospect, these questions might have been irrelevant if the Experimenter had just pushed his ideas through, regardless. Perhaps he was insensitive to the spin off effects of what he was doing. Perhaps those in authority preferred to deal with him to lead the project and so decided to remove from scene those who would be more cautious and thought it was impossible to ruin the Launch.

8. Background to the day

In the excitement of a special event what happens may depend on the background. The new man would had little time to settle in and learn the background information. There were no established corporate procedures that applied to taking over work that had safety responsibilities. There was no library of corporate information or of lessons learnt. When taking his responsibilities he might have turned to the Chief Mechanical and Electrical Engineer (CM&EE), who had previously expressed his opinion.

There had been just one occasion when the new man had met with the author and he could have learnt from the author about how the tilt and safety warning system had come about and how it functioned. The author had had continuous responsibility for the design of tilt from 1973 when he started the tilt system design. From the start it had been determined that the prime function of the tilt should be to reduce lateral unbalance for the passenger. The author had been delighted to design the tilt system (see figure 8 and appendix 1). Jerks and lateral vibrations, especially when they are persistent, acting on passengers would fatigue their internal muscles and the person becomes tired, and the ride becomes uncomfortable. In this, the first design, these were very low in practice.

There was a background to ride comfort. It had been the Commissioning Team's opinion that the tilt system, which was based on from the Experimental train's system, had provided a lateral ride was better than for the conventional trains. Later during commissioning and before the Project's new change of direction, the Commissioning Team had changed their mind about the lateral ride comfort and decided that tilt control function should be further improved. Their concerns might well have been discussed at high levels, but may have been difficult to understand. It was left to the designer to interpret this demand. The Commissioning Team did not measure the lateral ride comfort but it became their opinion that it was to be improved. Dr David, (see figure 9), had set the ride comfort standard.

If it was night time and one could not see whether there was a curve or if one was seated passengers were unaware of tilt and the contribution that tilt made to their comfort. The sensitive instrumentation could not give any guidance in which aspect the improvement was needed. The conventional trains was thought to show similar vibration levels and higher levels of unbalance on curves and transitions, when compared to the Prototype ride. There was no time to make predictions on the computer or to do laboratory tests to test out a range of changes and discover their performance. It had to be improved in one change and quickly.

Learning to design the Prototype tilt system had had similarity to learning to ride a bicycle in that before going round the corner to the left the bottom of the bicycle moves temporary to the right first, before going to the left for a while. This sort of thinking enable the design to be improved, particularly for standing passengers. People might have attempted to describe the design thinking as though it was in three phases trying to simplify it for the audience in their own way. When those above the Project later decided to change the tilt system control from the precedent one, little did they know that this tilt control concept was going to be used in 2006 by the "Pendolino" trains on the West Coast Main Line. Both systems actively detected the upcoming corners using sensors and tilting appropriately.

i) Dr Boocock was promoted from head of mechanical design to become Project Manager. He was known for his sincerity, honesty, thoroughness, excellent logic and depth of knowledge.

9. The Train journey

On the appointed day of 7th December, the Prototype Train departed from the depot early for Glasgow Station. This time it was not the BR's commissioning staff in charge. Fare-paying passengers and invited passengers, boarded the Train at the station. The new decor and seats, the journey times and much more were ready for discussion and criticism. They did not know about the Experiment.

The Experiment would have changed how the tilt system functioned and introduced some unbalance to the carriages. If drivers and on-board staff had not have been warned that about the implications of the Experiment. This time the trips would occur at lower over speeds than it had previously done in commissioning. The SWS had tripped a number of times during commissioning and did again multiple times on the journey. When the SWS tripped, the passengers in the uprighted carriages might suffered bad ride for the rest of the day, just as some during commissioning staff had done previously. If the staff and passengers had been prepared, they would have followed the safety procedure and and have activated the emergency train system.

On the day of the Launch, passengers experienced bad ride. Passengers in some carriages suffered bad ride. TheLaunch was a mistake, but on that day it was not acknowledged by those in-charge. Those there may not have known why the ride was bad in some carriages on curves.

Revised on Thursday, 7 May 2020

10. The Train nearly overturned

On that fateful day, the Prototype Train there was a chance that the Train might over turning on curves with hundreds of passengers on board. The SWS would trip, warning of the high risk of the Train over turning.

Due to the recent change of the direction of the Project, it became possible that those in-charge might not been adequately aware of the risks that they were taking.

The SWS continuously measured the amount of unbalance which the passengers felt when on curves. The Experimenter aimed to make carriages unbalanced. Unbalance could be generated by, both the overspeeding on curves and, also the Experiment's unbalance, acting alone, or acting together would trip the SWS. Whenever the Train ignored the SWS having tripped, then passengers in their uprighted carriages would have suffered from bad ride. The bad ride had been intended to warn that the Train had been seriously over-speeding. In fact the author had designed it to indicate that the Train would had been within <u>16% of the over-turning speed</u>.

While the Experiment was being undertaken, the onboard staff and passengers should have been adequately warned about their risks and train in the emergency procedure. The Train should have been slowed down, or stopped as soon as it was practical to do so, whenever a SWS had tripped. The evidence suggests that some of those people who were standing on the platform at Euston Station waiting for the return journey, hoping for a four hour journey, boarded their carriage which had a tripped SWS and so already been locked upright on the journey coming south.

In the event that one or more carriages had its SWS tripped, then the Train should have slowed down, as was the safety procedure, to the line speed. However if the safety warning was ignored, then bad ride should have been expected. Overlooking a safety warnings, provided further opportunities for the Train to come ever closer to overturning, next time, and again next day.

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If BR's people in-charge had understood the above warning on that fateful day, the design afforded them various remedies. Without such people at hand, it might have been difficult for them to remedy it;

- The Experiment needed to be withdrawn, until it had been adequately commissioned.
- The drivers needed to been mandated not to exceed the advisory speed while undertaking public services.
- The train should not have been returned to service before the investigation had concluded that it would be safe to do so. It clearly was not safe.
- If the Train had overturned, many fatalities might be found in carriages locked upright, and the event compared to the Titanic accident.

11. At the end of the day

In hindsight, steps to distance the Launch from two staff might have resulted in freedom to experiment with the Launch. In the author opinion the Experiment and the Launch were was a folly that he could not have imagined would come about.

Before they made the decision to change the direction, success in the Project might have been worth more than £1bn to BR. If the Launch had been a success, then BR may have generated many social benefits and profits, and BR and BR become a major exporter of well engineered railway products. The decision to Launch the Prototype Train like that was a failure, might have resulted in a loss in the same order. So decisions that made the difference between success and Project's failure might, in retrospect, have cost billions of pounds. In hindsight it resulted in BR's reputation being severely damaged and it may have influenced BR's closure, which happened a decade later.

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In Britain nuclear power stations had been designed to be safe and the Concorde had been designed to go fast, but the public will remember that British Rail demonstrated that its new train was a failure.

CHAPTER 3 LAST MOMENT CHANGE

Contents

1. *In Preface*

In retrospect it is nearly impossible the imagine why there was the last moment change of direction. The reasons for it and the context are described.

Late in 1981, a senior member of staff from the Research organisation claimed that if nothing was done to the Prototype Train then passengers might suffer from travel sickness when the Train went into public service.

The claim generated fear in the decision makers, and it might have encouraged them to accept a last moment Experiment as a necessity. This chapter describes the context and the crucial time that followed. It would have seemed impossible that this scientist could take over the Project and to achieve this there was there was a charge of direction. The elements that contributed to it are describe, not as justification but as lessons.

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2. Misleading Evidence

The story starts with those higher up needing, imagination and experience, to become aware of what might possibly go wrong. Just as though there was an impeding accident, which could been avoid if you had known the hazards, so in this situation there was a need to know the uncertainties that threaten success. What was about to unfold on the Launch could not have been conceived when they made a decision to change the direction of the Project. The decision was based on misleading evidence because they did not manage the uncertainties in a systematic manner.

Sometimes it only needs one thing to be over looked and things to go wrong and the result in substantial damage. The following illustrates a process which could have been used while directing the Project: They might use their authority to check and make sure that they had become fully aware of the plan to accomplish success. They might use their authority to become aware of all the uncertainties to achieving success. They had the opportunity to take steps to learn about the preparations which would reduce each of the chances of things going wrong and become aware of the steps to monitor each uncertainty. They could have prepared ways to mitigate the harm and damage before the event, prepare for times when things had go wrong and so reduce the potential adverse consequences. This problem is illustrated by examples.

a. The first example: An early example was the misconceptions about the drivers' strike in1972 and 73. The Experimental train started to run in July, and then there was a delay of a year before it ran again. The blame, for the delay was presented as having been caused by the drivers going on strike. At the time the drivers had concerns about driving the new train. There were uncertainties about <u>seeing</u> signals, such those on curved track, when passed at higher speeds than normal. The drivers would have shorter viewing periods. Also the drivers had been suffering from bricks being lower from bridges. The windows had smashed in front of the driver's face. The drivers' union claimed that a second man should be provided when driving they began driving trains faster than 100 mph, until the safety issues could be resolved. It had seemed coincidental that BR announced that they had rejected a request from the drivers union at the same time as very poor vertical ride of the Experimental train had been discovered.

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b. A year after finding that there was a ride comfort problem, the major change to the suspension was completed on the Experimental train. The train was assembled at the same time as the drivers' strike was resolved. So in 1973, when the press blamed the delay on the Union, the author became suspicious that BR had used deception. The fix to the suspension problem improved the ride but the fix was unsuitable for later trains. Those at the bottom of the Project, who hoped to be selected to design the next train, were told not to tell anyone about the design fault having caused the year's delay. The author learnt to refrain from talking to his colleagues about such concerns as it would be seen as disloyal.

c. The first review of the Project was established: The staff, who were selected, lacked relevant experience of designing successful closed-loop feedback control systems in other similar innovative projects. For example, people from Hawker Siddeley Ltd, who had designed the innovative experimental tilt and brake control systems were not included in this review. Some of the reviewers had been involved in the Experimental train and did not want its design picked apart. Some were expecting to go on to design the next train. Added to these people, there were a few reviewers from the CM&EE organisation. Those who read the review might have expected it to have been a full representative account. The reviewers might have understate the number and severity of uncertainties that would be faced when designing the next train. Because the Experimental train done little testing to find its design faults. it was hard to be aware of all the uncertainties.

d. Convenient: These reviewers would have been aware that an application to the Government for funds to invest in the Prototype Train was in-hand. Good news about the prospects for next train might be welcomed by those in BR who were going to decide about the investment in the Project. The prevailing culture indicated that the chance of bad news coming out from the review and going to those in authority was slim. Also the chances of next the design of the next train being flawed might have been down played or even covered up as information is communicated up the hierarchy.

e. Lesson missed and reputations protected: The recent vertical suspension design fault might have been used in the review as an example of something learnt and give confidence to the investors. The failure to comply of a standard could have been an example of the importance of development. So the first redesign of the suspension enabled the replacement of the suspension. There had been an opportunity to learn from the fault by making a dynamic comparison. The vertical isolation performance of each suspension could have been tested in the research organisation's bespoke laboratory. A computer model had been used to predict the performance of the first suspension and specify the spring stiffness and other parameters for the designers. This computer model, which could have been used together with the laboratory data, been improved in its accuracy to predict the suspension's isolation performance. The review did not result in the development work which could have built up the ability to predict the ride performance.

f. Opportunity to downplay lessons: The experimental carriages had been designed within the Research organisation and the carriages tilted by rotating on a ball joint, one at each end of the carriage below the floor. In event of a single tilt failure, such during a loss of electrical power, passengers would suffer from high lateral forces, up to 18 degrees of unbalance on curves. It was imagined that failed carriage would have remain tilted hard over to 9 degrees to one side or the other, until the train returned to the workshops. The reviewers came up with the second major suspension design change to make the carriage upright when the tilt system turned off. The innovative suspension used for the Experimental train was not suitable for the design of the next train, so another innovative suspension with a number of uncertainties would be needed by the prototype. A draft suspension which would upright was drawn and presented to the review meeting.

g. More cause for concern: During the time that the review meetings were being conducted the author was led to think that he would be given the sole responsibility for the design of the tilt and brakes systems, if the investment was approved. He had previously done a failure modes and effects study on a fuel system for a jet engine, so he took it on himself to do a failure modes and effect exercise, while the review was taking place. He found another design fault, which if repeated in the next design could have been a high risk to the next train. It was found that in event of any of a large group of component failures, the Experimental train's articulated suspension could be derailed . If adjacent carriages had tilted in the opposite directions, the power of the tilt pack could yaw the bogie and make it derail. In the background the author was asked to come up with a suspension redesign to the problem which he had raised. The author's boss told the review meetings of the problem which was hard to understand. The Research organisation did a test which confirmed the hazard existed and could derail the Experimental train. The design of the Experimental train was changed to restrict tilt down from 9 to to about 6 degrees for safety as a quick fix. This fix was unsuitable for the next designs. As a result there was a third major function design change to the draft suspension for the next train. It indicated uncertainty to the author.

There might have been other design faults in the Experimental train yet to have been found. The train had been laid up for the previous year and only a few months of operating had occurred before the first review was concluded. This absence of experience might have enabled the reviewers to overlook problems which might be yet to surface.

The mood from the chairman of the review was not cautious, but bullish. People were led to expect that the next train design would be a copy the Experimental train as far as possible and that this policy would reduce the risk and even make it risk free. In practice this approach was soon seen as so inappropriate that it resulted freedom especially when designing the innovative features for the next train. This mood created additional uncertainties.

A policy came from the review claiming that all was well and there were no uncertainties left in the Project. This was a misconception. As a result, there would be no need to budget for any development work to assist designing the next train or, after the train was made to put right things right when they did not meet the practical standards. This denial of reality was thought to be just "Politics" and staff were left hoping that BR would provide help when it was needed.

This decision time gave opportunity for the author time to imagine what the dynamics were in communication. Some of those in authority, who were lacking the specific education and engineering experience, perhaps in patience to listen and they might not understand why their demands were not met. In the communication space and the pervading culture, any signs of anger may have been answered by cold hard technical reasoning. In hindsight, emotional pressure might be an optimised technique when organising well over 100,000 staff. The reality and hardness of engineering is less malleable and it often requires talents to listen to what might at first sight appear to be technical excuses. It is easy to demand that staff explain why something has not happened and to demand that excuses must be submitted on three lines of text, or not more than one A4 page. For example it might have been easy for an ambitious person to demand that a train shall get to its final station on time on its launch, but in some situations this assertive behaviour is counter productive. When "get the job done" is repeatedly top priority, it can lead to disasters.

h. Second review:This time lead by two Consultants from outside the railways. Unlike the staff doing the work, these two Consultants could communicate with those in authority. If, the Consultants had learnt about the previous review and above examples, then they might have indicated the need for a cautious approach in directing the Project. For example there had been uncertainty about the train's ride comfort, and the question that should have been answered, "Was it better or worse than other conventional trains at their 20% difference in speed?" Then again the Consultants had the opportunity to question the Prototype Train's ride comfort measurement. It was obvious that no one would want to endure four hours of poor ride quality and face another fours hours coming home. By accepting the refusal to measure the ride comfort and compare it to the ride comfort standard, it allowed the opinion of the Commissioning Team to become the arbiter. This opened up scope for misleading information to be circulated. The Consultants had the opportunity to bring attention of those, who directed the Project, the need to get the ride comfort measured.

i. The articulated suspension's designer for the Prototype Train may not have been adequately aware of the lessons from the Experimental train, because the suspension links, between the carriage and the vibrating bogie suspension below, were designed without making them adequately dynamically balanced. If David Halfpenny had been asked to work with the designer to create dynamic balance, it could have been achieved. As it was forces from the rotational and linear inertia in the links would vibrate the carriage, in direct proportion to the vertical accelerations coming up from the bogie below. If high up people were uninformed about this lamentable failure to learn, it might allow false confidence the grow.

j. This second review came at time when most people would have been aware that the Prototype Train had derailed at speed due to the screws. The Project had no trained staff to do develop work, which increasingly became needed. Even, after it was known that the axle screws had loosened, no development contract was not set up with outside organisations or internally with the Research or the CM&EE organisation. The Consultants would have had the opportunity to explain the risk of short fat screws and might have insisted that the Research organisation should undertake the development work before entering the Train into public services.

k. A skirmish concerning the loading gauge and about the myth concerning overcoming travel sickness, both of which came from the Research organisation, might have been influenced positively or negatively by the Consultants.

3. The Travel Sickness Myth

The senior member of staff from the Research organisation would have known that those in authority over the Prototype Train would be anxious about the ride of the Prototype Train. A mention that there was the chance of travel sickness ruining the Launch of the Prototype Train might have grabbed the attention of those at the highest level.

Without having the ride comfort measured the opinion of the Commission Team and those doing the instrumentation became authoritative. When the author had ridden on the Prototype Train, it had provided exceptionally good ride comfort, and over the first year of commissioning he had found only one person who had ever felt unwell.

In the absence of proper measurements, the author had paid great attention to people's accounts of their experience of riding on the the Train. There was just one member of staff who, on just one day, had felt unwell while travelling in the Prototype Train, during his months of commissioning, some time in 1980. The dedicated CM&EE instrumentation specialists and the Commissioning Team nearly lived on the job. This staff member, who was doing instrumentation work, was carefully interviewed by the author after he was reported as having been feeling unwell. The author wanted to know if there was anything to learn from him. He was asked if he had been had not been sitting down watching the horizon going up and down, or looking down from the window to the track below. The answer was , "No". He told the author that he had been working in an uncomfortable position, underneath a table for hours, doing some instrumentation wiring, while the Train continued to be tested. He told the author that he had not vomited. He concluded by saying that he might well have felt just as ill had he not come to work but been resting at home. He added that the ride comfort had been good. No-one else had experienced any unusual riding characteristics and no one felt travel sickness, that day, nor at other times during normal operations.

Travel sickness was known to be possible when people were particularly anxious or in bad health and occasionally when passengers were suffering from excess alcohol. The only way known to the author to make a carriage ride badly had been when the SWS had tripped and the Train continued on the journey ignoring the warning.

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A few months before the Launch, an ambitious senior member of staff from the Research organisation conceived an hypothesis about travel sickness. Had this senior man enquired about the chance of the Train overturning, he might have been learnt that the Train had a SWS which used bad ride as a safety barrier to the train repeatedly going too fast round curves.

There was things about the SWS that this senior man might not have known but could have have learnt about if he had asked appropriately for advice:

- Tripping the SWS was a last resort safety warning concerning the risk of overturning. It had been expected to happen on average about once in 100 years, which is far away from an every day event.

- During commissioning the Train over the past year, the SWS had tripped causing carriages to become locked upright. This tripping should have been confined to checking the compliance to the relevant SWS standards.

- The standard was designed to trip at 30% above the advisory train speed. Over-speeding was hazardous. Special precautions were necessary when testing this standard as the Train would have been within 16% of the overturning speed.

- If, during commissioning, the SWS had tripped unintentionally, then immediate action should have been taken by those in charge of commissioning. These safety warnings should have been dealt with in a similar manner to a Signal being Passed At Danger (SPAD). The train and driver should have been constrained, and an investigation report should have been made and issued for each such incident.

- If the SWS had tripped and bad ride experienced in carriages without the driver and the commissioning staff on board being made forewarned that it might happen and if they had not been trained in the correct procedure for such a hazardous situation, then the manager and staff should have drawn the attention of Her Majesty's Inspector of Railways to the severe safety incident.

- When the author had been told that the ride been bad during the commissioning, he thought that the bad ride had only occurred during deliberately commissioning the SWS. The ride had been bad enough for the Commissioning Team to call for a ratchet to be designed, as a modification, to lock carriage upright to make the ride less bad. The Commissioning Team had insisted on the change even though it delayed the Launch. The author expressed his concern to the commissioning man, who had decided that the ride must be improved post tripping, that he may have mis-understood the hazardous situation. The author told the commissioning man that if a number of carriages had come upright on a journey, then it would not have been caused by many tilt packs being unreliable at the same time, but that it would have been caused by a single event, namely the Train had been severely over-speeding round curves. Nevertheless, the design change was done to order. When the SWS was tripped it locked carriages upright for the rest of the day.

- If, the commissioning manager had not reported the bad news properly to those higher up in the hierarchy, then the on board staff had told the bad news to those doing similar work in the Research organisation.

- If the Research organisation did not find out the safety facts about the SWS and did not understand the miss-management, then there had been a space for the travel sickness myth to be created.

- If the drivers lacked information about the permissible margin, for overspeeding beyond the advisory speed while in service, then they may have thought that, when going into public service, it would be safe to go round curves at the same speed as they had during commission unless told to the contrary.

4. *The Attack*

The Project Manager, Dr Boocock, was known for his sincerity, honesty, thoroughness, excellent logic and depth of knowledge. The author became suspicious when Boocock told the author to go to a meeting with a senior member of staff from the Research organisation. The author imagined that this senior member of staff might try to expose a fault with the tilt system, but the author was confident that it was as near perfect as practically possible (see Appendix 1). If the tilt performance was to be fully demonstrated, then the author was confident that this senior man from Research would be delighted at its outstanding excellence as other people had been before.

The best way to demonstrate the wonder the tilt had made, that had occurred to the author had been standing behind the driver on the curvaceous part of the route around the border between England and Scotland. It had been a delightful experience and one that the author would like to have shared with this senior person. Over the previous five years, the author had represented BR and given presentations where people had asked about tilt and sometimes wanted to tell the author how they thought that tilt would worked or how they thought tilt should work. Often comments and recommendations had been interesting, but nothing had prepared the author for what was to follow. At this meeting there was to be no opportunity to explain how the tilt system had been designed or how it performed to this man.

The arrangements were that the author should meet this senior member of staff from BR's Research organisation at Euston Station. On arrival, the senior scientist immediately told the author that he had no interest in listening to the author's opinion, and he had brought the author there to listen to his two guests from RAE at Farnborough. The Prototype Train had been ordered to come to Euston station for him to demonstrate the tilt performance to his guests. Having heard this, the author became aware that the meeting might have been arranged at high level for a hidden political agenda. The author continued to listen. The senior member of staff from the Research organisation set about protecting his personal status, and he showed his unalloyed enthusiasm for a modification to be made to the Prototype's tilt system to over come a travel sickness problem. He told the author that his Experiment was scientifically necessary to validate a hypothesis which he had created. He claimed that if his hypothesis was correct, then some unbalance would be necessary to prevent passengers from feeling travel sick. This lead the author to deduce that the two guests might be regarded as selected to endorse his "scientific approach".

On time the two invited guests from Farnborough arrived on the platform and the four of us were ready to embark. However, the Prototype Train had not arrived. We waited awkwardly and filled in the time with small talk until the Train arrived and then we boarded it. The senior BR scientist spoke as though he had personal contact with those at the top of BR and that he had been asked to speak for them.

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The Prototype Train's reputation for time-keeping was poor and when it arrived at the platform, it was substantially late. The Train's lateness would have already caused disruption to the dense traffic coming south along the West Coast Main Line (WCML) from Glasgow to London.

The consequence of this delay was significant. Originally the plan would have been to have a large headway for the Prototype Train in order to demonstrate high speed comfort and tilt. The Train would need to go about 20% faster than the other trains on the route. However, as a consequence of the Train's lateness, a number of revenue-earning non-tilting passenger trains had left Euston Station, ahead of the Prototype Train. To overtake a queue of slower trains is much easier done by a car on a motorway than on a railway! It was obvious that this demonstration had failed as there would be no opportunity to go faster than the conventional trains ahead. When the Train eventually set off, the senior scientist speaking for BR appeared unaware that the Train was going slowly. The Prototype Train was being kept by the signalling system at a safe distance from the train in front, with a gap of about two minutes.

Passengers in the conventional trains ahead would have experienced no unbalance on straight track, and little or none on the curves because the railway track was canted. This cant had been achieved by having the outer rail higher than the inner rail on curves. Cant at $4^1/_2$ inches is conveniently is the same as $4^1/_2$ degrees of cant, with the track gauge set at the Stephenson gauge namely 4 foot $8^1/_2$ inches, i.e. 56.5 inches between rail heads.

The BR scientist presented his hypothesis to the aeronautical experts whilst sat in a perfectly tilted carriage, with no unbalance while travelling in excellent comfort at slow speeds. Not a drop of tea or coffee was spilt nor did the surface liquid move when the Train went round curves. At these speeds, the tilt movements were imperceptible to passengers.

The host was undaunted by being unable to demonstrate the need to overcome travel sickness. He drew his guests' attention to the view out of the window pointing out that the horizon went up and down; but that was as it would have done in the conventional trains ahead of us. He asked them to look downwards and watch the ground passing by quickly. It was an uncomfortable view. The author felt increasingly uncomfortable as he became fearful of the implications of the host's hypothesis. Everything left the author doubting that BR's scientist had understood the Train. In his presentation he had appeared to have been unaware of importance of the risk of the Train overturning and there was no mention of the function of the SWS.

About twenty minutes out of Euston Station, the host quietly told the author to give him guidance on whether the tilt had been working or not. Without hesitation, the author quietly assured him that tilt had been switched on and was working! The host could not claim to have gained relevant personal experience of travel sickness on the Train. The host advocated having tilt modified to create unbalance for the passengers. The author noticed that the host was unable given his guests a comparison between "as is" and "as could be when modified for his Experiment". When preparing for the meeting, it would have been relatively easy to have changed a carriage to have partial tilt, but he not made such arrangements. The host only suggested that passengers might feel travel sick on the Train if it had been at its full speed and asked his guests for their comments. Pilots fly public services trying to minimise lateral unbalance to achieve passenger comfort.

Ensuing conversations politely assumed that everyone had understood the finer points about ride comfort, tilt, cant, unbalance (referred to as side-slip and cant deficiency). There had been no agenda and no text about the BR's scientist's Experiment on which to base a discussion. The author was horrified to think that those at the top of BR might have asked this man to decide for them whether to modify the tilt system as an Experiment to validate his scientific hypothesis. There was no-one present to input caution, no-one there with experienced travel sickness on the Prototype Train, nobody from the Commissioning Team and no medical input, nor was there a railway staff's point of view and no safety representative available at this meeting on the Train. Any discussion that there might have been was overtaken by a single-minded advocate for his hypothesis. Then the meeting returned to small-talk.

The author had been taught to fly and while enjoy performing aerobatics during his year long course at the College of Aeronautics. T he author had learnt that travel sickness was associated with the amount that internal muscles had been used to stop the stomach moving about within the body. When these muscles get tired, then the natural remedy is to reduce the mass in the stomach!

The host returned to his proposal and asked whether the guests supported using his partial tilt idea. The guests politely by-passed his question asking for support. Clearly none at the meeting had suffered from travel sickness that day or any other day on this Train. When pressed again, one of the guests said something to the effect that "if it was really important for BR to know whether the host's hypothesis was sound or not, then, in the end, the only way to find a robust answer might be to try it out in an experiment and ask passengers if they had felt travel sick". It seemed that this was important to the host because he ended the meeting by asking for the Train to be stopped for us to depart at the next convenient station. The selected guests certainly did not suggest that the host's Experiment with partial tilt should be first undertaken on the general public at the Launch of the Train.

At this crucial time for the Project, just before the Launch, the host had represented BR and he alone would be reporting back to people high up in the hierarchy of BR. The author was aware that after the meeting the host would be able to describe what he had achieved that day as it suited him.

In making their top level decision about the hypothesis and the implementation of an Experiment, it might have reminded them of the claim that Trains could collide with one another on the West Cost Main Line. The author went home wrongly believing that the Experiment would not be attempted, and if it was, then it would be certain that it would be rejected during commissioning.

5. Safety Checks

Those, who authorised the change of direction from the Research organisation to become in charge, had an opportunity to undertake last minute checks to make sure that the passengers would be safe. A couple of months later there was a heavy responsibility on many people that day. These elite BR people would have known that they had made a substantial change and changes can cause in an increase in risks. Top of their concerns might have been the risk of the Train overturning on curves and any thing that might have increased the chance of overspeeding.

The SWS had been designed to reduce the chance of the Train overturning. It would have been obvious to railway people that with tilt, the speed round curves was faster, so if the Train overturned there might be hundreds of fatalities. These responsible people must have made their decision to make changes while being aware that the change might bring uncertainties. It would not have happened but, if the author had been asked and the politics were sorted out, then the author could have exposed some hazards and if there were discussions he might have raised some of the following considerations, before leaving for his training course:

1. The decision makers, who had a couple of months before authorised the change of direction, the CM&EE and other senior people, could have asked:

   1.1. about the handover. Was it was fully satisfactory, and had it addressed the safety issues concerning the risk of overturning and the SWS in particular? In detail, the following sort of questions might have been appropriate.

      1.1.1. “Had the SWS had been fully commissioned?”

      1.1.2. “Was the bad ride always caused by the SWS system having been tripped carriages so they came upright?"

      1.1.3. whether the Experiment would increase the incidents of the SWS being tripped and bad ride?

   1.2. about the passengers and the train crew. Had they been made properly aware of the possibility that the ride would be so bad that it would cause passengers to feel travel sick, as had been claimed by the Research senior scientist a month or so before? Alternatively, had they been made properly aware that they were taking part in a scientific Experiment, one which might cure the Train from the travel sickness, but, if it did not work it, then was likely to lead to bad ride and an increase of the risk of overturning?

   1.3. whether the history of the experience of operating with uprighted carriages, which had presented bad ride comfort during commissioning, been investigated and understood correctly as a safety warning.

      1.3.1.“Had Her Majesty’s Inspector of Railways been informed properly about the risk of the Train overturning?”

1.3.2. "Had the Commissioning Manager overlooked the risk of the train overturning on curves when they were taken beyond the advisory speed?"

1.3.3. "Had someone been responsible for reporting the change to the tilt control system and for advising the Her Majesty's Inspector of Railways of the effect of the change on the safety warning?" In detail ask "Who was responsible to check that a process similar to the SPAD was applied whenever there had been a SWS trip?"

1.4. whether, in the event that the Experiment failing to prevent passengers from suffering travel sickness, there was someone, who was responsible for removing the Experiment and reverting the Train back before taking any more public passengers.

2. The man, who had only a few weeks ago been given responsibility for the Project, and so the Prototype Train's safety might have needed to ask:

2.1. whether the Commissioning Manager and his Team knew whether the SWS was compliant to the standard (see Appendix 2). Some simple question would be:

2.1.1. "During commissioning how had the Train's over speeding on curves been managed and who was the responsible person?"

2.1.2. "What was the closest to overturning that the Train had been, during commissioning?"

2.1.3. "What was the highest percent beyond the advisory speed on a curve that the Train had been?"

2.1.4. "How much over the advisory speed on curves did the SWS trip?"

2.2. whether the management knew what would be the effect of the modification on the level of overspeed when it would trip. "Had commissioning had been completed after the modification and before the Launch?"

2.3. whether the drivers had been reminded that, especially on this maiden journey, the Train should not exceed the advisory speed. It was physically possible for the Train to be driven so fast into a curve that the Train could overturn on the curve. "Had the drivers been cautioned that they must avoid a Titanic scale of accident, even when told to catch up on the timetable,?"

2.4. whether all the drivers knew how close to overturning the Train had been previously. "Had they been told what tolerance on the advisory speeds was acceptable?"

2.5. whether the drivers were aware that in the Experiment, the Train was significantly more likely to trip the SWS during his Experiment than it had been before the modification. "Had the drivers been told that they might have previously taken a curve at one speed during commissioning without having tripped the SWS, then in-service at the same speed during the Experiment, the SWS would trip?"

2.6.whether the drivers and on board staff had been trained to follow the specific procedure to deal situations, when one or more SWS had tripped and carriages had been locked up right. "Had the drivers during commissioning been told that if the SWS had tripped carriages upright then Train had been about 30% overspeed beyond the advisory speed on curves then it would have tripped at about 16% below from the over turning speed?"

2.7. whether all the staff had known the procedure for checking carriages to determine any carriage had been locked upright and what to do when they found one or more locked upright.

2.8. whether the management knew that, if the SWS was ignored, carriages would have bad ride. "Had the management known that, if the SWS was being systematically ignored, theTrain would be put at higher risk of overturning than for conventional train?"

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3. The proposal

The senior member of staff from the Research organisation would have known that he was being put in a position of trust. When he was appointed, he had had little reason to have known about the improvements made away from the Experimental train to designing the Prototype. He would have been expected to take on the full responsibility quickly, but his handover may have been unsatisfactory. For example, he might not have known that

- the tilt system should have been about 1,000 times more reliable than the Experimental train, and so it was very unlikely to fail on any one journey and extremely unlikely that two tilt systems would fail on the same journey.

- the Train had a SWS. It was based on measuring the unbalance in carriages. Hence when the Experiment added unbalance then it more likely that the SWS would be tripped.

- the SWS trip would reset automatically when the pantograph was lowered on entering the Depot.

When the Experimenter considering making his claim, he might have remembered the cover ups and the poverty in the vertical communication. He may have remembered when he had ridden on the Experimental train before it was known to have been at high risk of derailing. He would have been on the Experimental train when it had been operating for a short time before it was modified to make it safe. After the senior scientist learnt that the Experimental train had been at risk of derailing, he might have remembered this ride experiences with fear and come to think that he had felt travel sick. Later he had ridden on the Experimental train after the train had been modified to make it safer by making the tilt only partial. Eight years after the modification, he might have imagined that he had felt less travel sick when the train had been in the safer condition. He might have made a misconception.

If this new man's hypothesis had been based on these old subjective memories, then, when he might have mislead himself and those elite decision makers. They should not

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have been deceived by such unreliable evidence. They should have demanded that the average ride comfort obtained from four hour journeys between London and Glasgow be measured and compared to the ride comfort for the conventional trains doing their five hour journey and to the standard. This could have been obtained using the Jacobmeter both for normal operations and for abnormal times including when the SWS had tripped. Without such an assessment, those making their decision lacked a sound basis for believing that passengers might feel travel sick. At this last minute the elite people in BR seemed to have trusted that this man and his Experiment more than their staff who had been working for them over the last decade. In retrospect it seems that at the last moment they might have been so convinced that they removed two staff members from being involved and overlooked the potential consequences of the Experiment being a failure.

If the Experimenter had wanted to make a quick test, it might have taken only a few days to determine whether there was a travel sickness problem with the Prototype Train and possibly confirm that his proposed modification could make passengers less travel sick. A carriage could have been changed over night to partial tilt for testing his Experiment for the experts from Farnborough and the Commissioning Team on the next day. This comparison method could have enabled passengers to make a direct comparison in the difference between full tilt and partial tilt in carriages during a journey or two between London and Glasgow in exactly the same conditions as for the Launch. If this had been done, then any bad ride might have come to light and been recognise for what it really was. But the experimenter, who was a senior scientist, implied that he preferred to find evidence only on the biggest of stages, from passengers, on the Launch in front of the press. It would have been good if the tilt had worked as it normally had done and if the Train had been driven according to the adsorb speeds. in the event the passengers did not like the bad ride on the Launch and back in the depot that evening, they had not made appropriate arrangements.

On the day of the Launch, the SWS tripped indicating that the Train was less comfortable and less safe than for conventional trains as described in the Chapter 1. The next day they repeated the folly.

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4. *In Summary*

BR's Research organisation took an opportunity to demonstrate its confidence in their understanding of ride. It was claimed that an experiment was necessary to overcome a travel sickness problem. The creator of the proposal was put in charge. The last moment change of direction was predicated based on a misconception.

The Launch resulted in passengers feeling travel sick. BR continued to demonstrate their failure day after day.

CHAPTER 4 A SKIRMISH

Contents

1. In preface

The Launch was preceded by a skirmish which had the effect of undermining peoples' confidence in the Project. After a year of commissioning the Train, this skirmish took place. It was not the first time that a story depended on misconception. The author was a player in this story. If the timing and the means of delivery had been aimed at damaging the Project's reputation, then it could have been seen as successful by those who initiated it. The story illustrates a lack of trust and a poverty of communication.

It was a few months before the Launch that a misconception about the chance of the Prototype Train hitting other trains on adjacent tracks (see figure 10) was raised by the Research organisation. It was widely reported. The "APT - The Untold story" on page 100 indicates that there was a press release in February 1981 and I quote "*Public acknowledgement was given of the risk of 'hard-over' tilt failures putting a rainout of gauge in certain conditions and BR had hitherto been unable to accurately assess this.*" On page 101 he records that "Intensive running commenced in June [1981] between Glasgow and Preston and all went well for several months." It took until October [1981] for agreement to be reached between the Chief Civil Engineer and HM Railway Inspector concerning APT's kinematic envelope and clearances on the WCML. 'Normal' running was now sanctioned. The author did not know about how it went at high level.

The issue had originated with the Experimental train which had been designed with a tilt pivot below the floor, so, as a result of any of a number of single failures, the carriage would rotate fully over one way or to the other side. In contrast the Prototype Train was designed so any of this sort of component failure had occurred, it would result in carriages coming upright. An upright carriage was obviously inside the C1 gauge as shown by the lower image but in a failed hard over position was questionable.

The vulnerability of the Prototype train and the political manipulation by the powers above the Project Team were exposed first hand to the author.

2. *The stage was set*

In 1981, the Project Manager, Dr Boocock, told the author to represent the Project at a European railway conference, together with a representative of the CM&EE's organisation, the late Dick Ribbons. Ribbons was one of the engineers who made HST a success and he had a good reputation. The author had done many lectures publicising the Project but never been asked to represent BR at any similar conference before this occasion.

Dr Boocock had detailed knowledge of the Prototype Train, and this knowledge had been built up during a decade of working on the Project. The author respected Boocock for his good reputation and honesty. The author did just as Boocock had asked him to do, but this instruction left the author wondering whether there was a hidden purpose come from above Boocock. Before setting off for the meeting, the author had been told that he should be prepared to give a presentation about the Prototype Train's tilt system and its track forces which was easy for him and her looked forward to the opportunity to meet with his professional peers. When the author set off he was pleased to have been allowed to do this talk and took it to be a privilege.

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3. The trap

When at the conference, Ribbons warned the author that he had been told to ask this question in the meeting, “Could a Prototype Train hit another train coming in the opposite direction in any extreme situation; and, more precisely, could it possibly infringe the loading gauge when tilt fails hard over?” The author was take by surprise and began to fear that the question had originated as a conspiracy between the Research organisation and the CM&EE and was using international forum for their own purposes.

This was more than a century of history attached to understanding the loading gauge. If a wagon had been overloaded then its load might hit objects and it was practice that a wagon would pass through a gauge to test if it was small enough. If a wagon or a train was out of gauge it would be normal practice to prevent collisions by stopping the wagon or train from going further on the railway. The Experimental train had sides that were a 9 degrees from vertical and this had been done so that, at even when at its maximum angle of tilt, it would be within the loading gauge. However in a failure situation resting at 9 degrees, due to unbalance force on curves and dynamic deflections, the Experimental train could have occupied a little bit more space.

If the Prototype Train occupied more space than the other trains that had, in the past, been using, then there was a risk that the Train might hit another train on the track beside it. Tunnels, platforms and other structures are placed so that they do not become impacted by the trains that pass by. But this was not the situation.

The Prototype was designed with many differences to Experimental train. It had a SWS in every carriageway which was new to those who had not involved with the design. The differences would not have been obvious to a casual observer but the functional differences were important for the ride comfort, the Train’s safety and the gauge clearances round the Train.

- The Prototype tilt packs were designed to be easily replaced at the depot (see figure 11). The quality called reliability had to been improved to about 1,000 times more reliable than the Experimental equipment (see figure 12). To achieve the reliability there were three hydraulic valves in each pack: one valve that controlled the rate of tilt was wired into its carriage as one channel; the next valve should have been same and wired into the second channel which should be totally independent to the first channel; and lastly the changeover valve should have been separately wired into the SWS instrument. If the wiring had made a mistake and used any component in common between these three, then the reliability would be lower than had been specified.

- The mechanical tilt pivot of the Experimental train was replaced by links in the Prototype. The Prototype Train was designed so that the tilt's failure mode was to have carriages uprighted.

- If the Train had severely over-sped, then it would have been detected by the SWS and it would result in carriages becoming locked upright.

- In the event that the electrical supply to one of the Prototype tilt systems was turned off, then its carriage would become locked upright. The carriage would be well within the gauge when uprighted.

- In the event that the Train's main supply had been turn off, all the carriages would become locked upright. This happened regularly when the Train entered the depot and the pantograph was lowered, then later, on restoring the main supply, all the SWS trips would be re-set, the tilt systems would come alive and fully functional.

The Research staff were familiar with the Experimental train and its tilt failure mode of falling over one side or the other. The Research staff would have not been so familiar with the SWS and might not have been aware of its function. Unlike the Experimental train which initially had 9 degrees of tilt, but due a safety issue could only use 6 degrees, the Prototype Train had the full 9 degrees of tilt and did not have a loading gauge problem. The Prototype Train, when working normally and when in its failure mode was uprighted, and was well within the loading gauge. Previously the author had seen a loading gauge drawing and had been told that it had originated from the Research organisation. This issue was not part of the author's presentation.

The presentation went well, until Ribbons asked the question in front of the audience. The author felt as though a guided missile was about to destroy his reputation and the Project, but confusingly Ribbons appeared unsteady in its delivery. The issue was irrelevant to the audience at this international railway conference. The author was suspicious that Ribbons had been what was required of him. Perhaps the CM&EE and the Research organisation had planned to create this situation.

Ignoring the question or brushing it aside was not an option for the author. To say “NO” and go into open conflict with Ribbons would have exposed, what seemed to the author to be the deceit, which lay behind the question. The author was aware that many BR staff were determined to conserve the status quo and had naturally aligned their views to resist the Prototype Train because it was seen as BR’s prime agent of change. The audience could have been alerted to the conflict within BR. If the author said “YES, if it was to be held hard over” it could be minuted and probably be reported back to the people in BR who could terminate the Project.

4. The answer

Standing there at the conference the author felt that this situation might have been contrived and he knew that he was vulnerable.

If the author found himself saying “YES,” it was what the BR staff, who had had enough of cut backs and reorganisations would have wanted him to say. For example some design staff from within the CM&EE organisation had taken to attacking the author verbally at lunchtimes in the works canteen. In addition, some staff in the Research organisation had lingering resentment about their signature project, their most successful achievement, being taken from them.

When it came to deciding whether to give a “yes” or “No” answer, the author felt passionately involved. His answer might be “used” to facilitate killing off the Project (his baby, BR’s icon of change). There was only one truthful answer. To his extreme frustration, he had to answer, “Yes, if it were ever to become held hard over”.

Those who had authority over the Project, the Research organisation and the CM&EE should have communicated with Her Majesty’s Inspector of Railways and between them they might have recognised the Prototype’s SWS had been design to be like a guarantee

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against the possibility of the problem occurring. The Train was not out of gauge but if they thought it might have been, then the damage had been done and it would have influenced the important decision makers (see page 83 of "A promise unfulfilled").

The author was left wondering if he would ever get the opportunity to meet these high level people and be given the opportunity to explain the misconceptions. At that time he felt that if he had he been aware of an alternative job, he would have been keen to leave BR. Little did he know then that much worse was to follow when he would loose control and a last moment change would be imposed.

5. *In summary*

Those in BR above the Project, who were opposed to the Prototype, might have used the minutes of the international railways meeting to prove that the Prototype Train was out of gauge. With this misconception, they might have hoped that the Train would have been declared to be unfit to operate on BR routes. This might have slowed up the pace of change for a decade or more.

Shortly after this event, Dick Ribbons went out of his way to tell the author that his happiest time was when he was at the author's much lower level in engineering and that he was currently less satisfied in his current higher level job. Years later, after his funeral, his wife kindly told the author, what a favourite person the author had been to her husband. The author imagined that Dick Ribbons would have liked to tell the author this, himself, in respect of this loading gauge matter. The author had liked him and did not bear any resentment towards him.

Seven years before this skirmish, David Halfpenny and the author had been responsible for the Prototype Train's loading gauge calculations and this hostile claim was felt a personal attack on our competency without giving us any means to defending our work. again it had weakened the trust in the APT Project and the Prototype Train.

CHAPTER 5 THE AFTERMATH FOR THE AUTHOR

Contents

1. *In Preface*

When the author was away on a 12 weeks residential training course, his staff were misled to think that he would not be returning. His reputation was damaged and people had been mislead into thinking that the Prototype Train's tilt system, which he had designed, had frequently failed in public service, leaving them to think that this had caused the Prototype to ride badly. No component in the tilt system had been found to have failed.

2. *Preparations for Returning to Work*

While on a course at the BR staff college at Woking, the author had taken it for granted that he would be welcomed back to his office by his friends and colleagues. Those in authority, who had sent him on the course would have known when he was due to return to work. Perhaps before, or perhaps after, making this investment in the author, BR might have some plan of succession. The author was left wondering what he might find when he returned. The course gave no training which had equipped him to work in dark deception and tangled misconceptions.

That morning the author rode his bike as usual for the few miles from Darley Abbey to the Railway Technical Centre in Derby. This was the first time that he was to meet any of those who had said “Good bye” to him three months before. During these three months he had been fully occupied with the course. Before he left his responsibilities had been for up to two dozen staff and contractors, but the course was for those holding or about to hold responsibility for over 1,000 staff.

He arrived at the bike shed in a happy state of mind. He thought that if the Train had done well enough, he would have continued working on the Project on the fleet of trains. On the other hand, if the Launch had revealed some faults, such as screws loosening and brake dragging, then he pondered which of them would be top of his list. He expected those in authority may have decided that the Project urgently needed development work to be carried out to overcome non-compliances. Perhaps they would have reviewed the Train’s long-standing problems and concluded that more development work should have been carried out by the Research organisation. The author wanted to replace the short screws with long ones so that they would not come loose on the axles. The next design fault to be remedied might have been the brake’s unreliability. Like the Experimental train’s brake before it, the Prototype Train’s brake had needed to be tested on the purpose-made dynometer in the Research laboratory, but this time the laboratory work had been omitted and may be he would asked be setting it up. The author’s design achieved the Prototype’s requirements using, amongst other things, a bespoke floating ball valve. If the brake had dragged in service, and the author would have expected every part to have been carefully inspected. He guessed that the floating ball might become damaged in brakes that had been dragging. Additionally in the author’s mind was the first lesson from the Experimental suspension and it needed to be applied to the design of the Fleet suspension by designing suspension links that were dynamically balanced.

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3. The Day of Change

The author walked into the drawing office, just as normal, smiling to those who looked up, and he went into his personal office. There were three or four people crowded in this office, together with large drawing boards. There was no space for him. They let him know that they and the others in the main office were no longer his staff and the Project was suspended. The author felt physically sick. His now ex-staff were clearly embarrassed at the sight of him, standing there, looking lost.

This was a personal shock; sudden and severe. He was in a nightmare situation. His friends kept their eyes down. When asked, they told him they had to be loyal to their new boss who had ordered them to work in that office.

One of them told the author that bad ride had let the Train down and tilt had been blamed. It was said to have failed in a way that had resulted in bad ride, and that it had made carriages sway from one side to the other. Suddenly, he felt that he had to depart because he could no longer stand upright. He asked himself, 'Was I about to be sacked today?' No David Boocock for him to turn to for help; he learnt that Dr Boocock had been replaced by the man with the hypothesis. No work was available for him to do.

The manager of the "Bogie and Running Gear" team had become line manager for the author's staff and the many contract staff. A decade or so before the shortcoming of BR's bogie designs had held back British Railway from being able to compete with the motorways. It was not until the Research organisation modelled the guidance control mechanical system that designers could foretell when a suspension would be stable. This 'bogie' design manager had been known as hostile to the APT Project. The 'bogie' design manager was now in a strong position and could have mock and ridiculed the author. The 'bogie' design manager did not contact the author on his return. The author had never met the 'bogie' design manager's boss, the CM&EE, and the author knew that he would not even be permitted to get an appointment to meet the CM&EE. People kept away from the author as though he was invisible. He stopped going to the works canteen for lunch.

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4. The Deception

It had become clear that those above the author in the hierarchy had deceived his staff by saying the author might have left the Railways. This deception had been awaiting his arrival. After leaving the offices that morning, the author walked for a mile, then cried his heart out. He sat on the ground trembling for about an hour before returning to get on his bike and go home.

The author was no longer included in their world. There were no meetings to attend. A world of comradeship had built up over the previous decade, yet the author felt that everyone was turning their face away from him, in loyalty to their new boss. He had no boss, no work to do and no one to turn to. He was, in effect, being told that he was a nobody and nobody wanted him around. He had been privileged to be sent on the course, but there was no protection for him from those who saw themselves as having been passed over by the selecting of the author to attend the course in preference to them.

For years the author had been spending more time working on the Project than he had with his family. He hoped that the Train would have been a success, as much as anyone else. He had to tell his wife of his personal failure. Each month the author had to pay the mortgage in order to keep the family together. He was no longer employable. Anyone could ask him how he came to be blamed for such a mistake as to cause BR's downfall. This shame continued to haunt the author for another decade. There would be no single sentence that he could say in his defence and people had little appetite for more than one sentence.

5. The Result

Next day the author went back to his office. Before the end of the week he had sat there on his own for hours on end with nothing to do. It was clearly a punishment. This isolation continued for about six months before he became mentally ill and unable to go to work. There were many "<u>if only</u>" issues to ponder on.

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During the decade working on this Train, there were many periods when the author loved doing his job. He had become recognised as a master in tilt and brakes which could reduce the cost of intercity transport. The author had to take English "O" level five times due to dyslexic tendencies to become a member of the Institute of Mechanical Engineering. Later it was an honour to become a Fellow of the Institute of Mechanical Engineering (F. I. Mech.E). Despite this degree of recognition, there was no protection from the punishment.

THE APPENDIX

Preface

1 From the start the Experimental train's tilt control system had appeared fully satisfactory. After the Commissioning Team had gained much practical experience of the Prototype Train, they wanted it to be even better and that was achieved. There was no ride comfort measurement to back up the opinions of the Commissioning Team. However a late modification, which came from the Research organisation, was proposed and applied.

2 The Safety Warning System (SWS) was designed to provide warnings about the Train overspeeding on curves. The Experiment's modification to the tilt control system contributed to the SWS being tripped at speeds lower than it had done when commission. When this warning was overlooked, it resulted in low safety and often low comfort.

Appendix 1 Tilt development

1. The Experimental train's tilt control

The tilt system was intended to automatically reduce lateral unbalanced and so improve lateral ride comfort in carriages.

The way that this was to be done on the Prototype Train was to adopt the core control elements of the Hawker Siddelely Ltd tilt control system which had operated on the Experimental train. With little evidence from the Experimental train before the design of the tilt system and and some relevant information coming experiment exercise using the POP train, this had been reviewed and considered to be satisfactorily. It was adopted into the design of the Prototype Train.

1.1. In the Hawker Siddelely control system design, the speed of the movement of tilt was in proportion to the amount of unbalance detected in the carriage. It resulted in no steady unbalance when the train was on straight and on curved track.
However on the transition between these there was a small unbalance. This was barely perceptible (about 1 to 2 degrees unbalance). Seated passengers din not notice it but standing passenger's were aware of the beginning and end of the transitions such as when going from straight to a curved bit of track and vic a versa.
Note; for those educated about control systems either in man management, the phase lag of the closed loop control system lagged dynamically by 90 degrees or more, behind perfection.

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2. *The Prototype Train's tilt control improvement*

About a year into commissioning had started, there was a call to improve the lateral ride comfort by using the tilt system to make the improvement. It was considered true that the Prototype Train had already provided a lateral ride comfort that was better than conventional carriages travelling on the same journey, so long as the Prototype Train was being operated no faster than its advisory speed.

A new concept for the control of tilt was created.

2.1. The designers of this improvement established an ambitious set of new standards,
(a) on straight track the effect of turning tilt on, had been to deteriorate the ride comfort, but it shall be changed so that the effect of turning the tilt on will make the ride comfort better.
(b) furthermore there shall be no unbalance on transitions such as between straight and a constant curve.
(c) in addition, standing passengers shall be balanced at all these times. In other words, standing passengers will not feel the need to grab the seat backs when the Prototype Train travels at its advisory speed on transitions.

2.2. These three improvements were achieved with only one modification. The creative thinking that became known as the precedent tilt control system. David Halfpenny as contributed to the concept. Neil Wilson made a vital contribution to the detail designs. It was hoped to be designed in a month or so, and be supplied soon after.

2.3. The precedent control system was considered by the Commissioning Team to have been improved on straight and curved track, and especially around transitions between these two states. Evidence of the success was said to be there on straight track, curved track, on transitions was hard to detect especially while seated, but it was only evident to standing passengers who were almost unaware of their Train tilting. The tilt could go from straight via a short transition to curved and canted track within 5 seconds. The commissioning instruments had previously found a lag behind what was perfection on the transitions, but then they noticed there was none with the new tilt function. The tilt rate was similar to a second hand on a watch. The electrical work may have needed to be improved when there was time available to obtain the required reliability.

2.4. Those who should have been delighted by the achievement seemed unimpressed. The center of gravity stayed in the central position within an inch or so and so within the lateral bumpstops.
A simple illustration the tilt function is that it was like having a pole balanced vertically in your hand while being driven in a bus round its route. To balance the pole one would need to look forwards to anticipate what the bus was about to do by looking ahead.
As another illustration is to imagine cycling fast round a 4 inch wide prescribed route. This required looking and thinking ahead to guide it, while at the shorter wave lengths steering it to maintain full balance.
Before entering a transition going to the right, the railway carriage's floor under a standing passengers would need to be moved ahead of the curve, starting by going to the left for a short while.

This improvement was achieved quickly and cheaply without extra research expertise and without access to computers. It was the best tilt control system in the world.

3. *The Research organisation's proposal*

A senior research scientist proposed to modify the design of the tilt control system by deliberately introducing <u>unbalance to the passengers in the carriages</u>. He wanted his experiment in place for the Launch

3.1. The tilt control system was to be changed to move only to a portion of the correct tilt angle, leaving the remaining portion for the passengers to feel unbalanced.

3.2. This Proposer had told the author about his new concept which he said was based on his scientific understanding as expressed in an hypothesis. It seemed that he had interpreted it as being an"equilibrioception" problem. To the Proposer, it provided an explanation as to why railway passengers would prefer to experience unbalance on curves and not suffer travel sickness.

Appendix 2 Safety Warning System

1. *Intentions*

The Safety Warning System (SWS) was intended to give warning when the Train became unduly (within 16%) close to overturning.

The SWS was intended to give a warning when passengers had suffered from unbalance in their carriage. It would give a warning when the Train was severely over-speeding round a curve about 30% faster than the advised speed for the Train. Every severe overspeeding should have been monitored and reported to the Her Majesty's Inspector of Railways.

2. *Design to be reliable*

There was a well developed system that warned the driver in the event that the train might go going to pass a signal at danger. If a train passed a signal at danger it may become at a high chance of crashing. This safety warning device was known as the Automatic Warning System (AWS) and there was one in each train. When the AWS was tripped, there was a warning in the driver's cabin and if ignored it could put the train's brake on. The AWS was held to be adequately reliable for the task. So the designers of the SWS intended it to be no less reliable than the AWS. In the design of the Prototype Train, there was one independent system SWS in each carriage. That meant there were about 10 SWS's per train, so the reliability of catching a severe overspeeding on curves was expected to be many times better than one AWS.

When a SWS in a carriages had tripped, the Train should have been slowed down by activating the emergency train alarm. The driver, on being made aware of the emergency, would chose exactly where to stop so as to avoid the Train stopping in a tunnel. If a Signal was Passed At Danger (SPAD) then there was a set procedure to be followed and this type of procedure also was needed in the event of the Train had passed a curve at such a severe speed as to trip the SWS. The Train should not have gone into public service without this type of procedure being established first.

Even more severe was the case when the Train had tripped the SWS and it did not return to the conventional line speed but continued at speed. In this situation the people in the carriage, which had been ratcheted up to the upright, would feel bad ride. When the Train had finished commissioning it would be the only way to make carriage ride badly.

If a number of tilt system components failed on one tilt system on the same day then it was possible for this carriage to be tripped uprighted by the SWS and channel be reset at the depot that night. So long as the depot inspections had been carried out properly that each tilt system failing would be expected to occur about once in 100 years. The chances of two carriages tilt systems failing on the same day would be remote, unless the Train severely over sped. If more than one carriage tilt system had been damaged then those carriages could become locked upright.

3. Potential development

The SWS might have benefited from being developed and integrated into the Train communication system. When the SWS automatically uprighted and locked carriages upright, the driver was expected to be made aware of a SWS having tripped and so slow the train down to conventional line speed. as it was designed this relied on the staff and passengers alerting him by the Train emergency system. It was a weak link. It was chosen in part to avoid the displeasing drivers. It was known that moves to make the Train "automatically" driven would be miss-timed. However, if after experience the need was established, there was potential for development to aid safety:

- Development might have been explored making advisory speed being automatically drop the speed down to the line speed for the rest of the day, in the event of a SWS trip.

- Development might have been explored making the train speed be automatically dropped to the advisory speed for the rest of the day, in any event of specified margin for overspeed had been exceeded.

4. The function

overspeeding round curves

In designing of the Train for tilt, there were some fundamental design issues:

- The speed that the Train would overturn on a curve shall be no lower than it was for the conventional non-tilt trains. The centre of gravity was designed to be no higher that for a conventional carriage.

- Tilt, whether working switched off, or when working, shall not significantly make the overturning speed any different. The tilt was designed so that it rotated around the centre of gravity of the carriage.

- No single component failure should be able to make passengers unbalanced by more than 9 degrees and once that amount of unbalance occurred then it should be reduced and limited to 4½ degrees. The effective pivot was formed by a pair of inclined links so that when tilt was off it passively returned the carriage to being like a conventional carriage.

If a driver was asked to catch up time, he might have wondered just what the margin between the advisory speed as shown in his cabin and actual overturning speed. “Was the margin 5% overspeed beyond the correct speed, or as much as 25%?” The Commissioning Team had been in a good place to make it clear that the train should not exceed the advisory speed after the commissioning had ended.

warnings

It had been the Commissioning Team's job to check the SWS performance for operating safely on curves. Testing at speeds around 30% beyond the advisory speed would need precautions and extreme care because it was hazardous. If the severe warning had tripped carriages upright, it meant that the Train had been within around 16% of the overturning speed.

The frequency of a train at these seriously overspeeding speeds was at the time of designing expected to have been no more frequent than a SPAD, and this meant about once in 40 years per train.

Here are some illustrative warning speeds for a frequently recurring curve; a curve limited to **90 mph** for conventional passenger trains on the WCML.

a) The Prototype’s advisory system could have indicated **115 mph** on this curve. If the Train went at or below the correct speed, the passengers would have zero unbalance as designed.

b) The first trip of the SWS was in a carriage at 4 degrees of unbalance which, on this illustrative curve, would have been an overspeed of 16 mph. That’s a Train speed of **131 mph**. The first trip was designed to change the tilt channels and so advise the depot staff. The staff were needed to record each of these low level trip event, investigate the causes, monitor and keep records so that Her Majesty’s Inspector of

Railways was properly informed. During the commissioning this low level overspeeding should have been tested to determine its compliance.

c) The second stage was the severe trip which was set at 9 degrees of unbalance, meaning tripping at an overspeed of 34 mph above the correct speed on this curve. The speed to activate the trip would have been at **149 mph**. The severe trip was designed as a last resort to advise the driver to take action to slow down to the conventional line speed for the rest of the day. The Commissioning Team should have tested the SWS to determine the compliance.

d) The third step, automatically, followed the second. The trip resulted in the carriage uprighting and it staying there for the rest of the day. Staff should monitor and record each carriage that had its **tell-tale ratchet engaged** thereby holding the carriage in the upright condition. Each of these severe trip events should be investigated to find the cause or the causes, and the HM Inspector of Railways to be informed as soon as it was practicable.

e) The Train would <u>over turn</u> on this sample curve when it goes round the curve at 59 mph overspeed beyond the advisory speed. Whilst this overturning speed of **174 mph** was above the ability of the Prototype Train, there were many curves that were tighter and so on these tighter the Train had sufficient power to overturn itself, if it was not restrained.

6. *Communication.*

The SWS trip could turn off the electrical supply to the carriage's tilt system, and this would trip carriage upright. When a carriage uprights and becomes like a conventional carriage, the staff and passengers should activate the emergency Train system. The role of reporting this event to the driver should have been tested by the Commissioning Team. So long as there was no severe overspeeding, nor tampering with the tilt control system, carriage uprighting should have only occurred extremely rarely.

To reduce the chance of the serious warning being ignored or under reported a tell-tale sign had been designed to lock carriages uprighted and it was to persist locked upright for the remaining part of the day. The ratchet device was commissioned and found to hold the carriage upright. Following the fitting of this ratchet device the Train should be inspected frequently to check that no ratchets were engaged, starting on a daily basis and building up confidence and to reduce the frequency. Every time the ratchet device was seen to be engaged it should have been reported to Her Majesty's Inspector of Railways.

When a severe over speed had tripped the SWS and disregarded then the normally excellent ride comfort would become bad when they go round curves, until the Train becomes correctly slow down and kept to the conventional line speed. At conventional speed these upright carriages would ride comfortably like a conventional carriage. Obviously, failure to respond to the SWS was hazardous as the SWS should have been seen as a safety barrier to protect from a multiple fatality event.

7. Conclusion

During commissioning the Train had become used to being driven at speeds which had been tripping the SWS, so unless told otherwise the drivers might repeat the same severe over speeds.

If drivers were unaware that the tilt systems had been damaged or tampered they would need to be told that if the drivers repeated the same speeds (as they had become accustomed, before the change to the tilt system) then due to the experiment that changed the tilt system, the SWS could trip at slower speeds than it could have done previously.

If the Train was driven above the advisory speed as shown in the cabin, perhaps due to timetables and the excitement of the Launch of the public service, as for the Titanic accident, the SWS might trip to protect safety. If the drivers had been specifically forewarned not to overspeed and properly informed about what might happen if they did not obey, then it might have reduced the chance of the SWS locking carriage upright.

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A combination with these features would increase the chance of the SWS tripping the severe warning. However the Experimenter was in the position to direct the drivers to drive the Train at the advisory speed only and, if it was part of his experiment, to look out for SWS trips.

If the SWS was overlooked by those who controlled the Train, then bad ride could be anticipated, that is, unless the Train was no longer exceeding the conventional line speeds. If this severe overspeed was permitted by the management, then the drivers might wonder what margin of overspeed was appropriate. To illustrate the situation with an exaggeration, it might have been possible for a driver to experiment with the margin of overspeed in attempts to oblige orders to arrive on time.

Appendix 3 Chronology

CHRONOLOGY

1. The Experimental train, 1971 - 73

The Project's Experimental train was being made about the same time as the first HST. Both had been predicted to have stable lateral suspensions using pioneering work done in the Research organisation. From November 1970 when I joined BR, I was part of a substantial organisation within the BR Research organisation. The development staff (see (figure 13) and a design organisation (see figure 14) had been built up for the Advanced Passenger Train Project.

1.1. Progress so far
Trains in Japan had already gone fast and were stable operating on fairly straight track. In France and elsewhere there were attempts at high speed and tilt.

1.2. Hawker Siddeley Ltd had designed the Experimental tilt and brake systems. Their work proved in principle that both were viable options for the Prototype Train. However, with the arrival of the Experimental train, BR Research organisation ended the contract with this design company so I did not meet them and the technology was not passed on for the Prototype systems.

1.3. Much of the Experimental train had been designed within the Research organisation. The core feature was the suspension and it was hoped to provide ride comfort when operating at 20% higher speeds than the conventional.

1.4. After a few days of operating the Experimental train, we were told that there was a drivers strike. This lasted for a year. The train restarted with the swinging arm suspension having been replaced by a more conventional looking one. Before much experience had been fed back to the designers, the focus went on to raising investment for the next train. I felt that I had contributed little to the Experimental train and was on the bottom rung.

1.5. First Review

This took place in 1973. The Experimental train's achievements together with the draft design layouts for the next train were reviewed. If the review was successful and the money invested for the next train, then I was led to believe that I might be lined up to design the tilt and brake control systems. I was told that the job would be just a matter of changing the pipe layout and packaging for two packs of hydraulic equipment ignorer for them go under the carriage floor. I was interested in, but not not involved in, the review. It was led by Mike Newman. We were told that it had ended in poor relationships between the Research scientists, the engineers from the CM&EE managers and those who were forming the team to design the next train. After the review, I was told that Dr Boocock, who had been head of the Mechanical Design, emerged as the Project Manager for the Prototype Train.

1.5.1. The first review recommended that the tilt failure mode be changed from hard over to an upright condition. If electrical power was turned off in the Prototype then the carriage should not fall over to be 9 degree to the left or the right but be designed to passively fall upright to become like a conventional non-tilt carriage. There was a major design change during the review. A pair of inclined links replaced the ball joint between carriage and suspension. There was yet another fault found in the suspension design which resulted in another major change to draft layout drawing of the articulated suspension to make in less likely to derail.

1.6. After the first review, the designer noticed the tilt pack had to be substantially changed to make it about 1,000 times more reliable for public services. In addition there was a new need for a system to protect the train from over speeding round curves was known but not specified by the review. Also the brake energy capacity and cooling power had to be doubled for public services. When we noticed these issues, it increased our work some five fold. The pressure was on us to come up with ways to overcome these difficulties without increasing the time to delivered finish drawings, the mass and the space occupied in the Train. Time was precious - more pressure, for months on end.

2. *The Prototype design, 1973 to 1976*

During this period objects were drawn and issued with information that enable the parts to be manufactured. Parts were delivered for assembly into making the Prototype Train. New standards emerged to co-ordinate the efforts in creating the innovative features.

2.1. Ride comfort standards

2.1.1. The most important aspect of the suspension was the ride comfort which would be suitable for passengers on the WCML. The standard for lateral ride comfort was specified by the Project Manager as not more than 0.2 m/s^2 laterally and 0.3 m/s^2 for main-line track at speed of 244km/h (150 mph). The suspension designs should designed to deliver ride comfort that complied. Work in the Research organisation defined the spectral power density for the track roughness specified and issued the data (spring, papers rates and more) for the suspension that would they thought provide the desired insolation. The head of Mechanical Design was convinced that his staff could design suspensions according to this data.

2.2. Tilt reliability standards

2.2.1. The tilt designer decided that the tilt system shall not fail to perform more often that about 1 in 100 train years. This implied that each component, which had the potential to cause the pack to fail, had to have been previously used in a large number of similar application, (such as aircraft flight control) and had accumulated enormous working hours together with proper records of their historic reliability. The numbers had to be large to achieve certainty with narrow bands of confidence bands. We used these numbers to predict the reliability. We built up failure modes and the fault trees based on these historic hydraulic component reliability figures. Even with the best possible components in the world, the required reliability for the tilt system could not be achieved with a single channel control system. The reliability of a two channel control system was predicted to meet the standard but it had to be a special design. The tilt system did not have three channels (as did the Concorde flight controls). A spirit level was used to switch channels, see appendix 2. A tilt error (in other words a lateral unbalance) could, if it was above a certain level, indicate that there was a fault and change the channels.

2.2.2. To maintain the components of the tilt packs working reliably, it was essential to manage the oil cleanliness. The designers specified the level of cleanliness which would have been high by aircraft flight control standards on which historic reliability data was based. To make sure that the oil cleanliness standard would be monitored, the tilt designer decided to design and provide a special microscope and slide preparation set of equipment, in the form of a bespoke portable trolley. The quantity and size of the contaminants in the oil should be regularly monitored while in the depot. In addition if the level of cleanliness was not adequate the trolley was equipped to be able to flush the hydraulic pack until it was clean enough. These trolleys were designed, after all else, and was only just delivered to the maintenance depot before the Train was completely assembled.

2.2.3. When the Train was assemble and commissioning was beginning, a few of my design staff, who were familiar with the tilt system, were seconded to the Train's depot in Glasgow to help them understand what they were expected to do for tilt. They passed on their know-how and techniques for using the bespoke trolley to the depot staff and also to the commissioning staff.

2.2.4. On 9th June 1980, the short fat screws (see figure 15) that held the axle together had loosened to such an extent that it resulted in the Train's derailment . The author was there and it was reported by the press. No change was made to the design before the Launch. Each screw was being frequently checked and when a screw was found to have loosened it was replaced. The Train was less safe than it could have been. It was a some time after the Launch, when the Commission Team were no longer involved, that a development exercise was set up to find a remedy. The author, who had learnt as an apprentice that blind tapped holes and short fat screws, were forbidden in aircraft design. Months after the Train had been withdrawn from public services, the design fault was remedied by development.

2.2.5. The fundamental description of the tilt system was presented to the Railway Division of the Institute of Mechanical Engineers at Derby eventually on 15 December 1977. At the time of publishing the paper the tilt system and its dynamic performance was considered fully satisfactory.

2.3. Standard for the Protection from overturning on curves

2.3.1. The designer decided that the SWS shall be no less reliable than a traditional Automatic Warning System (AWS). When the traditional AWS was tripped, and if it was not acknowledged, then the system applied the Train's brakes to reduce the risk of Train collisions. Once the SWS was triggered, the Train should be slowed down and a discipline similar to the SPAD procedures adopted.

3. The commissioning work, 1979 to 81

- On 12 February 1979 the Train was marshalled.

- On 23 April 1980 that the driver strike ended (see page 90 of The Untold Story) and it was May that operations and commissioning fully began.

- On 18 April 1980 the first Launch date (9th June 1980) was made known but then the Train derailed at speed with Ian Campbell on board.

- On November 1980 that the in-house news paper expressed the corporate confidence.

- On 7th December 1981 the Train was Launched, and Commissioning had ended shortly before that.

When the Train was being commissioned between April 1980 to November 1981, we were asked to improve the vertical ride comfort. The unbalanced links between the carriage and the suspension again transmitted the mid to higher frequency vibrations. It was too much work to balance the links so the links remained unbalanced before the Launch. The second vertical ride problem was solved by creating an extra reservoir to make the suspension even softer and improve the damping. This change was almost invisible and it had a minimum effect on the progress of building the trains. For the third vertical ride problem we made dampers that kept the ends of carriages vertically together, and this kept the ends of adjacent vehicles at all train speeds. At each change the Commissioning Team was satisfied and then later asked for more improvement.

The dragging hk and friction brakes, which was probably the result of the floating ball becoming worn, and so leaking, remained undeveloped before the Launch. There was no frequent replacing that valve to prevent the hk and also as a result of that the friction brake over heated and both the hk and as a result the friction brake could become damaged during the Launch.

We, as designers, received less and less reports from testing for conformity to standards. As the months passed we were told that, we would be informed as and when we were required us to do something. We would have liked to have been better communication during the following events:

3.1. Tilt control system (see appendix 1)

3.1.1. For quite a time (perhaps the first 12 months of commissioning) the lateral ride was considered by the Commissioning Team as completely satisfactory.

3.1.2. After about a year later the Commissioning Team became increasingly anxious and demanded that the lateral ride be improved. This occurred when we had expected that the Train would in public service. There was no ride comfort reading that had been taken to support this change of their opinion. Bearing in mind the political constraints, the Project Manager asked the designers to find and make changes to the tilt control system to meet the need expressed by his Commissioning Manager. This new system was quickly conceived, designed and made. It became known as the precedence control system.

3.1.3. Precedence was not obvious. Here is some detail about the tilt system as we designed it in Summer1981 for those who are technically minded and who have imagination: sensors were placed ahead of the carriage. It would detect upcoming corners before the carriage had entered the curve. The sensor caused the carriage to tilt before the carriage actually came on to the beginning of the curve, like a bicycle. If the curve was going to the left, the carriage floor need to move to the right and this tilt action would start moving the top to the left because the floor went to the right. As the floor had moved to the right a standing passenger would start moving just as the carriage enters the start of the curve. If one looks at a bicycle's tracks in snow, the dynamic behaviour can be caught and studied at leisure. Shorter wave changes were for standing passenger balance while longer wave changes were for guidance.

3.1.4. After the precedent control was fitted, the Commissioning Team were again satisfied that the tilt system had performed as they needed. It had been comfortable for seated passengers before but afterwards it was amazingly good, even for standing passengers.

3.1.5. The Experiment aimed to test an hypothesis that claimed, by introducing some unbalance on curves, passengers would not be come travel sick. So it needed the tilt system to be changed so that the tilt angle was less on curves. If it was to be applied it needed to be tested by passengers, and the first opportunity was at the Launch.

3.2. The Safety Warning System, see appendix 2.

3.2.1. The SWS was designed from the very beginning of designing the Train. The lower setting, of two, was to alert the depot that marginal unbalance had occurred. So a marginal over-speed on curve or a small tilt performance errors could trip would be detected and investigated. The second stage warning would warn that a severe overspeed event had occurred on a curve. This alert could upright carriages for the rest of the day. The SWS should have been commissioned to demonstrate that t it performed correctly, and tripped at the correctly at right level of overspeed on curves.

3.2.2. The Commissioning Team correctly attributed carriages coming upright to the correct functioning of the SWS having been triggered. This trip indicated that there had been unbalance.

3.2.3. As a result of multiple experiences of bad riding in uprighted carriages, the Commissioning Team demanded a ratchet device to be designed and fitted to lessen the severity of the bad ride in uprighted carriages. The ratchet device, which locked carriages upright, was designed within a few weeks in the summer of 1981. It succeeded in improving the comfort at the conventional (non-tilt) at line speed, but at the advisory speed the ride in upright carriages was bad, as required to effect a warning. The advisory speed indication was not strengthened before the Launch.

3.3. When the Project Manager, Dr Boocock, asked the author, "who do you recommended to look after the mechanical design team while you are away on a 12 week residential course at Woking?" I replied that the Commissioning Manager should be offered it. This would give him direct access to information about the mechanical systems. In the unlikely event of anything untoward cropping up, this direct line of communication might be important. Dr Boocock agreed. At the time, my recommendation was not based on the Commissioning Manager's ability to do his own job or to manage my designers, but rather, that they could help him to learn about these systems and assist him in his work. I had not had direct communication and he was not available to handover to him directly.

3.4. In November 1980 those in authority had expressed their hopes for the Prototype in the House Newspaper (see figure 16). During the year before the Launch the Commissioning Team had been anxious and due possibly to their lack of confidence, competence and lack of development work, they had delayed the Launch.

3.4.1. Just before the Launch a managerial change was made. Dr Boocock, the Project Manager for the past decade was replaced.

3.4.2. A month or so after the change of Project leadership, the Train was launched into public service.

4. The Launch into public service, 7 December 1981

When I left for the training course I was confident that, if the Experiment was done, it would have been adequately commissioned beforehand. It was beyond my imagination that those in authority would fail to see the above defects that I had seen. It was inconceivable to me that they would test an experiment on the day the Train went into public service.

4.1. Before the replacement of the Project Manager, and I left for the 12 week course, the situation had been seen by me like this:

4.1.1. When carriages had been travelling at the APT advisory speed then the ride of the Prototype Train was fully comfortable.

4.1.2. When the Train was operating at about 25% faster round curves than the advised speed during Commissioning conditions, the ride had been poor. But if the over speed was more than 30% overspeed then the SWS would trip and would carriages correctly upright. Every unplanned incident of this severe overspeeding should have been treated like a SPAD.

4.2. The result of the Research organisation's Experiment (see figure 17), might have been as follows:

4.2.1. The effect of the unbalance created by the experiment would have fooled the trip of the SWS to operate at less than 30% overspeed beyond the correct speed. The more that the modification created unbalanced, then the lower would be the overspeed at which the SWS would trip carriages upright.

4.2.2. Instead of the chance of a carriage coming uprighting being once in a hundred years normally, the Train would have many carriages tripping during the experiment.

4.3. Had the modification been removed after the testing, and the Train driven at the advisory speed, then the SWS should not trip and carriages should not have tripped uprighted.

4.4. If the Train was driven with lateral bad riding, then there was a higher risk of the train over turning.

The train appeared to behave like this the day it was tested. The experiment continued unabated next day.

5. The end of the Project

5.1. In the absence of David Boocock and myself (respectively the Project Manager and his head of Mechanical Design), BR reduce its access to sound advice about what to expect from the modification which came from the Research organisation.

5.2. Eventually BR rightly cancelled the Prototype Train service, based on its failure to provide a proper service.

5.3. The blame for the bad ride was wrongly placed on the tilt system which was not prone to the system's failure and no component was found to be defective. The Experiment has not been blamed for it. The tilt system had been designed by me and those who worked for me.

5.4. Much had been achieved through the Project and its Prototype Train, which if it had not been for the disastrous Launch, would have contributed to a fleet of low cost and shorter journey time trains.

5.5. Following this disastrous Launch of the Prototype, BR and Britain's railway engineering, suffered.

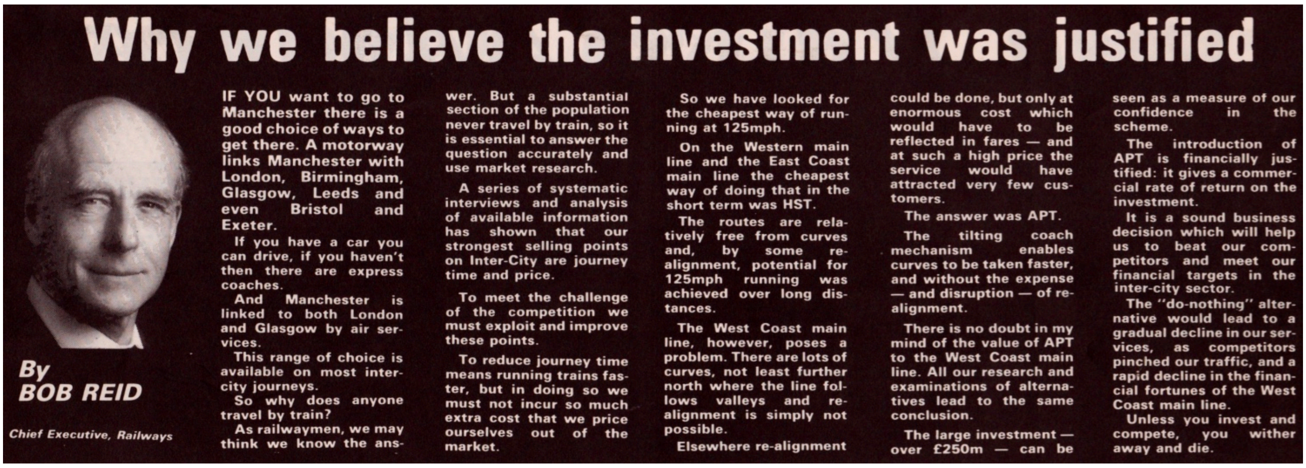
THE FIGURES

Contents

The figures 2, 9 and 10 are taken from "Railnews, the official monthly newspaper of British Rail, 222 Marylebone Road, London NW1 6JJ" November 1980 issue, which was a year before the Launch.

Revised on Tuesday, 25 February 2020

Figure 1 The Chief Executive's message



Why we believe the investment was justified

By
BOB REID

Chief Executive, Railways

IF YOU want to go to Manchester there is a good choice of ways to get there. A motorway links Manchester with London, Birmingham, Glasgow, Leeds and even Bristol and Exeter.

If you have a car you can drive, if you haven't then there are express coaches.

And Manchester is linked to both London and Glasgow by air services.

This range of choice is available on most inter-city journeys.

So why does anyone travel by train?

As railwaymen, we may think we know the answer. But a substantial section of the population never travel by train, so it is essential to answer the question accurately and use market research.

A series of systematic interviews and analysis of available information has shown that our strongest selling points on Inter-City are journey time and price.

To meet the challenge of the competition we must exploit and improve these points.

To reduce journey time means running trains faster, but in doing so we must not incur so much extra cost that we price ourselves out of the market.

So we have looked for the cheapest way of running at 125mph.

On the Western main line and the East Coast main line the cheapest way of doing that in the short term was HST.

The routes are relatively free from curves and, by some re-alignment, potential for 125mph running was achieved over long distances.

The West Coast main line, however, poses a problem. There are lots of curves, not least further north where the line follows valleys and re-alignment is simply not possible.

Elsewhere re-alignment could be done, but only at enormous cost which would have to be reflected in fares — and at such a high price the service would have attracted very few customers.

The answer was APT.

The tilting coach mechanism enables curves to be taken faster, and without the expense — and disruption — of re-alignment.

There is no doubt in my mind of the value of APT to the West Coast main line. All our research and examinations of alternatives lead to the same conclusion.

The large investment — over £250m — can be seen as a measure of our confidence in the scheme.

The introduction of APT is financially justified: it gives a commercial rate of return on the investment.

It is a sound business decision which will help us to beat our competitors and meet our financial targets in the inter-city sector.

The "do-nothing" alternative would lead to a gradual decline in our services, as competitors pinched our traffic, and a rapid decline in the financial fortunes of the West Coast main line.

Unless you invest and compete, you wither away and die.

Why we believe the investment was justified

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further north where the line follows valleys and in practice re-alignment is simply not. Elsewhere re-alignment could be done, but only at enormous cost which would have to be reflected in fares - and at such a high price the service would have attracted very few customers.

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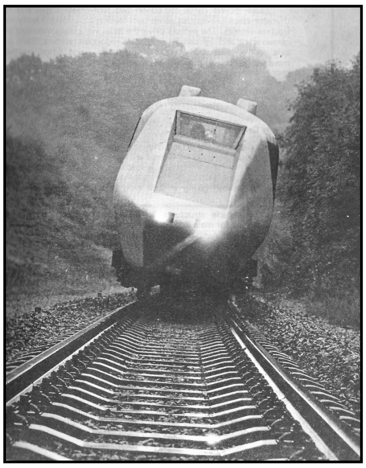
By Bob Reid
Chief Executive, Railways

As printed in Railnews APT Souvenir Extra

Figure 2 The Experimental and Prototype windscreens

The Experimental train's windscreens could withstand objects hitting them at top speed

The Experimental train



The Prototype Train had a tough screen too. There was provision for a second person to sit in the cabin.

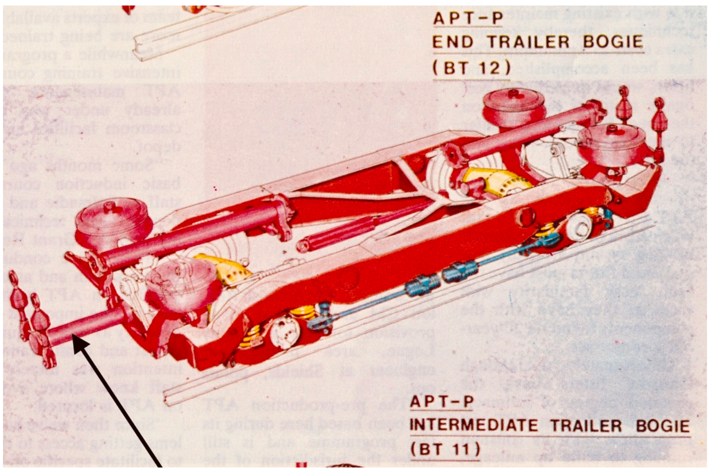
Figure 3 Shorting out the suspension

The Experimental articulated suspension had links that were not dynamically balanced so transmitted higher frequencies through them.

Here one of the POP train carriage structures is tilted one way, and the other was rotated the other direction. There was a hidden fault in the suspension.

The swinging arms (shown by the black arrow) had to pitch and its inertia transmitted forces up to the carriage. It had to be replaced .

The Prototype Train had poor ride at first. The airspring design was redesigned. With technical help from David Halfpenny, Alan Price drew the new parts. These parts were fitted into the carriages and were almost invisible.



This Prototype had this large anti role bar (shown by the black arrow) which had to pitch when linking the bogie to the Prototype carriage. Unless the two ends went up and down together, inertial forces were generated by pitching so transmitting forces at both ends. Inertia resisted pitching accelerations. If the train was going fast over a lump on the top of the rail, then large forces, from the bogie frame vibrating up and down, could impose vertical forces on the carriage.

Revised on Tuesday, 25 February 2020

Figure 4 Sir Peter Parker

"She'll be a world beater' Here is something to show we still lead the world in scientific and engineering innovation. Something to offer that is the best of its kind. Something for British Rail and Britain to be proud off.I welcome the APT for that reason, but also for many others. This pioneering development is proof of what the imagination and strong nerve that it takes to keep the railway running. And it is in that sense of past achievement, current performance, and the future that APT will take us forward. Yes, its many new features are in themselves advances that show BR's world ranking knowhow in rail technology. Its speed is revolutionary and breathtaking, and its performance is without precedent. Already the whole concept is beginning to catch the public imagination: it is drawing enquiries from other railway administrations all over the world who may want to adapt its features to their own needs. But it is not simply a technological extravaganza. It is an essential component in our strategy for success in the 80s and 90s and into the next century. It is not an extra, it is essential if we are going to modernise our network in a way that will leave an efficient legacy to our successors. Expenditure on the APT is, as we see it, essential for the future intercity service, that's the point. We need a decision on the APT as soon as possible so that we can get on with the backup works to Launch this elegant machine into service up the West Coast mainline by the mid 80's. That decision— and the big decision on more electrification for BR— are glittering prizes for the whole railway community to work towards. That we can do, if we show we are giving service throughout the system which is value for money. There is an interdependence on all parts of our great service to the public in winning our case for more investment. I congratulate all those who, with skill and stamina, have striven to put APT into revenue earning service. We are in to a new dimension of speed and change and flexibility - let's make the most of it.

'She'll be a world beater'

HERE is something to show we still lead the world in scientific and engineering innovation. Something to offer that is the best of its kind. Something for British Rail and for Britain to be proud of.

I welcome APT for that reason, but also for many others.

This pioneering development is proof of the imagination and strong nerve that it takes to keep the railways running. And it is in that sense of past achievement, current performance, and the future that the APT will take us forward.

Yes, its many new features are in themselves advances that show BR's world-ranking knowhow in rail technology. Its speed is revolutionary and breathtaking, and its performance without precedent.

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— Sir PETER PARKER
Chairman, British Rail

Peter Parker Chairman, British Rail, As printed by Railnews APT Souvenir Extra

Revised on Tuesday, 25 February 2020

Figure 5 Jacobmeter

Mike Jacobs designed this meter.

This portable instrument would detect the vibrations both, up and down, and also sideways. It modifies the vibrations giving less weight to some and more to others to reflect how humans feel the vibrations. For example humans are less sensitive to walking frequencies such as 1 cycle per second (as we walk around this frequency) and are much more sensitivity to lateral low frequencies, as in sea sickness. The readings are the root mean squared (RMS) of the acceleration after they have been weighted to represent the amount of body activity to keep us all together. When the muscles get tired, the human body becomes more sensitive.

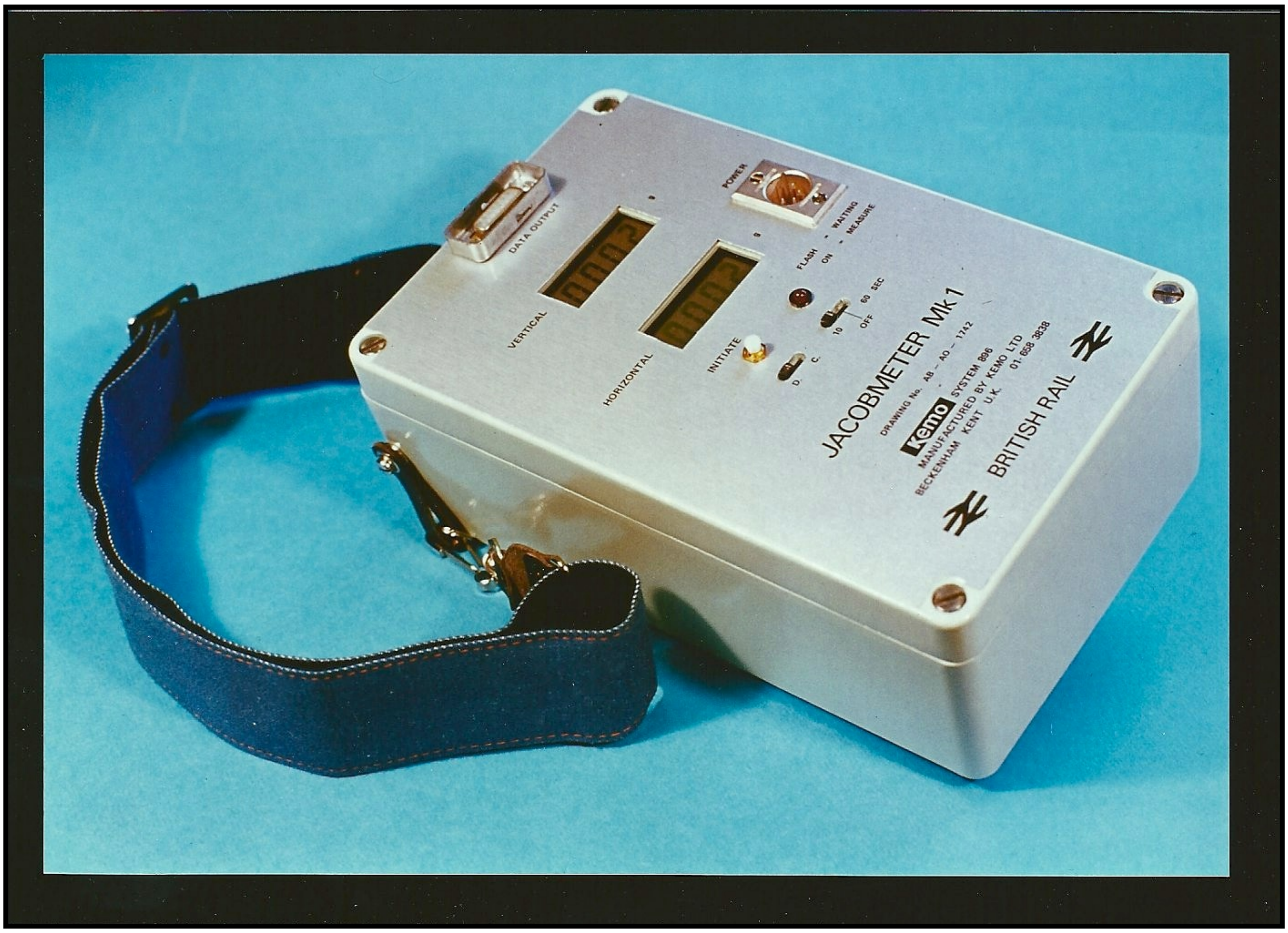

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Figure 6 Driver and C-APT

For the driver C-APT provided with a continuous indication of the advisory train speed at all times. The advisory speed was usually about 20% faster than the speed that the conventional train were driven at. The distances between signals remained unchanged so the Prototype had the stop at a faster rate of retardation.

For the man in the cab

C-APT ensures safety at any speed

SAFETY has been paramount in the minds of the designers of APT.

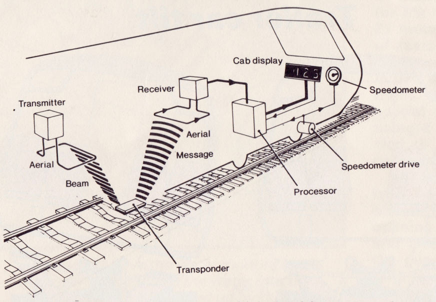
A revolutionary aid to drivers, based on micro-processors, is the C-APT, a speed limit advice mechanism fitted in the cab.

The men who drive APT will also drive conventional trains over the same route, yet APT is allowed to exceed speed limits by a substantial margin.

To prevent confusion, speed limits are displayed automatically in the APT cab.

C-APT leaves the driver firmly in control of the train, but gives him a digital advance warning on his desk of the higher APT speed limits.

On the track, beacons, called transponders, store permanent speed limit information in coded form. Sealed in glassfibre re-inforced cases the transponders, containing electronics and a loop aerial, are waterproof and need no external power supply.



The transponders are powered by a radio beam transmitted by a loop aerial under the front of the train. A coded message is re-transmitted by the transponder and fed to the train-borne processor unit. Micro-processor circuits check the validity of the code and display the approaching speed limit to the driver.

When the train approaches a speed restriction the display changes to the new limit at the appropriate braking distance. An audible warning sounds which the driver must acknowledge, otherwise the brakes are applied automatically.

The driver selects a suitable braking rate to bring the speed down to the new limit displayed. At the start of the restriction an indicator light on his desk is briefly illuminated, while at the end he receives a short warning sound to alert him to the higher speed.

C-APT has to fail safe so transponders are bolted to the sleepers at intervals of less than a mile. If the equipment fails to respond to a transponder the display goes blank and an audible warning is initiated which must be acknowledged by the driver.

With a blank display the driver reverts to conventional speeds.

To eliminate the risk of wrong speed limits being displayed, all the train-borne equipment, except for the display, is duplicated, while the electronic system has an inbuilt selfchecking routine.

A secondary use of C–APT is to close air intakes approaching tunnels to prevent ear discomfort to passengers.

APT will be able to run through the station at Berkhamsted, on a 1,170m radius curve, at 120 mph compared with the 90 mph restriction imposed on loco hauled trains.

APT will be able to run through the station at Berkhampstead, on a 1170 m radius, at 120 mph compared with the 90 mile an hour restriction imposed on locomotive hauled trains.

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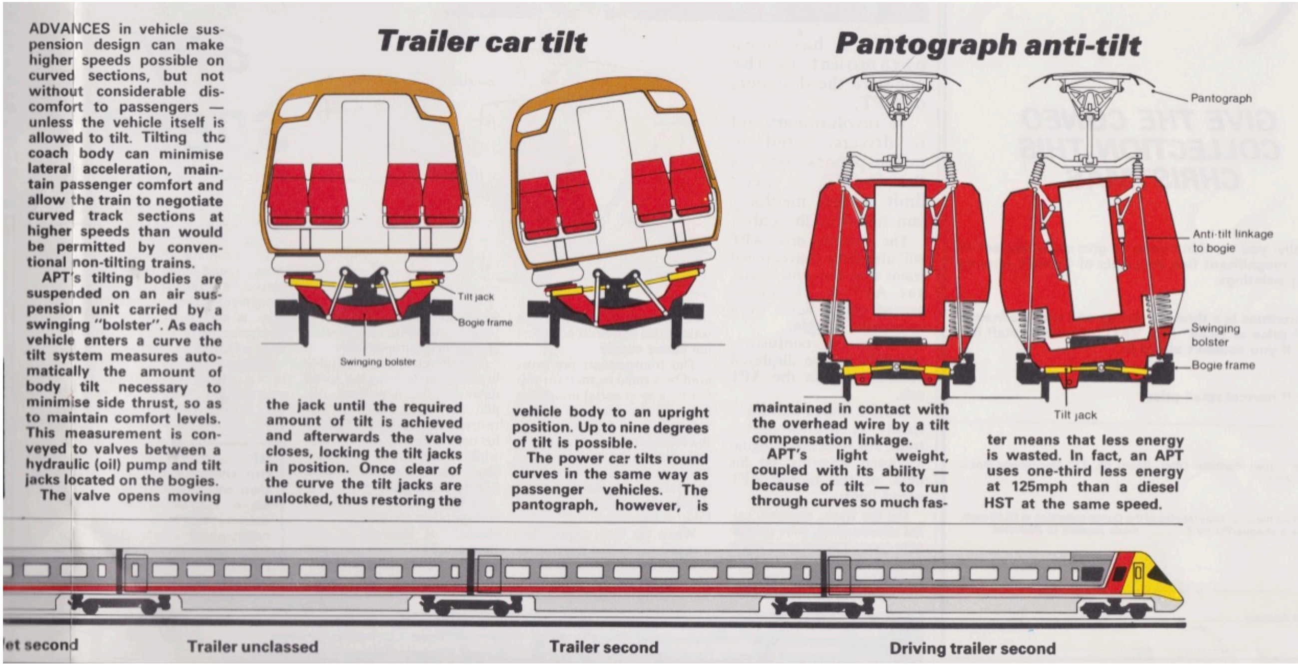
Figure 7 Testing for overturning

This test confirmed that the Prototype would overturn on a curve at the same speed as the conventional trains would overturn.

Conventional slower trains had large margin to the over turning speed on curves, but the Prototype, at about 20% faster speed, had a smaller margin and great care was needed to make sure there was never any over speeding.

Revised on Tuesday, 25 February 2020

Figure 8 Tilt system



ADVANCES in vehicle suspension design can make higher speeds possible on curved sections, but not without considerable discomfort to passengers — unless the vehicle itself is allowed to tilt. Tilting the coach body can minimise lateral acceleration, maintain passenger comfort and allow the train to negotiate curved track sections at higher speeds than would be permitted by conventional non-tilting trains.

APT's tilting bodies are suspended on an air suspension unit carried by a swinging "bolster". As each vehicle enters a curve the tilt system measures automatically the amount of body tilt necessary to minimise side thrust, so as to maintain comfort levels. This measurement is conveyed to valves between a hydraulic (oil) pump and tilt jacks located on the bogies.

The valve opens moving the jack until the required amount of tilt is achieved and afterwards the valve closes, locking the tilt jacks in position. Once clear of the curve the tilt jacks are unlocked, thus restoring the vehicle body to an upright position. Up to nine degrees of tilt is possible.

The power car tilts round curves in the same way as passenger vehicles. The pantograph, however, is maintained in contact with the overhead wire by a tilt compensation linkage.

APT's light weight, coupled with its ability — because of tilt — to run through curves so much faster means that less energy is wasted. In fact, an APT uses one-third less energy at 125mph than a diesel HST at the same speed.

Advances in vehicle suspension design can make higher speeds possible on curved sections, but not without considerable discomfort to passengers - unless the vehicle itself is allowed to tilt. Do you think the coach body can minimise lateral acceleration is, maintain passenger comfort and allow the train to negotiate curved track sections at a higher speed than would be permitted by conventional non-tilting trains.
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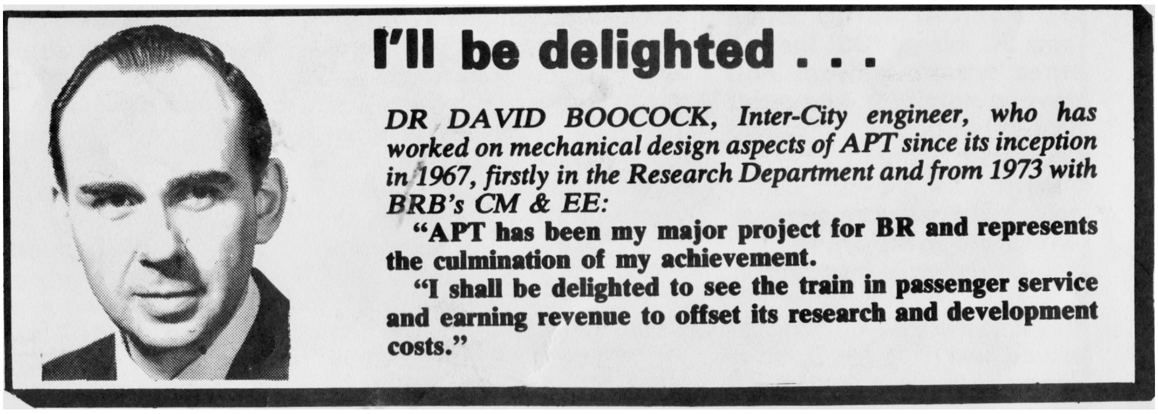
Figure 9 Dr David Boocock



I'll be delighted . . .

DR DAVID BOOCOCK, Inter-City engineer, who has worked on mechanical design aspects of APT since its inception in 1967, firstly in the Research Department and from 1973 with BRB's CM & EE:

"APT has been my major project for BR and represents the culmination of my achievement.

"I shall be delighted to see the train in passenger service and earning revenue to offset its research and development costs."

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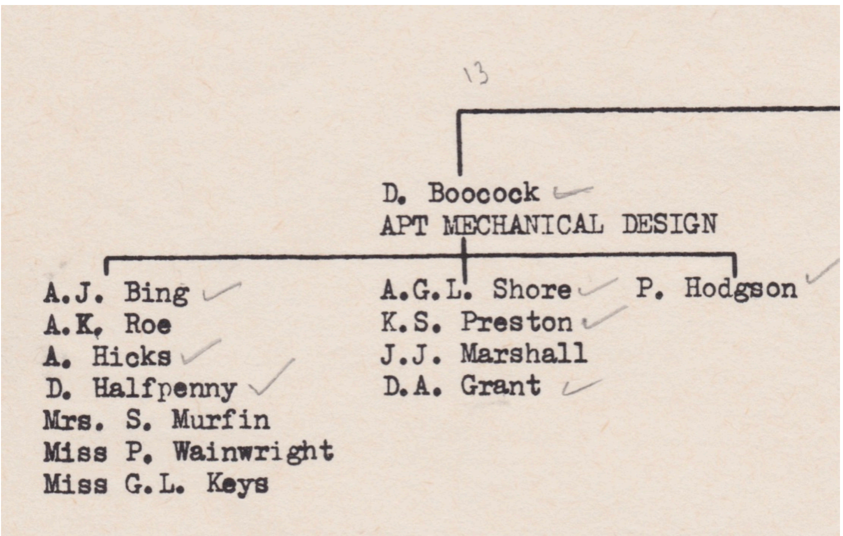
Dr David Boocock, who has worked on mechanical design aspects of APT since its inception in 1967, first in the Research organisation and from 1973 in the Project loosely within the BRB's CM&EE. As printed in Railnews APT Souvenir Extra.

In 1971 his staff consisted of the following:



13

D. Boocock
APT MECHANICAL DESIGN

A.J. Bing
A.K. Roe
A. Hicks
D. Halfpenny
Mrs. S. Murfin
Miss P. Wainwright
Miss G.L. Keys

A.G.L. Shore
K.S. Preston
J.J. Marshall
D.A. Grant

P. Hodgson

Later Dr David Boocock was moved to become the Inter-City engineer, making way for the new man (from the Research organisation) just before the Launch.

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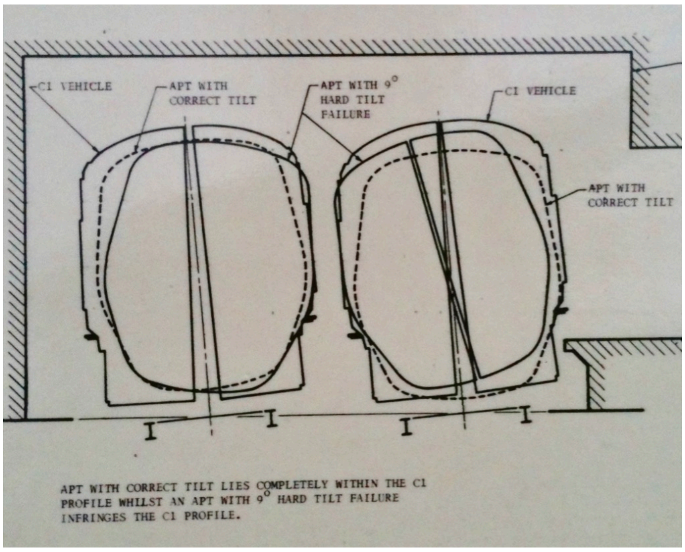
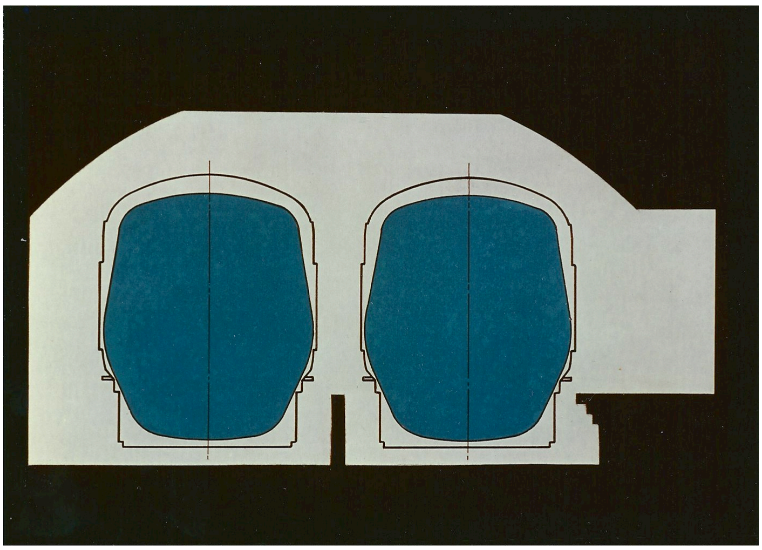
Figure 10 Loading gauge



If a tilt system on the Experimental train failed then the carriage would rotate 9 degrees to one side or the other and stay there until it was restored back at the depot This hard over failure was expected to occur on average once a year on each tilting experimental carriage. The carriage had to be within the C1 profile even in this failed state. The drawing from the Research organisation shows that when the carriage has stuck at 9 degrees over one side (called a hard tilt failure), it was possible that the carriage would be outside the C1 profile.

The Prototype, shown in blue below, was designed to occupy no more space than the carriages. They operated operating within the black line contour, called the C1 profile. In wagon sidings it was important that the loads were within the profile to make sure that line side objects and other trains were not hit. The platform and line side objects can be permitted within in the solid black area.

The Prototype profile had been designed using digital techniques with help from David Halfpenny.



Unlike the Experimental train the Prototype Train would in the event of a failure come upright and so still continue within C1 Profile.

Revised on Tuesday, 25 February 2020

Figure 11 The tilt pack

The tilt pack ready for assembling into the carriage.

The design of the tilt pack was drawn by Alan Price.

There had been a first stage trip designed into the SWS of each carriage. If this tripped then the tilt pack would have its channels automatically changed and the pack would be removed and investigations made to find the cause overnight at the depot.

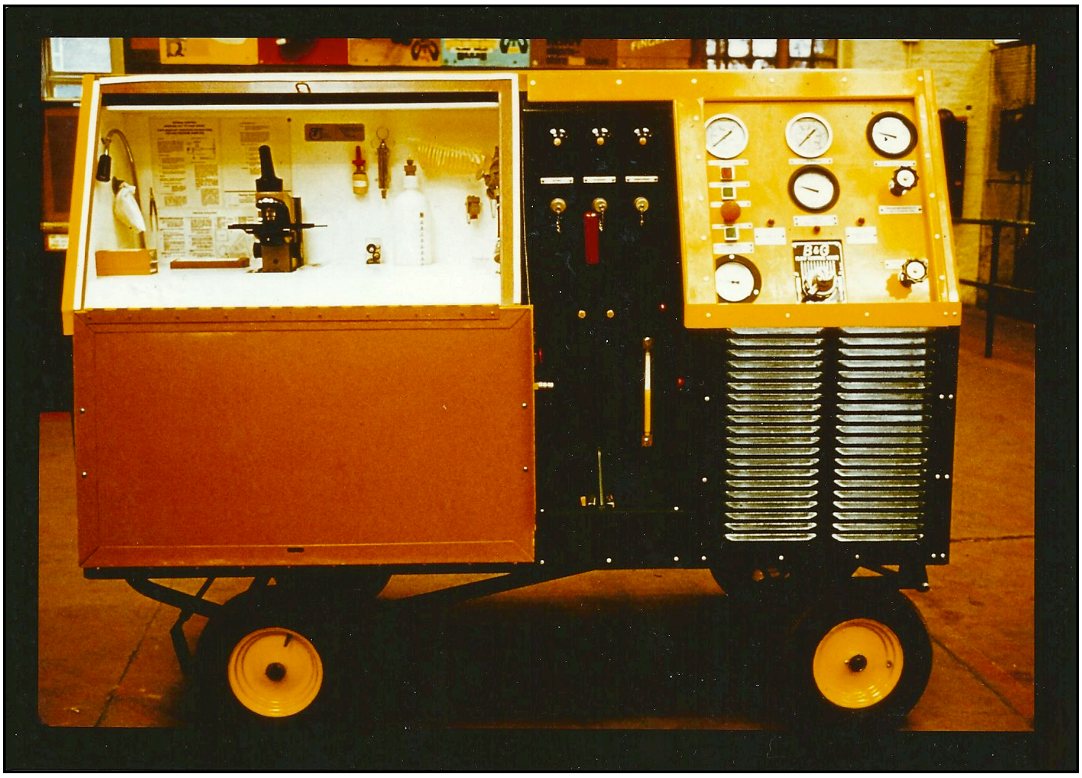
However, if there had been more severe trips, (often two or more carriages tripped on one day), then the trip would have been caused by the Train overspeeding. It was expected that this would be reported to Her Majesty's Inspector of Railways.

Revised on Tuesday, 25 February 2020

Figure 12 The flushing trolley

The innovative design of the flushing trolley was drawn by Alan Price. The tilt system had two channels so that no single failure could make the tilt get stuck over to one side or another. Due to the cleanliness, it was hoped that no hydraulic component would wear out, become silted up and no valve would become stuck. Some of the design staff went to the depot to educate the staff about the cleanliness and other special features.

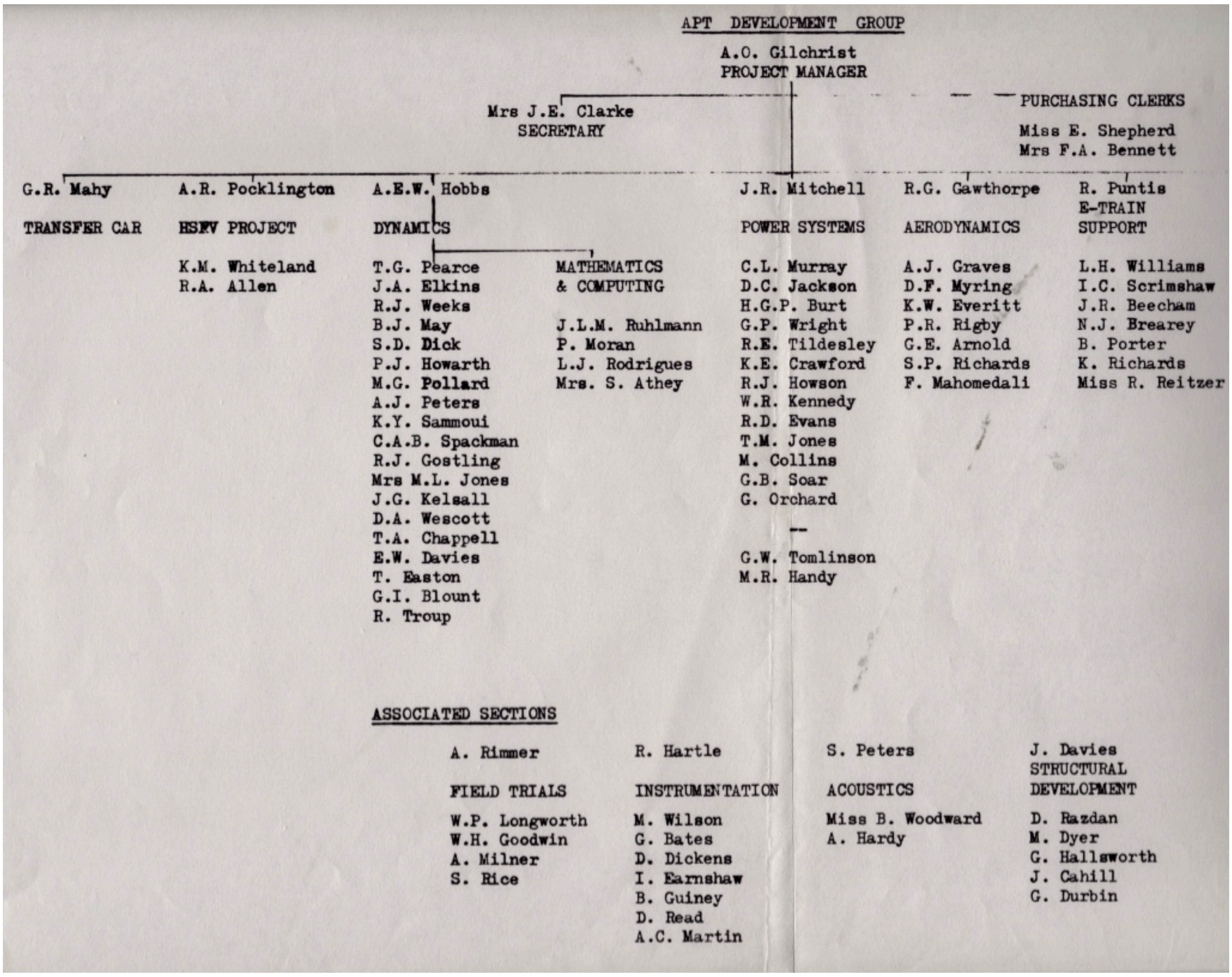
This trolley enables depot staff to count bits of debris in a fixed sample of oil. They would count bits down to the thickness of a human hair. If there would be less than 22 objects having size between 5 and 10 μm in 1 cc sample of oil, then the oil would be considered clean. If an oil sample was not clean, then this trolley would be used to flush the oil to get the required cleanliness restored.



Revised on Tuesday, 25 February 2020

Figure 13 The development organisation

In 1971 there was a large number of well qualified staff available to develop the various concepts which had been brought together by the Project. After the first review the Project was taken away from these people and a communication barrier became evident. The success of the Prototype was inhibited by the lack of development and poor transfer of the technology.



In addition to the above there were 17 staff under J.D. C. Brown for laboratory operations. R. L. Shallcross, W. J. Clark, A. Garton, R.Kniveton, R.McNeil, W.J.Critchlow, A. H. Goodley, D. P. Woodings, J. G. Towle, J.Prince, D. S. Fearn, J. A. Walsh, K. R. Whitehead, H. Waring, T. L. Riddell, J. N. Rodd and J. E. Parker.

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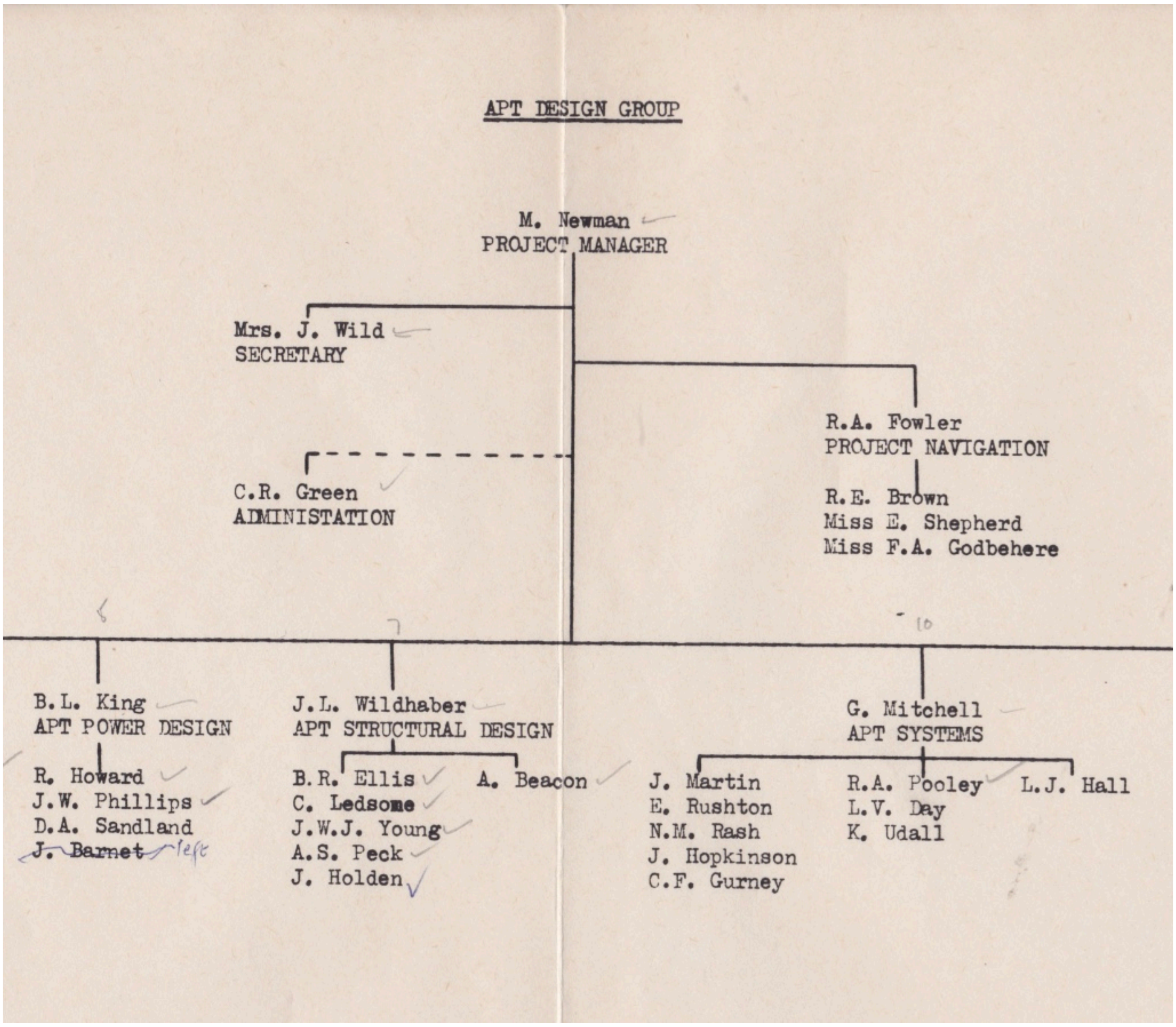
Figure 14 The design organisation

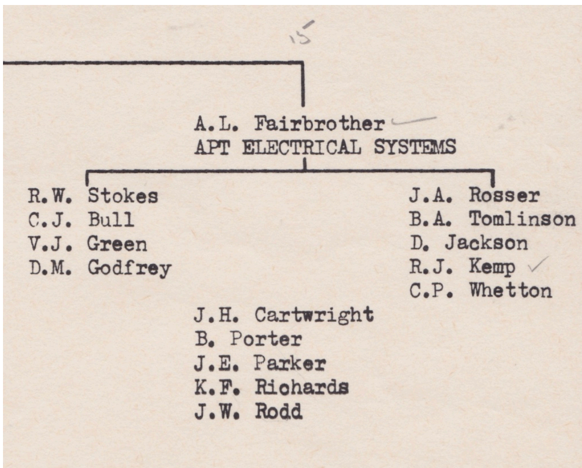
In 1971, the following staff were listed.



The ticks indicated those who signed the author's autograph book.

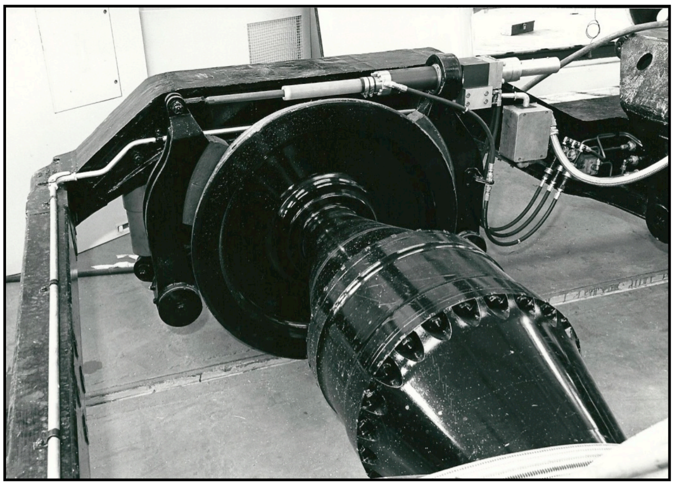
Dr David Boocock and his staff are shown on figure 9.

The electrical staff were as shown beside:

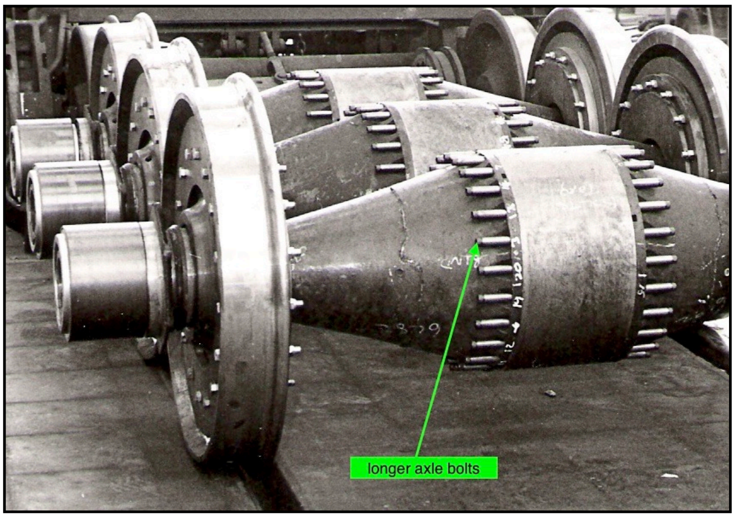


Revised on Tuesday, 25 February 2020

Figure 15 Axle screws



As before the modification with short fat screws going into blind tapped holes. The author had learnt as an apprentice in the aircraft industry that such a design was totally unacceptable. They would be likely to come loose. The screws were tighten to be close to end of their elasticity, nearly into their plastic behaviour. The metal parts would have changing temperatures and due to the brake inside the axle one or more screws might stretch further. The large forces acting on the wheel, when it goes over at rail joints at high speed, would cause vibrations that are about 30 times more than from gravity. If a screw had stretched beyond its elastic limit, then the retained clamping force would be reduced and with vibrating forces the screw can loosen.



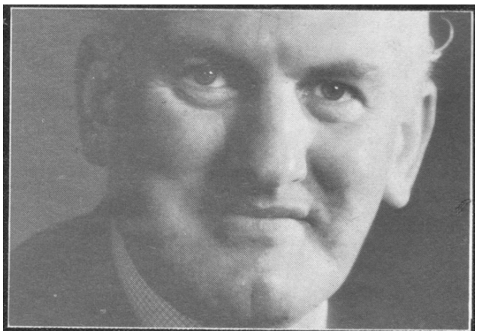
Later after the author became responsible for the suspension design and after the Launch, he proposed this modification.

These longer screws prevented the axle screws coming loose. The screws could stretch elastically and maintain their ability to clamp the joint together.

Revised on Tuesday, 25 February 2020

Figure 16. Top technical opinion

In May 1980 Ian Campbell, the Vice-Chairman expressed his view of the Train as it was at that time, in the "Railway Gazette puts APT in Perspective", published by Railway Gazette International and dated May 1980.



Ian M Campbell, Vice-Chairman, British Railways Board

Shorter journey times are paramount for success in the highly-competitive inter-city market. APT, developed in little more than a decade, represents the first serious attempt to blend scientific appraisal of tracked transport fundamentals with 150 years' experience of rail vehicle engineering. It is already clear that—far from being a technological marvel with no commercial future—APT can offer major cuts in journey time at little extra cost in terms of energy or investment in track and signalling

Revised on Tuesday, 25 February 2020

Figure 17. Information for the passengers

The first passengers boarding the Prototype Train would expect that their journey would be no less safe than it would have been on the conventional service trains. The following information was **not** made available to the passengers, before obtaining their ticket. Had it been known then the situation might have unravelled.

> **The equilibrioception experiment**
> Passenger should be aware that they would be guinea pigs for an important scientific experiment about travel sickness. Never before, has such experiments been attempted. The experiment has just been formulated, and changes are made to reduce the amount of tilt, to be deliberately less than needed. It will result in a small amount of leftover centrifugal force that will be perceived by the equilibrioception system as being perfectly natural. Any passenger feeling travel sick should activate the train emergency system.

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The risks within the experiment

There was a chance that this Experiment might have been validated or might be a failure. If passengers indicated that they had felt travel sick, it was a failure.
There were three outstanding risks associated with the Experiment:

There was a risk that the Prototype Train would overturn. If the severe safety warning had tripped then it indicted that the Train had been at risk of overturning on curves. When this severe safety warning was commissioned and they would have checked that it tripped at 16% below the overturning speed.

There was a risk that the severe safety warning would trip. If passengers found their carriage being locked upright by the safety system, it would behave like a conventional carriage for the rest of the day. In this situation, the Train should not have been used in excess of the normal line speed.

There was a risk that the Train would be driven at speeds above the normal line speed, so the passengers in the carriages, that had been locked upright, would be move out or suffer from a bad ride.