The Pandrol Fastclip Concrete Crotste on CSXT

by Mark Hardy, Assistant Chief Engineer, Public and Passenger Projects, CSXT

In March 1992, we got our first glimpse of the Pandrol FASTCLIP concept at an informal gathering during the AREA conference in Chicago. What we saw was a wooden model of the system with all the components. It was a working model that could be assembled or disassembled to demonstrate where Pandrol was headed with the development of PANDROL FASTCLIP. The few people in the room played with the model, asked questions and left thinking “all this looks nice, but we’ve got the ‘clip’ system that works great for an so why bother?”

We didn’t give FASTCLIP too much thought until the Fall of 1992 when Pandrol called to say that the system was designed, lab tested and ready for an in-track installation. CSXT agreed that they would be interested in a test, so plans were made with KSA, the CSXT concrete tie manufacturer, to retrofit eight crotste in the tie line to produce 150 FASTCLIP ties. The ties were installed with the Fairmount Tamper P811S, as part of the regular concrete tie program, on a 67° curve near Natural Bridge, Virginia on the James River Subdivision on a very hot July 14, 1993.

The primary reason for the test was to determine if the rail could be bedded in the P811S into the smaller rail seat area with ease. The test would also allow for performance observation. Everyone watched in sweltering heat as the rail flowed from the rollers on the machine into the rail seat. What really jumped out at us was the great convenience of a system where all parts are shipped with the tie at the same time allowing major labour and equipment reductions in the tie laying process. In addition to the heat, it got even more uncomfortable when the track labourers assigned to the project observed “you’re trying to get rid of all our jobs”. Actually I’ve never seen the day on the railroad when there wasn’t plenty for people to do. As we completed the FASTCLIP test section, the obvious advantages of this system seemed to make the heat a little more bearable.

The first PANDROL FASTCLIP trial on CSXT lay installed by Fairmount Tamper P811S near Natural Bridge, Virginia.
The Pandrol Fastclip System

Over the last few years there have been many developments designed to reduce the cost of rail fastening systems, generally directed towards minimising the quantity of material required. This has been achieved by a combination of the more efficient use of base materials, the use of more technically advanced materials, and improved manufacturing processes. Whilst these measures have been very effective in controlling hardware costs, this being particularly relevant at a time of such strong pressures on the operating costs of railways, it has also been realised for some time that there is another major cost factor in the total cost of a fastening system, namely the cost of installing it in track.

The need to reduce this latter element, and at the same time produce further performance improvements, has led to the development of the Pandrol Fastclip Rail Fastening System.

Fastclip has been conceived as a total system. Whilst the system was developed with a completely open mind as regards materials and shapes it was established that the clamping force required on the rail foot could be generated most economically by a steel spring, and that the most efficient section to resist fatigue loading was round bar. A simplified finite element programme was developed specifically to investigate the stress and deflection characteristics of a wide range of shapes before the present clip design was established.

All the fastening components are delivered to site pre-assembled on the sleeper [Figure 1] and, after installation of the rail, the fastening is applied to hold the rail to the sleeper by means of a simple...

Mark Handy (left) personally checking gauge on newly laid track near Winchester, Kentucky.

Pandrol: Could the shoulder and the various components be supplied at a reasonable cost?
KSA: Could the form conversion and plant installation of the components be done to meet their part of the economic puzzle?
Fairmont Tamper: What needed to be done to the Pandrol Fastclip tie? Could the materials be supplied at an acceptable price?

Fairmont Tamper: On January 26, 1994 parties from all the above met with CSXT officials and economic analyst in a somewhat emotional meeting in Jacksonville, Florida. By this time, CSXT wanted the Pandrol system but was not willing to sell the Greenbrier* Resort to pay for it. After a lot of huddling and pencil sharpening, everyone agreed an economic solution was on the horizon. An analysis was needed to prove the FASTCLIP system could be justified by labour savings, equipment savings and increased production, even though the unit cost of the tie was somewhat greater than the 'e' clip tie. The meeting concluded with the agreement that Pandrol would supply the FASTCLIP fastener system to allow KSA to manufacture 1,000 ties. This meant Pandrol could continue to develop the fastener and the associated economics while KSA could study manufacturing techniques associated with the production and assembly of the system. Fairmont Tamper, in the meantime, would look at redesigning the PB115 as primarily a FASTCLIP tie machine. CSXT's assignment was to study all the economic benefits of the system to arrive at a bottom line unit cost for the FASTCLIP tie. Everyone also agreed the 1,000 ties would be installed as part of the 1994 concrete ties program. By early Summer 1994, all parties had completed their assignments. Pandrol had developed and shipped to KSA a fastening system that would meet the physical challenges of heavy freight service at an acceptable price. KSA had costed the equipment after developing a very efficient in-plant machine to put together the pads, clips and insulators to make the FASTCLIP tie ready for shipment. Fairmont Tamper had come up with the concept of an on-board anchor remover, rail heater and clip applicator. All this allowed CSXT to cost out a tie laying process with no laying equipment behind the PB115. It also allowed for the economic consideration of a 10% increase in production.

To look at the fastening system to be certain all economics have been obtained, KSA must continue to develop its assembly process for maximum efficiency and Fairmont Tamper must bring out a new generation machine compatible with the benefits the fastening system offers. CSXT must streamline its tie laying operation to take advantage of all the FASTCLIP system has to offer in order to fulfill its obligation to management and stockholders to install the best concrete tie at the least unit cost, as quickly and safely as possible.

*For the non-golfers, the Greenbrier Resort is a luxury resort, owned by CSXT, and was in fact the venue for the Stealth Cup, the ladies version of the Ryder Cup, in October 1994.
which the sidestep insulator can be freed and replaced (Figure 1). The bearing area of the sidestep insulator against the rail foot has been increased by a minimum of 30% compared to current fastening systems and a considerable increase in service life is expected, particularly in the sharper curves. The outer legs of the clip are also designed to provide further restraint on the sidestep insulator to minimise distortion under the effects of high lateral loads. The spring steel clip is separated from the rail electrically by a “tie insulator”. This insulator is captive on the clip and remains so when the clip is in a partly driven position for transport to site, rail changing or destressing. The clip must be removed completely to change the tie insulator, but this again is expected to be an infrequent requirement since the function of resisting lateral and vertical forces by two insulators rather than one has given exceptional performance results in laboratory testing and in track. In all test positions, the transport, fully installed, partially withdrawn for destressing, and further withdrawn for sidestep insulator change, the clip is located positively by detents in the clip and mating projections on the cast shoulder.

A further feature of the system is that by the use of laps (optional) in the shoulder design, the clip can be prevented from deflecting more than a predetermined amount beyond its normal installation value. This is known as “lateral stiffness” and is seen as being useful in applications such as concrete sleepers where high loads can be placed on the fasteners when the rails are used for lifting during installation.

The system has been tested on a variety of rail pads, ranging from EVA and polyurethane-based designs of relatively high stiffnesses intended for heavy haul opening conditions, to very low resilient rubber pads suitable for High Speed passenger and for Transit traffic. The fatigue endurance limit of greater than 1mm dynamic deflection for the clip makes it particularly suitable for use with rail pads having the lower stiffness characteristics recognised as necessary to minimise the effects of high speed impact forces and vibration. Prototype installation/extraction machines, incorporating provision for lifting low sleeper, have been developed to demonstrate the operational principles of the system, and development of production machines is now proceeding. A range of hand tools for installation/extraction and lifting low sleeper, together with destressing rollers and sleeper lifting clamps for sleeper handling, has also been produced.

Laboratory Testing
FASTCLIP has been subjected to a comprehensive programme of laboratory testing, consisting of the following elements which include current/proposed EN/ENV/AREA tests:
- Repeated dynamic load
- Rail creep resistance
- Shoulder extraction
- Electrical resistance
- Clip fatigue resistance
- Lateral load resistance
- Torsional resistance
- Compression resistance

Many of the above tests were carried out at very low (<40°C) and very high (>100°C) temperatures as well as under ambient conditions. In all cases results were considered to be encouraging and to justify proceeding to track trials.

Track Trials
The first trial was installed in Norway (SNB) in November 1992, using a Flender SM 80 type machine. The site chosen was a 400m curved carrying main line passenger (freight incorporating rail) and commuter traffic to a total of 9 MCT tonnes. Performance to date has been excellent, particularly in respect of retention of line and gauge. The first British installation was a small number of sleepers in the Severn Tunnel in March 1993. This was primarily to assess corrosion resistance and was followed by the installation of several lengths in British track in 1993 and 1994 totalling over 1000 sleepers.

In the meantime, trials have also been installed in Finland and the USA (1200 sleepers in both the CSX and Burlington Northern using Asea Brown Boveri FB1 type machines), 2000 sleepers in Germany (DB) and 200 sleepers in Australia (Humeley Iron). The track trials, which now total over 6000 sleepers, have proved to be helpful in refining the design of both the fastener and the installation technique, and have demonstrated that significant installation cost savings can be achieved as well as future savings in maintenance costs.

Commercial supply has begun in 1995.
Wheel-rail interaction noise is frequently regarded as the most important source of railway noise. Usually wheel-rail noise is subdivided into three categories:

- Rolling noise
- squeal noise
- Impact noise

Rolling noise occurs as a result of roughness of the wheel and rail running surfaces. The observed maximum noise level occurs at around 1-2 kHz for high speed trains on ballasted track. The frequency content varies with travel speed. It is recognised that both the wheel and the rail contribute significant proportions of the radiated noise. In terms of total radiated noise in dBA, noise from the rail is domineant for low train speeds, and noise from the wheel dominates at speeds above 120 km/h. Rolling noise levels increase significantly if the rail surface is corrugated, and thus corrugation prevention (by ensuring appropriate track resilience) and rectification (by rail grinding) may both be effective in reducing noise. Squeal (sponky) noise arises as a result of excitation of the wheel contact surface on very sharp curves. This can be significant on urban transit systems which often have small radius curves. Impact noise results from wheels passing over discrete elements such as rail joints, or switches and crossings.

Noise from bridges is the result of structure borne vibration, excited by the passage of train, which in turn excites vibration of surfaces in the bridge structure which may radiate noise. Vertical surfaces of exposed steelwork within the bridge become major sources of this "re-radiated" or "secondary" noise. Because the vibration which causes this noise must first pass through the track structure, the resulting noise level is critically dependent on the track design.

**Experimental Work**

In order to improve the understanding of some of these factors, experiments were carried out in the laboratories at South Bank University on the UBR (UIC) and Nordic, and track measurements were made on the DLK, at Glasgow Underground and on British Rail. The UBR laboratory tests, and the track tests, had the specific objective of seeking correlations between track vibration (measured in terms of displacement or accelerations) and noise levels. The tests carried out by Pandrol's laboratories were used to verify that track support stiffness designs would also meet standard requirements for structural strength and for general acceptance for railway use.

The track measurements were made on three types of track: Ballasted track at ground level (DLK figure 2 and UIC), non-ballasted track on light weight sleepers (DLK figure 3) and non-ballasted track in tunnel (Glasgow Underground). On the non-ballasted tracks, tests were also made on track with different support stiffness.

The principal measurements made were of relative displacements of the rail and sleeper or track slab, accelerations of rail and supporting structure sound levels very close to the track, and sound level some distance away from the track. Figure 4 shows some typical results of such measurements — in this case from Glasgow Underground. The rail displacement measurements indicated a change in track support stiffness of about one order of magnitude. Sound levels were measured in the tunnel, 1 metre from the rail, and also in an adjacent fire escape passage. Clearly, the general level of noise in the passage was less than in the running tunnel and was also dominated by noise re-radiated from the walls which were excited by structure borne vibration.

The trackside noise data shows that at frequencies below about 40 Hz and above 1 kHz the support stiffness has little or no effect on noise. Between 40 Hz and 250 Hz, the noise level is reduced dramatically by up to 10 dB in this case. In this frequency range, even the noise measured close to the track is dominated by re-radiated noise from the tunnel walls. Between 250 Hz and 1 kHz there are a series of peaks which represent resonant frequencies for various modes of vibration of the track. In some cases the soft support is beneficial, but at some frequencies there is a very slight increase in noise with the soft support. This is generally no more than 1 dB and is confined to very narrow frequency bands at which the increased freedom of the rail to move on its support results in greater noise radiation from the rail itself. This result is at variance with other published literature. If the total sound level is evaluated by using the dBA weighting; a 1 dB increase in noise at around 1 kHz may appear to be more important than a 10 dB reduction at around 100 Hz. Results have also been used to base arguments against the use of soft rail pads in noise critical areas. However, two other factors must be taken into account. Firstly, with the stiffer supporting structure, rail corrugations will tend to develop more rapidly. Corrugation may become a major factor in increasing running noise, so that a small initial reduction in dBA may result in an increase in dBA after a period of time. Secondly, it is worth repeating the comments on the annoyance caused by low frequency noise — there is a growing body of evidence to support the view that dBA based parameters may not be appropriate for evaluating all noise nuisance.

The sound levels measured in the fire escape passage also show that below 40 Hz and above 1 kHz, the change of track stiffness is ineffective. Throughout the range between those frequencies, the reduction in track stiffness is very effective in reducing structure borne noise. The location is shielded from all directly radiated noise from the rail, and thus the resonant peaks discussed above are absent. Throughout the middle frequency range, the noise has been reduced by 7 to 10 dBA.

Attempts were made to repeat these results in laboratory conditions. It was found that the vibration response of the rail support could be measured in the laboratory very effectively, and that results could be obtained which correlated well with the track test results. However, attempts to measure sound levels during laboratory tests produced no meaningful results.

**Conclusions**

The final report on this project (which runs to more than 100 pages) concludes with the following:

1. Under similar operating conditions it is possible to obtain consistent noise measurements suitable for use in a comparative analysis of noise radiated from operating railway tracks.

2. The level of low frequency structure borne vibration, and consequent noise emitted from urban railways was found to be dependent on the type of noise radiated by the rail and, appeared to be better than the stiffer one. In the Glasgow Underground the decrease in vibration measured in the vicinity of the railway. The transmission of vibration into the supporting structure can be reduced by the correct choice of fastening elements.

3. High frequency noise directly radiated from the track, and high frequency structure borne vibration and consequent noise, are not influenced by any large extent by track design parameters on urban railways with relatively low speeds. High frequency noise due to wheelrail interaction appears to radiate most effectively in the vertical direction.

4. Laboratory experiments are of limited use for the prediction of noise radiated from real track, and the effects of changes to the track support on noise.

5. Where noise regulations are specified in terms of dBA, changes to the track design which affect low frequencies can have only a limited influence on the ability of the railway to meet those regulations. However, large reductions in low frequency noise may be achieved on certain types of supporting structures and there may be a significant reduction in perceived noise nuisance in communities near urban railways.

6. Test and design methods have been proposed to facilitate the specification of the performance of low stiffness rail fastening assemblies for use in appropriate locations.

This project was funded by Pandrol International Limited (15%), the Scottish and Engineering Research Council (17%), the Department of Transport (13%) within the UK Government's "LIME" programme for "Transport Infrastructure and Operations".
Rail Flaw Detection in Europe

Pandrol Seco is introducing the latest ultrasonic rail flaw inspection system into the European market, utilising the inspection techniques that have been under development at Pandrol Jackson Technologies Inc. during the past four years.

Pandrol Jackson Technologies Inc undertakes rail flaw detection contract work in North America using its own designed and manufactured ultrasonic equipment mounted in road vehicles provided with hi-rail units which allow the vehicle to be operated on railway tracks. The operation of hi-rail vehicles is not permitted on many European railway systems, including the United Kingdom, and to provide a rail flaw detection unit to undertake work in the Channel Tunnel to fulfil a contract awarded to Pandrol Seco, it has been necessary to mount the ultrasonic equipment on a full-size rail vehicle. The vehicle specification required it to be self-propelled and capable of being towed in a train formation.

The most readily available and appropriate vehicle was found to be a Plasser & Theurer 07 Lining, Levelling and Tamping machine which was no longer required for tamping duties. The work of modification to suit the rail flaw detection requirements was undertaken by the staff of the Plant Department of the South East

Production Unit of British Rail’s Network South East at their Ashford Depot. The modifications included the replacement of some major mechanical components, the removal of the tamping bank and aligning units and the extension of the main operating cab. An air compressor and water supplies were added and numerous pivot points, brackets, tanks etc. added to provide theEMENTS and anchorages for the installation of the inspection carriage: the computer and display units, the rail marking paint guns etc. After a thorough check of all the mechanical functions and a complete repaint, the unit was ready for operation by the end of September 1994 after almost three months of work.

The unit has been equipped with Pandrol Jackson Technologies SYS 1000 flaw detection system. This allows for detection operation at up to 40 kph with real time identification of the location 40 kph with real time identification of the location and extent of faults. The ultrasonic transducers are mounted in polyurethane rubber wheels. The transducers are orientated at 0°, 45° and 90° (the 90° sensor comprising a three unit array) together with an additional side looking transducer to search for vertical splits. All transducers are simultaneously fired at a frequency which produces exceptional output signals at intervals between 1.6mm and 6mm along each rail, the interval being dependent upon trolley speed of probe wheels, with their transducers contra-directed, are run over each rail. Data from the sensors is processed faults are verified, tracked and then identified using pattern recognition techniques and displayed in colour, using icons to register the type of flaw on a scrolling screen. At the same time, a second display registers the location, type, depth and extent of each fault as it is recognised and the rail is paint marked to facilitate location on the rail. All data is stored and can be recalled for the closer examination of particular faults, with the facility to zoom in and enlarge specific areas of the display. Each individual transducer signal is colour coded and can be identified. Colour prints of the displays can be produced on-board. At the end of each shift, a defect report is produced which provides a written summary of all the activities undertaken during the shift. These reports can be tailored to suit the needs of any individual customer.

British Rail Infrastructure Services ultrasonic inspection staff have been trained in the use of the equipment and opportunities are being sought to extend its operation beyond the contract with Eurotunnel.
Design and Construction of TGV Lines
The Belgian Solution

by M. M. Raviart, administrateur-directeur, SNCB

The TGV Network in Belgium

The SNCB network currently owns 1310 route-km of railway lines (about 6000 km of main line track). The high speed (GV) or very high speed (TGV) network is being financed by the SNCB and will have at the most, according to the layout options chosen:

- 152 km of new line operating at 300 km/h
- 29 km of new line operating at 200 km/h
- 78 km of line operating at 200 km/h and 61 km at 160 km/h included in zones of 3 or 4 tracks developed and upgraded for this purpose.

As can be seen in Figure 1, the new tracks are split into several sections separated by sections of upgraded or existing tracks. The "GV Network" is fully incorporated and integrated into the existing network.

Choice of Technical Solutions

The integration of the GV and TGV elements into the existing network has directly influenced the technical solutions adopted. In effect, the limited length of new track and of each of the sections led SNCB to use solutions which differ substantially from conventional solutions only in those cases where GV operation made it essential. The basic aim was to improve the existing solutions wherever possible and to endeavour to preserve the "general philosophy" of the network.

Electricity Supplies

Where the technical solutions differ most is in the electrical field. The power to be provided for GV prevents the use of a 3 kV power source. The choice fell on 2 x 25 kV catenary system for speeds in excess of 200 km/h. The standard SNCB catenaries will be fed from a single point using auto transformers supplied at 50 kV by 25 kV anti-phase feeders slung from the backs of the masts.

The 3 kV system is reserved for the other speeds.

Signalling

SNCB is gradually installing in its network the TBL (transit-beacon locomotive) systems developed by ACEC-Transport. The aim was to use an extension of this system (TBL 3) on the 300 km/h sections too, but since the validation of TBL 3 had not been completed, the TGV 430 system made by CS Transport (formerly CECE) and installed by SNCB on the TGV-Nord line will also be used in Belgium for the first TGV line serving France. A temporary CS Transport ACEC Transport consortium was formed to develop the signalling system for this initial line, which requires, inter alia, the development of an interface between TGV 430 and the P.L.P. programme logic signalling system used by SNCB.

Civil Engineering

With regard to civil engineering and track laying, the solutions adopted are within the current general philosophy of the network. I will now dwell at some length on the solution chosen for the track.

Figure 2 - Layout features of the new 300 km/h lines
A. Features in Plan
1. Cast h = 11.85 V° - 50
2. Deficit of Cast
   - Usual maximum: 50 mm
   - Maximum: 100 mm (v = 300 km/h)
3. Length of parabolic connection
   L = 8 x V° x 1
4. Horizontal curvature ≥ 6,000m
5. Exceptionally 4,000 m
6. Minimum length of curves and tangents 300 m
B. Features of Longitudinal Section
1. Vertical radius: R ≥ 25,000 m
2. Exceptional radius: 19,500 m
3. Maximum gradient: 15 mm/m
4. Exceptional gradient: 21 mm/m

Track Bed

The regions through which the new lines run abound with quarries located very close to the alignment, providing excellent quality stone for ballast.

The track beds are therefore comprised of:
- Aggregate without a binder phase course 70 cm, sub-base 20 cm, well compacted
- Porphyry ballast (DBC higher than 21) with a minimum thickness of 35 cm

A standard cross-section is shown in Figure 3.

Sleepers and Fastenings

Reinforced twin block sleepers and prestressed monoblock concrete sleepers were developed some years ago for use in both higher speed and busy commuter lines. They were subjected to tests specified by the ORE-ITR committee and can also be used on TGV lines. The dimensions of the blocks and tie-bars for these sleepers have however had to be increased. The prestressed monoblock concrete sleepers were also strengthened (57t in place of 42t).

In conventional track SNCB uses 50 or 60 kg/m rail fastened with TRN-91 'S' 1817 clips, cast iron shoulders, glass filled nylon insulators and 5mm EVA rail pads. The shoulders are cast into the sleeper during manufacture. This type of fastener is preferred to threaded types which in our own experience are prone to higher maintenance costs. The shoulder is a robust component which is superior to screw holes which weaken the sleeper, or screw bolts which are prone to damage and corrosion. In the case of the twin block sleeper a different shoulder design is necessary to allow for the instant moulding method used in sleeper production.
After extensive track tests and measurements, the only important changes to the fastening for TGV application are in the clip (larger diameter PANDROL ’e’ 2039 clip) and the introduction of a highly resilient, 10mm studded rubber rail pad which gives significantly better impact attenuation and compensates for the rigidity of the formation (Figure 4).

**Rail**

- UIC 60 rail type 900A will be used. For the GV trains, the requirements are:
  - closer tolerances in rail geometry
  - closer tolerances in levelling and lining, with continuous recording of these parameters;
  - continuous monitoring of surface defects (eddies currents).

The new welding line in SNCF’s Schaerbeek plant includes a press operation on a large base which is capable of welding rails according to the tolerances required for the GV operation.

**Points and Crossings**

Since the principles of operation of the Brussels – Paris line must remain constant throughout the line, crossovers at 170 km/h are also envisaged for Brussels.

The equipment used is constructed in the same way as SNCF’s other UIC 60 equipment:
- UIC 60 stock rail laid at 1/2l.
- UIC asymmetrical low-level points (UIC 60b).

**Implementation of the GV Tracks in Belgium**

**Creation of TUC Rail**

SNCF is a small network and internally did not have the resources needed to undertake the study and follow-up on construction of the GV network. Consequently, it was faced with the following choices:
- to develop its own facilities (including the engagement of specialists) even though they would only be used for a limited period
- to entrust the studies to consultants, who are generally unacquainted with the particular characteristics of the railways and of the network itself
- to set up a temporary partnership whereby specialists from both SNCF and private consultants could come together and complement one another harmoniously

The latter solution was adopted.

**TUC Rail**

TUC Rail was set up as a limited company with its own board of directors. SNCF holds 79% of the shares and T.U.C.

**Conclusion**

The course of action taken by SNCF is clearly set within the context of its own network. However, the problems encountered in the construction of a GV network are of the same nature as for all networks, except for scale. In fact, at the technical level there exists only one objective for the GV and TGV track, i.e. total quality at every stage of design, specification, construction and supervision, and total quality can only be achieved if it is present at all stages as well as in the motivation of all concerned.
The past 140 years of Australia's history and growth from tiny separate colonies to a single modern nation is inevitably intertwined with the development of its railway network. Sadly, the railway history is one that demonstrates a lack of foresight by the early colonists, parochialism and procrastination (or stupidity) of their political masters and their railway managers, offset only by the ingenuity of latter-day railway operators and the forbearance of long suffering travellers.

Historical Background

With its present six states each tracing its establishment (over a period of several decades) to independent British colonies, it is not surprising that each major locality developed separately, subject to its own peculiar geographic, economic and governmental influence. The middle of Australian railway gauges is an excellent example of that fierce independence and competition between colonies, and later between states.

This hindrance to the free movement of transcontinental traffic was brought about at the very beginning of railway construction in Australia. Although originally both the Victorian and New South Wales (NSW) Governments planned to use the same broad (Irish) gauge (19\(\text{ft}, 1,600\text{mm}\)), petty differences over inconsequential matters resulted in NSW ultimately selecting standard gauge (4\(\text{ft}, 8\text{\frac{1}{2}}\text{in}\), 1,435mm) and Victoria remaining committed to broad gauge.

The impact was first felt when the NSW and Victorian railways met at Albany in 1883. The smaller, flung settlements in Western Australia (WA), Queensland (north–west areas of the continent), the Northern Territory and the island state of Tasmania, each chose narrow gauge (19\(\text{ft}, 1,000\text{mm}\)) for logical reasons of stringent economy and ease of construction in the very difficult terrain or vast distances of largely unpopulated countries which confronted engineers right from the start. Furthermore, the mainline systems were far removed from the main colonies in Melbourne and Sydney. Why spend more money just to adopt a common gauge? But as the mainlan colonies thrived, so the railways inevitably linked usually at state borders where every passenger and every ton of freight had to change trains.

South Australia (SA) followed Victoria's stand, adopting broad gauge for its lines radiating from its capital, Adelaide, and by 1886 Melbourne and Adelaide were linked. Until 1922 it remained the only single-gauge route. Ironically, it has become the last intercapital line to be standardised, in 1995.

With a decided lack of (course and Sydney) funds, South Australia chose narrow gauge for several isolated lines built to link outlying sea ports to inland farming/racing areas. Inevitably, these lines extended and soon there were several "break of gauge" stations throughout SA. Moves made in the 1920s and 1930s eliminated two of the narrow gauge operating divisions, and others followed in the 1960s-80s. South Australia's situation became even worse in the 1970s when it was decided to build a compressor. By 1984, after several gauge standardisation projects, there were 12 breaks of gauge in 36,300km of line. In 1994 there were some 35,913km of track as follows:-

**Broad gauge**
- 6,088 km (SA and Victoria)

**Standard gauge**
- 14,055 km (mainly NSW, Victoria, SA and into Brisbane, Alice Springs and Perth)

**Narrow gauge**
- 15,418 km (Queensland, Tasmania, WA and an isolated line in SA)

While the necessity to change trains was an inconvenience to passengers, it was grossly inefficient for freight movement between states and horrendously complex (especially at times of national stress) for railway operation. Every wagon load was manually transferred, much in the earlier days without the aid of handling equipment or machines. Early efforts at containerisation helped, and so did cars.

The break of gauge was such a major impediment to railway operations that Lord Kitchener, reporting in 1910 to the Commonwealth Government on military defence said "...railway communications has, while developing the country, resulted in lines which appear to be more favourable to an enemy invading Australia than to the defence of the country."

In 1933, the Commonwealth Railways experimented with the "jugglback" method as a temporary measure during a gauge conversion project. Three train sets, each of 16 standard gauge bogie flat wagons, were fitted with a narrow gauge track. Propelled up a ramped track, the narrow gauge wagons were then pushed into the standard train, and were secured. They were then conveyed to their destination on the standard line.

Co-operation between the broad and standard gauge systems saw the introduction in the 1960s of wagons with interchangeable bogies which moved freely between WA, SA, Victoria, NSW and into Brisbane, Queensland. The bogies stayed on their home gauge while the wagons moved on. This system reached its ultimate development in 1982 with the opening by Australian National of a highly automated bogie exchange depot in Adelaide. This will lose its raison d'être when the Adelaide-Melbourne line is standardised.

Recycling the Problem

Many efforts have been proposed by railway administrations and State Governments to rectify Australia's gauge maze, but it has been a slow process.

Until 1932, it was only possible to travel interstate between Adelaide and Melbourne on one train; then Sydney and Brisbane were linked by a new standard gauge line into Queensland. In 1962 Sydney and Melbourne were joined by a new standard gauge line into Melbourne. Over the next decade, extensive new work in SA and WA made it possible to travel from 1971 to travel on one train all the way from Sydney via Broken Hill to Perth. That line was linked to Alice Springs in the Northern Territory in 1980 and to Adelaide from 1984. While all mainland capitals had a link into a transcontinental standard gauge line, the only Melbourne to Adelaide line remained broad gauge. Thus 1991 will see the end of interstate broad gauge trains and predictably the early demise of all broad gauge non-urban lines in SA.
Melbourne to Adelaide Rail Standardisations (MARS) Project

The Missing Link

by Peter Millan, Project Manager, Australian National
Section, Melbourne to Adelaide Rail Standardisations.

Six years of planning and construction work will culminate on 7th May 1995 when the Melbourne to Adelaide broad gauge (1600mm) mainline opens as a standard gauge (1435mm) track. The Melbourne to Adelaide section of the rail network is the last remaining section of the main trunk network connecting the Australian capital cities to be converted for standard gauge train operations.

Capital for the Project has been provided by the Federal Government under the One Nation Program and from the Australian Land Transport Department fund.

Project Scope

Three rail authorities own and control various parts of the corridor being converted to standard gauge, namely TransAdelaide (19km), Australian National (290km) and Public Transport Corporation (PTC) Victoria (404km).

The PTC section of track in Victoria has a number of alternative methods being adopted to provide the new standard gauge track. These include:

- conversion of the 27km of track from broad gauge to standard gauge on timber sleepers during a three week closure period
- construction of 99km of new standard gauge track on pre-stressed concrete sleepers
- conversion of 17km of broad gauge track in Victoria to dual gauge track on timber sleepers
- during a three month track closure, reconstruction of 16km of broad gauge tracks with standard gauge concrete sleepers

The TransAdelaide gauge conversion work between Adelaide and Belair involves the separation of a dual broad gauge section of track to one broad gauge suburban passenger line (with new crossing loops) and one standard gauge line. The future standard gauge freight line has been reconstructed with concrete sleepers, incorporating gauge adjustable rail seat assemblies for the change over.

In addition, the Australian National’s 290km of track will also be converted from broad gauge to standard gauge using the gauge convertible prestressed concrete sleepers.

History of the Gauge Convertible Prestressed Concrete Sleepers

In 1989, Australian National (AN) was experiencing problems with the performance of timber sleepers on its 206km section of the Melbourne to Adelaide line. The preferred solution was to replace the deteriorating timber sleepers with new prestressed concrete sleepers. At the time of planning the re-profiled program the track was to broad gauge (1600mm) standards and there were no firms that would take the time to convert the Melbourne to Adelaide corridor to the more widely used standard gauge (1435mm).

After some preliminary investigations, design work and field trials, Australian National concluded that there were practical applications for a gauge convertible concrete sleeper which could be justified on an economic basis. The additional costs of producing such a gauge convertible concrete sleeper could be offset by the considerable saving in labour during the gauge change and the re-use of the same sleeper and fastening components under standard gauge operations.

Australian National called for tenders in December 1990 for the manufacture of 200,000 gauge convertible prestressed concrete sleepers fitted with elastic fasteners. The Safelok fastening system was selected, which involved a central rotating shoulder concept to switch the rail position by the 165mm (i.e. 1650 - 1485mm) on one rail seat only.

Contracts both to manufacture and install the concrete sleepers were awarded to International Rail Road Contractors, a subsidiary of John Holland Construction and Engineering. Manufacture of the concrete sleepers commenced in July 1991 with installation in track commencing during November 1991. All the sleepers had been manufactured and installed by March 1993. A total of 202,800 sleepers were installed during stage 1 of the project at a spacing of 667mm (1500 per kilometres).

The success of the Stage 1 work and the availability of funds under the Federal Government One Nation program resulted in the decision to complete concrete resleepering on the A.N. section of the corridor in South Australia.

At the completion of concrete resleepering, the A.N. track would be converted to standard gauge in conjunction with work by TransAdelaide and PTC National Rail Corporation was given the task to co-ordinate efforts of the three rail authorities to achieve a co-ordinated standardisation of the mainline between Melbourne to Adelaide.

The contract for Stage 2 of the reconstruction of existing broad gauge tracks with gauge adjustable concrete sleepers was awarded to Concrete Constructions (SA) who were to manufacture the remaining 238,000 concrete sleepers for the A.N. section of track between Belair and Coomadyn. These 238,000 gauge convertible prestressed concrete sleepers incorporated the PANDROL rail fastening assembly which retained the same unique rotating shoulder concept in Stage 1 of the project, but modified to accept a PANDROL clip.

Stage 2 track reconstruction involved installing the gauge convertible concrete sleepers in the Adelaide Hills which have numerous 200m radius curves. In 45 grades, and a reasonably constant winter rainfall. Trials of broad gauge concrete sleepers in the Adelaide Hills over a 12 year period have indicated rail seat abrasion occurs and therefore Adelaide and PTC concluded that some form of preventative action would be undertaken.

To overcome rail seat abrasion and other rail pad problems identified during testing, PANDROL Australia Pty Ltd recommended that a heavy duty Polyurethane pad, abrasion plate and gasket should be used in designated areas of the Adelaide Hills instead of the high attenuation rubber pads that were to be incorporated in the sleepers in the less arduous areas.

The polyurethane pad system is the same one that has been used in the USA, but modified to suit the A.N. rail seat configuration.

Heavy duty insulation was also developed for use in the sections of tracks through 200m to 700m radius curves mainly due to the high lateral loads that reduce the effective life of the more traditional GRN type insulators.

The simplicity of the gauge convertible concrete sleeper concept has resulted in the installation of 24,000 sleeper sets on the 14km of the Trans Adelaide line in preparation for the switch over which will bring the use of broad gauge tracks in Australia nearer to its end.

The Gauge Conversion Process

The process of gauge conversion on the concrete sleepers is relatively simple involving the following steps:

1. Rail fasteners are removed.
2. Rail is removed from the broad gauge rail seat.
3. Pud system is replaced.
4. Rotating shoulder is rotated 180° to the standard gauge position.
5. Pads are replaced in the standard gauge rail seat.

Stage 1: Commences mid April 1995 when Tailem Bend to Assiet section of track is closed to all rail traffic which will be diverted via other existing broad gauge and standard gauge routes to Adelaide and Perth.

Stage 2: Commences end of April 1995 when Tailem Bend to Adelaide section of the lines closes for conversion work. In 1995 all traffic is diverted via the existing standard gauge network. Approximately one week later in early May 1995, the first standard gauge train operates Adelaide to Melbourne on the new standard gauge line.