



AUSTRALIAN RAIL TRACK CORPORATION LTD

Engineering (Track & Civil) Manual

Rail Grinding Manual for Plain Track

ETN-01-02

Applicability

ARTC Network Wide	✓	Western Jurisdiction		New South Wales		Victoria	
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Document Status

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1.0	18 Mar 08		First issue
1.1	21 May 08		Minor changes for clarification of referencing points. Rail Templates included as Appendix 1.

Introduction

This document establishes more detailed guidelines for rail profiles to be used on plain track owned by Australian Rail Track Corporation (ARTC) and describes the methods by which the rail profiles are to be applied and the quality standards to be achieved. Plain track is defined as all track up to the last of the 1:20 rail cant plates before and after turnouts. More stringent and/or specific requirements may be applied as part of a regional grinding strategy.

The guidelines have evolved from work initially undertaken by the Wheel/Rail Committee (RailCorp (formerly RIC), ARTC, StateRail and Asciano (Formerly Pacific National) to develop suitable, matching rail and wheel profiles.

Significant additional work was then undertaken in the implementation and assessment of these profiles through grinding strategies in the Heavy Haul areas of the Hunter Valley, the North Coast and the Metropolitan Regions.

This document deals more specifically with rail profiles and grinding requirements in the ARTC Regions, and has been based on the extensive experience gained from the application of the initial standards over several years, together with reviews of overseas practices (in particular the European UIC).

References

Important: This manual must be read in conjunction with the following ARTC Standards:

- *ETM-01-02 Rail Grinding Standard for Plain Track*

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1 Purpose

The main general objectives of rail grinding are to:

- Establish rail profiles that improve the wheel/rail interaction characteristics, and hence reduce rail (and wheel) wear, surface defects, and the risk of unstable vehicle performance (hunting), as well as increasing the rail wear life.
- Rectify or control existing rail surface defects, and hence reduce the risk of rail failures and track deterioration.
- Control rail surface condition so that defects such as Rolling Contact Fatigue (RCF) do not shield/prevent efficient Ultrasonic Testing of rail.

The application of appropriate rail profiling and grinding procedures will lead to considerable technical/economic benefits, including the extension of rail life, a reduction in rail defect numbers, and the ability to operate at higher axle load/speed combinations than were previously possible on relatively light weight rails on much of the interstate lines in Australia.

This document describes procedures for rail profiles to be used on plain track owned or leased by Australian Rail Track Corporation (ARTC) and describes the methods by which the rail profiles are to be applied and the quality standards to be achieved by the rail grinding process. Plain track is defined as all track up to the last of the 1:20 rail cant plates before and after turnouts. For Vossloh Cogifer turnouts this should be at the end of the stock rail and at the end of the vee crossing. More stringent and specific requirements may be applied as part of a regional grinding strategy.

Recommended rail grinding frequencies are detailed.

All rail grinding work must be conducted in accordance with all relevant OH&S requirements, ARTC Standards and Environmental Licenses, relevant legislation and relevant Safeworking requirements (including for work affecting interlocked points).

2 Scope

The following sections provide details of the implementation process associated with rail grinding, and include:

- (Section 3) Common definitions applied in rail grinding.
- (Section 4) Rail Profiles and associated templates, including fabrication and tolerances.
- (Section 5) Preparation for Grinding.
- (Section 6) Application of templates and associated tolerances.
- (Section 7) Vehicle Mounted Measuring System.
- (Section 8) Minimum metal removal requirements for corrective/transitional grinding.
- (Section 9) Metal removal requirements for preventive grinding.
- (Section 10) Surface finish requirements.
- (Section 11) Grinding operation.
- (Section 12) Monitoring and control.
- (Section 13) Personnel competency requirements.
- (Section 14) Grinding application decisions.
- (Section 15) Grinding strategy.

It should be noted that the Rail Grinding Strategies to be adopted by ARTC, both overall and regional, have been discussed in more detail in the following separate documents:

S Marich, "Rail Assessment on the North Coast and Hunter Valley Regions", ARTC Internal Technical Report, 28 September 2006.

S Marich, "Rail Assessment on the Main South Region", ARTC Internal Technical Report, 11 October 2006.

S Marich, "Rail Assessment on the North East and West Lines in Victoria", ARTC Internal Technical Report, 27 November 2006.

S Marich, "Rail Assessment on the South, ACB and TAR Lines in South Australia", ARTC Internal Technical Report, 2 December 2006.

S Marich, "Main Line Rail Grinding Strategy and Justification for ARTC", ARTC Internal Technical Report, 8 December 2006.

3 Definitions

ARTC Delivery Manager	A person who has formally been allocated maintenance responsibility for a particular area/region at Engineer level.
ARTC Delivery Manager or nominated representative	An ARTC Delivery Manager or nominated representative who has been delegated with the engineering authority with respect to Rail Condition/Grinding Management by the appropriate ARTC Corridor General Manager or nominated representative.
ARTC Grinding Manager	An ARTC National Manager with responsibilities for grinding, or a delegated representative.
Cant bar	A flat bar section that sits over the rails to provide a measure of the actual rail cant when taking rail profiles manually.
Checking locations	Specific points marked on the rail, within a track segment, where the achievement of the defined rail profile and/or metal removal is checked and monitored,
Contact band	The contact position of the wheels on the rail as evidenced by the shiny worn surface. This generally applies to contact occurring on the running surface of the rail but in the high rails of sharper curves the contact band extends into the gauge corner region and face (refer to Figure 1 (b)).
Contractor	The organisation conducting the rail grinding activities.
Corrective or defect grinding	Grinding to remove specific defects in the rail. Such defects may occur over a relatively long track section (for example: rail corrugations or extensive rolling contact fatigue) or over relatively short track sections (for example: wheelburns, squats or isolated rolling contact fatigue defects).
Field side	The side of the rail opposite the gauge face (refer to Figure 1 (a)).
Field side relief	Clearance between the wheel profile and the rail profile to reduce wheel rail contact on the head of the rail on the far field side (refer to Figure 1 (a)).
Gauge bar	A rod or bar section which sits between and normal to the rails to provide a superelevated reference for the application of the template.
Grinding Supervisor	The person representing the Contractor who is responsible for the rail grinding operation.
Gauge corner	The top corner of the rail above the gauge face (refer to Figure 1 (a)).
Gauge face	The zone of the rail head facing the inside of the track. In the tighter curves the gauge face may be worn due to contact with the wheel flange.
Gauge corner relief	Clearance between the wheel profile and the rail profile to reduce wheel rail contact in the gauge corner region (refer to Figure 1 (a)).
Maintenance Contractor	The organisation responsible for the overall track maintenance work on the Region.
Minimum metal removal	Generally a specified depth of the minimum metal to be removed from the contact band – See Fig 1(b). Usually determined by measurements taken before and after grinding.
New rail grinding	Grinding to profile of rails that have been in track for less than 5-10 Million Gross Tonnes (MGT) of traffic.
Preventive or cyclic grinding	Grinding carried out to a regular schedule for the purpose of maintaining the rail profiles, preventing or inhibiting the growth of defects, and maintaining the surface condition of the rail (particularly in terms of corrugations and local vertical irregularities), with a minimum metal removal of 0.2 mm from the rail contact surface each grinding cycle.

Previously ground rail grinding	Grinding to profile of rails which have been profile ground previously but are beyond the specified preventative cycle, noting that the actual rail grinding effort in this case will depend on the tonnage level beyond the specified cycles which the rails have experienced, i.e. more grinding effort will be required as the tonnage beyond the specified limits increases.
Rail grinding template	A template used to fit over the head of the rail to show the relationship of the ground rail to the defined rail profile.
Running surface	The zone on top of the rail head which generally makes contact with the wheel tread (refer to Figure 1 (a)). However, it should be noted that in the high rails of sharper curves the wheel/rail contact extends into the gauge corner region (refer to Figure 1 (b)).
Track Segment	A section of track in which the rail is ground to a uniform profile, for example: a curve from the start TP to the end TP, or a tangent from the start TP to the end TP, or the mid point of a short (< 200m) tangent separating two curves.
Transitional grinding	Grinding carried out usually over several cycles to transfer from a corrective/defect to a preventative/cyclic grinding regime.
Vehicle mounted measuring system	A system mounted on the rail grinding unit or auxiliary vehicle that is capable of measuring the rail head profiles, metal removal and/or surface characteristics.

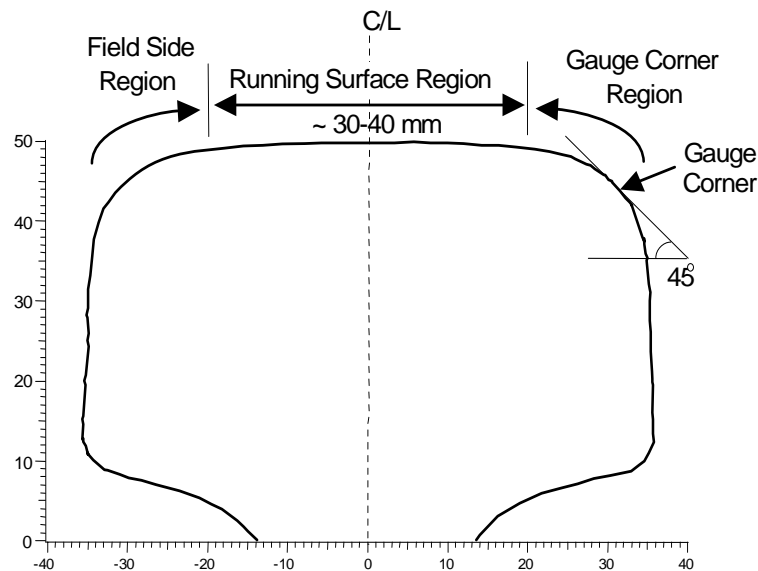


Figure 1(a): Regions in 60kg/m Rail (Vertical Orientation)

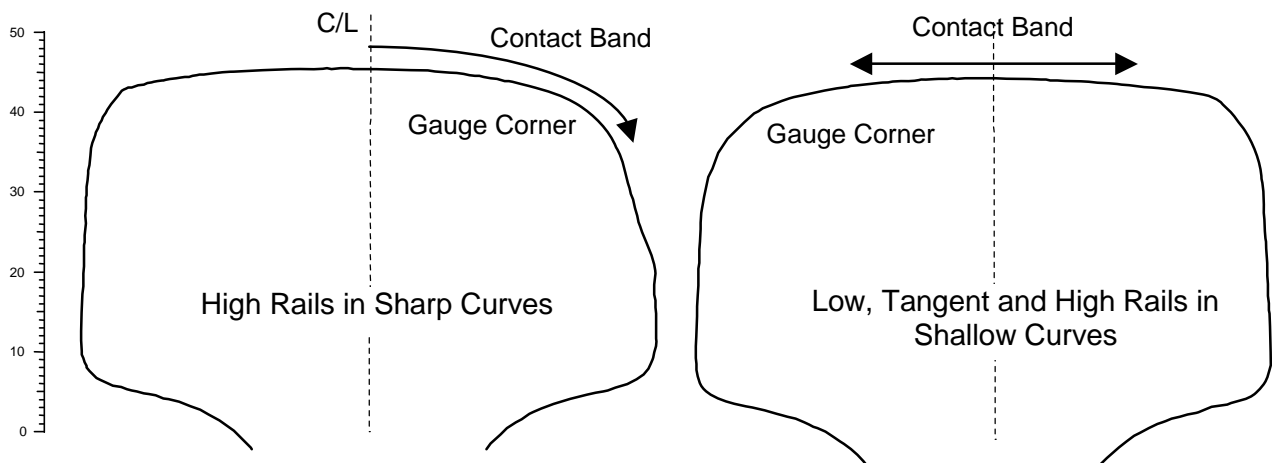


Figure 1(b): Schematic Examples of Rail Contact

4 Rail Profiles

4.1 Profiles and Templates

The rail shapes required have been determined for tangent track and curved track (including for high and low rails). The same basic shapes apply to all rail sizes and types.

The main rail shapes are designed to suit current wheel profiles in both the new and worn conditions, if the latter are within the prescribed wear tolerances. As part of the design the contact band width and location position is determined. The designed rail shapes required have been converted into matching templates for use with the rail grinding operation.

The templates to be used are summarised in Table 1 and the details of each template design are given in Appendix 1. Figure 2 provides an illustration of the modified profiles in relation to a new 60 kg rail.

Profiles ARTC H3, ARTC L3 and ARTC TGT1 are applied in special circumstances, as discussed in more detail in later sections of this document.

From Figure 2 the following main variations are evident:

- In the high rails the ARTC H2 profile exhibits a minor undercut in the gauge corner region relative to the new rail, with the aim of establishing a relatively conformal contact with the wheel profiles and hence reducing the contact stresses in this region. The ARTC H3 profile exhibits an additional undercut in the gauge corner region with the aim of reducing the wheel contacts in this region. The ARTC H2R profile exhibits additional field side relief and is implemented where wheel hollowing is excessive.
- In the low rails both the ARTC L1 and ARTC L2 profiles have similar gauge corner region details, which exhibit very minor undercuts relative to the new rails, with the aim of centralising the wheel/rail contact on the running surface. However, ARTC L2 has more field side relief than ARTC L1, to prevent contact in this region with the more hollow wheels present in freight and coal traffic. The ARTC L1 profile is applied only as part of a transitional grinding strategy, to reduce the field side grinding effort required. The ARTC L3 profile has additional field and gauge side relief, and is implemented where wheel hollowing is severe.
- In the tangent rails, the ARTC TGT profile exhibits an even greater undercut in the gauge corner region, to ensure that wheel/rail contact is made near the centre of the running surface, which enhances vehicle stability at higher operating speeds. The gauge corner undercut is increased further with the ARTC TGT1 profile, which is implemented to reduce/eliminate plastic flow/mushrooming in this region.

However, it should be noted that in worn rails or rails that are outside the specified grinding cycles the metal removal requirements could be considerably greater than for rails that are within the preventative grinding cycles.

It will be the responsibility of the Contractor, in consultation with the ARTC Grinding Manager or nominated representative, to assess the metal removal and hence the grinding requirements.

In certain cases, there may be a requirement to apply corrective/defect grinding, which will entail the removal of a considerable amount of metal primarily from the running surface of the rail along a certain length of track. In all of these cases, the grinding shall be completed by the implementation of the relevant rail profiles as specified in Table 1, which shall conform with all of the standards applied to the normal preventive grinding practice. The only allowable exception is when the rail profiles before grinding are significantly different to the required profiles, due to excessive gauge corner and/or field side relief applied during previous grinding cycles. In these cases, the rails can be treated as transitional and a relaxation of the required tolerances outside the contact band may be applied at the discretion of the ARTC Grinding Manager or nominated representative (refer to Section 6).

The templates used for tangent and low rails contain positioning lugs, as illustrated schematically in Figure 3. The purpose of this lug is to provide a referencing point for the template relative to the centreline of the rail. The application of the positioning lug is detailed in later sections of this document. It should be noted that due to rail manufacturing tolerances the locating lug may not make contact on the gauge face even in new rails.

The measurement of profiles and tolerances before/during/after grinding is to be conducted by the Contractor preferably using a non-contact profile measuring system. However, contact systems may be used by the ARTC Grinding Manager or nominated representative or the Contractor as a means of conducting any post grinding quality assurance assessments.

Table 1: Rail Templates

Situation	Profile Name	Template
Tangent track and curves with radius > 900m Also used for the high rails in very sharp curves (radius less than 300m) and low operating speeds (less than 25 kph)	RTG2000	ARTC TGT
Curved track (\leq 900m radius), mainly freight or coal traffic as part of a transitional grinding strategy, low rails	RPL2000	ARTC L1
Curved track (\leq 900m radius), mainly freight or coal traffic, high rails	RMH2000	ARTC H2
Curved track (\leq 900m radius), mainly freight or coal traffic, low rails	RML2000	ARTC L2
Curved track (\leq 900m radius), high rails transitional, exhibiting severe RCF defects in the gauge corner region	H3	ARTC H3
Curved track (\leq 900m radius), low rails with additional field/gauge side relief	L3	ARTC L3
Tangent track and curves with radius > 900m with additional field/gauge side relief	TGT1	ARTC TGT1
Curved track (\leq 900m radius), high rails with additional field side relief	H2R	ARTC H2R

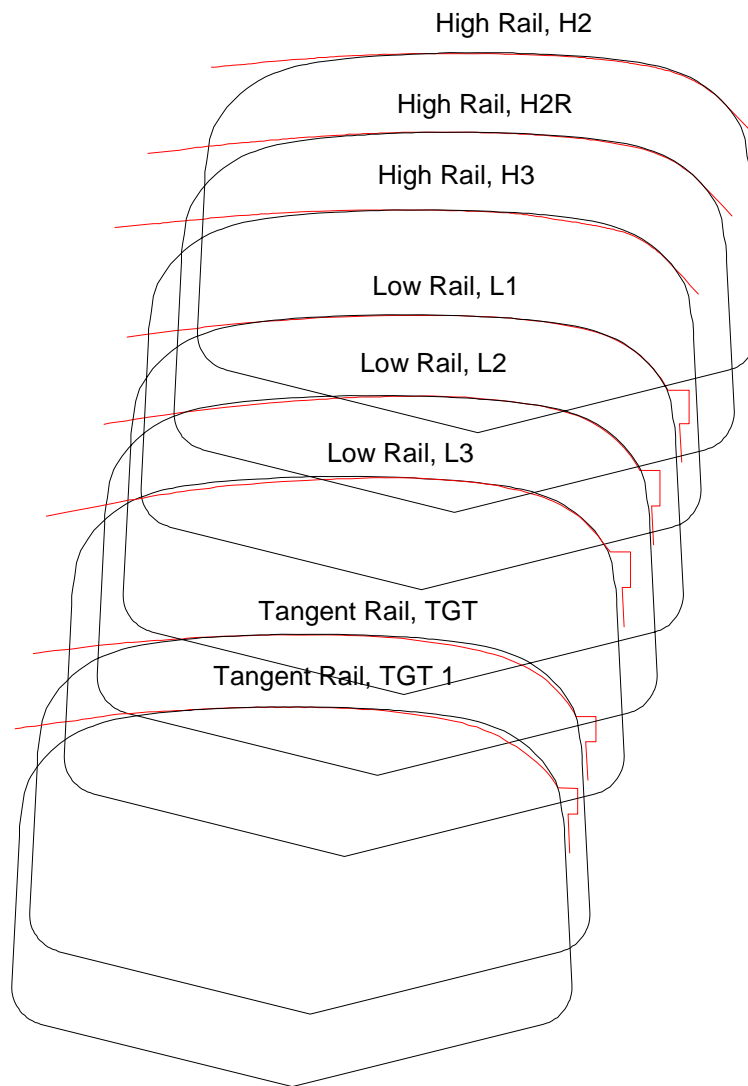


Figure 2: New 60kg Rails with Templates (Rails Shown in a Vertical Position)

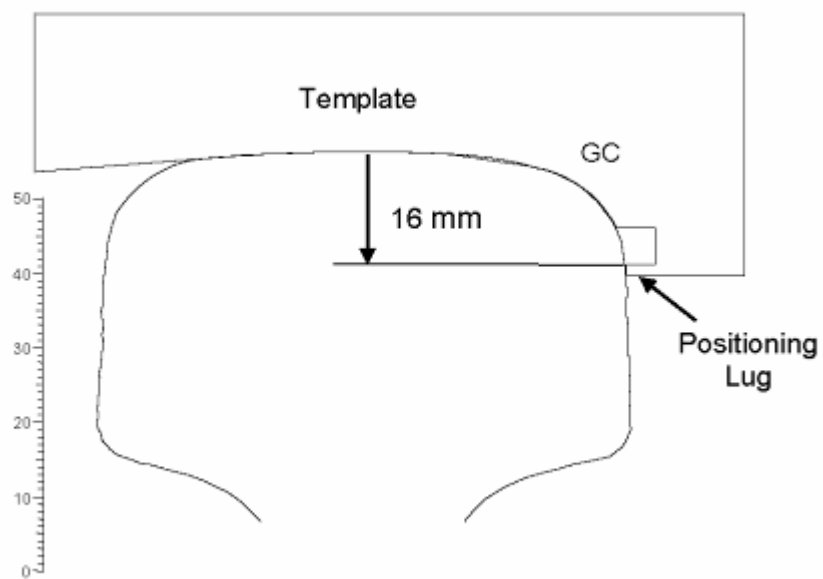


Figure 3: Schematic Illustration of Template and Positioning Lug (Rail Shown in a Vertical Position)

4.2 Template Fabrication

Rail templates are to be constructed of hardened steel (or a product of equivalent or superior strength, wear resistance, dimensional stability and durability) to a tolerance of ± 0.025 mm at the profile surfaces. Tolerances at the fixing points for connection to the gauge bar must be adequate to ensure that the overall super-elevated profile tolerances (as detailed below) are not compromised. The template name, date of manufacture and designed contact band details are to be permanently scribed on the face of the template. The template is to be manufactured with the 1 in 20 (2.86°) rail cant included, as per the details given in Appendix 1.

A gauge bar is to be used with the rail template. The gauge bar provides fixing holes that are to match those on the template. The gauge bar is to provide a reference to the other rail to give a super-elevated reference plane for the application of the template to within ± 0.2 degrees (i.e. a deviation of less than 2.6mm from a 1.5m straight edge). The gauge bar is to be made of mild steel, aluminium or other product of equivalent or superior rigidity, dimensional stability and durability. The gauge bar must be insulated so that there is no electrical contact between the rails during its application.

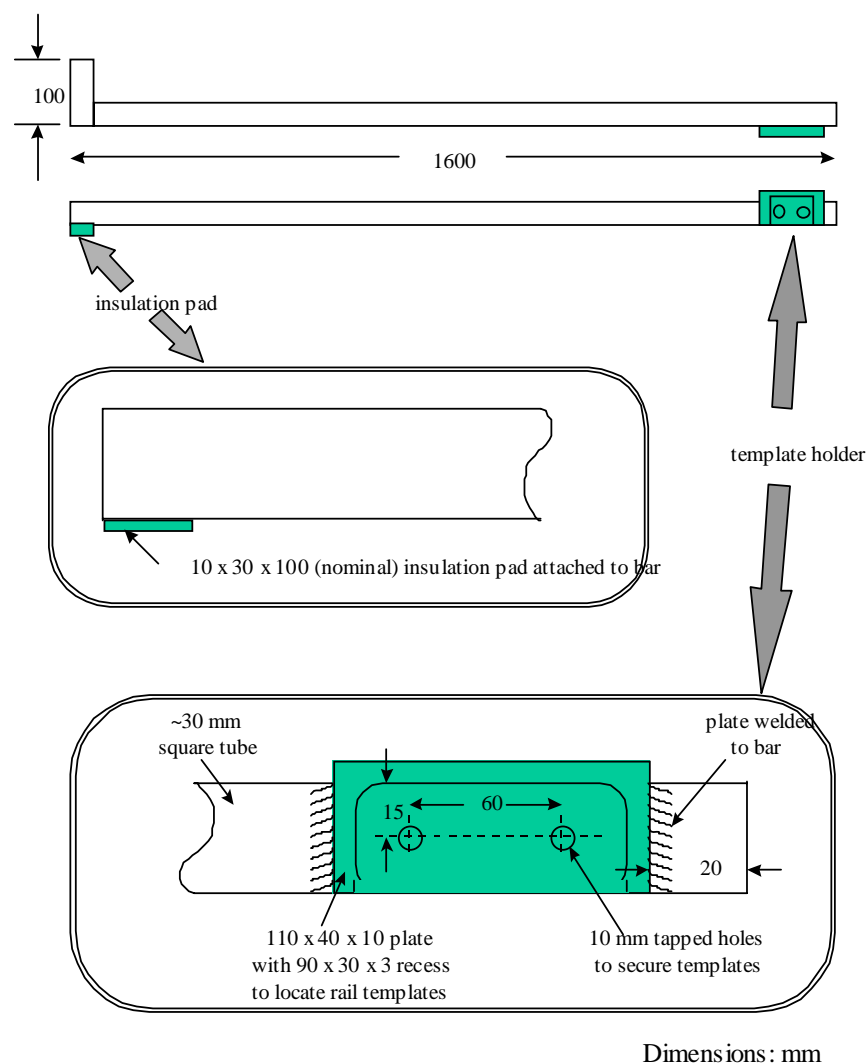


Figure 4: Possible Holding Bar for Single Template

Figure 4 illustrates a gauge bar that could be used to hold a single profile template and applied for quality assurance purposes during or after rail grinding.

5 Preparation for Grinding

Grinding shall ideally be conducted on track that has good top and line, preferably after the track has been surfaced. All track obstructions that prevent grinding within a section (including high ballast, lubricators and wayside monitoring devices) shall be removed before grinding and replaced within 2-3 days after grinding in accordance with the requirements specified by the ARTC Delivery Manager or nominated representative, which in some cases could be the Maintenance Contractor.

6 Template Application

6.1 Placement

The rail template is to be affixed to the gauge bar.

With the non-template end of the gauge bar resting on the other rail, the template is to be placed onto the rail to be checked and moved down and across to maximise the contact of the template onto the rail. In all cases, the rail contact point, as illustrated in Appendix 1, must make contact with the rail gauge face. The contact point generally occurs at an angle of $50^{\circ} \pm 1^{\circ}$ to the vertical for the high rails and $65^{\circ} \pm 1^{\circ}$ for the low and tangent rails.

Where the template is provided with a gauge positioning lug (for low and tangent rails) the lug must be pushed up against the gauge face of the rail (subject to the details given in Section 6.2).

For the high rail templates without lugs, the template must make contact with the gauge region of the rail at the start of the template run off (the rail contact point), as illustrated in Appendix 1. The run off is not part of the profile.

Note: It is important that no excessive force be placed by the operator on the template or gauge bar, which may lead to their distortion or accelerated wear.

6.2 Tolerance to Template

The rail is to be ground so that the profile matches the template. When applying mechanical means, the tolerance is to be checked by measuring the visible gap between the rail and the template using a feeler gauge no more than 3-4mm wide at the end. The maximum allowable gaps between the rail profile and the template (refer to Figure 5 (a) and Appendix 1 will be as follows:

- 0.20mm (i.e. a 0.25mm feeler gauge must not pass between the template and the ground rail head covered by the template) within the contact bands (minimum and maximum) on the contact band of any template. This includes the gauge corner region in the case of the high rail templates (ARTC H2, ARTC H3 and ARTC H2R).
- 0.40mm (i.e. a 0.45mm feeler gauge must not pass between the template and the ground rail head covered by the template in the gauge corner and field side (up to 5mm from the field side corner) regions outside the contact bands (minimum and maximum) where low and tangent rail templates have been used, and the field side region where the high rail templates have been used.

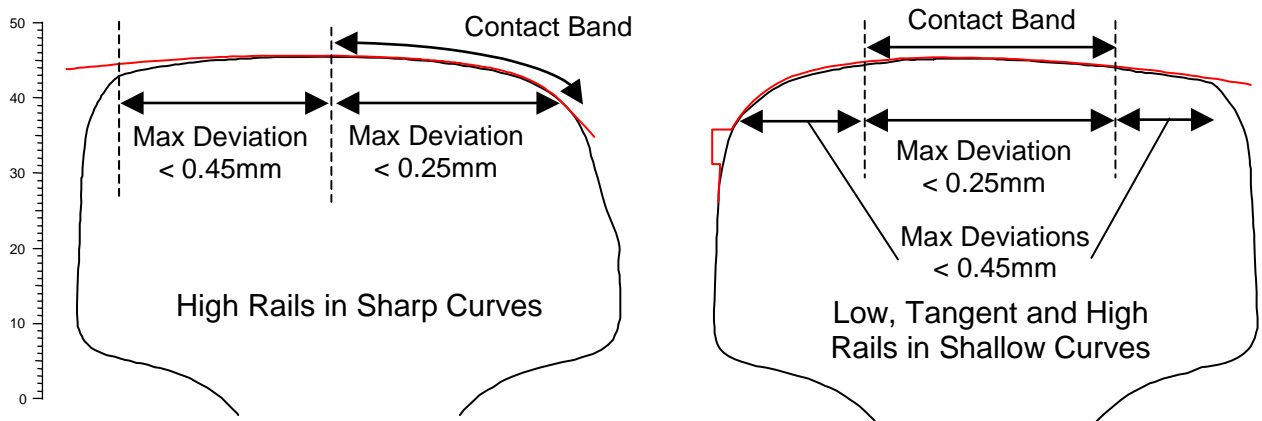


Figure 5(a): Schematic of Rail Tolerances to Templates

To provide appropriate referencing for the above measurements, the rail templates shall contain scribe marks indicating the position of the contact bands and the respective contact angles.

The required tolerance levels for non-contact rail profile measuring systems are described in Section 7.

Some rails may exhibit plastic flow lips, which may increase the difficulty of matching the templates with the locating lugs to the rails.

For the low rail and tangent rail templates the Contractor shall follow the following requirements for application of the positioning lugs:

- The distance of the lug from the gauge face after grinding must be no greater than the distance before grinding.
- The distance between the lug and the gauge face of the rail must be reduced by at least 50% during each grinding cycle, and eventually must be less than 0.5mm.

For example: Figure 5(b) illustrates rails in tangent track before and after grinding with the templates containing the locating lug, showing the acceptable reductions obtained between the lug and the rail gauge face.

In certain cases the application of the above tolerances may necessitate the requirement for additional grinding effort particularly on the gauge corner/face region. It will be the responsibility of the Contractor to advise the ARTC Grinding Manager or nominated representative of this aspect.

Furthermore, as indicated in Section 4, when the rail profiles before grinding are significantly different to the required profiles, due to excessive gauge corner and/or field side relief applied during previous grinding cycles (refer to Figures 5 (b) and (c)), the rails can be treated as being in a transitional regime. To reduce the number of grinding passes that may be required to establish the most appropriate profiles, as summarised in Table 1, a relaxation of the required tolerances outside the contact band may be applied at the discretion of the ARTC Grinding Manager or nominated representative, as follows:

- The grinding applied during each cycle must reduce the maximum deviation of the rail profile relative to the template outside the contact band by at least 0.3mm.
- Within the contact band the tolerances shall remain as specified above.
- A minimum metal removal of 0.2mm shall still be achieved within the contact band, as specified in Section 9.

In such cases, the Contractor shall record the fact that the rails before grinding did exhibit excessive gauge corner and/or field side relief and that a transitional grinding strategy has been applied.

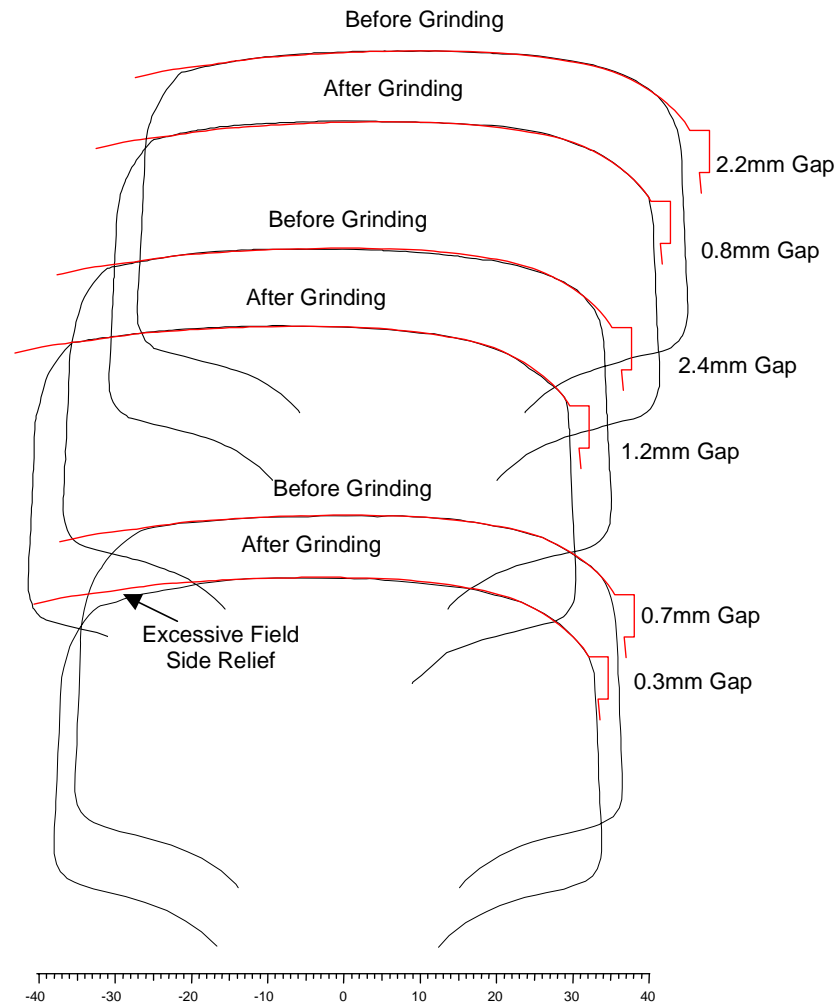


Figure 5(b): Examples of Rails in Tangent Track Before and After Grinding and Tangent Template (TGT1) with Positioning Lug

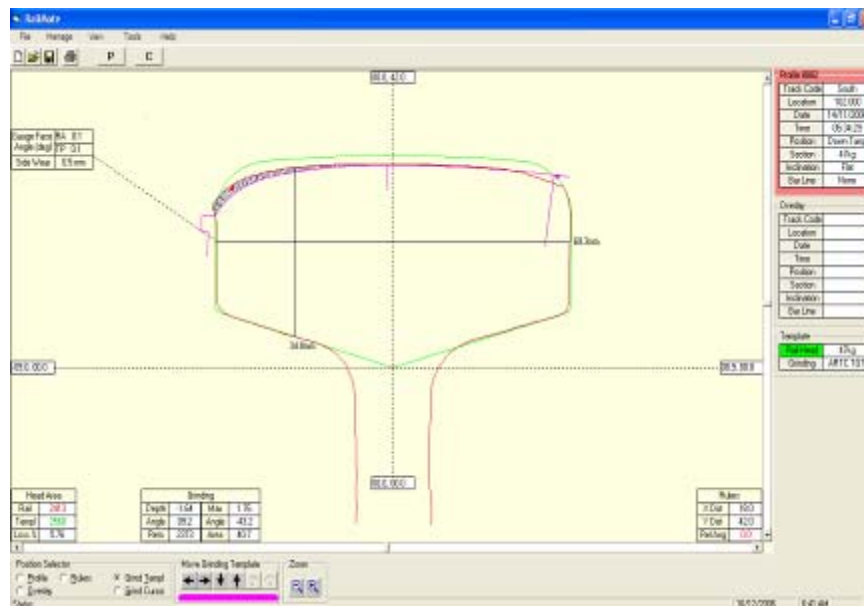


Figure 5(c): Example of Metal Removal Requirements and Acceptable Tolerances in a 47 Kg Tangent Rail Exhibiting Excessive Field Side Relief

6.3 Gauge Corner Relief

Generally any required gauge corner relief is built into the rail templates.

If it is felt that due to severe RCF damage in the gauge region of high rails, as illustrated in Figure 6, additional gauge corner relief is required, this relief shall be applied to the high rails to control such damage. This can be achieved by the ARTC Grinding Manager or nominated representative directing the application of the ARTC H3 template (refer to Table 1 and Appendix 1) in accordance with Section 14.1.

When applying the ARTC H3 template, the grinding facet limits as specified in Section 10.1 must still be observed, together with the tolerances specified in Section 6.2.

It should be noted that uncontrolled excessive gauge corner undercutting leads to two point wheel/rail contact conditions in the sharper curves as illustrated in Figure 7(a) and (b), which in most cases is not desired.



Figure 6: Example of Severe Gauge Corner RCF Defects on High Rails Requiring Application of the H3 Profile

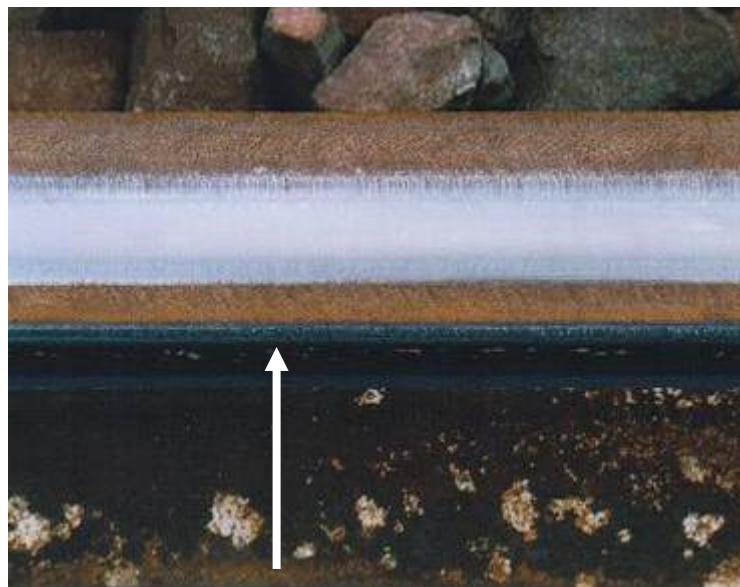


Figure 7(a): Example of Unacceptable Gauge Corner Undercutting on High Rail In Sharp Curve (Arrow Points to Gauge Corner)

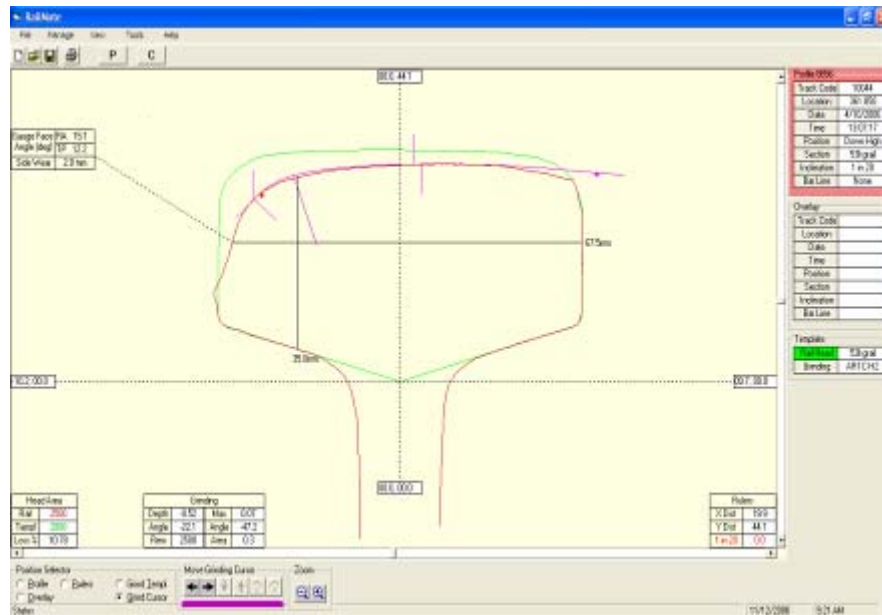


Figure 7(b): Example of Unacceptable Gauge Corner Undercutting on High Rail In Sharp Curve (Arrow Points to Gauge Corner)

6.4 Field Side Relief

Any required field side relief is built into the templates.

If additional field side relief is required relative to the main low, tangent and high rail templates, the ARTC Grinding Manager or nominated representative may specify the application of templates ARTC L3 or ARTC TGT1 or ARTC H2R respectively (refer to Table 1, Appendix 1 and Figure 8). In these cases the finished profile will still conform to the tolerances specified in Section 6.2.

It should be noted that the implementation of the above templates will require additional metal removal and hence possibly grinding passes. It will be the responsibility of the Contractor to advise the ARTC Grinding Manager or nominated representative of this aspect.

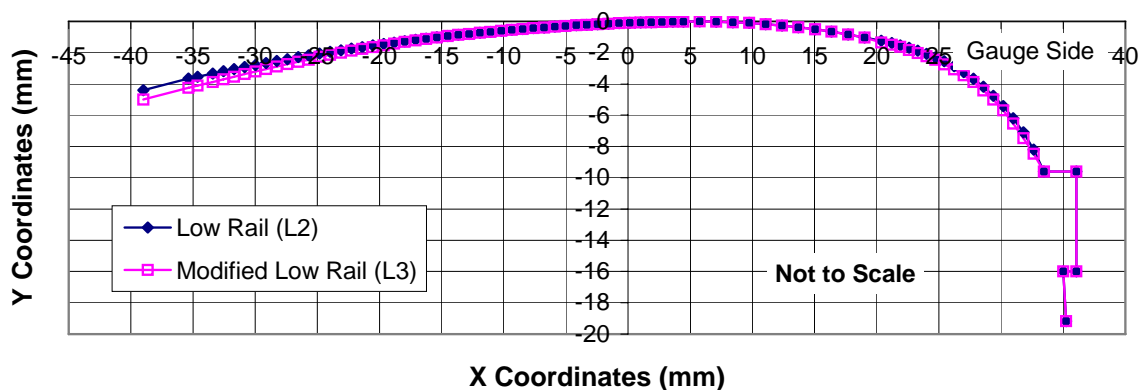


Figure 8(a): Comparison of ARTC L2 and ARTC L3 Templates, Showing Additional Field Side Relief in the Latter (Rails with 0° Cant)

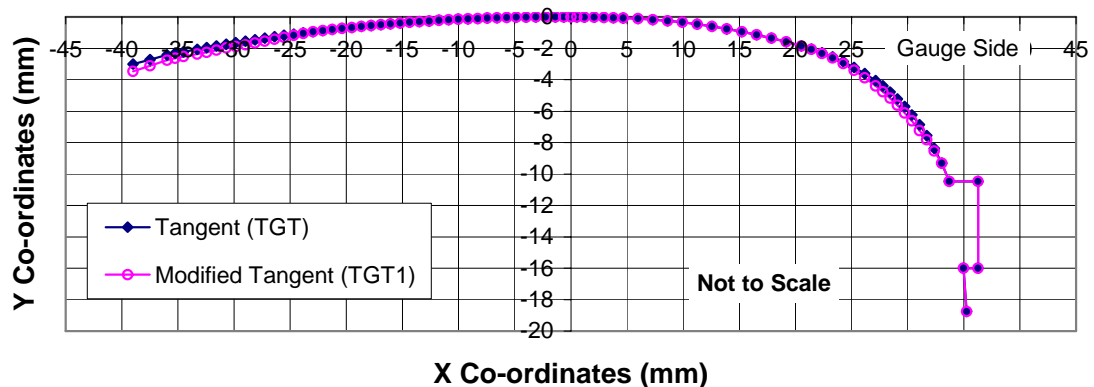


Figure 8(b): Comparison of ARTC TGT and ARTC TGT1 Templates, Showing Additional Field (and Gauge) Side Relief in the Latter (Rails with 0° Cant)

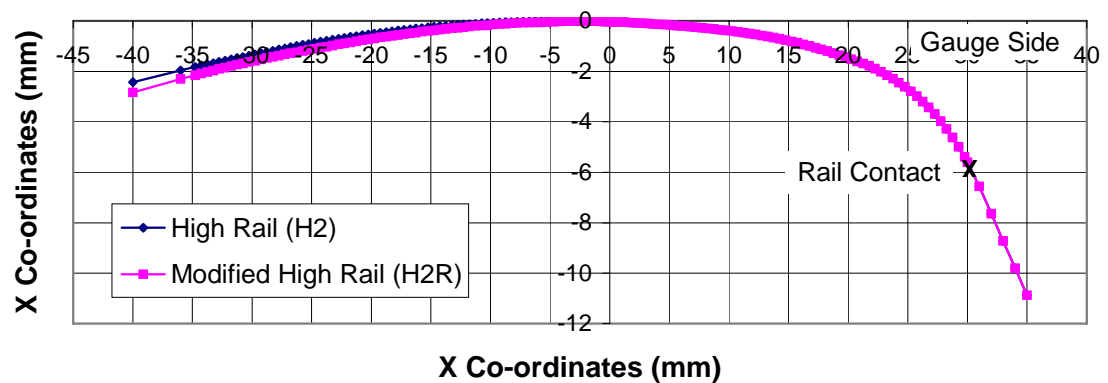


Figure 8(c): Comparison of ARTC H2 and ARTC H2R Templates, Showing Additional Field Side Relief in the Latter (Rails with 0° Cant)

7 Vehicle Mounted Measuring System

As indicated in Section 4.1, a vehicle mounted procedure for monitoring rail profiles before/during/after grinding, based on non-contact measuring systems, should be applied by the Contractor.

All of the tolerances specified for the manual measurement system, as specified in Section 6, shall apply to the vehicle mounted measurement system.

The measuring system must have a proven accuracy and repeatability of better than $\pm 0.13\text{mm}$. This will be checked by the Contractor at intervals no longer than 3 months.

Initially, it is envisaged that the vehicle mounted systems would be used in a manner similar to the manual measurements, i.e. at the specific checking locations, each representing a track segment. In this case the allowable maximum deviations from the template shall be $+0.05\text{mm}/-0.20\text{mm}$ within the contact band and $+0.05\text{mm}/-0.40\text{mm}$ outside the contact band (refer to Figure 5 (a)).

At the checking location in at least one track segment (refer to Section 12) ground in each grinding shift (or day), the average profile deviations from the template shall be determined within 5mm segments across the rail surface, including the gauge corner and face regions up to

an angle of 50° to the vertical for the high rails and 65° to the vertical for the low and tangent. At least 5 segments shall represent the region within the contact band and 4 segments the region outside the contact band. The deviations shall be presented graphically, as illustrated schematically in Figure 9 (a) for tangent, low and high rails in shallow curves, and in Figure 9 (b) for high rails in sharper curves, noting that for the high rails in the sharper curves the contact zone extends from the gauge corner region towards the centre line of the rail.

Furthermore, within each 5mm segment, the average metal removal shall also be measured. This will require rail profile measurements to be taken both before and after grinding.

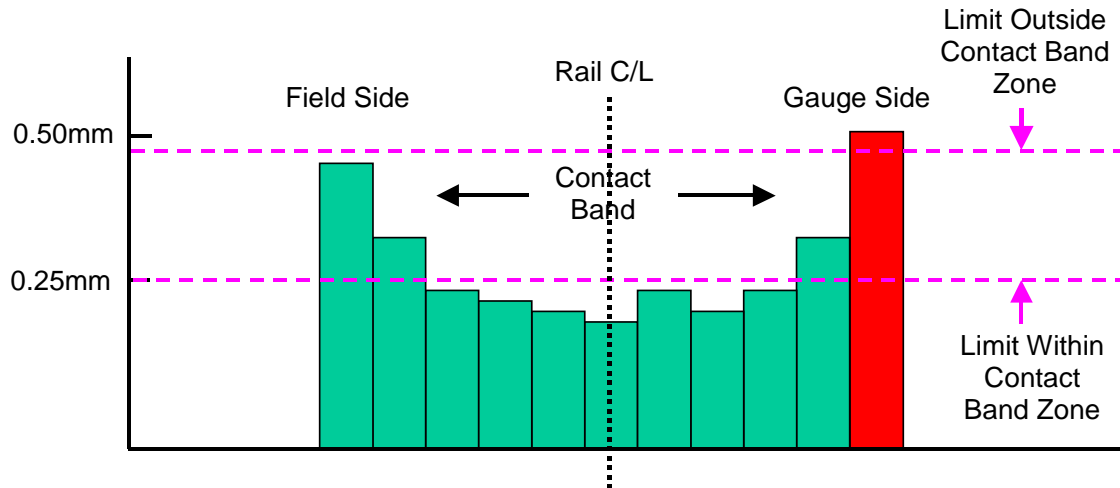


Figure 9(a): Example of Graphical Output of Profile Deviations from Template for Tangent, Low and High Rails in Shallower Curves (red indicates outside the specified limits)

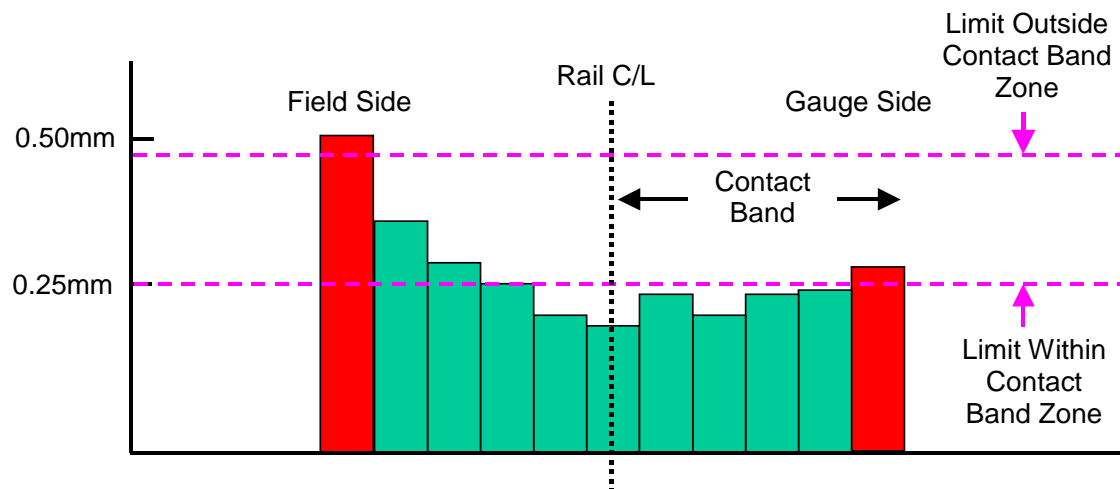


Figure 9(b): Example of Graphical Output of Profile Deviations from Template for High Rails in Sharper Curves (red indicates outside the specified limits)

Alternatively, the Contractor may propose an equivalent acceptable monitoring System or adopt a proven quality assurance procedure to ensure that the required metal removal is achieved. The latter must entail consistent and documented relevant rail grinding operations throughout the track segments ground, including grinding stone type, number of active grinding stones, grinding stone patterns, motor pressures and grinding speed. Furthermore, rail profiles shall be taken manually before and after grinding at the checking location in at least one track segment (refer to Section 12) ground in each grinding shift (or day) and be made available to the ARTC Grinding Manager or nominated representative, so that the metal removal achieved can be quantified. This procedure would only be applicable to rails that are within the preventative maintenance regime.

In the longer term (within 12 months from the start of the grinding contract and following appropriate field grinding and assessment trials) it is envisaged that additional and more

detailed rail profile measurements after grinding will be taken using the vehicle mounted system on at least one track segment (refer to Section 12) ground in each grinding shift (or day).

The measurements will be taken at 20-25m intervals along the track segment. The profile deviation values as illustrated in Figure 9 will then be used to determine and meet the following maximum allowable deviations from the respective templates:

Within the contact zones (refer to Appendix 1 and Figures 5 (a) and 9 (a) or (b)):

- 90% of values must be less than 0.25mm
- 95% of values must be less than 0.30mm
- 98% of values must be less than 0.35mm

Outside the contact zones (refer to Appendix 1 and Figures 5 (a) and 9 (a) or (b)):

- 90% of values must be less than 0.45mm
- 95% of values must be less than 0.50mm
- 98% of values must be less than 0.55mm

Excessive exceedences that may occur at rail irregularities such as welds and closures will be ignored in the above statistical analysis.

The detailed measurements described above will be in addition to the profile measurements taken at the checking locations in all other track segments, which will follow the same tolerance levels as for the gauge bar, specified in Section 6.2.

When using the non-contact measuring system, the acquired rail profile can be aligned to the following reference points on the respective template:

- The top of the template, i.e. the (0,0) point; and
 - The rail contact point, which is located at a distance of about 7.5-7.6mm from the top of the template, for the ARTC H2, ARTC H3 and ARTC H2R profiles.
 - The top contact point of the lug, which is located at a distance of 16.0mm from the top of the template, for the ARTC TGT, ARTC TGT1, ARTC L1, ARTC L2 and ARTC L3 profiles.

8 Minimum Metal Removal for Corrective / Transitional Grinding

The ARTC Grinding Manager or nominated representative in consultation with the Contractor will specify the metal removal requirements for corrective or transitional grinding of transverse profiles. This may also allow some gauge corner or running surface cracking/checking defects to remain in track after grinding as illustrated in Figure 10.

As indicated previously, notwithstanding the metal removal requirements, the recommended rail profiles shall always be achieved. Thus, in the case of high rails exhibiting gauge corner RCF defects up to a moderate classification (refer to Figure 11 (a)) the ARTC H2 template shall be applied to the high rails, while for severe gauge corner RCF defects (refer to Figure 11 (b)) the ARTC H3 template shall be applied.

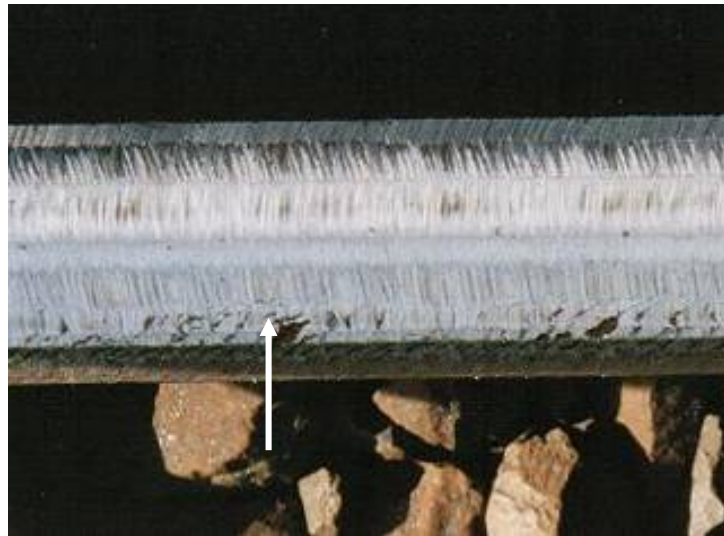


Figure 10: Example of Gauge Corner Checking Defects Left in the High Rails After Transitional Grinding (Arrow Points to the Gauge Corner)



Figure 11(a): Example of Moderate Gauge Corner RCF Defects on High Rails Requiring Application of the ARTC H2 Profile



Figure 11(b): Example of Severe Gauge Corner RCF Defects on High Rails Requiring Application of the ARTC H3 Profile

9 Minimum Metal Removal for Preventive Grinding

When the rails are ground under the preventive grinding regime a minimum amount of metal is to be removed.

In conjunction with restoration of the rail profile to the designed template as specified in Table 1, a **minimum** of 0.2mm of metal must be removed from the contact band as specified in Section 6 and Appendix 1. The exception being the gauge face of the high rails (at an angle $>50^\circ$ to the vertical) in the sharper curves, where gauge face wear has been occurring.

In sharper curves (with radii up to 900m), the minimum metal removal of 0.2mm will generally be achieved each specified grinding cycle. However, in shallower curves and tangent track the metal removal may be reduced if the track sections are ground more frequently than the specified cycles (refer to Table 5), as long as the minimum metal removal is achieved within the specified cycles.

Rail profile measurement devices will be used to measure the metal removal achieved by the grinding at the centre of the rail's running surface, at a particular checking location or locations. This will require taking rail profiles both before and after grinding. Subject to the proven accuracy and repeatability obtained (preferably better than $\pm 0.05\text{mm}$), suitable procedures will involve the use of:

- A vehicle mounted non-contact system, as described in Section 7. This is the preferred option.
- A portable rail profile measuring system such as 'Railmate', 'MiniProf' or other device approved by ARTC capable of achieving an accuracy and repeatability of better than $\pm 0.05\text{mm}$. The portable system is likely to be applied during the quality assurance process (refer to Section 7) or auditing process (refer to Section 12).

All of the above measuring systems shall have the measurement accuracy required to quantify the metal removal achieved by the grinding process.

It should be noted that the metal removal requirements of rails that are within the preventive grinding regime should be less than about $18\text{-}20\text{mm}^2$. Rails having greater metal removal requirements are to be treated as out of preventative cycle.

10 Surface Finish

10.1 Grinding Facets

The grinding process leaves visible facets on the head of the rail and gauge face. These facets must be controlled if excessive contact stress points are to be avoided. The maximum facet width shall be:

- 6 mm in the gauge corner region (refer to Figure 1).
- 10 mm elsewhere on the ground surface.

When necessary, a lower power/higher speed finishing grinding pass shall be applied in track sections to cross cut facets and improve the surface finish of the contact band.

10.2 Other Surface Irregularities

The ARTC Grinding Manager or nominated representative will specify the requirements for removal of isolated defects identified prior to grinding (such as corrugations, dipped or peaked welds or wheel burns). Noting that they may not be able to be removed efficiently by the grinding process and do not necessarily have to be removed in one grinding cycle.

Otherwise longitudinal rail surface defects such as corrugations must be removed and the overall surface finish must also meet the following minimum standards:

- There must be no sharp ridges especially at the interface of facets.
- There must be no excessive gouging on the rail surface and sharp grinding marks, as illustrated in Figure 12.
- There must be no indentations in the rail.
- There must be no cyclic grinding marks, as illustrated in Figure 13.

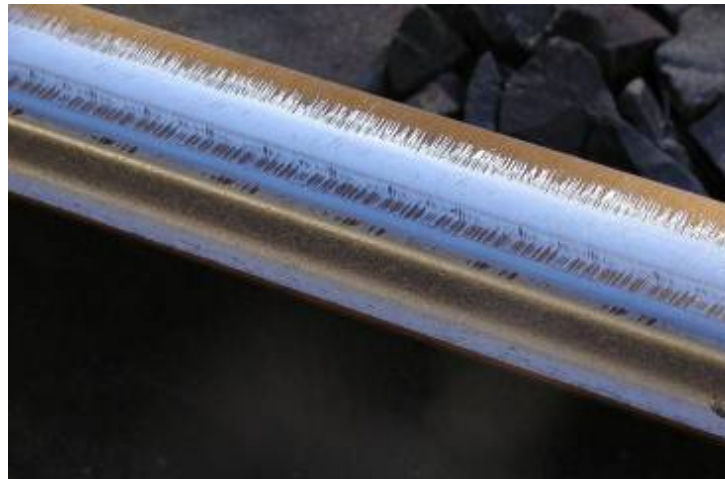


Figure 12: Example of Unacceptable Severe Grinding Scratches



Figure 13: Example of Unacceptable Cyclic Grinding Scratches

- There must be no continuous indication of overheating (bluing) of the rail surface.
- The ground surface must be no rougher than an average of $10\mu\text{m}$ R_A if within 5 kms of any dwellings or $15\mu\text{m}$ R_A elsewhere.

The resultant surface roughness shall be measured by the Contractor, within at least one track segment (refer to Section 12) ground in each grinding shift or day, with a typical roughness measuring system (as illustrated in Figure 14), or equivalent, using a measurement travel of 25mm. Surface roughness measurements shall be taken on both rails at or near the checking locations, and will consist of at least three longitudinal traverses taken on each rail at the rail centre line and 10-15mm on each side of the centre.

Note: A poor quality surface roughness will increase rail noise and may enhance the future development of rail surface defects.

- Short pitch surface irregularities (30-150 mm in wavelength), which could be introduced by the grinding process (refer to Figure 13), shall be removed so that the remaining **cyclic** average longitudinal unevenness along the rail running surface (peak to peak) shall be less than $15\mu\text{m}$, and the remaining longitudinal unevenness along the rail running surface shall be less than 0.10mm, when measured at the centre of the running surface over any 1m length (excluding welds), using a suitable measuring system, which would generally be laser based (as illustrated in Figure 15).



Figure 14: Measurement of Surface Roughness with a Typical Measuring System

10.3 Longitudinal Profile

Generally, the assessment of corrugations shall be conducted by the Contractor on both rails at the checking location on at least one track segment (refer to Section 12) ground in each grinding shift (or day). However, additional measurements may be conducted at any location within a ground section in which visual examination indicates the presence of cyclic irregularities after grinding.

Special treatment required for Long Wave corrugations and peaked welds.

On some parts of the ARTC network (particularly the 47 kg/m rail manufactured at Port Kembla which is mainly in SA and WA), axle loads and speeds have produced long wave corrugations. Typically these have a pitch of about 0.8m to 1.5m and an amplitude of up to about 1 mm, peak to peak. Special grinding procedures will be required to correct these rails to achieve the parameters in Table 2 below. ARTC audits will particularly focus on this area of the contractors' operations.

It is important that the process is managed so as not to produce widely varying hardness profiles i.e. grind too far into the work hardened section of the head.

It is anticipated that sections containing long wave corrugations will be defined from roughness and impact readings from AK car accelerometer readings.

Finished longitudinal profiles.

The longitudinal profile shall be processed to provide a filtered profile within each of the wavelength ranges given in Table 2. The cut-off wavelengths for each wavelength range and the length of the corresponding window within which the pertinent moving average is to be calculated are also given in Table 2.

The percentages of any site in which the moving average RMS amplitudes exceed the values specified in Table 3 shall be calculated. These percentages shall not exceed the limits given in Table 4 for the specified rail type specified.

Table 2 - Parameters for Calculation of RMS

Wavelength range (mm)	10-30	30-100	100-300	300-1000	1000-1500
Window Length (m)	0.15	0.5	1.5	5	15

Table 3 – Moving Average RMS limit

Limit of moving average of RMS amplitude (mm)	0.004	0.004	0.012	0.040	0.040
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Table 4 - Maximum Allowable Percentage Exceedence

All rail sections ≥53 kg	5%	5%	5%	10%	No requirement
<53 kg rail	5%	5%	5%	10%	10%

To demonstrate compliance one of the following methods (or approved equivalent) must be used.

- An accelerometer or mechanical based hand operated system, such as the 'CAT' or equivalent (as illustrated in Figure 16). In this case, both rails in at least 5% of the ground track per shift (or less if approved by the ARTC Grinding Manager or nominated representative) shall be measured.
- An accelerometer, mechanical or non-contact based system incorporated on the rail grinding unit or auxiliary vehicle. This would be the most preferred option. In this case, both rails in at least 10% of the ground track per shift shall be measured.



Figure 15: Measurement of Short Pitch Corrugations



Figure 16: Measurement of Long Pitch Corrugations with a Typical Measuring System

10.4 Prevention of Grinder "Skipping"/cyclic grinding on gauge corner

Some sections of track, in particular shallow curves and tangents, may contain indications of a cyclic gauge region wear pattern that has been produced by wheelset/bogie hunting. This requires special grinding procedures to remove/control.

In sections of track that have no prior indications of hunting wear on the rails, the rail grinding operation shall not induce any form of cyclic wear, in the form of 'skipping', as illustrated in Figure 17.

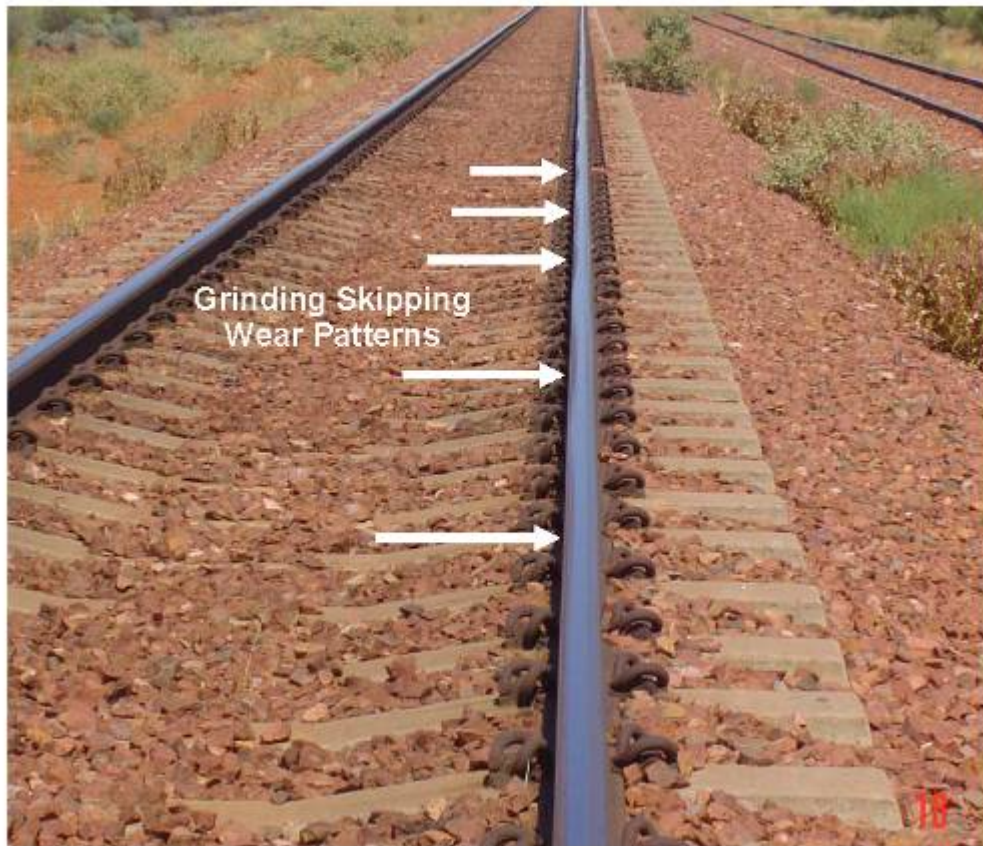


Figure 17: Example of Cyclic 'Skipping' Wear Induced by Rail Grinding

To ensure that the grinding operation does not introduce any cyclic 'skipping' wear on the rails, the Contractor will measure after the completion of grinding on at least one track segment (refer to Section 12) ground in each grinding shift or day the deviation of the rail profile from the template at an angle of 10-15° from the vertical towards the gauge corner region, on a grinding facet that is clear of any encroachments from adjacent grinding facets. If possible, the track segment shall be either a shallow curve or a tangent section, and both rails will be measured, excluding any rail closures that may be present within the track segment.

In taking these measurements use can be made of the rail profile deviation data illustrated in Figure 9. The required measurement location will generally correspond to the last 5mm block within the contact zone towards the gauge corner region, for high rails in shallow curves, low rails and tangent rails.

The measurements will be taken at 1m intervals along the track segment ground over a distance of at least 100m.

Within each 10m length of the 100m segment, the maximum deviation from the mean value measured within each 10m length shall be less than 0.5mm.

The Contractor may recommend an alternate quality assurance procedure for ensuring that no 'skipping' wear is introduced on the rails, as long as the procedure ensures that the above profile deviations are not exceeded.

Once confidence is established in relation to the performance of the rail grinder in terms of 'skipping' wear, the detailed measurements described above could be extended to once every 5-7 days or longer at the discretion of the ARTC Grinding Manager or nominated representative.

To quantify skipping the following measures shall apply:

- Rail profiles are measured every 0.5m for 200m

- For each measured profile the variation from the appropriate template (using the alignment given in section 3) is to be calculated at 1° intervals from 0 -50° (measured from the track plane).
- For each profile the maximum variation is determined.
- The standard deviation is to be calculated for a moving window 20m in length for the 200m section.
- The mean of the standard deviation is calculated over the 200m length.

For any 200m length the mean of the standard deviation shall be less than 0.2mm.

The Contractor may recommend an alternate quality assurance procedure for ensuring that no 'skipping' wear is introduced on the rails, as long as the procedure ensures that the above profile deviations are not exceeded.

Once confidence is established in relation to the performance of the rail grinder in terms of 'skipping' wear, the detailed measurements described above could be extended to once every 5-7 days or longer at the discretion of the ARTC Grinding Manager or nominated representative.

11 Grinding Operation

Each curve must be fully ground between the tangent points (TPs) defining that section, as indicated in the appropriate Track Geometry Data Sheets. Generally it is not permissible to grind only a portion of a curve, unless for defect grinding.

It should be noted that some curves or track sections have multiple radii. In these cases, to simplify the process, to avoid the need to cover the curve or track section at different grinding cycles and to ensure that a continuous rail profile is established, the full curve or track section shall be ground according to the cycle associated with the smaller or smallest radius within the curve or track section, which satisfies the requirement of making up at least 20% of the total curve length or track section.

A limited number of track sections may require special consideration in relation to the grinding cycles and profiles to be adopted. For example, when two curved track sections are joined by a relatively short (less than 200m but generally less than 100m) tangent section. In these cases, the middle tangent segment shall be treated the same as the adjoining curve segments. On the other hand, if short curved sections (less than 80m) are separated by tangent sections, they shall also be treated the same as the adjoining longer tangent segments.

The characteristics of the rail grinding unit applied within the ARTC Region shall include:

- Full dust aspiration.
- Maximum noise emission during grinding of less than 90 dBA sound pressure level at 10m from the work site. However, the maximum noise level may be changed depending on local EPA requirements.

12 Monitoring and Control

12.1 Inspection of Grinding

12.1.1 Contractor's Responsibility

In the process of grinding the track is broken up into segments. Each segment must be assessed separately by the Contractor. Each segment shall have a consistent rail surface shape and condition. A segment cannot be longer than a whole curve, although individual curves can be broken up if required, depending on the curve length.

At this stage, set locations in each segment will be nominated as checking locations and shall be used for the ongoing grinding programme. These are to be positioned towards the centre of the segment to be ground but avoiding closures or anomalous profile conditions. The rail web and foot is to be clearly paint-marked on both the field and gauge sides and its location recorded. An equivalent procedure may be adopted that will allow the checking location to be accurately

defined. Each checking location will represent a track segment generally no longer than 500m in curved track with radii up to 900m, and 1000m in tangent track and shallower curves, or no longer than 300m in the case of corrective/defect grinding. The length of the track segments may be increased at the discretion of the ARTC Grinding Manager or nominated representative.

The achievement of grinding tolerances, metal removal and surface roughness must be checked on completion of the grinding work and prior to the running of trains as described below.

Checking locations must be examined for profile, metal removal, surface roughness, short and long pitch corrugations, and the remainder of the rail checked to ensure that the specified defect removal requirements and surface condition have been achieved, as specified in Section 10.

The Contractor will take the necessary measurements after the completion of grinding on at least one track segment ground in each grinding shift or day, or at the discretion of the ARTC Grinding Manager or nominated representative.

The vehicle mounted rail profile measuring system (or equivalent) will record profile deviations from the template and metal removals at the checking locations, as specified in Section 7. If it is felt that vehicle mounted non-contact systems do not have the required accuracy to measure metal removal, the Contractor shall then use a mechanical system (such as 'Railmate' or 'MiniProf') to measure both the metal removal at the rail centre line and the overall metal removal area.

The required contact band width on the running surface (indicated in Appendix 1) shall be checked by painting the running surface of the rails at the checking locations following grinding by the Contractor, and inspection after a minimum of at least 3 or 4 trains or preferably after several days of operations. A preliminary check of the running band by the Contractor can be conducted using the contacts achieved by the wheels on the rail grinder. Any abnormal observations (i.e. when the actual contact band is outside the recommended limits) will be reported to and recorded by the ARTC Grinding Manager or nominated representative during the auditing process and monitored for possible future action.

12.1.2 ARTC's Responsibility

For quality assurance purposes, profile deviations, metal removal, surface roughness, contact band width and corrugations will also be assessed and recorded by the ARTC Grinding Manager or nominated representative as part of the auditing process. Such an assessment will be conducted within 1-2 days after rail grinding. It is noted that when taking rail profiles with the 'Railmate' system, the cant bar must be used at all times to allow compensation for any deviations from the design rail cant of 1:20. Field audits of the grinding operations by competent personnel shall be conducted at regular intervals, which would range from about 2-4 weeks in the Hunter Valley, where grinding is conducted more regularly, to 8-12 weeks in other regions, where grinding is conducted less regularly.

12.2 Calibration

Template calibration must be checked at initial fabrication and thence six-monthly. The template must be within $\pm 0.025\text{mm}$ at manufacture and thence within $\pm 0.05\text{mm}$ of the designed shape. Calibration shall be carried out with the template fitted to the gauge bar or with a suitably designed calibration block that will allow the proper alignment and matching of the template and the calibration block.

If a calibration block is used it must be within $\pm 0.025\text{mm}$ of the design geometry.

To ensure that the gauge bar has not been deformed, it shall also be checked against a straight edge at monthly intervals. The gauge bar needs to be within the original specification of ± 0.2 degrees (i.e. a deviation of less than 2.6mm from a 1.5m straight edge).

Any other equipment (including electronic measuring devices and vehicle mounted systems) used for the application of or verification of templates, rail profiles and surface characteristics must meet equivalent calibration requirements.

Calibration of measuring systems shall be the responsibility of the Contractor and in accordance to the quality plan accepted by ARTC.

12.3 Monitoring

The ARTC Grinding Manager or nominated representative is responsible for monitoring rail condition. Basic rail inspection is carried out as part of the Track Examination System. In addition the rail condition is to be assessed visually, by a suitably qualified person, prior to grinding. This assessment will assist in determining the specific requirements for the grinding operation.

Spot checks are also to be carried out of the rail grinding efficiency and the continued effective functioning of the profiles in terms of the contact bands evident and any other rail surface anomalies. These checks will form part of the auditing process. Variations to the designed contacts are to be investigated and if required adjustments made to the templates used or grinding strategies. Spot-checking shall be carried out on at least 5% to 10% of grinding locations as a follow up to the grinding operation. In addition a visual inspection shall be carried out for all ground track at about 60% to 70% of the way through the planned grinding period.

Where inspections identify any unusual deterioration conditions these are to be registered and an appropriate response determined. Additional inspections are to be scheduled for such locations. The timing will depend on the condition assessment.

12.4 Records to be Kept by the Contractor

The technical details for preventive, transitional or corrective rail grinding, which need to be recorded in an electronic database, such as Microsoft Access, are as follows:

- Grinding machine.
- Date of grinding and inspection.
- Location of grinding carried out (start and end points), to closest 10 metres.
- Location of checking points, to closest 5 metres.
- Nature of the grinding strategy adopted (eg preventive/transitional/ corrective/defect).
- Grinding template(s) used.
- Rail type and size.
- Finished (work completed satisfactorily) and pass track kilometres ground within 20m.
- Location of any section within a track segment that has not been ground and the reason for not grinding (for example: high ballast, crossing, etc).
- Minimum metal removal at the rail centre line, to the closest 0.05mm, and the overall metal removal area.
- Deviations of the rail profile from the template.
- Rail surface roughness achieved after grinding.
- Residual rail corrugations after grinding.
- Cyclic rail wear after grinding, including any visual indications of 'skipping' or any other surface irregularity.
- Number of grinding passes applied to each rail.
- Grinding efficiency of machine, i.e. number of grinding motors working.
- Details of any condition from pre-grinding inspection or any other specific inspections of rail condition.
- Details of the rail contact band assessments carried out immediately after grinding.
- Details of any non-conformances in the grinding process or standard of completion.

The above information shall be available in daily form within 24 hours of the end of each shift/day.

It will be the responsibility of the ARTC Grinding Manager or nominated representative to ensure that the above information has been appropriately collected and recorded.

13 Competencies

13.1 Grinding & Grinding Supervision

The grinding supervision must be undertaken by personnel who have the following demonstrated competencies:

- Competent in the use of rail condition and rail grinding terminology.
- Competent in the use of rail grinding for rail profiling and defect correction.
- Competent in the inspection of rail surface condition and identification of common rail defect conditions (as discussed in the Section 14).
- Competent in the inspection of contact bands on rail arising from wheel contacts.
- Competent in the assessment of completed rail grinding work.
- Competent in the compilation of detailed records relevant to on-board operations as specified in this standard.
- Experienced in the operation of rail grinding and rail condition assessment for not less than three months (this can be under the supervision of more experienced personnel).

Grinding supervisors and grinding personnel nominated by the contractor shall undergo a suitable training course to obtain appropriate accreditation.

Grinding supervisors and grinding personnel nominated by the contractor shall also obtain Track Safety Awareness certification for the relevant state jurisdiction and appropriate training in fire risk management.

13.2 Engineering Authority for the ARTC Grinding Manager or Nominated Representative and the Rail Grinding Supervisor

To be allocated Engineering Authority with respect to Rail Condition/Grinding Management the ARTC Grinding Manager or nominated representative should have undergone a suitable training course in Rail Management and have demonstrated competency in the assessment of rail conditions and suitable remedial measures as outlined in ARTC Standards.

The Contractor's rail grinding Supervisors shall also undergo a similar suitable training course.

It will be the responsibility of ARTC to establish and conduct appropriate training courses.

14 Grinding Application Decisions Required by the ARTC Grinding Manager or Nominated Representative

14.1 The Application of Templates

In the case of predominantly Freight operations the low rail ARTC L2 (RML2000) template may require substantial metal removal particularly when rail has never been ground (or not ground for some considerable time). For such cases the application of the ARTC L1 (RPL2000) template shall be considered, as part of a transitional grinding strategy. If tread hollowed wheels are still causing problems then the ARTC L2 template shall be used (refer to Section 6 and 14.6 for Field Side Relief). If the wheel hollowing levels exceed the recommended limits, and field side contacts still occur with the ARTC L2 and ARTC H2 templates, consideration shall then be given to the application of the ARTC L3 and ARTC H2R templates.

In shallow curves and tangent track, if the rails exhibit some plastic flow/mushrooming in the gauge corner region that is adversely affecting the track gauge and/or if the wheel hollowing levels exceed the recommended limits, consideration shall then be given to the application of the ARTC TGT1 template, as part of a transitional grinding strategy.

The ARTC Grinding Manager or nominated representative may also approve application of the ARTC TGT (RTG2000) template to sharper radii curves down to 800m radius after an assessment of the particulars of the location, the rail performance (in terms of wheel flanging) and the operational requirements. The ARTC TGT (RTG2000) template should also be used for the high rails in very sharp curves (radius less than 300m) and low operating speeds (less than 25 kph), as long as the rails are lubricated efficiently.

The ARTC Grinding Manager or nominated representative may also approve application of the ARTC H3 high rail template in sharper curves in which the high rails exhibit severe gauge corner RCF defects, as part of a transitional grinding strategy.

14.2 Removal and Replacement of Obstructions

The ARTC Grinding Manager or nominated representative must specify removal and replacement requirements for trackside equipment such as rail lubricators and trackside warning devices. It is noted that the period such devices are absent does have an impact on infrastructure and operations.

14.3 Application of the Locating Lug on Low Rail and Tangent Rail Templates

The ARTC Grinding Manager or nominated representative shall specify the application requirements for the locating lug on low and tangent rail templates (beyond those given in section 6.2). These may take the form of a strategy to bring the template into conformance over successive grinding cycles, as described in Section 6.2.

In adopting the above procedure, appropriate matching of the lug and the side of the rails shall be achieved within three grinding cycles, and any excessive plastic flow of the rail in the gauge corner region will be progressively removed.

14.4 Gauge Corner Relief

The ARTC Grinding Manager or nominated representative will specify any special gauge corner relief requirements for the application of the high rail template.

Gauge corner undercutting leads to undesirable two point wheel/rail contact conditions in the sharper curves as illustrated in Figure 7. Figure 7 also shows that the grinding facet produced at the gauge is greater than the maximum allowable limit of 6 mm (refer to Section 10.1).

However, where the high rails exhibit moderate to severe gauge corner RCF defects the use of an additional gauge corner relief can be approved to extend the rail life and to ensure that the ultrasonic testing of rails is not inhibited. In this case use can be made of the ARTC H3 template, which contains a suitable gauge corner relief with the aim of minimising contacts in

this region as part of a transitional grinding strategy. The template tolerances and grinding facet limits as specified in Section 6 must still be observed.

More details of the procedure to be adopted in these special cases are given in Section 6.

14.5 Field Side Relief

The ARTC Grinding Manager or nominated representative shall specify additional field side relief when, after the application of the normal templates, there is still evidence of excessive tread hollowing on wheels (this is normally observed as a well developed contact band extending beyond the contact bands shown in Appendix 1 and towards the field side of the rail head).

Under the above circumstances, additional field side relief needs to be applied to ensure that minimum wheel contact occurs in the field side region, i.e. within approximately 15 mm from the field side rail face. In such cases, the ARTC Grinding Manager or nominated representative shall nominate one of the following options:

- Implement the ARTC L2 rail profile in the low rails of curves where the ARTC L1 has been used (the ARTC L1 exhibits less field side relief).
- Implement an additional field side relief in the low rails of curves (relative to the ARTC L2 profile), or an additional field side relief in the high rails of curves (relative to the ARTC H2 profile), or additional field and gauge side relief in tangent rails (relative to the ARTC TGT profile), by the application of the ARTC L3, ARTC H2R or ARTC TGT1 profiles respectively. However, in introducing such relief, the required tolerancing shall be applied with reference to the template (refer to Section 6.2).

The additional field side relief shall not extend into the contact zone, as illustrated in Appendix 1.

The grinding facet limits as specified in Section 10.1 must also still be observed within the field-relieved zone.

14.6 Minimum Metal Removal for Corrective Grinding

The ARTC Grinding Manager or nominated representative must specify the metal removal requirements for corrective grinding. These arise primarily because of rolling contact fatigue defects present in rails that have not been cyclic ground. Such damage may inhibit the routine ultrasonic inspection of the rails, particularly if located in the gauge corner region (gauge corner checking) or running surface region (running surface checking/flaking).

Complete removal of the severe gauge corner or running surface checking defects is **NOT** recommended as it requires considerable metal removal and hence rail grinding effort and it removes at least some of the protective work hardened material from the surface.

The recommended procedure to be implemented in these cases is as follows:

- Remove a minimum of 0.2mm (and usually more than 0.4-0.5mm but generally no more than 0.8mm subject to approval from the ARTC Grinding Manager or nominated representative) of metal from all contact surfaces including the gauge region, as specified in Section 8.
- Ensure that severe checking cracks have been removed from the running surface above the rail web, and preferably from a distance of 20-25mm from the gauge corner (exclusive) towards the field side, to ensure that the rails are capable of satisfactory ultrasonic testing. As illustrated in Figure 10, some gauge corner checking defects may be left on the rails.
- Establish the recommended profiles, and where the gauge corner is affected by severe checking defects implement the ARTC H3 template on the high rails, to reduce the gauge corner contact for a limited time. It should be emphasised that the grinding facet limits as specified in Section 10.1 must also still be observed within the gauge corner relieved zone.
- Note the track sections in which the above procedure has been implemented, so that (depending on the degree of damage) in following grinding cycles the additional gauge corner relief will be able to be reduced to within the normal limits specified in Section 6.2 for the ARTC H2 profile.

It is emphasised however that the above procedure should not be required when the rails have been subjected to a number of preventive grinding cycles.

14.7 Transitioning the Removal of Long Wavelength Corrugations or RCF Defects

Where considerable grinding effort is required to achieve full correction to profile or to remove long wavelength corrugations or severe RCF defects, the ARTC Grinding Manager or nominated representative may approve **transition** grinding arrangements. These must involve the correction of the problem over time such that each grinding cycle brings about a progressive improvement. However, in all such cases the appropriate rail profile must be established, within the tolerance limits specified in Section 6.

The ARTC Grinding Manager or nominated representative may also approve a reduction in the length of track that is monitored by the Contractor for rail corrugations after grinding as described in Section 10.

15 Grinding Strategy

15.1 General

This grinding strategy contains: highly desirable requirements for grinding new rail and other rail where its orientation has been altered; guidelines for preventive grinding; and guidelines for corrective grinding. The requirements are applicable to all of ARTC's tracks. Where targeted grinding strategies have been developed for specific lines or regions then these will take precedence. Such alternative strategies must be approved by the appropriate Corridor General Manager or authorised representative.

The guidelines are given for the preventive grinding strategy and as such will provide an indication of the minimum rail grinding requirements. In the initial stages additional grinding may be necessary to rectify defective track sections.

15.2 Grinding of New or Reoriented Rail

In tracks with loaded coal traffic and heavy duty freight traffic, any new rails placed in track as part of re-railing (and not as closures for replacement of defects) shall be profile ground ideally within 5 MGT (or 20% of the grinding cycle for preventive grinding as indicated in Table 5 whichever is the larger) following the re-railing. This shall apply even if the re-railing occurs in only part of a curve or section. In tracks with general freight traffic, the new rails shall be ground within 10 MGT after installation or at the latest no longer than the next grinding cycle.

Special care is required in sections within which partial re-railing has occurred between grinding cycles. In these sections, the new rails will require some additional initial grinding prior to the final profile grinding applied to the whole section.

In addition, special grinding is required when the rail orientation is substantially altered. In such cases the grinding shall be applied within 5 MGT (or 20% of the grinding cycle for preventive grinding whichever is the larger) following the event. Applicable situations include:

- Reuse of rail when concrete sleepers are installed.
- Reuse of rail when substantial back-canting is corrected.
- Cascading or transposing of rail.

15.3 Guidelines for Preventive Grinding

The optimal guidelines for preventive rail grinding cycles are summarised in Table 5.

Table 5 - Guidelines for Preventive Grinding

Track Curvature (m)	Nominal Periods Between Grinding (MGT)					
	Tracks with Loaded Coal Traffic (30 tonnes nominal axle loads)		Tracks with Heavy Duty Freight Traffic (>23 tonnes nominal axle loads)		Tracks with General Freight Traffic or Empty Coal Traffic (≤23 tonnes nominal axle loads)	
	Std	HH	Std	HH	Std	HH
450 or less	5	10	7.5	15	10	20
> 450 to 900	10	20	15	30	20	40
> 900	20	40	30	45	40	60

To allow for track possession and grinding irregularities a tolerance of 3MGT may be applied to the nominal grinding period or up to 20% of the recommended cycle tonnages given in Table 5 (whichever is the larger). The nominal grinding period however will generally be maintained.

Because of adverse wheel/rail contact conditions, the grinding cycles in Table 5 might not be suitable for some track sections. Such sections shall be reported, monitored and if necessary adjusted to a different cycle category.

An example could be rails subjected to higher tractive efforts, which may exhibit higher deterioration rates and hence would require more frequent grinding.

The nominal grinding period between grinds in Table 5 shall be achieved at least on average. If necessary, individual cycles may be adjusted to suit particular circumstances but generally within the maximum allowable periods given in Table 5.

The curve classes and the grinding frequencies given in Table 5 may change in the future, depending on the characteristics of the rail performance observed between grinds, and recognising that the most efficient strategy would consist of grinding cycles which are multiples of each other, thus allowing relatively long sections of track, containing several curve classes, to be covered at any one time.

To improve the logistics of the grinding operation and hence efficiency, the ARTC Grinding Manager or nominated representative may programme the rail grinding to cover track sections containing different curve classes at the same time, even though the shallower curves may be within the specified cycles. In this case, as discussed in Section 9, the metal removal requirements in the shallower curves and tangent sections may be reduced, as long as the minimum metal removal is achieved within the specified cycles.

15.4 Corrective Grinding

Special grinding requirements apply for the treatment of various rail defect conditions, such as:

- Rail corrugations.
- Rolling contact fatigue (RCF) defects in the form of gauge corner and running surface checking and shelling.
- Rail plastic flow in the form of mushrooming.
- Squats and other thermal/mechanical defects.
- Wheel burns.
- Cyclic rail wear due to wheelset/bogie hunting or grinder 'skipping'.

The above will require separate assessment and must be dealt with on a case by case basis. The more serious of these will be identified by the track examination process and suitable remedial measures planned in advance.

Lesser conditions that are uncovered in the pre-grinding inspection may be dealt with in association with the normal grinding operation. If this cannot be done economically the work will be rescheduled for special treatment at a later date.

Localised defects such as wheel burns, dipped welds or squat defects may be more effectively treated by other means, such as weld repairs or straightening. These would be preferably applied prior to grinding, which would then achieve a better final finish.

It should be noted that where considerable grinding effort is required to achieve full correction to profile or to remove long wavelength corrugations, transition strategies might be utilised as outlined in Section 14. Such strategies must involve the correction of the problem over time such that each grinding cycle brings about a progressive improvement. Appropriate expert advice should be sought for the development of such strategies.

15.5 Periodic Reviews

The ARTC Grinding Manager or nominated representative should conduct annual reviews of the effectiveness of the rail grinding programme, to assess whether the original purpose for grinding has been achieved. The factors to consider include:

- Rail corrugation recordings.
- Rolling contact fatigue issues.
- Affect on track component life, and in particular rail fastenings, rail seat pads in concrete sleepers and sleeper deterioration affected by poor rail surface.
- Broken rail history and trends.
- Fouled ballast or mud holes at rail surface irregularities or rail corrugations.
- Tamping cycles.
- Evidence of vehicle hunting.

A technical review of Sections 2 to 14 of this Standard should also be conducted by technical experts at least every 5 years, to ensure the technical aspects are achieving the strategic objectives of ARTC.

16 Appendix 1 – Rail Templates

Main Templates

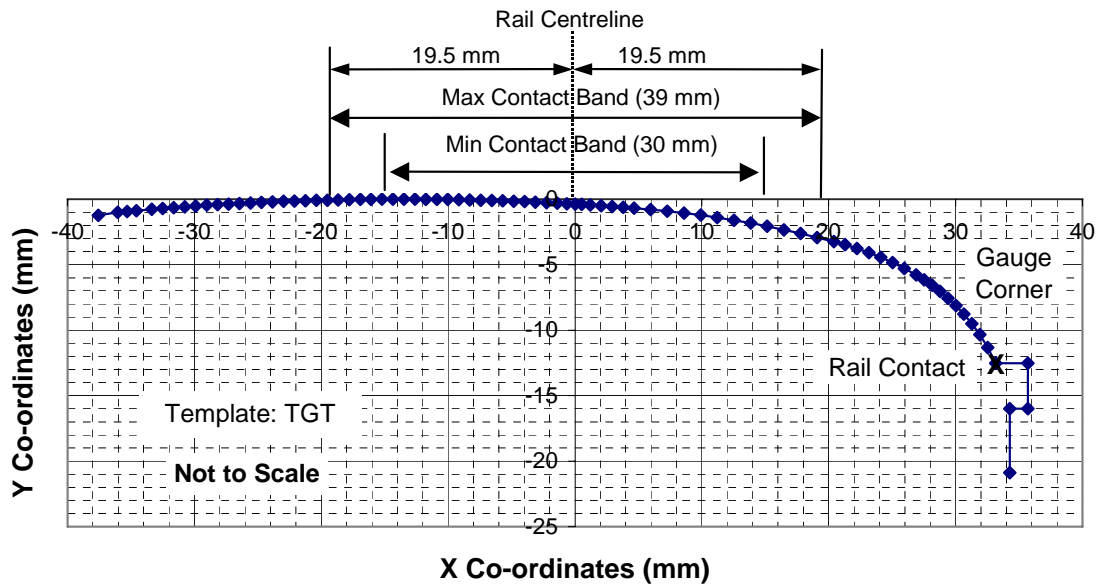
Fig A1: ARTC TGT	Template for tangent track and curves with radii $>900\text{m}$, with lug
Fig A2: ARTC L1	Template for low rails in curved track with radii $\leq 900\text{m}$, applied in transitional grinding, with lug
Fig A3: ARTC H2	Template for high rails in curved track with radii $\leq 900\text{m}$, without lug
Fig A4: ARTC L2	Template for low rails in curved track with radii $\leq 900\text{m}$, with lug

Special Templates

Fig A5: ARTC H3	Template for high rails in curved track with radii $\leq 900\text{m}$ exhibiting moderate/severe RCF defects, without lug
Fig A6: ARTC L3	Template for low rails in curved track with radii $\leq 900\text{m}$ requiring additional field/gauge side relief, with lug
Fig A7: ARTC TGT1	Template for tangent track and curves with radii $>900\text{m}$ requiring additional field/gauge side relief, with lug
Fig A8: ARTC H2R	Template for high rails in curved track with radii $\leq 900\text{m}$ requiring additional field side relief

Note: All profiles have been specified for rails with a cant adjustment of 1:20 (2.86°).

Figure A1: ARTC TGT – Template for tangent track and curves with radii >900m, with lug



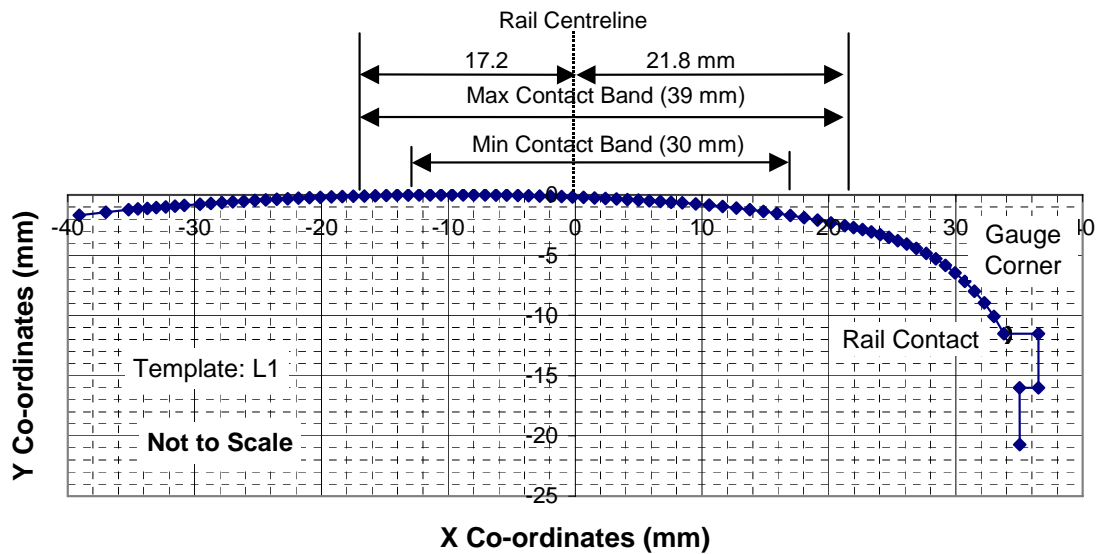
X Coordinates of Contact Band

Min Contact Band		Max Contact Band	
+15	-15	+19.5	-19.5

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-39.10	-1.44	-19.53	-0.07	-1.39	-0.31	21.29	-3.49
-37.59	-1.23	-18.67	-0.06	-0.63	-0.35	22.23	-3.76
-36.05	-1.00	-17.79	-0.04	0.00	-0.38	23.16	-4.08
-35.31	-0.94	-16.93	-0.02	0.54	-0.41	24.10	-4.44
-34.58	-0.87	-16.07	-0.02	1.21	-0.45	25.03	-4.84
-33.35	-0.78	-15.21	-0.01	2.07	-0.50	25.97	-5.29
-32.49	-0.71	-14.35	0.00	2.94	-0.56	26.90	-5.79
-31.62	-0.65	-13.48	-0.01	3.79	-0.62	27.53	-6.16
-30.76	-0.58	-12.62	-0.01	4.66	-0.68	28.16	-6.58
-29.89	-0.53	-11.76	-0.01	5.97	-0.79	28.78	-7.04
-29.03	-0.47	-10.88	-0.02	7.28	-0.91	29.41	-7.56
-28.17	-0.42	-10.02	-0.03	8.60	-1.06	30.03	-8.13
-27.30	-0.38	-9.16	-0.04	9.91	-1.21	30.66	-8.78
-26.44	-0.33	-8.29	-0.07	11.22	-1.40	31.28	-9.51
-25.58	-0.28	-7.43	-0.08	12.53	-1.61	31.90	-10.35
-24.71	-0.25	-6.57	-0.10	13.85	-1.83	32.53	-11.34
-23.85	-0.21	-5.70	-0.13	15.15	-2.08	33.16	-12.53
-22.98	-0.17	-4.84	-0.16	16.46	-2.34	35.70	-12.53
-22.12	-0.15	-3.98	-0.19	17.78	-2.62	35.70	-16.00
-21.25	-0.12	-3.12	-0.22	19.09	-2.92	34.26	-16.00
-20.39	-0.09	-2.25	-0.27	20.40	-3.25	34.26	-20.87

Figure A2: ARTC L1 - Template for low rails in curved track with radii $\leq 900\text{m}$, applied in transitional grinding, with lug



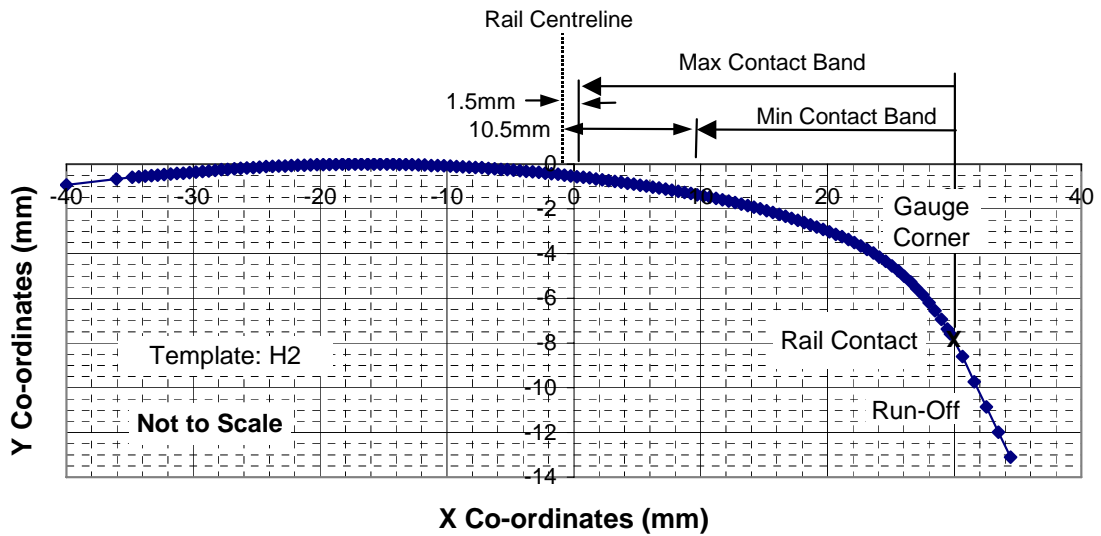
X Coordinates of Contact Band

Min Contact Band	Max Contact Band
-12.7	-17.2
17.3	21.8

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-39.10	-1.69	-18.34	-0.13	0.66	-0.21	21.95	-2.71
-37.00	-1.45	-17.48	-0.11	1.53	-0.26	22.65	-2.87
-35.20	-1.23	-16.62	-0.08	2.39	-0.30	23.34	-3.07
-34.46	-1.17	-15.75	-0.06	3.25	-0.34	24.04	-3.29
-33.74	-1.11	-14.89	-0.05	4.11	-0.39	24.73	-3.53
-33.00	-1.04	-14.03	-0.03	4.98	-0.44	25.43	-3.79
-32.27	-0.99	-13.16	-0.01	5.84	-0.49	26.13	-4.08
-31.54	-0.93	-12.30	-0.01	6.71	-0.55	26.89	-4.44
-30.80	-0.86	-11.44	0.01	7.57	-0.61	27.66	-4.85
-29.58	-0.77	-10.57	0.01	8.44	-0.67	28.43	-5.31
-28.71	-0.70	-9.70	0.00	9.50	-0.75	29.19	-5.85
-27.85	-0.64	-8.84	0.00	10.57	-0.85	29.95	-6.47
-26.98	-0.57	-7.98	0.00	11.64	-0.96	30.72	-7.17
-26.12	-0.52	-7.11	-0.01	12.70	-1.08	31.49	-7.99
-25.26	-0.46	-6.25	-0.02	13.78	-1.22	32.25	-8.94
-24.39	-0.41	-5.39	-0.03	14.84	-1.37	33.02	-10.08
-23.53	-0.37	-4.52	-0.05	15.91	-1.54	33.79	-11.52
-22.67	-0.32	-3.66	-0.07	16.97	-1.71	36.52	-11.52
-21.80	-0.27	-2.80	-0.09	18.05	-1.89	36.52	-16.00
-20.94	-0.24	-1.93	-0.12	19.11	-2.10	35.03	-16.00
-20.08	-0.20	-1.07	-0.15	20.18	-2.32	35.04	-20.72
-19.21	-0.16	-0.20	-0.18	21.25	-2.54		

Figure A3: ARTC H2 - Template for high rails in curved track with radii $\leq 900\text{m}$, without lug



X Coordinates of Contact Band

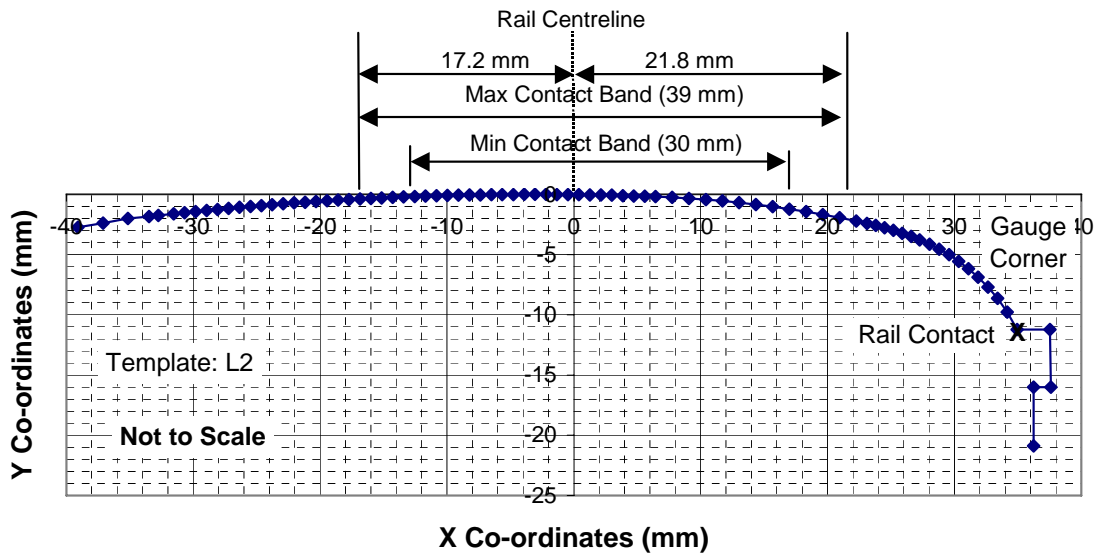
Min Contact Band Max Contact Band
 + 9.5 to rail contact point on + 1.0 to rail contact point on
 gauge side (at 50°) gauge side (at 50°)

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-40.00	-0.94	-18.25	-0.01	-0.75	-0.49	16.68	-2.33
-36.06	-0.67	-17.75	0.00	-0.26	-0.52	17.17	-2.43
-34.80	-0.59	-17.25	0.00	0.24	-0.56	17.67	-2.52
-34.30	-0.57	-16.75	0.00	0.74	-0.58	18.16	-2.62
-33.80	-0.54	-16.25	0.00	1.24	-0.62	18.66	-2.71
-33.30	-0.52	-15.75	0.00	1.74	-0.66	19.15	-2.82
-32.79	-0.49	-15.25	0.00	2.24	-0.70	19.65	-2.92
-32.29	-0.47	-14.75	0.00	2.74	-0.73	20.14	-3.03
-31.79	-0.44	-14.25	-0.01	3.24	-0.77	20.64	-3.14
-31.29	-0.42	-13.75	-0.01	3.73	-0.81	21.14	-3.25
-30.79	-0.40	-13.25	-0.02	4.23	-0.86	21.63	-3.37
-30.29	-0.38	-12.75	-0.02	4.73	-0.89	22.12	-3.50
-29.78	-0.35	-12.25	-0.04	5.23	-0.94	22.62	-3.66
-29.28	-0.33	-11.75	-0.04	5.73	-0.98	23.11	-3.81
-28.78	-0.30	-11.25	-0.06	6.23	-1.03	23.60	-3.98
-28.28	-0.28	-10.75	-0.06	6.73	-1.07	24.09	-4.16
-27.78	-0.25	-10.25	-0.08	7.22	-1.12	24.58	-4.35
-27.28	-0.24	-9.75	-0.09	7.72	-1.16	25.07	-4.55
-26.77	-0.21	-9.25	-0.11	8.22	-1.22	25.56	-4.77
-26.27	-0.19	-8.75	-0.12	8.72	-1.26	26.05	-5.01
-25.77	-0.17	-8.25	-0.14	9.22	-1.32	26.54	-5.27
-25.27	-0.16	-7.75	-0.15	9.71	-1.37	27.03	-5.55
-24.77	-0.13	-7.25	-0.17	10.21	-1.42	27.51	-5.86
-24.27	-0.12	-6.75	-0.19	10.71	-1.47	28.00	-6.19
-23.76	-0.10	-6.25	-0.21	11.21	-1.54	28.48	-6.56
-23.26	-0.09	-5.75	-0.23	11.71	-1.59	28.96	-6.95

-22.76	-0.08	-5.25	-0.25	12.20	-1.66	29.44	-7.37
-22.26	-0.07	-4.75	-0.27	12.70	-1.72	29.68	-7.60
-21.76	-0.05	-4.25	-0.30	13.20	-1.79	30.63	-8.61
-21.26	-0.05	-3.75	-0.32	13.70	-1.85	31.57	-9.73
-20.76	-0.03	-3.25	-0.34	14.19	-1.93	32.52	-10.86
-20.26	-0.03	-2.75	-0.37	14.69	-2.00	33.46	-11.99
-19.76	-0.02	-2.25	-0.40	15.19	-2.09	34.41	-13.11
-19.25	-0.02	-1.75	-0.43	15.68	-2.16		
-18.75	-0.01	-1.25	-0.45	16.18	-2.25		

Figure A4: ARTC L2 - Template for low rails in curved track with radii $\leq 900\text{m}$, with lug



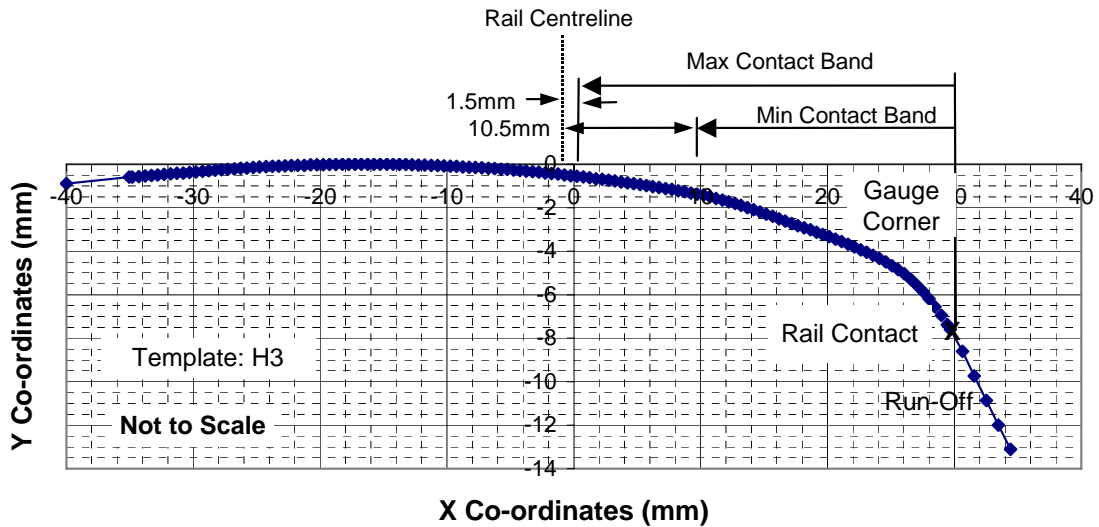
X Coordinates of Contact Band

Min Contact Band		Max Contact Band	
-12.7	17.3	-17.2	21.8

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-39.10	-2.74	-17.72	-0.43	0.40	-0.03	23.79	-2.58
-37.10	-2.38	-16.87	-0.38	1.26	-0.04	24.50	-2.78
-35.15	-2.01	-16.00	-0.33	2.13	-0.06	25.19	-2.99
-33.50	-1.84	-15.14	-0.29	2.99	-0.08	25.88	-3.23
-32.77	-1.76	-14.28	-0.25	3.85	-0.10	26.58	-3.49
-31.54	-1.62	-13.41	-0.21	4.72	-0.13	27.27	-3.78
-30.67	-1.52	-12.54	-0.17	5.58	-0.16	28.04	-4.13
-29.81	-1.42	-11.68	-0.15	6.44	-0.19	28.80	-4.54
-28.95	-1.34	-10.82	-0.12	7.76	-0.25	29.57	-5.01
-28.08	-1.25	-9.95	-0.09	9.08	-0.33	30.33	-5.55
-27.22	-1.16	-9.09	-0.08	10.40	-0.43	31.10	-6.17
-26.35	-1.08	-8.23	-0.05	11.72	-0.55	31.87	-6.87
-25.50	-1.00	-7.37	-0.04	13.03	-0.69	32.64	-7.69
-24.63	-0.92	-6.51	-0.03	14.36	-0.85	33.40	-8.64
-23.77	-0.86	-5.64	-0.02	15.67	-1.02	34.17	-9.78
-22.90	-0.78	-4.77	-0.01	16.99	-1.22	34.94	-11.22
-22.04	-0.71	-3.91	0.00	18.31	-1.44	37.54	-11.23
-21.18	-0.65	-3.05	-0.01	19.63	-1.68	37.59	-16.00
-20.31	-0.59	-2.19	0.00	20.95	-1.94	36.25	-16.00
-19.45	-0.53	-1.33	-0.01	22.27	-2.21	36.25	-20.87
-18.58	-0.47	-0.46	-0.02	23.10	-2.41		

Figure A5: ARTC H3 - Template for high rails in curved track with radii $\leq 900\text{m}$ exhibiting moderate/severe RCF defects, without lug



X Coordinates of Contact Band

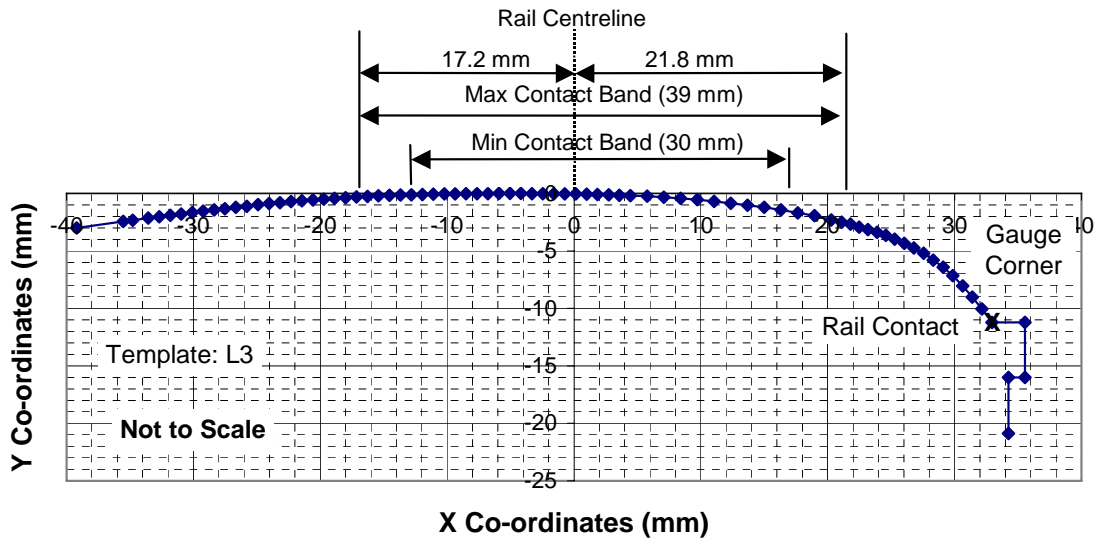
- Min Contact Band
+ 9.5 to rail contact point on gauge side (at 50)
- Max Contact Band
+ 1.0 to rail contact point on gauge side (at 50)

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-40.00	-0.89	-18.25	-0.01	-0.75	-0.49	16.66	-2.62
-35.05	-0.60	-17.75	0.00	-0.26	-0.52	17.16	-2.72
-34.80	-0.59	-17.25	0.00	0.24	-0.56	17.65	-2.82
-34.30	-0.57	-16.75	0.00	0.74	-0.58	18.15	-2.92
-33.80	-0.54	-16.25	0.00	1.24	-0.62	18.64	-3.02
-33.30	-0.52	-15.75	0.00	1.74	-0.66	19.14	-3.13
-32.79	-0.49	-15.25	0.00	2.24	-0.70	19.63	-3.23
-32.29	-0.47	-14.75	0.00	2.74	-0.73	20.13	-3.34
-31.79	-0.44	-14.25	-0.01	3.24	-0.77	20.62	-3.45
-31.29	-0.42	-13.75	-0.01	3.73	-0.81	21.12	-3.56
-30.79	-0.40	-13.25	-0.02	4.23	-0.86	21.61	-3.68
-30.29	-0.38	-12.75	-0.02	4.73	-0.89	22.11	-3.80
-29.78	-0.35	-12.25	-0.04	5.23	-0.94	22.60	-3.93
-29.28	-0.33	-11.75	-0.04	5.73	-0.98	23.10	-4.05
-28.78	-0.30	-11.25	-0.06	6.23	-1.03	23.59	-4.19
-28.28	-0.28	-10.75	-0.06	6.73	-1.07	24.08	-4.32
-27.78	-0.25	-10.25	-0.08	7.22	-1.12	24.58	-4.49
-27.28	-0.24	-9.75	-0.09	7.72	-1.16	25.07	-4.66
-26.77	-0.21	-9.25	-0.11	8.22	-1.22	25.56	-4.85
-26.27	-0.19	-8.75	-0.12	8.72	-1.26	26.05	-5.03
-25.77	-0.17	-8.25	-0.14	9.22	-1.32	26.54	-5.29
-25.27	-0.16	-7.75	-0.15	9.71	-1.37	27.03	-5.55
-24.77	-0.13	-7.25	-0.17	10.21	-1.42	27.51	-5.86
-24.27	-0.12	-6.75	-0.19	10.71	-1.49	28.00	-6.19
-23.76	-0.10	-6.25	-0.21	11.21	-1.57	28.48	-6.56

-23.26	-0.09	-5.75	-0.23	11.70	-1.65	28.96	-6.95
-22.76	-0.08	-5.25	-0.25	12.20	-1.72	29.44	-7.37
-22.26	-0.07	-4.75	-0.27	12.70	-1.80	29.68	-7.60
-21.76	-0.05	-4.25	-0.30	13.19	-1.89	30.63	-8.61
-21.26	-0.05	-3.75	-0.32	13.69	-1.99	31.57	-9.73
-20.76	-0.03	-3.25	-0.34	14.18	-2.09	32.52	-10.86
-20.26	-0.03	-2.75	-0.37	14.68	-2.19	33.46	-11.99
-19.76	-0.02	-2.25	-0.40	15.18	-2.29	34.41	-13.11
-19.25	-0.02	-1.75	-0.43	15.67	-2.40		
-18.75	-0.01	-1.25	-0.45	16.17	-2.51		

Figure A6: ARTC L3 - Template for low rails in curved track with radii $\leq 900\text{m}$ requiring additional field/gauge side relief, with lug



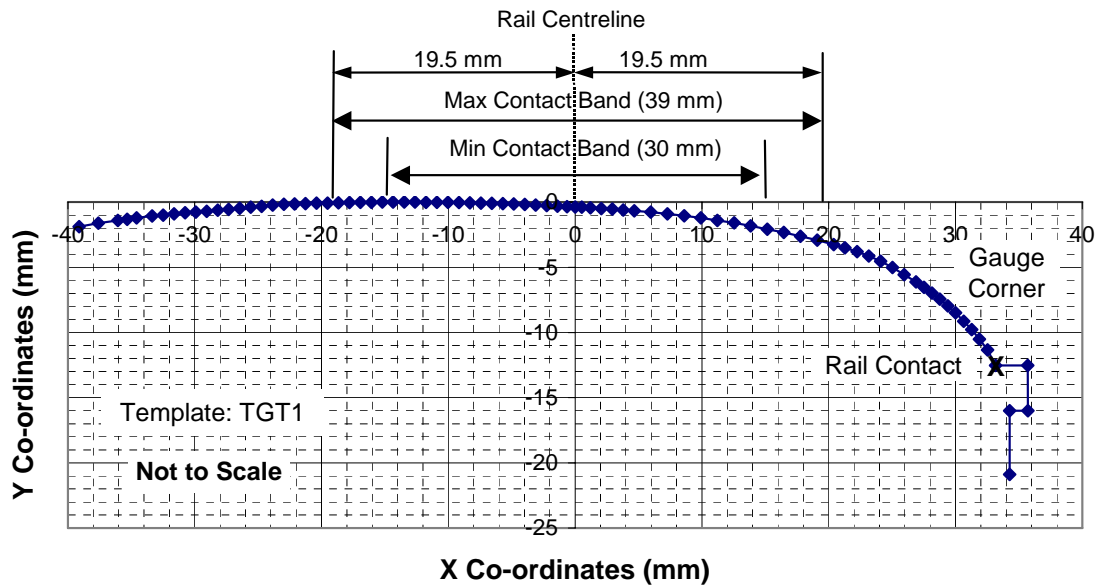
X Coordinates of Contact Band

Min Contact Band	Max Contact Band
-12.7	-17.2
17.3	21.8

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-39.20	-3.01	-18.87	-0.44	-1.60	-0.03	21.10	-2.51
-35.53	-2.44	-18.00	-0.37	-0.74	-0.04	21.79	-2.68
-34.79	-2.33	-17.14	-0.32	0.14	-0.06	22.49	-2.93
-33.56	-2.16	-16.28	-0.27	1.00	-0.08	23.18	-3.14
-32.69	-2.03	-15.41	-0.22	1.86	-0.10	23.88	-3.38
-31.83	-1.90	-14.54	-0.17	2.73	-0.13	24.58	-3.64
-30.97	-1.79	-13.68	-0.15	3.58	-0.16	25.26	-3.98
-30.10	-1.67	-12.81	-0.12	4.44	-0.19	26.03	-4.33
-29.24	-1.55	-11.95	-0.09	5.76	-0.25	26.79	-4.74
-28.37	-1.44	-11.09	-0.08	7.08	-0.33	27.56	-5.21
-27.51	-1.33	-10.23	-0.05	8.41	-0.43	28.32	-5.80
-26.65	-1.22	-9.37	-0.04	9.72	-0.55	29.09	-6.42
-25.78	-1.13	-8.50	-0.03	11.04	-0.69	29.86	-7.15
-24.91	-0.99	-7.64	-0.02	12.36	-0.85	30.63	-8.03
-24.05	-0.89	-6.77	-0.01	13.67	-1.02	31.39	-9.01
-23.18	-0.81	-5.91	-0.01	15.00	-1.22	32.16	-10.04
-22.32	-0.73	-5.05	-0.01	16.32	-1.44	32.94	-11.22
-21.45	-0.65	-4.19	0.00	17.64	-1.68	35.55	-11.22
-20.59	-0.57	-3.33	-0.01	18.95	-1.94	35.55	-16.00
-19.72	-0.51	-2.46	-0.02	20.27	-2.31	34.25	-16.00
						34.25	-20.87

Figure A7: ARTC TGT1 - Template for tangent track and curves with radii >900m (with lug) requiring additional field/gauge side relief



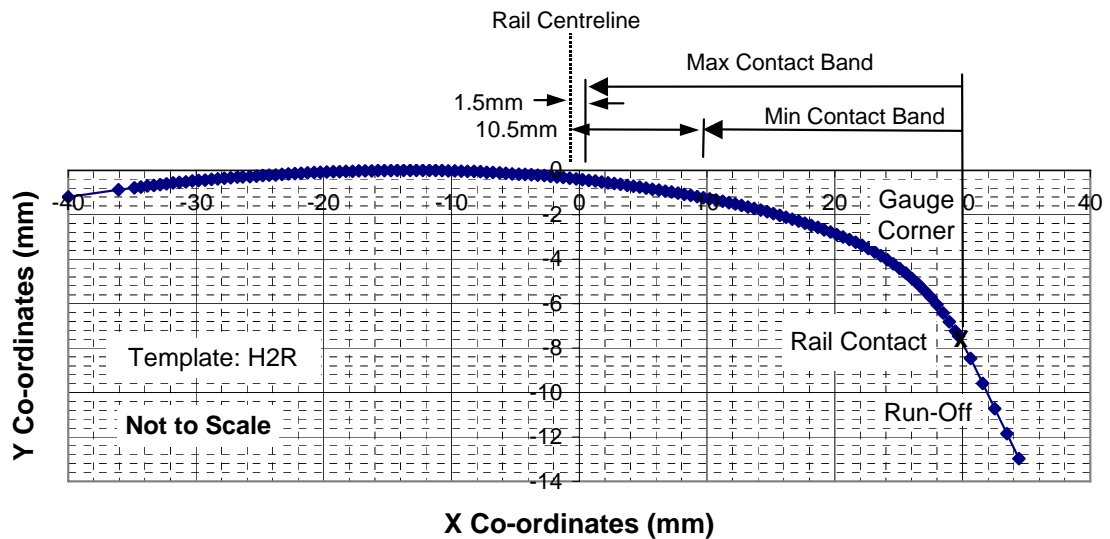
X Coordinates of Contact Band

Min Contact Band		Max Contact Band	
+15	-15	+19.5	-19.5

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-39.12	-1.89	-19.53	-0.07	-1.39	-0.31	21.29	-3.51
-37.61	-1.62	-18.67	-0.06	-0.63	-0.35	22.23	-3.81
-36.06	-1.40	-17.79	-0.04	0.00	-0.38	23.16	-4.15
-35.33	-1.32	-16.93	-0.02	0.54	-0.41	24.09	-4.55
-34.59	-1.23	-16.07	-0.02	1.21	-0.45	25.02	-5.02
-33.37	-1.08	-15.21	-0.01	2.07	-0.50	25.95	-5.56
-32.50	-1.01	-14.35	0.00	2.94	-0.56	26.89	-6.12
-31.64	-0.91	-13.48	-0.01	3.79	-0.62	27.51	-6.53
-30.77	-0.83	-12.62	-0.01	4.66	-0.68	28.14	-6.97
-29.91	-0.78	-11.76	-0.01	5.97	-0.79	28.76	-7.44
-29.04	-0.71	-10.88	-0.02	7.28	-0.91	29.39	-7.97
-28.18	-0.62	-10.02	-0.03	8.60	-1.06	30.01	-8.50
-27.31	-0.56	-9.16	-0.04	9.91	-1.21	30.64	-9.15
-26.45	-0.48	-8.29	-0.07	11.22	-1.40	31.27	-9.78
-25.58	-0.40	-7.43	-0.08	12.53	-1.61	31.89	-10.51
-24.72	-0.33	-6.57	-0.10	13.85	-1.83	32.53	-11.34
-23.85	-0.23	-5.70	-0.13	15.15	-2.08	33.16	-12.53
-22.98	-0.17	-4.84	-0.16	16.46	-2.34	35.70	-12.54
-22.12	-0.15	-3.98	-0.19	17.78	-2.62	35.72	-16.00
-21.25	-0.12	-3.12	-0.22	19.09	-2.92	34.26	-16.00
-20.39	-0.09	-2.25	-0.27	20.40	-3.25	34.26	-20.87

Figure A8: ARTC H2R - Template for high rails in curved track with radii $\leq 900\text{m}$ requiring additional field side relief



X Coordinates of Contact Band

- Min Contact Band
- Max Contact Band
- + 9.5 to rail contact point on gauge side (at 50°)
- + 1.0 to rail contact point on gauge side (at 50°)

X-Y Co-ordinates

X	Y	X	Y	X	Y	X	Y
-40.00	-1.20	-18.26	-0.05	-0.75	-0.35	16.68	-2.19
-36.07	-0.87	-17.76	-0.05	-0.25	-0.39	17.18	-2.29
-34.81	-0.79	-17.25	-0.03	0.25	-0.42	17.67	-2.38
-34.31	-0.75	-16.75	-0.03	0.75	-0.45	18.17	-2.48
-33.81	-0.71	-16.25	-0.02	1.25	-0.48	18.66	-2.57
-33.31	-0.68	-15.75	-0.01	1.74	-0.53	19.16	-2.68
-32.80	-0.64	-15.25	-0.01	2.24	-0.56	19.65	-2.78
-32.30	-0.61	-14.75	-0.01	2.74	-0.60	20.15	-2.89
-31.80	-0.57	-14.25	0.00	3.24	-0.63	20.64	-3.00
-31.30	-0.54	-13.75	0.00	3.74	-0.68	21.14	-3.11
-30.80	-0.52	-13.25	0.00	4.24	-0.72	21.63	-3.23
-30.29	-0.49	-12.75	0.00	4.74	-0.76	22.13	-3.37
-29.79	-0.46	-12.25	-0.01	5.23	-0.80	22.62	-3.52
-29.29	-0.44	-11.75	0.00	5.73	-0.85	23.11	-3.68
-28.79	-0.41	-11.25	0.00	6.23	-0.89	23.61	-3.84
-28.29	-0.38	-10.75	-0.02	6.73	-0.94	24.10	-4.03
-27.78	-0.36	-10.25	-0.03	7.23	-0.98	24.59	-4.21
-27.28	-0.33	-9.74	-0.03	7.73	-1.03	25.08	-4.42
-26.78	-0.31	-9.24	-0.03	8.22	-1.08	25.57	-4.63
-26.34	-0.30	-8.74	-0.04	8.72	-1.13	26.06	-4.88
-25.78	-0.28	-8.24	-0.05	9.22	-1.18	26.55	-5.13
-25.28	-0.26	-7.74	-0.07	9.72	-1.24	27.03	-5.42
-24.77	-0.24	-7.24	-0.08	10.22	-1.28	27.52	-5.72
-24.27	-0.22	-6.74	-0.10	10.72	-1.34	28.00	-6.05
-23.77	-0.20	-6.25	-0.12	11.21	-1.40	28.48	-6.42

-23.27	-0.19	-5.75	-0.14	11.71	-1.46	28.96	-6.81
-22.77	-0.16	-5.25	-0.15	12.21	-1.52	29.44	-7.24
-22.27	-0.15	-4.75	-0.17	12.71	-1.59	29.68	-7.46
-21.77	-0.13	-4.25	-0.18	13.20	-1.65	30.63	-8.47
-21.26	-0.11	-3.75	-0.20	13.70	-1.72	31.58	-9.60
-20.76	-0.10	-3.25	-0.22	14.20	-1.79	32.52	-10.73
-20.26	-0.09	-2.75	-0.23	14.69	-1.87	33.47	-11.85
-19.76	-0.08	-2.25	-0.27	15.19	-1.95	34.41	-12.97
-19.26	-0.06	-1.75	-0.29	15.69	-2.02		
-18.76	-0.06	-1.25	-0.32	16.18	-2.11		