Rogers Pass

By Edward H. Taylor
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C P Rail's plan to increase capacity on their route through the Rocky Mountains by constructing a lower level route with easier grades meant that two tunnels aggregated to a length of 16.51 km would be required to carry traffic through the Rogers Pass area near Revelstoke, B.C. These tunnels, built to carry westbound traffic including unit trains up to 110 cars with a gross consist weight of approximately 15,000 tons, 950 feet below the summit of Rogers Pass, and 3,100 feet above sea level, reduce the present mainline gradient from 2.2% to 1% compensated. The Mount MacDonald Tunnel, 14.66 km in length, is the longest mainline tunnel in North America, with the shorter Mount Shaugnessy Tunnel extending 1.85 km. Track maintenance in tunnels has always been difficult, particularly when, as in this case, the traffic can be expected to be some 50% per annum. A reliable, minimum maintenance track structure was therefore essential.

After a thorough analysis of various designs of non-ballasted track, Paved Concrete Track – PACT – designed and developed by British Rail and McGill Paving Limited, was judged likely to give the necessary low maintenance solution for the new tunnels. All PACT installations incorporated Pandrol brand rail fastenings, but although there are thousands of miles of Heavy Haul cross-sledder track with Pandrol fastenings, PACT track had not been used previously in such a demanding combination of heavy annual traffic tonnage and axle loading.

As a result, in conjunction with C P Rail, British Railways engineers proposed that a test length of slab was necessary to fully evaluate performance of both the slab and the fastening system under a Heavy Haul operation. A suitable site was selected where a mainline re-arrangement was being constructed at Albert Canyon near Revelstoke in British Columbia and plans were made to install the test length in the fall of 1984.

Testing of Fastenings

Prior to this installation, Pandrol’s research and development facilities were to be utilized to develop and evaluate the proposed fastening designs, to ensure that the direct fixation assemblies met the requirements for the eventual Heavy Haul traffic conditions in the tunnel. As a result of these torsion and extraction tests the epoxy grout (Seltix Resiflex 15), and galvanized shoulders were chosen as most appropriate for the expected operating conditions.

Clip Endurance

Galvanized and untreated type ’0’ 2009 clips were fatigue tested to determine their life under simulated track loading and ’SN’ curve developed from the results. The endurance limit thus obtained showed that the clips would not fail in fatigue as a result of the expected rail deflections.

The Rail Pad

Dynamic loading of components in any track assembly can cause problems over a period of time. In PACT there is no ballast to provide a resilience to the system, and the resilient pad between the rail and the concrete slab is therefore of vital...
importance. It is necessary for the pad to provide some attenuation of impacts generated by wheel and/or rail head imperfections which would otherwise be transmitted to the concrete slab. The pad must also be sufficiently durable to last at least the life of the rail, or preferably a multiple of that life.

To assess impact attenuating properties a drop weight rig (Figure 1), of form originally developed by Battelle Columbus Laboratories was used to carry out impact tests on both rubber bonded cork and grooved rubber rail pads.

Low temperature was obtained by packing solid carbon dioxide around the fastening assembly and sleeper. The candidate pads were assembled in turn on a strain-gauged sleeper (together with rail and clips) and the strains generated by dropping a weight on the rail head were measured. The tests were carried out at +20°C and also at −30°C to simulate conditions in the Rocky Mountains.

The results indicated that the attenuating characteristics of both tested pads were very good over the full range of temperature, reducing the impact by 22% in the case of the rubber cork pads and 17% for the bonded cork. A further test comparing the performance of the two types of pad revealed that the rubber cork pad would be the more effective in reducing impact damage over a wide range of temperature conditions.

The abrasion of rubber pads was found to be minimal and these pads, therefore, provide an effective means of reducing impact damage to the concrete slab and extending the life of the rail.

**Albert Canyon Test Slab slabs**

Based upon the results of the Laboratory test programme, a test length of PACT with Pandrail fastenings was laid in Albert Canyon in September 1984 in a rock cut replacing a section of the existing track long. The track length of 1383.5 metres is on an 8° curve but with a short length of straight at the end. Eights units and mixed freight traffic, with axle loads of 53 tons primarily in a weight direction with maximum train consist weight of approximately 15,000 tons. Annual tonnage was some 150,000 million, giving a total tonnage over the test section to date of 250 million tons.

Detailed monitoring of the performance of the Albert Canyon installation is continuing but in 1987, after 3 years of satisfactory experience, C P Rail decided to install the PACT system, with Pandrail fastenings, in the Mount MacDonald and Mount Skaugness tunnels.

As a result of this extensive programme of tests, the final fastening assembly to use on the PACT track was chosen, which included:

- **Galvanised Pandrail rail clips** type ‘P’ 2003
- **Galvanised Pandrail cast shoulders**
- **Heavy duty Pandrail insulators with galvanised cast cover**
- **Continuous, longitudinally grooved, 100 mm thick rubber rail bar pads**

**The PACT Slab slabs**

The PACT track form consists of a continuously reinforced, profiled concrete pavement laid by a purpose-designed and built slip form paver. The paver runs on the permanent long welded running rails temporarily set up as guide rails on either side of the slab.

The C P Rail installation at Rogers Pass was typical of many similar PACT installations throughout the world. Work was commenced as soon as the first half of the main tunnel was completed, with work to the shorter Skaugness tunnel and the second half of the main tunnel following.

The limited space available in the tunnels necessitated a thorough design process, including the selection of materials, to achieve an optimal combination of performance and cost. The reinforcement mats were manufactured in the tunnel during the night shift and stored against the tunnels for the PACT paver operating. The rail fixings, the epoxy resin and rail pads were distributed along the length of the tunnel in the alcoves.

Once everything was ready the paving machine was moved to the centre of the tunnel, set upon the guide rails and commenced paving operations from the centre of the tunnel. The paving machine was equipped with a continuous flow of concrete to the paver. Having been mixed by a computer-controlled on-site batching plant, the concrete was transported in seven 6 tone dump trucks. These concrete pads were then laid one on top of another and in the correct place.

**Concrete slabs**

Concrete slabs were spayed with a curing agent and left to set for 12 hours. The finished slab was then surveyed and any small high spots removed by grinding in readiness for the fixing of the rail fastening three days after the slab had been laid.

**Fastenings**

Once the concrete was ready to take the fastenings, the resilient pad layout was laid into place; the guide rails were fitted into the pads to become the running rails, and holes were drilled and cleaned to take the Pandrail shoulders.

The epoxy grout was mixed and poured into the hole, and the shoulders were inserted and the insulators placed in place. When the epoxy resin had reached service strength, the rail was clipped down securely using a Pandriver. A programme of quality control tests were carried out to ensure the shoulders were firmly bonded to the concrete, samples were proof loaded to 2600 pounds force for one minute and samples were checked for the correct toe load.

Concrete sleepers with Pandrail fastenings were laid over the 1.3 km of new alignment adjoining the Mount MacDonald and Mount Skaugness tunnels, and a transition arrangement between the slab track with the concrete sleeper track. The finished track was handed over to C P Rail in October 1988, ready for the official opening in Spring 1989 of the Rogers Pass Project. The finished track was the most ambitious rail building scheme undertaken by C P Rail since it completed the transcontinental railway one hundred years ago.

As of January 1990, the slab track installation has performed in a flawless manner since being placed into regular traffic service in December 1988.

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**Table 1. - Results of rail pad load deflection tests.**

<table>
<thead>
<tr>
<th>Test</th>
<th>Rail Pad Type and Testing Condition</th>
<th>40 kN (4.02 tons)</th>
<th>Max. Rail Deflection for Loads of</th>
<th>100 kN (10.04 tons)</th>
<th>175 kN (17.57 tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bonded Cork Ambient +0°C</td>
<td>0.24 mm (0.009&quot;)</td>
<td>0.60 mm (0.024&quot;)</td>
<td>0.96 mm (0.037&quot;)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bonded Cork Subzero −30°C</td>
<td>0.06 mm (0.002&quot;)</td>
<td>0.15 mm (0.006&quot;)</td>
<td>0.36 mm (0.014&quot;)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Grooved Rubber Ambient +20°C</td>
<td>0.34 mm (0.013&quot;)</td>
<td>0.56 mm (0.022&quot;)</td>
<td>0.70 mm (0.028&quot;)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Grooved Rubber Subzero −30°C</td>
<td>0.13 mm (0.005&quot;)</td>
<td>0.36 mm (0.014&quot;)</td>
<td>0.70 mm (0.028&quot;)</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1. - Diagram of Battelle – type drop weight rig.**

**Figure 2. - Diagram of dynamic load test rig.**

**Impact test on pads in Pandrail's laboratory using Battelle type drop weight rig.”**
Ultrasonic rail flaw detection

For over 50 years Pandrol has specialised in the design and development of rail fastenings and associated components. In order to gain the expertise required to produce rail fastenings suitable for every type of track, it has been necessary to investigate how the track structure behaves under traffic. Therefore Pandrol has built up a wealth of experience on the interaction between ballast, ties, sleepers, pads and rail and the resultant problems that can arise.

Until recently, Pandrol has only been in a position to offer rail grinding in North America to help solve these problems. Plans are now underway to build up a range of services through expansion of the Pandrol Group, the first of which took place in October 1989 with the acquisition of Dapco Industries of the United States.

(As Track Report went to print, negotiations were concluded to acquire a controlling interest in Jackson Jordan Inc., manufacturer of tamping equipment and contractor in switch and crossing grindings. This further expands the range of maintenance-of-way products and services which the Pandrol Group are able to offer.)

Dapco Industries, Inc. was incorporated in January, 1973 from an individual proprietorship that was started in 1969 and has established itself as a technological leader in the field of non-destructive testing and rail inspection. Having pioneered the first computer-controlled instrumentation as early as 1976 with the introduction of minicomputers, the company's deepest penetration to date with electronic and computer expertise has been in the development of non-destructive test systems for rail and pipe applications.

A plan has been developed that provides systems and services that first assures the quality of the rails as they are being produced, and secondly monitors the integrity of rails in service with minimal interference to normal operations. A 440 foot rail line at Dapco's facility is used for research and quality assurance of newly developed rail inspection systems.

Dapco’s family of computerised, non-destructive test systems consists of rail test vehicles for on-track inspection and distributed real-time computer based systems for high speed inspection of rail and pipe in-plant applications. The Company has either sold or serviced the rail inspection needs of up to 20 U.S. railroads including the Union Pacific Railroad, Missouri Pacific Railroad, Chicago & North Western Transportation Company, Chicago, Milwaukee, St. Paul & Pacific Railroad, and the Soo Line, as well as the Canadian National and the Canadian Pacific Railroads. Currently, a second generation vehicular system has been developed and sold to the Union Pacific, Burlington Northern and CSX Transportation Company. Systems for in-plant assembly line inspection for rail and pipe are also in their second generation. In-plant rail inspection systems are in use at Bethlehem Steel, Wheeling-Pittsburgh Steel, Algoma Steel and Inco Steel in Canada, Bhagal Steel and Ispat in India, and SOMISA in Argentina. In 1983 Dapco were initially selected as the contractor for Bethlehem Steel as a result of a world survey as to existing technology and capabilities. Bethlehem Steel concluded that Dapco had by far the most advanced system available anywhere.

The System

The test system is oriented around ultrasonic wheels, a means of transporting arrays of ultrasonic transducers and the fluid couplant that provide a more reliable means of coupling ultrasonic energy into the rails. These patented wheels have achieved a sensitivity of detection not achievable by other means. The "Dual Web Wheel" used for in-plant systems is capable of detecting a 3/4" flat bottom hole in the web area of the rail under typical steel mill operating environments. For in-plant rail systems five wheels are orientated to inspect the head, base and web areas. For in-service inspection four wheels are used with as many as six transducers per wheel to inspect the head and web areas (see Fig. 1 overleaf).

Starting with the first generation test system, a largely analog RTS-100 Ultrasonic Inspection System, the minimization of "false alarms and operator interaction" have been major goals during the past ten years in the design and development of Dapco’s ultrasonic non-destructive testing systems. In the third generation RTS-300 system, the approach taken to solve this problem has been to apply computer techniques to collect and analyse ultrasonic data sets. Through the use of built-in intelligence, on-line testing systems are able to achieve a high consistency of performance in the real-time test environment. Every effort has been made to human engineer these systems so that only a minimum of computer knowledge is required to operate them.

One of the keys to the success of these ultrasonic testing systems has been the ability to apply pattern recognition techniques to the ultrasonic data as it is received in real-time. This has been achieved through a high performance, multiple microprocessor distributed "pipelined" architecture which allows for each data channel to be controlled by its own microprocessor during the test process. Pattern recognition techniques, defined by Dapco, are applied to the digitized data, generated by each ultrasonic data channel via a software algorithm which has been tailored for each particular channel type to minimize the occurrence of non-anomalous indications. In particular, the system is relatively immune to random occurrence of noise spikes. As a result, the amount of data which must be stored for later analysis is also greatly reduced.

Another key feature of the testing system is the correlation of positional information with every potential defect. The distance travelled by the ultrasonic wheels are maintained by the system at all times. The resolution of the system provides a potential for locating problems in a given joint to within less than an inch.

Test data once collected is processed off-line to further refine and characterize defect information. Dapco has been researching sophisticated high-level pattern recognition techniques and algorithms as well as the hardware needed for our fourth generation testing system, the RTS-4000 System. For the future, the patented RTS-1000 has been
under research for the last four years. It represents a quantum leap in both the analysis and presentation of the inspection results. A distributed pipeline computer architecture is still used. However, now there is shared memory between each stage. The total pattern recognition task is distributed into sets of stages with several different types of recognition activity integrated into a format that provides for smooth, extremely high speed operation. Features can be extracted in both two and three dimensions in real time. This allows the user through the generation and visualisation of the three dimensional flaw surfaces to decide what size anomalies are to be detected.

Dapco has performed research for the detection and classification of rail flaws in conjunction with the United States Department of Transportation and the Federal Railroad Administration. Results over the last fifteen years have been innovative non-destructive testing techniques to accomplish reliable high speed testing of railroads networks. Dapco is a leader in both ultrasonic research and the application of ultrasonic wheel technology to high speed non-destructive testing.
Developments in rail support systems for non-ballasted light rail tracks

(This article is based on a paper presented at the "Light Rail ‘99" Conference at Bristol, November 1999).

Many Light Rail systems make extensive use of non-ballasted concrete slab tracks, as well as conventional ballasted railway tracks. In tunnels, where very sharp curves are required, the slab track is sometimes used in combination with the conventional ballasted railway. The slab track is particularly advantageous in tunnels, since it allows for the freedom of movement of the rolling stock. Other advantages of the slab track in tunnels include the reduced noise and vibration levels. The slab track consists of a concrete slab supported by steel beams or other similar structures. The concrete slab is typically 150-200 mm thick and is reinforced with steel bars. The slab track is usually laid on concrete sleepers, which are supported by metal rail fasteners. The concrete slab is then covered with a layer of ballast to protect the concrete surface from wear and tear. The ballast also helps to distribute the load of the rolling stock over a larger area, which reduces the stress on the concrete slab. The slab track is often used in combination with the conventional ballasted railway tracks, which are usually used in areas where the curves are not very sharp. The combination of the two systems allows for the flexibility of movement of the rolling stock in tunnels, while also providing a smooth ride for passengers. The slab track is also used in areas where the ground conditions are not suitable for the installation of conventional ballasted railway tracks.
The Gauge-Lock rail assembly — extended for application on softwood sleepers

The Gauge-Lock Rail Fastening System was developed to meet a need for a resilient rail fastening that could be used with hardwood sleepers without the requirement for a baseplate between rail and sleeper.

Basing the concept on the highly successful Pandrol rail clip shape and load application, the technicians within Pandrol International’s Research and Development Laboratory conceived the idea of anchoring the spring clip into the hardwood sleeper by extending the central ‘centre-leg’ portion of the clip and bending it downwards through ninety degrees so that it could be inserted into a drilled hole immediately adjacent to the edge of the rail. A second hole would have to be drilled a predetermined distance from the first hole, which would accept a screwplug for tensioning the clip.

When fully installed and tensioned the two Gauge-Lock clips per rail seat provide a simple but very effective restraint against both lateral and longitudinal movement of the rail. Although it is less than two years since the Gauge-Lock was developed, more than 10,000 clips have been supplied for controlled test lengths on railways in Europe, Africa and South America.

The initial reaction to this concept for hardwood sleepers has been a “baseplateless” fastening that has been very encouraging. Its simplicity of installation, with the minimum of components, coupled with the relative ease in which it can be removed if necessary, has made it very appealing to railway operators. The high level of performance and maintenance conditions has been the key to its initial success.

The Gauge-Lock clip was first manufactured from fully heat-treated silicon-manganese spring steel of the same quality used for the “Pandrol” clip used in 1½ inch (12.7 mm) diameter bar and generated a toe load within the range 450-550 Kg, dependent upon the thickness of the rail foot and rails within the range of 25-40 Kg/M. However, with interest now coming from other sectors of the railway industry, the application range has been increased to two bars diameters — 12 mm and 14 mm. These two sizes would cover a range of rails up to 30 Kg/M with 12 mm clips and 35-45 Kg/M with a 14 mm clip. The resultant toe load ranges have been established at 350-450 Kg and 500-650 Kg respectively.

Following the positive performance of trials in railways using hardwood sleepers, requests for trials have now been received from railways using semi-hardwood and softwood sleepers which in both cases, require a baseplate to distribute the wheel loading over a greater area than the base of the rail and to provide an acceptable wear resistant surface on which to support the rail. The initial solution was to support the rail on a flat mild steel plate. One test length was installed in South America, with rail inclination being obtained by adding the two rail seats. Whilst this flat plate concept remains the cheapest solution, some railroads are reluctant to adze sleepers due to the loss in sleeper section and additional work that has to be carried out either at the trackside or in the sleeper fabrication workshop.

It was, therefore, necessary to develop a simple baseplate that would provide the desired rail support, the rail inclination and Gauge-Lock fastening application. A ductile iron casting of similar shape to standard AREA type baseplates was considered, but did not produce any significant price advantage over the conventional Pandrol baseplates.

What was needed was a rail support system that could provide an inclined rail seat and Gauge-Lock fixation by combining components that could withstand the rigours of in-track service and be cost effective. It was decided to evaluate the concept of supporting the rail on a flat mild steel plate which in turn would be supported by a plastic tapered shim, thereby providing a good support/wear surface for the rail and the appropriate rail seat inclination.

When a basic design had been conceived, it was presented to plastic materials and moulding specialists, Hoechst-Celanese Plastics Limited, who agreed to assist in the development of this plastic shim plate into a component durable enough for application in tracks with axle loads up to 29 tonnes under specified environmental conditions.

At around the same time, a meeting with Banverket (formerly the track department of the Swedish State Railways) indicated a possible application for an improved rail fastening system for their secondary lines. These tracks currently use pine-softwood sleepers, generally with single rib AREA type baseplates and dogspikes.

Banverket have many hundreds of kilometres of this type of track. They are currently not heavily used for either freight or passenger traffic, but have to remain operational under Government Legislation with financial support in certain instances coming from the local authorities.

The current problem with these tracks is the level of maintenance required in relation to the number of trains operated. Application of the Gauge-Lock rail fastening was considered potentially capable of improving the track standard and reducing maintenance requirements with a possible increase in train speeds wherever the local operating conditions would permit.

Hoechst-Celanese Plastics Limited continued their development work based upon the Swedish criteria of a summer to winter temperature range of +40°C to -40°C with individual rail seat loadings of up to 10 tonnes.

From their extensive range of materials, they considered that the first Scandinavian trial should be conducted using “HOSTAFORM” C9012 (Black) 10 - 150, Acetal resin.

The final shim plate profile incorporated a nominal 3 mm thickness ribbed profile to support an 8 mm thickness mild steel baseplate at the required 1 in 30 rail seat inclination. Snap-on connectors and plastic location tabs were incorporated in the moulding to align the components and fasten them together for shipment to site.

Drainage grooves incorporated at each peripheral pocket were incorporated to prevent the build-up of ice during winter periods.

The components for the 150 sleepered trials were installed at Västmanland, Sweden, in November 1989 on Ramnas on one of the secondary lines near to Wimmeri in the Eastern Region of Banverket.

The test site was 850 metre (200 metre) radius curve consisting of 75 mm width of sleepers with a second 73 sleepers which were already in track and had single rib nailed steel baseplates with dogspikes’ rail hold-down. On these sleepers the old baseplates and spikes were removed and the Gauge-Lock baseplates seated within the pocket produced in the sleeper top by the old spike baseplates.

Most of the installation was completed without difficulty by a team of three trackmen equipped with a sleeper inserting machine, motorised sleeper drilling and screwspike tensioning equipment. The trial length was installed just days before the first snows of winter in November 1989, but did not prevent initial clip toe loads being measured on selected sleepers throughout the length. It is planned to repeat these measurements at six monthly intervals at which time additional checks for lateral/longitudinal rail displacement will be made.

Banverket consider the Gauge-Lock assembly to be the type of fixation they require for softwood sleepers in secondary tracks and will maintain a strict surveillance on the site. If the Gauge-Lock assembly performs as expected, Banverket would like to field weld the 20 metre rail lengths into 40 or possibly 60 metre rail lengths, thereby reducing the number of joints, which is at present one of their major maintenance problems in these tracks.
Resilient pads for curved track

For a number of years, Pandrol have been studying the effects of resilient rail pads on concrete sleepers, and as a result are now supplying significant quantities of studded rubber rail pads for railways around the world. The improved performance of such pads has been demonstrated in a range of different track and traffic conditions.

The greater adhesion of resilient rail pads has been shown in track carrying high speed trains, where strain levels in concrete sleepers are substantially reduced. However, even in systems operating at lower speeds some benefit can often be derived from the reduced dynamic forces transmitted to the track structure associated with a resilient rail pad, and in some circumstances from improved distribution of the axle load along the track. Any advantage must of course be weighed against the generally greater cost of more resilient rail pads. The use of these pads is also subject to the limitations imposed by the allowable deflections of the rail and the fastening system.

In general it has been thought that at speeds below about 80-100 kph the advantages are not great enough to justify the increased cost, except where it is desirable to use common rail fastening components throughout a section of track which includes both sharp curves and higher speed track. A series of tests have recently been carried out in order to quantify any benefits from resilient pads at low speeds and in curves, and to establish whether the rail and fastening system deflections measured with very resilient pads are acceptable. The tests were carried out on a section of line at Pont-à-Celles, near Charleroi in Belgium, on a 1000 metre radius curve; at Falköping, Sweden; at Kajatiya in Japan on a 410 metre radius curve; and at Grindvoll, north of Oslo in Norway on a 247 metres radius curve. The measurements were made of sleeper and rail pad strains and of rail displacements. In Norway, a parallel test was also carried out in order to provide measurements with different rail pads using the same track over a range of speeds in Norway.

Some of the test results are illustrated in Figure 1, which is taken from the results of the tests in the UK and Japan. The top row of charts in the figure shows the overall deflection of the six rail pads tested, averaged over both high and low rails, a number of axles, and a range of test speeds. It is included only to give an indication of the resilience of the range of pads tested. The average axle load was approximately 16 tonnes.

The lower three rows of charts in the Figure 1 show the strain measured on the sleeper by gauges at the low rail seat, central, and high rail seat respectively. Each chart consists of seven bars which represent test speeds of 20 kph to 80 kph in steps of 10 kph. Each bar consists of two sections. The smaller section represents the average strain caused by bending of the sleeper under each axle. Superimposed on this is the additional strain arising from vibration of the track as the train passes over. (The profile of the low rail was measured and found to have corrugations of approximately 0.16 mm depth).

As might be expected, the test results show a gradual transfer of load from the low to the high rail as the train speed increases from a condition of excess, through the balanced speed, to the condition of cant deficiency. This results in a reduction in the strain under the low rail at the rail seat as speed increases, and an increase in strain at the high rail. There is also some indication that strains measured under the more resilient pads tend to be lower, even at the relatively low speeds of the test.

In tangent track there is obviously some deflection of the fastening system due to compression of the pad. In curves there are more complex components of displacement, due to the lateral force components applied to the rail head. The tendency for the rail to "roll" in a curve can cause unacceptable gauge widening. During the tests the vertical movement of the rail foot relative to the sleeper was measured at two positions, one on each side of the rail. The average of these measurements is the pad compression, and the difference is the "roll" component. Using this measurement, the measured lateral movement of the rail foot, and the geometry of the rail section, it is possible to estimate the amount of gauge widening under each axle.

In the Figure 2 typical movement of the rail is shown for both a 5 mm hard plastic pad, and a 10 mm studded rubber pad, under an 80 kph freight train on the Norwegian test site. The deflections have been grossly exaggerated in this diagram, but it can be seen that when the non-resilient pad is replaced by a very resilient one the amount of roll is not increased by as much as the amount of vertical deflection. Indeed in previous tests in North America, under extreme conditions of heavy axle load and sharp curvature, reductions in the amount of roll have been measured when more resilient pads were installed.

It was possible to draw some general conclusions from the three tests by comparing trains of similar type and speed (e.g. EMU stock in Belgium and Japan, freight trains in Japan and Norway).

The lateral and roll components of rail deflection were found to vary more than vertical components with vehicle type. This is not a surprising result, as in recent years a great deal of design effort has been applied to the problems of designing railway vehicles and their bogies to reduce track forces in curves. Rail road codes and the tests carried out to date have not given sufficient specific data to comment in detail on this subject.

The limiting factor for the use of rail pads in curved track is the acceptable level of deflection imposed on the rail fastening by the combination of quasi-static and dynamic components of applied load. In practice, the tests described have shown that for any given vehicle type these in turn depend on a combination of axle load, maximum speed and maximum cant deficiency. Cant excess is usually a less severe design criterion for a given axle load, as it implies a lower train speed and thus lower dynamic forces. However, in some cases allowance must be made for slow trains with high axle loads, or where trains have to stop at signals on curves with a high level of cant. In the three tests it has been shown that rail pads selected for tangent track can be used under the same trains and in the same sleeper design for cant deficiencies up to at least 130 mm on standard gauge track (or about 100 mm on 1067 mm gauge) without imposing any unacceptable loading on the other components of the fastening system.

As well as the three tests described, which were set up with the specific purpose of examining the performance of resilient pads in curves, Pandrol have carried out other tests which have also provided important relevant data. The table lists details of all of the test sites on which rail displacement measurements have been made between 1986 and 1989, using Pandrol's Dichroic Displacement Measurement System. (Those described in detail above are marked with asterisks.)

Much of information on such as this, we are now able to discuss with railways the suitability of different types of rail pads for their particular operating conditions. For example, there is some indication that under typical North American freight railway conditions the forces in sharp curves may cause purely lateral loading on the one of the Norwegian test pads, when resilients pads are used, which may be a more demanding design criterion than the resistance to rail deflections. This difference in
The proposal to change RENFE’s track gauge from 1668 mm to 1435 mm poses many problems. In particular, how can the operation be carried out without closing tracks for long periods and therefore, losing valuable revenue? This problem is especially acute on single track routes.

A possible solution is to re-laying existing track with sleepers carrying three rails, one rail common to both gauges, the others set 1668 mm and 1435 mm from it. Change over would be gradual, with trains at both gauges using the track for several years as the broader gauge was gradually phased out. This concept is well tried. Figures 1 and 2 show examples of 3 rail dual gauge in Brazil (FEPASA) and Australia (West Rail). The main disadvantage of the system is that the centre lines of the two track gauges would be 116.5 mm apart. Thus, if trains with standard

Figure 1. Brazil: Gauges of 1000 and 1600 mm on the same FEPASA concrete sleepers.

Figure 2. Australia: Gauges at 1067 and 1435 mm in a combined West Rail turn-out. RENFE loading gauges were to be run on both track gauges. Structures would have to be enlarged along the entire route to accommodate them. Similarly there would be problems with the position of station platforms and overhead catenary wires for electric traction.

Figure 3. ‘Hook-in’ Ponderl assembly with alternate rail positions 116.5 mm apart.

A better but impractical solution would be to place four rails on the sleeper, providing both gauges on a common centre line. Unfortunately there is insufficient space between adjacent rails to allow this.

An alternative is to devise and install a track system which will permit a very rapid change from one track gauge to the other. The procedure would be to run broad gauge trains on a particular stretch of track until the change-over date, then to close the track completely, to change the track gauge and to re-open the track to standard gauge trains, all in the shortest possible time. This paper describes a rail fastening system which has been designed specifically to achieve such a quick change of track gauge.

The design is shown on Figure 3. It is for concrete sleepers. A pair of standard Ponderl shouldered are cast into each sleeper at either end of each rail seat. Between each pair of standard shoulders a ‘hook-in’ shoulder housing is also cast into the sleeper. The standard shoulders and the shoulder housings are integral with the sleeper once it is made. A loose ‘hook-in’ shoulder is placed in one of two possible positions in the shoulder housing. Movement of the ‘hook-in’ shoulder to the second position moves the centre line of the rail seat, and therefore of the rail, by 116.5 mm. Thus track gauge may be changed from 1668 mm to 1435 mm by moving both rails inwards, and vice versa. The standard shoulders are made of pressed steel, the ‘hook-in’ shoulders and their housings of cast malleable iron. To change track gauge, the following steps are taken:

1. Remove the clips
2. Remove the insulators
3. Lift both rails
4. Lift the rail pads
5. Place the ‘hook-in’ shoulders into their alternate positions
6. Replace the rail pads
7. Place the rails into their new ‘hook-in’ shoulder positions
8. Replace the insulators
9. Replace the clips

Typical components, except the new ‘hook-in’ shoulders, are visible at Figure 4, which shows a rail stressing operation.

Maximum use of mechanisation will be essential in order to save time.

Removing the Ponderl clips

Any convenient track-mounted vehicle may be used. Sturdy fixed hammer, appropriately placed, will drive out the clips as the vehicle moves down the track. Since clips are installed in opposing directions two runs are required to extract all the clips, i.e. 2 clips per sleeper per run.

Clips may be extracted at 20 kph, i.e. 10 kph for two runs. A Ponderl Mark V may be used to drive the clips back into their housings at the end of the operation.

Lifting both rails:

The rails must be lifted well clear of the sleeper, ensuring there is no disturbance to the sleepers in the ballast.

Lifting the Rail Pads:

Materials which tend to stick to the sleeper must be avoided. Ethyl vinyl acetate is selected.

Moving the ‘hook-in’ shoulders to their alternate positions:

Each shoulder is lifted from one position and hooked into the other. The shoulders weigh less than a kilogramme and there is plenty of clearance, so that they will be easy to move while their housings are blocked by dirt. "In-track" trials will determine whether this is a real problem. It may be necessary to fill unused holes temporarily with expanded polystyrene or a similar material, but the fact that they will be covered by the rail pads will probably prove sufficient.

Replacing the rails:

Curves present a problem in that more rail will be required for the new gauge on the inside of a curve and less on the outside. Furthermore, unless the track is jointed, each rail will have to be restrapped so that it is stress-free at the specified neutral temperature. These considerations are beyond the scope of this paper, except to point out that the Ponderl shouldered provides convenient anchor points for side support rollers. Figure 4. These rollers are designed to prevent the rail overturning or moving inwards during the stressing process.

Replacing the insulators:

This operation should present little problem because the sleepers will not have been moved and should therefore be nicely aligned and free of dirt. A simple hand tool is available to ease the rail way one at the other if required.

Replacing the clips:

A Ponderl Mark V will clip up
corrosion is unlikely to become a major problem. If necessary, the shoulder housing will be galvanised to eradicate the possibility.

Once the gauge changing operation has been completed, it may be felt that the "hook-in" shoulders should be made more permanent. If so, they may be cemented into their housings with a suitable grout. More than a million standard Pandrol shoulders have been similarly fixed into concrete sleepers as part of sleeper re-conditioning programmes, usually replacing an obsolete fastening system, with excellent results.

If the testing and development work is successful, and there is no reason to suppose that it will not be, the "hook-in" shoulder will provide RENFE with a method of changing track gauge which is as rapid as any likely to be achieved using current technology.

Latest:

2200 monobloc concrete sleepers incorporating the assembly have now been delivered to RENFE who have installed the first trials (see Figures 5 & 6) and development of a more economic pressed steel version is well advanced.

Figure 5
Trials on RENFE showing rail in different gauge positions.

Figure 6
Overhead view of self-aligning shoulder

Self-aligning shoulders installed on SEPTA.

Self-Aligning Shoulder for turnouts

Since the first installation on a No. 10 crossover on SEPTA's Warminster Branch, USA in November, 1988, the Pandrol self-aligning shoulder is gaining wide acceptance from railroad and transit engineers interested in innovative labour saving ideas when it comes to turnout installation and maintenance.

The self-aligning shoulder is designed to be inserted on a flat 4" wide plate (1/2" or 1" thick) with a milled keyhole which allows the shoulder to rotate and take on the various angles of the frogs, wing rails and closure rails within the turnout without having to angle the plate on the tie.

Using two per tie the self-aligning shoulder plates will replace – one for one – the twin hook plates (1 and 8 Plates) that are commonly used on most freight railroads and transit systems in the U.S. With the ability to add vertical restraint throughout the frog casting, the life of the frog point will be greatly enhanced and maintenance significantly diminished. Tests at Pandrol's Bridgeport, New Jersey facility as well as independent test laboratories have shown that the self-aligning shoulders match or exceed the twin hook plates in lateral restraint and repeated load performance testing, and are superior in vertical uplift and longitudinal restraint.

Although Pandrol clips have been used in frogs with weld-on shoulders, these installations generally require a shop environment to achieve the precision that is required for locating the weld-on shoulder and the welding itself. The self-aligning shoulders, however, are easily installed in the field without the precision, labour intensity or the exact tie spacing that is required with weld-on shoulder assembly.

CSX Transportation, Inc. has installed ten No. 16 turnouts in Knoxville, Tennessee using self-aligning shoulders to anchor their frogs. The ease of installation, the reduction of labour costs and the successful performance of this system indicate considerable potential for the self-aligning shoulder at CSX and other railroads and transit systems across the country.