



AUSTRALIAN RAIL TRACK CORPORATION LTD

Discipline: Engineering (Track & Civil)

Category: Code of Practice

Track Geometry

Section 5

Applicability

ARTC Network wide	✓
-------------------	---

Primary Source

Document Status

Version	Date Reviewed	Prepared by	Reviewed by	Endorsed	Approved
2.5	26 Sep 13	Standards	Stakeholders	Manager Standards	GM Technical Standards 02/10/13

Amendment Record

Version	Date Reviewed	Clause	Description of Amendment
2.0	31 Jul 09		Implementation draft of network wide document which is an amalgamation of the CoP for SA/WA & Vic and NSW requirements.
2.1	22 Mar 10	5.1.2	Implementation draft update. Gauge widening requirements updated.
2.2	18 Jan 11		Track classification A,B,C and D amended to show "Heavy Haul Lines", "Interstate lines", "Intrastate Lines", , and "Light Weight Lines".. Deleted reference to Class E Lines
2.3	30 May 11	5.3.2 (b) (ii) and Table 5.5	Text and Notes to table 5.5 simplified
2.4	08 Nov 11		Banner added regarding elements of RISSB National CoP being incorporated
2.5	26 Sep 13	5.1.1(a) & (c) and	Introduction of 110mm cant deficiency for curves between 235m radius and 501m radius. Table 5.2A heading 'Intrastate' corrected to

© Australian Rail Track Corporation Limited 2013

Disclaimer:

This document has been prepared by ARTC for internal use and may not be relied on by any other party without ARTC's prior written consent. Use of this document shall be subject to the terms of the relevant contract with ARTC.

ARTC and its employees shall have no liability to unauthorised users of the information for any loss, damage, cost or expense incurred or arising by reason of an unauthorised user using or relying upon the information in this document, whether caused by error, negligence, omission or misrepresentation in this document.

This document is uncontrolled when printed.

Authorised users of this document should visit ARTC's intranet or extranet (www.artc.com.au) to access the latest version of this document.



		Table 5.2A & 5.5	'Interstate', 1442mm corrected to 1441mm (being 6mm over gauge), and other minor editorial changes.
--	--	------------------	---

This ARTC CoP has drawn on the Rail Industry Safety and Standards Board (RISSB) National Code of Practice Volume 4, Track and Civil Infrastructure, but is not identical. The ARTC CoP has been subject to Risk Assessment as required by the various State Rail Safety Regulators. The results of these risk assessments have made it necessary to deviate from the RISSB CoP in some areas. ARTC maintains traceability of the differences.

Contents

5	Section 5: Track Geometry	4
5.1	Design and Rating.....	4
5.1.1	Main Line Track Geometric Alignment.....	4
5.1.2	Sidings Geometric Alignment.....	11
5.2	Construction and Maintenance.....	12
5.2.1	Construction Track Geometry.....	12
5.3	Inspection and Assessment.....	12
5.3.1	Inspection.....	12
5.3.2	Assessment.....	14

5 Section 5: Track Geometry

5.1 Design and Rating

5.1.1 Main Line Track Geometric Alignment

The design geometry may be derived using the equations given in this Clause. Nomenclature and units used in these equations are defined in Table 5.1. Inputs to these equations should be determined through rigorous analytical or empirical processes, or alternatively the design data given in Tables 5.2A, 5.2B, 5.2C and 5.2D may be adopted.

In Tables 5.2A, 5.2B, 5.2C and 5.2D the "typical" values represent normal design limits, and the use of values between "typical" and "recommended limit" shall require infrastructure owner approval. The use of values more severe than the "recommended limit" shall require full site specific justifications including risk assessments as appropriate, infrastructure owner approval and verification of the characteristics of the rolling stock affected.

The "typical" design limits provide for general business requirements for comfort and safety, and represent preferred engineering practice. They allow for normal low maintenance track, based on current experience. All design should normally conform to these typical design limits.

The "recommended limit" (maximum or minimum) allows for the track to be maintained within the safety limits but may result in higher maintenance requirements and costs.

Exceptional design limits, shown in Table 5.2E, using short transitions and higher rates of change of deficiency than is currently permitted have been utilised on the design of some infrastructure. These limits may only be used on short sections of plain line track and in tangential turnout designs.

Turnout design limits for basic parameters are shown in Table 5.2F

Table 5.1 – Nomenclature and Units

PARAMETER	SYMBOL	UNIT
Speed (Design)	V	km/h
Equilibrium superelevation	E_e	mm
Applied superelevation	E_a	mm
Applied negative superelevation	E_{na}	mm
Difference in applied superelevation	ΔE_a	mm
Superelevation ramp rate	E_r	1 in _
Rate of change of superelevation	E_{aroc}	mm/s
Superelevation deficiency / excess (negative deficiency)	D	mm
Superelevation deficiency horizontal bend	D_β	mm
Difference in deficiency	ΔD	mm
Rate of change of superelevation deficiency / excess	D_{roc}	mm/s
Length of transition	L	m
Length of superelevation ramp	L_r	m
Horizontal bend angle	β	degrees
Horizontal curve radius	R	m
Vertical curve radius	R_v	m
Grade (compensated)	G	1 in _
Nominal vehicle bogie spacing	B_c	m

Design geometry is as follows:

a) Circular curves

On circular curves of constant radius:

$$V = \sqrt{\frac{R \cdot E_e}{11.82}} \quad \dots \text{ (Eq. 5.1)}$$

where

$$E_e = E_a + D$$

Calculated speed should be rounded up or down to the nearest 5km/hr speed band eg 73 km/hr becomes 75km/hr and 71.5k m/hr becomes 70 km/hr.

Where track is designed for a controlled system with basically one operation and hence a choice of superelevation and cant deficiency, the normal value of cant deficiency to be applied is 25mm. This requirement is in line with the principle that a level of positive deficiency is desirable to promote consistent vehicle tracking.

Main line curves between 160 and 200m radius shall have the gauge widened by 6mm to 1441mm.

b) Transition curves

Transition curve geometry should be a cubic parabola or a clothoid.

On a transition curve from a tangent track to a circular curve or between curves of similar flexure with no intervening straight (i.e. compound curves):

$$V = \frac{3.6 L \cdot D_{roc}}{\Delta D} \quad \dots \text{ (Eq. 5.2)}$$

Where the adopted transition curve is less than B_c in length, that is the nominal spacing between the vehicle bogies, a virtual transition is adopted where:

$$V = \frac{3.6 B_c \cdot D_{roc}}{\Delta D} \quad \dots \text{ (Eq. 5.3)}$$

Where

$$B_c = 13 \text{ m}$$

The length of the superelevation ramp in a transition curve is given by:

$$L_r = \frac{E_r \cdot \Delta E_a}{1000} \quad \dots \text{ (Eq. 5.4)}$$

Where the actual transition curve length is not sufficient to allow full development of superelevation on the transition curve (i.e. $L < L_r$) the development of superelevation on straight or circular curved track at either end of a transition curve is permitted.

Where the length of superelevation ramp is less than the transition length (i.e. $L_r < L$), the superelevation should be developed over the full length of the transition.

c) Vertical Curves

Vertical curves of suitable average curve radius should be used where there are changes in gradient greater than 1 in 500. They should be parabolic and not less than 15m in length.

For the purpose of determining the length of the vertical curve, the actual parabolic curve is often equated to a circular curve with an average vertical curve radius. Rather than provide for a large number of vertical curve lengths, the length selected for a vertical curve is generally rounded up to the next length in a range of incremental curve lengths defined by the infrastructure owner.

The "typical" values for average vertical curve radii given in Table 5.2B are based on limiting vertical acceleration and are calculated as follows:

$$V = \sqrt{2 \cdot R_v} \quad \dots \text{(Eq. 5.5)}$$

Table 5.3 also defines the recommended minimum vertical curve radii for sags and summits.

d) Horizontal bends

On a bend of β degrees between straights:

$$V = \sqrt{\frac{4.85 D_B \cdot B_c}{\beta}} \quad \dots \text{(Eq. 5.6)}$$

Note: Horizontal bends in the track are undesirable and should be avoided.

e) Length of straights and curves

Between similar-flexure curves a transition curve should be provided.

Between contra-flexure curves a straight of minimum length B_c should be provided, see note.

Circular and transition curves should have a minimum length of B_c .

Superelevation ramps should have a minimum length of B_c including between curves in a compound curve.

Where a transition length of B_c or greater is not necessary a transition curve is not required.

Where a straight is to be placed between adjacent main line curves the desirable straight length is 60m. The minimum length is 13m.

Note: The minimum length of straight may be reduced at crossovers.

f) Geometric design documentation

The design details pertaining to the current design should be maintained and should include:

- Survey coordinates and datums if available.
- Location details.
- Curvature.
- Grade.
- Superelevation.
- Maximum speed.
- Transition length.
- Superelevation ramp.

Table 5.2A – Typical and Recommended Limits for Design Parameters Heavy Haul and Interstate Lines and XPT Type Trains

Ref	Parameter	Symbol (unit)	Recommended limit ^[1]	Typical ^[2]
1	Applied superelevation Except at platforms: Interstate Lines Heavy Haul lines At platforms: Heavy Haul and Interstate Lines	E _a (mm)	150 mm 140 mm 110 mm	125 mm 125 mm 75 mm
2	Applied negative superelevation (only applies to divergent roads over contraflexure turnouts)	E _{na} (mm)	55 mm	Nil
3	Superelevation ramp rate	E _r	1:300	1:500
4	Superelevation deficiency Plain track: XPT type passenger trains Heavy Haul lines Interstate lines Interstate lines for operation at enhanced performance speed (EP) for curves between 235m and 501m radius Diverging track in conventional turnouts ^[3] : XPT type passenger trains Heavy Haul lines Interstate lines Diverging track in tangential turnouts ^[3] : XPT type passenger trains Heavy Haul lines Interstate lines Horizontal bend (calculated) ^[4]		110 mm 75 mm 80 mm 110mm 110 mm 50 mm 75 mm 110 mm 80 mm 85 mm 40 mm	110 mm 70 mm 75 mm 110mm 100 mm 50 mm 75 mm 100 mm 75 mm 75 mm NA ^[5]
5	Superelevation excess (negative deficiency) ^[6] Interstate Lines lines Heavy Haul lines	D (mm)	-75 mm -50 mm	-75 mm -50 mm
6	Rate of change of superelevation deficiency / excess XPT type passenger trains Heavy Haul and Interstate Lines Diverging track in conventional turnouts: Diverging track in tangential turnouts:	D _{roc} (mm/s)	65 mm/s 55 mm/s 110 mm/s 135 mm/s	55 mm/s 35 mm/s 85 mm/s 110 mm/s
7	Rate of change of superelevation XPT type passenger trains Heavy Haul and Interstate Lines	E _{aroc} (mm/s)	65 mm/s 55 mm/s	55 mm/s 35 mm/s
8	Horizontal bend angle	B (degrees)	1° 50´	Nil
9	Horizontal curve radius ^[7]	R (m)	150 m	200 m
10	Vertical curve radius	R _v (m)	Table 5.2B	Table 5.2B
11	Grade (compensated) ^[8]	G	1 in 30	1 in 80
12	Nominal spacing of vehicle bogies	B _c (m)	-	13

Notes:

- [1] Refer to the start of this section for conditions on the use of values less restrictive than "typical" limits.
- [2] Typical limits are based on timber sleepered, jointed track. Less restrictive limits may apply to track of better configuration.
- [3] Calculated from the minimum of:
 - the radius calculated from a versine at the point toe using a chord of length B_c , and
 - the radius in the body of the turnout curve.
- [4] The superelevation deficiency or rate of change of superelevation deficiency for a horizontal bend is dependent on speed and may be calculated assuming a virtual curve based on a chord of length B_c .
- [5] Not applicable as "typical" limit for horizontal bends is nil.
- [6] This limit is for the purpose of determining the allowable speed differential when designing curve speeds and superelevation for a mixture of traffic classes. It does not limit the allowable applied superelevation.
- [7] Gauge widening may be necessary for design curves of less than 200 metre radius. Where feasible the design of new track alignments should provide for a minimum horizontal curve radius of 800 m.
- [8] Grade should be calculated over the length of the train. Characteristics of the traffic should be considered when selecting grading.
Curve compensation can be calculated empirically by:
$$n = 1.65R$$
Where R is the curve radius in metres and n is the equivalent gradient 1 in "n"
- [9] When determining allowable curve speeds using the data in this Clause, the following shall apply:
 - Calculate maximum speed applying above formula.
 - As curve speeds are posted in multiples of 5km/h, round the speed to the nearest 2.5km/h (eg 87.4 becomes 85, 87.5 becomes 90)

Table 5.2B – Average Vertical Curve Radius for Heavy Haul and Interstate Lines (for sags and summits)

Maximum Train Speed	Recommended Limit [see Note]	Typical
< 80 km/h	1300 m	1800 m
80 - 99 km/h	2000 m	3200 m
100 - 119 km/h	2800 m	5000 m
120 - 160 km/h	5000 m	7200 m

Note: Where feasible the design of new track alignments should provide for a minimum vertical curve radius of 7200 m.

Table 5.2C – Typical Limits of Basic Parameters for Intrastate and Light Weight Lines

Parameter		Intrastate Lines	Light Weight Lines
Max speed (km/h)	Normal	100	100
	XPT	140	100
Nominal spacing of vehicle bogies (m)		13	13
Max bend angle (degrees)		1°	1°
Max superelevation deficiency in bend (mm)		25	25
Min radius (m)		400	400
	Max applied superelevation (mm)	Mainline	100
		Platforms	75
		T/out Contra	20
Max super deficiency (mm) (Note 1)	Heavy Freight Lines	N/A	N/A
	Freight & Pass	±50	±40
	XPT	+75/-50	±40
Max rate of change of deficiency (mm/s)	Normal	37	37
	XPT	55	45
Min superelevation ramp rate (1 in)		900	750
Min vertical curve equivalent radius (m)		1300	1300
Max vertical acceleration (m/s ²)		0.2	0.2

Note 1: The design limit for negative D applies to the normal operation of the most significant trains over the track being designed.

Table 5.2D – Recommended Limits (Maximum or Minimum) of Basic Parameters for Intrastate and Light Weight Lines

Parameter		Intrastate Lines	Light Weight Lines
Max speed (km/h)	Normal	100	100
	XPT	140	100
Nominal spacing of bogies (m)		13	13
Max bend angle (degrees)		1° 50'	1° 50'
Max superelevation deficiency in bend (mm)		40	40
Min radius (m)		160	120
	Max applied superelevation (mm)	Mainline	100
		Platforms	100
		T/out Contra	40
Max superelevation deficiency (mm)	Heavy Freight Lines	N/A	N/A
	Freight & Pass	+50	+40
	XPT	+75	+40
Max rate of change of deficiency (mm/s)	Normal	55	55
	XPT	65	55

Min superelevation ramp rate (1 in)	400	400
Min vertical curve equivalent radius(m)	1300	1300
Max vertical acceleration (m/s ²)	0.4	0.4

Table 5.2E – Exceptional Design Limits of Basic Parameters

PARAMETER		Heavy Haul and Interstate Lines	Intrastate and Light Weight Lines
Max D (mm)	Freight	+80	N/A
	Passenger	100	N/A
Max D _{roc} (mm/s)	Normal	135	N/A
Min E _r (1 in)		300	300

Table 5.2F – Turnouts – Design Limits of Basic Parameters

PARAMETER/TRACK			Heavy Haul	Interstate	Intrastate	Light Weigh
Max V (km/h)	Normal/XPT		115/160	115/160	100/140	100/100
Typical Limits						
Diverging track tangential turnouts	Max D (mm)	Heavy Haul	75	N/A	N/A	N/A
		Freight/Pass	75	75	N/A	N/A
		XPT	100	100	N/A	N/A
	Max D _{roc} (mm/s)		110	110	N/A	N/A
Diverging track conventional turnouts	Max D (mm)	Heavy Haul	50	N/A	N/A	N/A
		Freight/Pass	75	75	50	40
		XPT	100	100	75	40
	Max D _{roc} (mm/s)		85	85	*	*
Contraflexure turnouts	Max E _a (mm)		20	20	20	20
Recommended Limits						
Diverging track tangential turnouts	Max D (mm)	Heavy Haul	80	N/A	N/A	N/A
		Freight/Pass	85	85	N/A	N/A
		XPT	110	110	N/A	N/A
	Max D _{roc} (mm/s)		135	135	N/A	N/A
Diverging track conventional turnouts	Max D (mm)	Heavy Haul	50	N/A	N/A	N/A
		Freight/Pass	75	75	50	40
		XPT	110	110	75	40
	Max D _{roc} (mm/s)		110	110	*	*
Contraflexure turnouts	Max E _a (mm)		55	55	40	30

5.1.2 Sidings Geometric Alignment

a) General

This clause specifies the requirements for sidings which by definition have a maximum operating speed for all vehicles of 25 km/hr.

(i) Circular Curves

The designed minimum radius for sidings shall be

Connected to Heavy Haul and Interstate tracks 200m

Connected to Intrastate and light Weight tracks 180m

The minimum radius for loco operation is 160m. This may be reduced to 140m with special permission of ARTC where site considerations make 160m impossible to achieve economically.

Where pre-bored timber sleepers or steel or concrete sleepers are used gauge widening is not required for curves at or greater than 160m radius.

Where locomotives are not intended to operate, the radius may be reduced to 100m.

The gauge shall be widened on curves as follows:

Table 5.3

Radius (m)	Gauge (mm)
200 - 160	1440
160 - 140	1445
140 - 120	1450
120 - 100	1455

Note that gauge widening applies to both main lines and sidings.

(ii) Superelevation

Superelevation is not required on sidings except as required to connect to a mainline turnout. The maximum rate of removing mainline superelevation shall be 1 in 500 which must commence clear of the turnout timbers.

(iii) Transitions

Transitions are not required on curves in sidings.

(iv) Reverse Curves

A desirable straight of 20m shall be provided between reverse curves of 200m radius and less. For reverse curves of greater radius the length of straight may be reduced to 13m.

If, because of existing restraints, this straight cannot be obtained economically, the straight may be reduced to 10m provided it is understood long vehicles may require shunting separately to avoid buffer locking.

(v) Vertical Curves

Vertical curves are to be provided wherever there is a grade difference equal to or greater than 0.2%. Preferably they are to be similar to adjacent mainlines. Otherwise the minimum radius for sidings connected to the following class lines should be:

Connected to Heavy Haul and Interstate tracks 2000m

Connected to Intrastate and light Weight tracks 1200m

The absolute minimum should be 800m

In hump type yards, the vertical curve at the hump may be 400m if constructed on a concrete slab.

(vi) Gradients

Gradients should not exceed 0.66% (1 in 150) unless gravity shunting is proposed.

Examination sidings grading must not exceed 0.66% (1 in 150).

Gravity shunting grade is to be 1% (1 in 100) plus $\frac{60\%}{R}$ for curve compensation.

The maximum permissible gravity shunting grade is 1.25% (1 in 80).

Gradients of up to 3.33% (1 in 30) will be allowed for short grades with approval of the ARTC Manager Standards or nominated representative.

The maximum grade permissible where loco and wagon coupling is required is 3% (1 in 33).

Mainline gradients are to extend into a siding for a minimum of 15m before commencement of any vertical curve.

Track centres are to be widened where tracks are at different levels and grades to ensure that the correct batter slopes and formation widths are obtained for each track. If this is not possible, retaining walls and standard cess drainage is to be provided.

5.2 Construction and Maintenance

5.2.1 Construction Track Geometry

a) Additional restrictions at worksites,

If construction takes place whilst trains are in operation and the track geometry is at significant variance from the designed horizontal or vertical alignment (for example skeleton track following ballast cleaning or through track deviations) the following additional guidelines should apply:

- (i) The maximum speed allowed should be 20km/h. These operations would normally require the operation of trains to be piloted from trackside.
- (ii) The vertical alignment measured using the mid-ordinate offset of a 20 metre chord at any location should not exceed 75 mm
- (iii) The horizontal alignment measured using the mid-ordinate offset of a 20 metre chord at any location should not exceed 330 mm.
- (iv) The limitations on working in hot weather specified in Section 6 Track Lateral Stability should apply.

5.3 Inspection and Assessment

5.3.1 Inspection

The guidelines for the inspection of track geometry including inspection intervals are set out in Table 5.4. The inspection intervals may be adjusted where approved by ARTC e.g. in an approved Technical Maintenance Plan. They shall be carried out as follows:

a) Patrol inspection

Track patrols shall keep a lookout for track geometry defects and conditions (i.e. indicators of a defect) that may affect the ability of the track to guide rolling stock or cause unacceptable rolling stock response including the following:

- (i) Track geometry defects including those that may indicate problems with the underlying track and civil structure.
- (ii) Locations where the deterioration in track geometry is abnormal since last inspected.
- (iii) Indications of track geometry and alignment defects including:
 - (A) evidence of recent or current movement;
 - (B) unusual wear patterns on the rail; or
 - (C) locations where the geometry is inconsistent with the track either side (eg. a sudden change in curve radius).
- (iv) Obvious variations in track alignment that may for example, affect clearances or track stability.
- (v) Alignment defects and signs of movement that could cause excessive vibration of track-mounted signalling equipment.
- (vi) Alignment defects and signs of movement that could affect the operation and/or reliability of switches, crossings and associated equipment.
- (vii) Other obvious defects that may affect track stability and support.

The speed at which the inspection is carried out should be consistent with the local conditions and the full scope of the inspection being carried out (e.g. the type and number of other infrastructure elements being inspected).

Table 5.4 – Inspection Guidelines

TYPE	FREQUENCY	METHOD
Scheduled track patrol inspection, see Note 1 (Walking or on-rail vehicle)	All main lines at intervals not exceeding 7 calendar days or as specified otherwise by ARTC e.g. in an approved Technical maintenance Plan. Crossing loops at intervals not exceeding 28 days or as specified otherwise by ARTC e.g. in an approved Technical maintenance Plan. see Note 2	Visual inspection On-rail vehicle ride where used Manual measuring equipment as required
Scheduled on train inspection	All main lines at intervals not exceeding 6 months or as specified otherwise by ARTC e.g. in an approved Technical maintenance Plan.	Visual inspection Vehicle ride
Scheduled track geometry car inspection or equivalent	All main lines at intervals not exceeding 4 months or as specified otherwise by ARTC e.g. in an approved Technical maintenance Plan. Crossing loops at intervals not exceeding 12 months or as specified otherwise by ARTC e.g. in an approved Technical maintenance Plan., see Note 2	Measuring car with ability to measure gauge, top, horizontal alignment, cross level, short twist, and long twist Record type, size and location of defects
Un-scheduled inspection in response to defined or other events	As necessary to ensure safety where for any reason (eg slips, floods, earthquakes, driver reports, irregularity reports etc) it may be suspected that the geometry may have been significantly affected	As required

Notes:

- [1] *Where on-rail patrol inspections are used, patrollers should have the capacity to carry out more detailed examination of suspect sections or locations prone to rapid or abnormal deterioration. Such locations may require more frequent inspection. This may include stopping or slowing down, going back to the location identified or arranging for others to carry out a more detailed inspection.*
- [2] *Crossing loops with track speeds over 60 km/h are to be regarded as main line.*

b) On-train inspection

Arrangements shall be made to inspect the track by riding in the cab of locomotives. These inspections should be carried out from the driver's cab or compartment of the leading locomotive of the train, such that identified defects can be located with the highest possible degree of accuracy. The highest speed freight train should be used for this purpose. .

The inspections should be used as follows:

- (i) To identify suspected geometry defects.
- (ii) To determine the relative ride performance on the various lengths of track as a means of setting priorities for maintenance of the track.
- (iii) To observe any other obvious non-geometry related defects in the infrastructure.

Suspected defects include those that cause:

- (A) sharp/high accelerations of the locomotive
- (B) abrupt motion of the locomotive
- (C) rough riding or any feeling of discomfort (to drivers or inspecting officers) or
- (D) resonant type motions of the locomotive (i.e. Cyclical motions of increasing amplitude) resulting from suspected cyclic track geometry defects.

Although the drivers of the locomotive should at no time be imposed upon or distracted from their job, at appropriate times their advice with respect to defects should be sought. Problems or defects identified by drivers at any time should be documented as suspected defects and acted upon accordingly.

c) General inspection

A general inspection shall be carried out at specific locations when suspected defects are identified from conditions determined during patrol inspections and as defined by the responses in Table 5.6. The geometry at the location should be measured and compared with specified limits. The cause, restrictions and repair work should be determined taking into account the local conditions at the site that may affect deterioration rates. General inspections should also identify the need for further specialist inspection.

d) Detailed Inspection

Scheduled inspections shall be carried out by continuous track geometry recording car or equivalent to achieve the following:

- (i) Identification of track geometry defects in a way which will allow priorities for remedial action to be assessed.
- (ii) Provision of statistical measurements of the quality of track geometry which can be used as a predictive or planning tool.

A local area representative (inspecting officer) should be on board during track geometry recording car measurement runs. Where a local area representative cannot be on board procedures should be put in place to effectively communicate emergency and priority defects to those responsible for general inspection and rectification of identified defects. These procedures should set out responsibilities in relation to:

- (A) initiating actions for the inspection, application of restrictions resulting from defects identified by the track geometry car and the repair of those defects; and
- (B) receiving the production outputs including the track chart and exception reports from the operator of the track geometry car.

5.3.2 Assessment

The assessment of track geometry condition should incorporate the following:

a) Assessment and actions

For track designed and constructed in accordance with the guidelines in this Code the assessment and response criteria for track geometry defects are given in Table 5.5. This

Table groups defects into defect bands for each measured parameter and method of measurement. The track is also grouped into speed bands. The response for a specific defect is determined from the intersection of the defect band (row) and the speed band (column).

Table 5.6 gives the response codes which define the maximum period which can be allowed to elapse before inspection and response action of identified geometric defects should be undertaken.

Imposing a lower speed restriction may moderate the response, i.e., by using the restricted speed to determine the response as though it were the original track speed. Speed restrictions can therefore be used to manage and prioritise the inspection and response action of defects.

The responses defined in Table 5.5 are based on isolated geometric defects. A more stringent response than that mandated by the geometry alone may be necessary if deterioration of the infrastructure both at the defect and on adjoining track is in evidence.

Defects may be reassessed. This reassessment may result in a response action that is more stringent or less stringent.

b) Geometry defect categories

Limits have been specified in Table 5.5 for the following geometry defect categories:

(i) Gauge

Gauge is measured between points on the gauge (or inside) face of the rails 16 mm below the top.

The wide gauge values in the table apply to well tied timber sleepers track only. For tracks with concrete and steel sleepers, where a higher than expected deterioration in gauge has been detected between inspections the track should be subjected to an un-scheduled detailed inspection and appropriate actions taken.

Measurement of tight gauge includes the effect of any rail head flow present.

(ii) Horizontal alignment

Horizontal alignment is measured using the mid-ordinate offset (versine) of a 10 m chord. Limits in *Table 5.5* have been set based on the variation from the actual design versine.

For defect bands A and B in Table 5.5, the minimum radius negotiable by rolling stock is used as the limiting criterion.

(iii) Top (vertical alignment)

Vertical alignment is assessed using the mid-ordinate offsets shown in Table 5.5 (see note 3 and 4).

(iv) Cross level variation

Cross level is the difference in level of the two rails at a single point along the track. The variation in cross level is measured as the variation from the design cross level.

(v) Twist

Twist is the variation in actual track cross level (i.e., the difference in level of the two rails) over a defined length. Twist is to be assessed using two criteria, Short twist is measured over 2 m and long twist is measured over 14 m. Different long twist parameter limits apply in transition curves than in other track (ie. tangent and circular curves), where the long twist may be primarily the result of a designed cross level variation.

c) Application

The geometry conditions when measured by the AK track geometry inertial recording car are set out by parameter band widths in Table 5.5.

Table 5.6 (which details the response categories and actions) is to be used for all types of locomotives and rolling stock in operation on the ARTC NSW network.

This section is provided to limit risk of derailment either by control of lateral to vertical force (L/V) ratio or conditions subject to rapid geometry deterioration.

Table 5.5 sets out the required geometry conditions for safe train operations on main running lines in NSW managed by ARTC.

Note: "Main lines include crossing loops, refuge loops and "sidings" where operating speed in excess of 25km/hr is possible".

Table 5.5 nominates the default speed of trains appropriate to these geometry conditions. It is in the form of geometry exceedences at given speeds with response categories.

Where geometry conditions are found to be worse than those for full speed (as shown in Defect Band G in Table 5.5 they are to be dealt with in accordance with Table 5.6.

The speeds are based on geometry exceedent considerations only. Material condition may require lower speed limits until repaired. This is particularly relevant for gauge exceedences.

It should be noted that more restrictive criteria may be imposed due to the application of other standards eg clearance requirements.

Table 5.5 – Geometry Defects – Response Category Maintenance Limits

Measured parameters in mm under loaded track											Max. speed (f/p) <small>see note 1</small> <i>f/p refers to Freight/Passenger speed bands</i>						Defect Band																																											
Gauge		Horiz. Align.		Top <small>see note 2</small>			Twist				20/20	40/40	60/65	80/90	100/115	115/160																																												
Wide	Tight	10m chord <small>see note 2</small>		20m Inertial <small>see note 7</small>	Long 20m Chord <small>see note 3</small>	Short 4m Chord <small>see note 4</small>	Long 14m		Short																																																			
		A	B				Transition	Non Transition	2 m																																																			
											A	B																																																
>38	>20	>124 <small>see note 5</small>	>108 <small>see note 5</small>	>42	>90	>23	>74	>70	>24	>20	E1	E1	E1	E1	E1	E1	A																																											
35-38	19-20	90-124 <small>see note 5</small>	83-108 <small>see note 5</small>	40-42	72-90	20-23	65-74	61-70	23-24	19-20	E2	E2	E2	E1	E1	E1	B																																											
29-34	17-18	>45	>34	36-39	67-71	17-19	56-64	53-60	21-22	17-18	P2	P1	P1	E2	E1	E1	C																																											
27-28	15-16	35-45	25-34	33-35	57-66	15-16	50-55	47-52	19-20	15-16	N	N	P2	P1	E2	E1	D																																											
25-26	13-14	25-34	19-24	29-32	52-56	13-14	43-49	41-46	17-18	13-14	N	N	N	P2	P1	E2	E																																											
23-24	11-12	19-24	15-18	27-28	47-51	11-12	38-42	36-40	15-16	11-12	N	N	N	N	P2	P1	F																																											
21-22		15-18	11-14	24-26	38-46	9-10	33-37	31-35	12-14	9-10	N	N	N	N	N	P2	G																																											
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th rowspan="2"></th> <th rowspan="2">Cross level- Variation from design <small>see note 6</small></th> <th rowspan="2">Tangent track (Tangent & Radii >2000m)</th> <th colspan="2">Curved track including transitions (Radii <2000 m)</th> <th rowspan="2">Additional action required for insufficient superelevation</th> </tr> <tr> <th>Insufficient cant based on Maximum design speed</th> <th>Excess cant based on maximum design speed</th> </tr> </thead> <tbody> <tr> <td></td> <td colspan="5" style="text-align: center;">Absolute superelevation >170mm requires E response <small>see note 6</small></td> </tr> <tr> <td></td> <td>>75</td> <td>E1</td> <td>E1</td> <td>E1</td> <td></td> </tr> <tr> <td></td> <td>51-75</td> <td>P2</td> <td>E2</td> <td>P1</td> <td>Restrict 40km/h below posted speed</td> </tr> <tr> <td></td> <td>41-50</td> <td>P2</td> <td>E2</td> <td>P2</td> <td>Restrict 30km/h below posted speed</td> </tr> <tr> <td></td> <td>15-40</td> <td></td> <td>P1</td> <td>P2</td> <td>Restrict 20km/h below posted speed</td> </tr> <tr> <td></td> <td><15</td> <td></td> <td></td> <td></td> <td>No action required</td> </tr> </tbody> </table>																		Cross level- Variation from design <small>see note 6</small>	Tangent track (Tangent & Radii >2000m)	Curved track including transitions (Radii <2000 m)		Additional action required for insufficient superelevation	Insufficient cant based on Maximum design speed	Excess cant based on maximum design speed		Absolute superelevation >170mm requires E response <small>see note 6</small>						>75	E1	E1	E1			51-75	P2	E2	P1	Restrict 40km/h below posted speed		41-50	P2	E2	P2	Restrict 30km/h below posted speed		15-40		P1	P2	Restrict 20km/h below posted speed		<15				No action required
	Cross level- Variation from design <small>see note 6</small>	Tangent track (Tangent & Radii >2000m)	Curved track including transitions (Radii <2000 m)		Additional action required for insufficient superelevation																																																							
			Insufficient cant based on Maximum design speed	Excess cant based on maximum design speed																																																								
	Absolute superelevation >170mm requires E response <small>see note 6</small>																																																											
	>75	E1	E1	E1																																																								
	51-75	P2	E2	P1	Restrict 40km/h below posted speed																																																							
	41-50	P2	E2	P2	Restrict 30km/h below posted speed																																																							
	15-40		P1	P2	Restrict 20km/h below posted speed																																																							
	<15				No action required																																																							

Notes:

- [1] Speed band "F/P" refers to Freight / Passenger speed bands (in km/h) respectively. Passenger operations refer to locomotive hauled passenger trains with carriages not exceeding 16TAL.
 - [2] The horizontal alignment and top parameters relate to the specific chord lengths nominated. The values specified cannot be directly related to values for use with other measurement systems.
 - [3] Long top defect limits have been adapted from the Track Safety Standards of the U.S. Federal Railroad Administration to assist track inspectors making manual measurements, and are measured using the offset at the mid ordinate of a 20 m chord.
 - [4] Short top defects are provided to assist track inspectors making manual measurements, and are measured using the offset at the mid ordinate of a 4 m chord.
 - [5] Defect Bands A and B are actual versine measurements (not variation from design) for simple and compound curves. Where curves are reversing the actual versine should not exceed 125 mm. The remaining exceedences – i.e. Defect Bands C to G - are variations from design.
 - [6] To determine the cross level variation knowledge of the design cross level is required. Some track recording cars may not be able to determine this parameter and alternative methods such as manual onsite assessment may be required.
 - [7] These figures are calculated from a 20m wave length inertial output from the system.
 - [8] Wide gauge on curves due to curve wear may be permitted to up to a maximum of 30 mm without action, provided the track is secure against further widening due to lateral movement of the rail and the rail side wear limits are not exceeded.
 - [9] All geometry parameters used (except the long 20m chord) are based on the loaded conditions. Where static or unloaded measurements are taken, due allowance should be made for the additional impact of loading and dynamics.
 - [10] The measured parameter limits set in the above table are derived from commonly occurring defects in actual conditions. Normally occurring multiple defects are provided for in the limits set, for example top and twist defects would commonly be expected to occur together. In such cases the most stringent response criterion of the two should be selected. Unusual combinations of defects that are considered to act together, for example horizontal alignment with twist should be subject to special consideration. A more stringent response than that specified for rectifying the defects individually should be considered.
 - [11] Actual defects shall be rounded down to the nearest mm when using this table.
 - [12] Limits for alignment and short twist headed "A" and "B" are to be applied as follows:

Limits in Column B - apply for curves that are operated at enhanced performance speeds (EP) with greater than 80mm cant deficiency. These limits apply to the transition as well as the curve.

Limits in Column A - apply to all other ARTC tracks.
-

Table 5.6

Response Category	Inspect see Note 1	Repair see Note 2	Other Responses
E1 (Emergency)	Prior to next train	Prior to next train	Where the response category cannot be reduced below E1 by a reduction in speed, trains may only pass the site under the control of a pilot. Assessment of the defect by a competent worker should be made to determine if the train can be piloted.
E2 (Urgent Class 1)	Within 2 hours or prior to the next train, whichever is greatest	Within 24 hours	If the defect cannot be inspected or repaired within the nominated time and the response category cannot be reduced below E2 by a reduction in speed, trains may only pass the site at speeds up to 20 km/h following assessment by a Competent Worker.
P1 (Urgent Class 2)	24 hrs	7 days	
P2 (Priority Class 1)	7 days	28 days	
N			<i>A deviation from design geometry up to the lowest level of P2 defect does not require any action above the normal inspection regime.</i>

Notes:

- [1] *In the event of failure to inspect reported faults by the specified time the allowable speed should be reduced by at least one speed band. A revised inspection period in line with the lower speed band may then be used. If the defect is subsequently inspected the speed may be raised to the higher band subject to repair being achievable within the nominated period for the higher band.*
- [2] *In the event of an inability to repair the track, the fault should be reassessed on site prior to expiry of the repair response time. The Repair period can only be extended by the Civil Engineering Representative or a person with a delegated authority from the Civil Engineering Representative.*
- [3] *If the cause of a defect is known and it is known that it will not deteriorate into an unsafe condition an alternate response to that shown is permitted with appropriate documentation and approval by the Civil Engineering Representative or nominate representative.*