SUMMARY  The company of Thompsons-Byron Jackson, a Division of Borg-Warner (Australia) Limited, has been associated with the supply of Railway Points & Crossings since the year 1880. Initially our supply satisfied Victorian Railways and Tramways requirements. However, since the development of iron ore mining in the Pilbara region of Western Australia the company, since 1967, has supplied to the Heavy Haul Iron Ore Railways a total of 455 turnouts ranging in sizes from No. 8 to No. 20 in 59, 66 and 68 kg/m rail and incorporating both railbound and solid frogs. In addition, a total of 215 frogs and 130 sets of switches have been supplied separately.

The purpose of this paper is to outline the developments resulting from co-operation with the iron ore companies in Western Australia, in an endeavour to overcome the problems that existed.

INTRODUCTION

Consulting engineers, involved in the design of the Railway systems in the North West, specified 'The American Railway Engineering Association Standards' (A.R.E.A.) as a basis for the initial design and construction, which in the early stages was acceptable, but with increased loads and usage, demanded changes in design.

Major factors affecting the life of turnout components in the Railway systems are:

a) Extremely high surface contact stresses due to high axle loads (30-33 tonnes), and train speeds.

b) High frequency of stressing due to train lengths and number of trains per day.

c) Turnout angle (size number) and geometry.

Our contribution, therefore, centres around frogs and switches and these will be discussed in respect to material existing designs, new designs and repair.

1 MATERIALS FOR FROG CASTINGS

1.0 There are four main types of steel which have been suggested for use in cast frogs. These are:

1. High-carbon steel similar in composition to rail steel (0.7 to 0.8% C).

2. Low alloy steel, hardened and tempered to produce a higher level of toughness than rail steel (typically 0.3% Cr, Mn).

3. Austenitic manganese steel (1.2% C, 12% Mn) or one of a number of composition variants.

4. Medium carbon steel flame-hardened on the running surfaces (0.45% C).

As far as the authors are aware only austenitic manganese steel is allowed by any national or network specification.

Before considering the founding and metallurgical implications of these four types of steel, it is enlightening to review the differences in dimensions to be expected between the pattern and the casting as removed from the mould.

See Table I

It is necessary to allow this contraction to take place in the mould, otherwise the casting will tear at those positions which are last to solidify. In order to prevent tearing it is necessary to use all the founders art in mould construction and in the location of feeding heads and runners. Usually it is necessary to remove partially the top part of the mould to prevent the feeding heads hindering contraction.

Steels of differing composition vary in their susceptibility to tearing. Some of the reasons for these differences are understood though the whole story can only be guessed at in the present state of knowledge. However, the following rating of tearing susceptibility represents the current experience.

Greatest susceptibility..Low-alloy steel

..Rail steel

..Medium-carbon steel

Least susceptibility ..Austenitic manganese steel

A further effect of thermal contraction is to cause the castings to curve as they cool in the mould and depending on the design of the castings, the running surfaces may be concave or convex. This effect is also noticeable when castings are water quenched - that is when they are made in low-alloy or austenitic manganese steels. Castings in the latter steel can be pressed straight with relative ease because of their low yield point to ultimate tensile strength ratio but the reverse is true of low alloy steels if
are heat treated to 250 BHN or more and attempts to straighten almost always result in cracked castings.

### TABLE I

<table>
<thead>
<tr>
<th>Steel</th>
<th>Tensile Strength N/mm²</th>
<th>Yield Stress N/mm</th>
<th>Elongation per cent</th>
<th>Impact Resistance, Izod, Joules</th>
<th>Hardness, Brinell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail steel</td>
<td>850/1000</td>
<td>465/620</td>
<td>15/20</td>
<td>14/20</td>
<td>255/300</td>
</tr>
<tr>
<td>Low-alloy steel</td>
<td>850/1000</td>
<td>770/925</td>
<td>15/20</td>
<td>30/45</td>
<td>255/300</td>
</tr>
<tr>
<td>Austenitic Manganese steel</td>
<td>620/1000</td>
<td>340/420</td>
<td>15/40</td>
<td>100/135</td>
<td>180/300</td>
</tr>
<tr>
<td>Medium-carbon steel</td>
<td>620/770</td>
<td>325/400</td>
<td>12/18</td>
<td>23/33</td>
<td>180/225</td>
</tr>
</tbody>
</table>

### TABLE II

<table>
<thead>
<tr>
<th>AREA Solid</th>
<th>Finished Casting Length mm</th>
<th>Contraction from Pattern for Carbon and Low-alloy steels mm</th>
<th>Contraction from Pattern for Austenitic Manganese Steel mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frog No.</td>
<td>20</td>
<td>minus 116</td>
<td>minus 147</td>
</tr>
<tr>
<td></td>
<td>6384</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>minus 90</td>
<td>minus 114</td>
</tr>
<tr>
<td></td>
<td>4343</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>minus 72</td>
<td>minus 91</td>
</tr>
<tr>
<td></td>
<td>3467</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rail steel castings are also difficult to straighten due to the low elongation of these steels. It might be thought that as it is possible to bend rail through quite large angles, the same would be true of castings. However, the mechanical properties of castings are usually found to be the average of the properties in the direction of and across the direction of rolling of wrought steels and the ductility of cast materials is not sufficient to allow any substantial bending.

Heating, both low-alloy and rail steels to 450°C and straightening at this temperature gives the steels somewhat greater ductility than operating at room temperature but handling difficulties and the rapid rate of cooling of frogs does not make this a very attractive procedure.

Austenitic manganese steel is subject to criticism because of the amount of in-track maintenance required, but ironically, the property of the steel which is at the root of most in-track maintenance problems involving mushrooming and metal flow - its low yield point - is the one which is of most use to the foundryman in carrying out straightening operations. Many attempts have been made to increase the yield point of austenitic manganese steel and at the same time preserve its good founding characteristics by varying the composition. It has proved impossible to find an element which fully dissolves in austenite and substantially raises the yield point though many have been tried, notably chromium. The other approach of precipitating out carbides using such elements as molybdenum and again chromium have resulted in severely reduced life through cracking of the castings in service. This effect has presumably been due to the relatively low ductility and impact resistance of the resulting steels. When it is considered that large annual tonnages of austenitic manganese steel are consumed in crushing and grinding equipment and that an increase in the yield point would result in increased service life, it is not surprising that the search for a suitable modification in composition has been going on for at least fifty years. No marked success has been achieved to date and the chances of developing successful composition variants are, therefore, remote.

A more hopeful approach is to use work-hardening as the means of achieving the desired increase in yield point. One of the characteristics of austenitic manganese steel is its ability to work-harden rapidly and the rolling of the train wheels...
over the surfaces of a frog increases the hardness of the top 0.10 to 0.15mm from about 200 B.H.N. to about 500 B.H.N. With the wheel loads found in most public transport networks no other effect is obvious but with the higher wheel loads on mineral railways, distortion of the running surface is likely to occur because localised and sub-surface stress concentrations exceed the yield point.

The advent of sheet explosive has enabled the running surfaces to be pre-hardened before installation. Not only does this technique harden the running surfaces but it substantially raises the yield point of the steel to a depth of approximately 25mm below the surface. Work carried out by one of the authors (D.H.J.) about six years ago established the parameters for successful technical application of the technique and gave some insight into the amount of distortion to be expected on hardening.

Long term results of explosively hardened castings are just starting to accumulate. For instance, the first explosively hardened No. 20 solid frog, installed in November 1972 was removed from the track in May 1977. Unfortunately this casting was re-sited during its life, but it seems to have sustained a minimum of 140 million gross tons of traffic without having been welded. Wear in the nose area was the reason for removal and this casting has been repaired, refurbished and re-hardened. (See 2.6).

In the present state of the founder’s art and with present metallurgical knowledge, there seems little likelihood that austenitic manganese steel will be replaced by any other steel for use in cast frogs. This steel when used in the explosive hardened condition seems to give a satisfactory life under heavy-haul conditions and any increase in life might well depend upon more sophisticated techniques being applied to designs.

TABLE III

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>Rail Steel</th>
<th>Low-alloy Steel</th>
<th>Austenitic Manganese Steel</th>
<th>Medium Carbon Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Knock-out from mould treating the castings gently</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>2. Keep castings at 100-200°C</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>3. Heat treat</td>
<td>N</td>
<td>N</td>
<td>WQ</td>
<td>N</td>
</tr>
<tr>
<td>4. Shot blast</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>5. Pre-heat to 300°C</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6. Remove heads and runners</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>7. Temper at 640°C-680°C</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>8. Shot blast</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>9. Inspect</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>10. Pre-heat to 300°C</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11. Arc-air head and runner stubs</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>12. Remove defects</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>13. Pre-heat to 300°C</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>14. Weld defects</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>15. Heat treat</td>
<td>NT</td>
<td>WQ&amp;T</td>
<td>-</td>
<td>NAT</td>
</tr>
<tr>
<td>16. Shot blast</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>17. Inspect</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>18. Dress to dimensions</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>19. Pre-heat to 450°C</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>x</td>
</tr>
<tr>
<td>20. Straighten</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>21. Inspect</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

x = an operation
NT = normalise and temper
N = normalise
WQ&T = water quench and temper
2 FROGS

2.1 Spliced-Rail Frogs

As an alternative to manganese cast steel frogs, spliced rail frogs are used by one of the mining companies. They are a conventional design with cast spacers bolted between the heel and wing rails. Sizes in use are numbers 10 and 14 in 50 kg/metre rail section.

The nose and the wings in the transfer area require 'in track' maintenance consisting of gouging, grinding, welding and re-grinding to original profile at least three times per annum, with complete rejection after twelve months service.

Some of the No. 14 frogs have been replaced with solid cast manganese steel frogs that have been explosive hardened. No rework has been necessary other than occasional maintenance in grinding the flowed metal off the edges of the nose and wings in the transfer area. The metal flow has been slight and the grinding has prevented crack propagation and eventual shelling of the nose.

The life of the cast manganese frogs in this application has so far exceeded two and a half years.

2.2 Rail-Bound Cast Manganese Steel Frogs

This type of frog would be most commonly in use with number 10 for yard application, number 12 for maintenance loops, and number 15 in mainline turnouts. Explosive hardening is carried out on all new frogs with a resultant increase in track life.

Maintenance consists principally of grinding flowed metal to prevent crack propagation and shelling. The chief mode of failure is metal fatigue and shelling on the nose and wings in the transfer area. Continuous flexing of the frogs under traffic contributes also to an occasional cracked wing.

Weld repair of frogs has been carried out in track, field, and under workshop conditions. Success rate varies due to many factors and a discussion on this appears in Section 2.7.

2.3 Solid Cast Manganese Steel Frogs

This type of frog is also supplied in the explosive hardened condition with performance equal to or exceeding that of the rail-bound frogs. Whereas previous use was restricted to number 20 in 68 kg/metre section, the present use is extended to numbers 10 and 12, gaining preference in some instances over the rail-bound frogs.

Fatigue is again a problem in the transfer area and grinding becomes a maintenance requirement. Tang breakage is a problem when the frog bolts slacken but experience has shown that even with the tang completely separated from the body of the casting the frog performance is not impaired. In an effort to reduce repair costs, frogs have been installed in this manner, with the tang completely separated from the casting and acting only as a separator.

2.3.1 Design Changes

Tang failures seemed to occur suddenly; usually after five years service. A hollow-boxed tang section was adopted to increase its strength, i.e. increased modulus of section at the tang joint by a factor of 1.59 and in the beaded section of the tang by 1.33.

A similar modification was reported in a recent A.R.E.A. Bulletin. The length of service in track of this modification has been insufficient to determine the effectiveness of the change. Refer to Diagram 2.

Although the foregoing alterations are designed to give a better service life, the final results depend on good maintenance, such as bolt tightening and tamping of ballast.
Pandrolising of complete turnouts led to complex shapes and multiple variations of pandrol tie plates for both rail-bound and solid cast manganese steel frogs having a curved A.R.E.A. profile at the bottom flange. To simplify the plating a solid frog with parallel flange sections was developed. The benefit was that a number 20 frog, normally requiring 32 different designs of plates now only requires 8, some of which are usable in both the right and left hand configuration, and also for the number 10 and 12 frogs.

2.4 Machining Austenitic Manganese Steel

Machining cast manganese steel is not without its problems but with the use of tip tools and the correct speeds and feeds, satisfactory results are obtained, even with milling and planing.

As the Mining Companies strive toward increasing the life of their turnout components, track installation contractors were given closer tolerances to maintain. Aiming at zero tolerance on the gauge of an initial turnout installation set a standard that could not be achieved without machining of the running faces of the cast manganese frogs.

Machining is carried out on the top face of the nose and wings of the frogs, also the running edges to provide an accurate face to which to gauge.

2.5 Swing-Nose Frogs

With the collapse of metal occurring in the transfer area of the frogs it was inevitable that interest would turn toward solving this problem. The swing-nose frog came to the fore because of its continuous running surface and the elimination of the transfer area in a conventional frog.

The major problem in the use of these frogs is with the installation of fail safe equipment for both power and hand operation.

Two types are currently being tried in the North West.

2.5.1 Rail type swing-nose frogs

These consist of conventional rail forming the wings and heel rails of the nose pieces. The nose consists of two forgings in rail and steel, machined as mating and sliding components. The forged nose pieces are flash butt welded to the heel rail forming an uninterrupted joint.

The total frog is then Thermit welded in to continuous welded track. Two of this type are currently under test in size No. 20.

The major difficulty in the manufacture of this type of frog is in procuring a billet of steel to the same composition as the rail. The billet is removed from the mill at the time of rail rolling. The billets are forged to shape before machining and flash-butt welding. The most significant development in the use of this frog appears to be in West Germany where Axle loads are in the region of 45 tonnes, and it has been observed after 3 years service, and 220 million gross tonnes, the test frogs had never been rebuilt. (reference 1).

2.5.2 Solid cast manganese steel type swing-nose frogs

A critical design parameter for this frog was that it be directly interchangeable with an existing No. 20 solid cast manganese steel conventional frog. Essential that the dimensions - length, width of the parallel feet section, and position with relation to the theoretical point are all identical with other frogs.

The tongue of the frog is operated on a simple pivot system with all mating faces machined to guarantee the accuracy of fit. The tongue fits inside the hollow centre of the casting and slides on the machined floor within the casting, somewhat similar to a tramway crossing.

All the running faces, wheel support areas, and any critical metal flow areas are explosive hardened, and the nose is replaceable and repairable.

These developments are not original on our part and not necessarily the answer to every Railroad operator's problems. They do, however, represent a new look at tried components in the light of available modern technology and the operating conditions of the companies involved.

2.6 Explosive Hardening
In the first three or four days life of an explosive hardened casting the metal at the edges may flow slightly, requiring grinding; thereafter the metal stabilises and further deformation usually ceases to be noticeable.

Two No. 15 frogs were used in a siding as a trial to determine the value of explosive hardening. A normal frog at 200 B.H.N. was installed at one end of the siding with loaded traffic travelling from the heel of the nose to the point of the frog. An explosive hardened frog was installed at the other end of the siding with loaded traffic travelling from the toe on to the nose. The hardness of this casting was 350 B.H.N. Four days after installation both were hardness tested and measured with templates to determine metal flow. The hardness of the normal frog was 300 B.H.N. and metal flow evident, whereas the hardness of the explosive hardened frog increased to 400 B.H.N. with only slight movement on the running edges.

Fifteen days after installation the normal frog was at approximately 300 B.H.N. with serious deformation. The hardened frog was approximately 420 B.H.N. with very little further deformation.

Twenty one days after installation the normal frog was at approximately 450 B.H.N. but the nose height near the point showed a loss of 12mm. The surface exhibited metal crazing and the flowed metal had been repeatedly removed by wheel flanges. The hardened frog was also at 450 B.H.N. and after slight metal flow had been ground off the loss in height of the nose wedge was less than 1.5mm.

Explosive hardening, by increasing the sub-surface yield point reduces the loss of profile, enabling the casting to stay in the track for longer periods. Depending on the particular railroad conditions, the life of an explosive hardened frog could range from 2 to 5 times that of a conventional spliced rail or normal rail frog. All frogs supplied to the North West are now explosive hardened.

The initial No. 20 test frog installed in the North West was removed from service after 4½ years and 140,000,000 gross tonnes of traffic. This frog has been repaired and re-hardened for use.

2.7 Repair of Cast Manganese Steel

Procedures have been developed for the repair of cast manganese steel frogs, resulting in this being an accepted service.

The largest single factor in the quality of the end result lies with the operator, who needs to be meticulous in searching for and removing defective metal and cracks. It is then essential to control the quality of the weld and the temperature of the casting at each weld run, ensuring that each run is sound before proceeding to the next layer.

Repairs are currently being performed:

i) in track

ii) in the workshop

The composition of the electrode for the best results needs to match the casting in carbon and manganese content. Successful repair has been carried out with high nickel and high chromium electrodes but not always do they react favourably to explosive hardening.

2.7.1 Failures

Two types of failures have occurred in repaired frogs:

i) Incorrect chemical composition of the welding wire resulting in excessive brittleness and cracking.

ii) Insufficient depth of metal removal.

2.8 Frogs - Summary

The performance of cast manganese steel in the Railway systems of the North West indicate this to be the best material currently available. There is a definite advantage in explosive hardening because of reduced metal deformation and increased life.

The cast manganese steel frog is very suitable for repair using proven techniques, returning it almost to the 'as-new' condition.

3.0 SWITCHBLADES

There are two different switchblade profiles in use in the North West, but four different types.

3.1 Knife Edge, Uniform

This knife edge profile employs a uniform riser from behind the heel to the toe of the blade. This blade does not use reinforcing bars at all in the web to compensate for the reduced strength due to machining away of the metal from the ball and foot of the rail. These blades are usually for low density traffic, where wear is not as severe as for other applications. Performance under these conditions is usually satisfactory.

3.2 Knife Edge, Graduated

This knife edge profile employs a graduated riser from ahead of the heel to the toe. The blade has reinforcing bars on both sides and it is the most commonly used, the major benefit being that it can be placed against a standard piece of rail for the stockrail.

3.3 Vee Nose

The Samson or Vee nose profile with a graduated riser, reinforced both sides and mated with an undercut stock rail. Where used, they seem to give a longer life in track.

The main objection to the use of the Samson type blade appears to be the need for a specially machined stockrail. It is also argued that metal flow on the head of the stockrail prevents the switchblade from housing fully, resulting in regular grinding maintenance.

3.4 Manganese Steel Tips

On all blades the major problem is wear and subsequent collapse or breaking out of the first
600 mm of the tip. Any switchblade, regardless of its size, is subject to varying degrees of wear due to the pressures exerted by axle loads.

The answer to this problem appears to be the manganese steel tip. They are currently being fitted as standard to No. 10, 12, 15 and 20 switchblades. An example of improved life can be cited in a mainline turnout where switchblades were being replaced every three to four months. The addition of a manganese tip extended the life to twenty-six months before being removed, and depending on the turnout conditions, life expectancy can be even longer than this.

Manganese steel tips are not explosive hardened due to manufacturing problems.

![Diagram 5 - Various Switch Points](image)

3.5 Straight Vs Curved Blades - Machining

The majority of blades in service are a straight cut profile from the heel to the toe and can be used in right hand or left hand turnouts.

The initial installation of No. 20 switchblades consisted of curved blades. However, as the central offset of the curve was only 3mm over 7 metres, these blades were converted to a straight cut.

Where Samson or Vee nose blades are in use the switchblades are curved and this is probably a contributing factor towards the lesser wear that these blades seem to undergo. The performance of these blades indicates a possible advantage in curved profiles for all short blades for No. 10, 12, and 15 turnouts.

3.6 Elliptical Turnout (or Spiral Curved Turnout)

In a specific application, a left hand No. 10 turnout with a reverse curve lead was presenting serious problems in the straight cut right hand blade (i.e. turnout blade) which needed replacement every seven to ten days. A Samson blade was tried in this situation. The wear on the blade was equally as severe but since it was safely housed under the stockrail there was no fear of splitting the turnout and it was able to remain in service for over twenty-one days.

The design and manufacture of an elliptical curve turnout was undertaken in an effort to overcome problems. Because of space restrictions the same lead from the frog to the toe of the blade had to be employed. The blade length increased from 5.016 to 6.180 metre and the angle of entry from 1 in 32 to 1 in 75. This reduced the rate of change of direction of the traffic over the point of blade, gave a larger radius of turnout at the blade toe and heel whilst maintaining the pre-existing turnout radius at the frog.

As the above turnout is to be positioned in the yard and that carries all loaded traffic, it has not yet been possible to install it since the down-time required to realign the turnout from the toe of the frog to the toe of the blade would disrupt operation.

In the meantime the life of the existing blade has been increased to eleven weeks by the use of a cast manganese steel guard rail just ahead of the left hand switchpoint.

3.7 Turnout Sizes

The most common sizes in use are the No. 10 for yard application, No. 12 for maintenance loops and No. 15 and No. 20 for mainline.

The No. 10 turnout conserves yard space but its performance is not good under loaded traffic. If it were possible, changing to No. 12 turnouts would give better life expectancy.

The current trend towards No. 20 turnouts for mainline use has been stimulated by the good performance of those that are currently in use. Frog and switchblade life is extended and faster traffic handling can be achieved.

3.8 Heel-less Blades

Every joint in a track poses a maintenance problem and as such the heel of a conventional blade is probably the major one and for this reason the step has been made towards heel-less bladed welded in-track.

It applies mainly to No. 20 mainline blades and the longest blade in service is 13.83 metres. The blade is bolted to the stock rail, through a series of short heel blocks, commencing 11.85 metres from the toe of the blade. The next step is to eliminate the bolting of these blocks and retain them in some other way as every hole is a potential initiator of fatigue failure.

3.9 Repair of Switchblades

Welding of the worn point of the switchblades has often been very successful but on other occasions pieces have broken out and the blades sometimes curl upwards during cooling. A regular replacement program is now under way where all worn switchblades are returned to the factory. The existing stops, bolts and reinforcing bars are used and fixed to a new piece of rail and fitted with a manganese tip. This represents a considerable cost saving when compared with a completely new manufactured switchblade. It ensures also that the blade will fit without distortion at the point.

4.0 OTHER DEVELOPMENTS

Staying within the confines of the turnout area, improvements in other components have been pioneered by the Mining companies. Some of these are mentioned below.

4.1 Stockrail Movement

This problem results in a blade that distorts to the shape of the stock rail and makes it impossible to gauge without realigning the turnout. Two trials are currently under surveillance:

1) Rail braces on every chair plate from the point of the switch to the heel of the blade.
ii) A series of six gauge plates regularly spaced from the point of the blade back to the heel.

No extensive results are yet available from either of (i) or (ii) above.

4.2 Spreader Bars

Four different designs of bars and side jaw clips are in use in the North West area. Some are costly to manufacture because of casting shape, fitting time required in assembly, and a different spreader bar is needed for each position along the switch.

A design was developed by one company to help eliminate this problem. The result was one spreader bar, adjustable to suit all positions between the switchblades on all sizes of turnouts, including the front rod. The overall cost to produce is half that of the previous design with interchangeability and reduction in stockholding. The insulation of this bar occurs at each end - it is simple and just as effective.

4.3 Pandrolising

Wherever possible turnouts are completely pandrolised throughout. Every chairplate, except those that employ a rail brace, contains a welded lug in to which the pandrol clip can be driven.

Some difficult areas exist between the feet of closely converging rails near the heel of the switch and the toe and the heel of the frog. In these limited instances an upstand on the plate or a screwspike helps to retain the foot of the rail in position.

Pandrolised twin tie plates are used adjacent to the heel of the switchblade and under the total area of the frog.

4.4 Guard Rails

The most common guardrail in use is the one piece cast manganese steel to A.R.E.A. design. The other design in use is the adjustable tee bar guardrail, made from standard rail.

The one piece cast manganese steel guardrail is expensive to replace, difficult to adjust and seems to promote 'cut throating' of the dog spikes due to movement between the stock and guard rails. The tee-bar guardrail is easier to adjust, gives a longer guarded area near the transfer area of the frog but has increased wear rate.

The ultimate development from this is a manganese steel guardrail, with a cross section similar to that of standard rail. The length is 3.95 metres and is standard for all sizes of turnouts. This guardrail is bolted through the running rail with adjustable blocks between to give 12mm of movement. Both rails then sit on a chairplate fitted with a pandrol lug against the running rail and an adjustable rail brace on the guardrail side.

The whole configuration is a solid and well tied unit with the rail braces effectively resisting any overturning movement imposed by the flange action on the guardrail. The initial installation is more expensive due to the plates and braces required.

5.0 CONCLUSION

A review of materials which might be considered for the manufacture of frogs used under heavy haul conditions indicates that austenitic manganese steel will be used into the foreseeable future because of increased manufacturing difficulties with other possibilities. Explosive hardening will be used to decrease the maintenance necessary and to increase the service life of these components. It has been shown that it is technically possible to repair and refurbish turnouts and return them to the track for periods of service approaching that of new equipment. Modifications to A.R.E.A. designs are described and these have proved effective under heavy-haul conditions. Improvements in switchblade design by application of manganese steel tips has provided a worthwhile addition to the turnout serviceability and life.

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7.0 REFERENCES

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