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Track Geometry

Section 5

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ARTC Network Wide SMS

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Amendment Version #	Date Reviewed	Clause	Description of Amendment
3.0	12 Aug 21		Standardised document structure.
		5.2	Added clause to allow turnout geometry in return curves Removed light weight and intrastate line design criteria
		5.3	Consolidated ETG-05-01 and ETF-05-01 into maintenance and construction requirements. Aligned variation to design with clearance requirements
		5.4	Added missed detail inspection requirements Consolidated ETN-05-01 Added 6m chord to Table 5-15, removed 20m and 4m chords. Amended notes. Changed P2 repair or re-assess Aligned VTI exception management to EGW-10-07

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5 Section 5: Track Geometry

5.1 General

5.1.1 Reference Documents

The following documents support this Standard:

- ARTC Code of Practice Section 7: Clearances
- PP-135 – Mechanised Track Surfacing
- EGW-10-07 – Vehicle Track Interactions Exception Management

5.1.2 Definitions

The following terms and acronyms are used within this document:

TERM OR ACRONYM	DESCRIPTION
ARTC	Australian Rail Track Corporation Ltd.
CER	Civil Engineering Representative as per PEO-PR-008 Engineering, Design and Project Management Identification of Competence Procedure
Clearance Point	The point between two converging tracks where one vehicle is able to pass another on the adjacent track with sufficient clearances.
COP	ARTC Track & Civil Code of Practice
Superelevation	The height difference, at a common location, between the running surface of both rails. Also known as cross level and track cant.

5.1.3 Parameters

The following parameters are used within this document:

Table 5-1: Parameters 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

PARAMETER	SYMBOL	UNIT
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

5.2 Design

The design geometry should be derived using the equations given in 5.2.1.1. Terms 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
- the design data given in Table 5-2, Table 5-3, Table 5-4 and Table 5-5.

In Table 5-2, Table 5-3, Table 5-4 and Table 5-5 the "desirable" design limits provide for general business requirements for comfort and safety, and represent preferred engineering practice.

Desirable limits are based on timber sleepered, jointed track. Less restrictive limits may apply to track of better configuration. They allow for normal low maintenance track, based on current experience.

All design should normally conform to these desirable design limits. The “absolute limit” (maximum or minimum) allows for the track to be maintained within the safety limits but may result in higher maintenance requirements and costs.

The use of values between “desirable” and "absolute limit" shall require approval from the relevant business unit maintenance budget authority.

The use of values more severe than the “absolute limit” shall require an Engineering Waiver supported by full site-specific justifications including risk assessments as appropriate and verification of the characteristics of the rolling stock affected.

Turnout design limits for basic parameters are shown in Table 5-4. Design limits for turnout geometry may be applied both the turnout and the adjacent return curves.

Values specified for Interstate are to be used for Intrastate and Light Weight Lines.

5.2.1 Main Line Track Design

5.2.1.1 Design geometry

5.2.1.1.1 Track Speed

Track speeds are posted in multiples of 5km/h. Calculated speed should be rounded up or down to the nearest 5km/hr. speed band e.g. 73 km/hr. becomes 75km/hr. and 71.5 km/hr. becomes 70 km/hr.

5.2.1.1.2 Circular curves

For standard gauge on circular curves of constant radius:

$$V = \sqrt{\frac{\mathrm{R.E}_e}{11.82}} \quad \text{(Eq. 5.1)}$$

For narrow gauge on circular curves of constant radius:

$$V = \sqrt{\frac{\mathrm{R.E}_e}{8.9}} \quad \text{(Eq. 5.2)}$$

Where $E_e = E_a + D$

Where track is designed for a controlled system with basically one operation and hence a choice of superelevation and superelevation deficiency, the normal value of superelevation deficiency to be applied is 20mm to the typical operating speed. This requirement is in line with the principle that a level of positive deficiency is desirable to promote consistent vehicle tracking.

Equation 5.1 and 5.2 are such that in dual gauge track the sleeper position will result in the same operating speed for both gauges.

5.2.1.1.3 Gauge Widening

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

Main line narrow gauge curves between 160 and 300m radius shall have the gauge widened by 6mm to 1073mm.

5.2.1.1.4 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):

$$V = \frac{3.6\ \mathrm{L.D_{roc}}}{\Delta D} \quad \text{(Eq. 5.3)}$$

Where the adopted transition curve is less than Bc in length, a virtual transition is adopted where:

$$V = \frac{3.6\ \mathrm{B}_C.\mathrm{D_{roc}}}{\Delta D} \quad \text{(Eq. 5.4)}$$

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

$$L_R = \frac{E_r.\Delta E_a}{1000} \quad \text{(Eq. 5.5)}$$

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.

5.2.1.1.5 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 "desirable" values for average vertical curve radii given in Table 5 3 are based on limiting vertical acceleration and are calculated as follows:

$$V = \sqrt{2.R_V} \quad \text{(Eq. 5.6)}$$

Table 5 3 also defines the absolute minimum vertical curve radii for sags and summits.

5.2.1.1.6 Horizontal bends

On a bend of β degrees between straights:

$$V = \sqrt{\frac{4.85\ \mathrm{D}_B.B_C.}{\beta}} \quad \text{(Eq. 5.7)}$$

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

5.2.1.1.7 Length of straights and curves

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

Between contra-flexure curves a straight of minimum length Bc should be provided

The minimum length of straight may be reduced at similar-flexure crossovers.

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

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

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

5.2.1.1.8 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 5-2: Desirable and Absolute Limits for Design Parameters Heavy Haul and Interstate Lines and XPT Type Trains

REF	PARAMATER	SYMBOL (unit)	DESIRABLE	ABSOLUTE LIMIT
1	Applied superelevation	E_a (mm)		
	Except at platforms: Interstate Lines		125	150
	Heavy Haul lines		125	140
	At platforms (all lines)		75	110
2	Applied negative superelevation (only applies to divergent roads over contraflexure turnouts)	E_{na} (mm)	Nil	55
3	Superelevation ramp rate	E_r	1:500	1:300
4	Superelevation deficiency	D (mm)		
	Plain track:			
	XPT type passenger trains		110	110
	Heavy Haul lines		70	75
	Interstate lines		75	80
	Interstate lines for operation at enhanced performance speed (EP) for curves between 235m and 501m radius		110	110
	Diverging track in conventional turnouts [1]			
	XPT type passenger trains		100	110
	Heavy Haul lines		50	50
	Interstate lines		75	75
	Diverging track in tangential turnouts [1]:			
	XPT type passenger trains		100	110
	Heavy Haul lines		75	80
	Interstate lines		75	85
	Horizontal bend (calculated) [2]		NA [3]	40
5	Superelevation excess (negative deficiency) [4]	D (mm)		
	Interstate Lines lines		-75	-75
	Heavy Haul lines		-50	-50
6	Rate of change of superelevation deficiency / excess	D_{roc} (mm/s)		
	XPT type passenger trains		55	65
	Heavy Haul and Interstate Lines		35	55
	Diverging track in conventional turnouts:		85	110
	Diverging track in tangential turnouts:		110	135
7	Rate of change of superelevation	E_{aroc} (mm/s)		
	XPT type passenger trains		55	65
	Heavy Haul and Interstate Lines		35	55
8	Horizontal bend angle	B (degrees)	Nil	1º 50´
9	Horizontal curve radius [5]	R (m)	200 m	160 m
10	Vertical curve radius	R_v (m)	Table 5-3	Table 5-3
11	Grade (compensated) [6] [7]	G	1 in 100	1 in 80
12	Nominal spacing of vehicle bogies	B_c (m)	25	13
13	Max Vertical Acceleration	a (m/s^2)	0.2	0.4

Notes:

1. *Calculated from the minimum of:*
   - *the radius calculated from a versine at the point toe using a chord of length Bc, and*
   - *the radius in the body of the turnout curve.*
2. *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 Bc.*
3. *Not applicable as "desirable" limit for horizontal bends is nil.*
4. *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.*
5. *Where feasible the design of new track alignments should provide for a minimum horizontal curve radius of 800 m.*
6. *Grade should be calculated over the length of the train. Characteristics of the traffic should be considered when selecting grading. Curve compensation shall be added to the grade for assessment to these values.*

   Curve compensation can be calculated by an amount:

   $n = 1.65R$

   Where R is the curve radius in metres and n is the equivalent gradient 1 in "n".
7. *The Inland Rail Program has a special dispensation to design grades in accordance with the Inland Rail Program Requirements Specification (PRS).*

Table 5-3 - Average Vertical Curve Radius for Heavy Haul and Interstate Lines (for sags and summits)

MAXIMUM TRAIN SPEED	ABSOLUTE LIMIT [see note]	DESIRABLE
< 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.*

5.2.2 Turnout Design Geometry

Table 5-4 - Turnouts – Design Limits of Basic Parameters

PARAMETER/TRACK			Heavy haul	Interstate
Max V (km/h)	Normal/XPT		115/160	115/160
Desirable Limits				
Diverging track tangential turnouts	Max D (mm)	Heavy Haul	75	N/A
		Freight/Passenger	75	75
		XPT	100	100
	Max D_{roc} (mm/s)		110	110
Diverging track conventional turnouts	Max D (mm)	Heavy Haul	50	N/A
		Freight/Passenger	75	75
		XPT	100	100
	Max D_{roc} (mm/s)		85	85
Contraflexure turnouts	Max E_a (mm)		20	20
Absolute Limits				
Diverging track tangential turnouts	Max D (mm)	Heavy Haul	80	N/A
		Freight/Passenger	85	85
		XPT	110	110
	Max D_{roc} (mm/s)		135	135
Diverging track conventional turnouts	Max D (mm)	Heavy Haul	50	N/A
		Freight/Passenger	75	75
		XPT	110	110
	Max D_{roc} (mm/s)		110	110
Contraflexure turnouts	Max E_a (mm)		55	55

5.2.3 Dual Gauge Track Design (Standard/Narrow)

5.2.3.1 Requirements

Design of dual gauge track needs to consider both the standards and operational environment of narrow gauge and standard gauge traffic. Single narrow-gauge track must also comply with the requirements below.

Table 5-5 - Desirable and Absolute Limits for Design Parameters Dual Gauge Track of Standard/Narrow.

REF	PARAMETER			SYMBOL (UNIT)	DESIRABLE	ABSOLUTE LIMIT
1	Applied superelevation			Ea (mm)		
		Mainline:	Narrow Gauge		80	135
			Standard Gauge		105	150
		At platforms:	Narrow Gauge		50	50
			Standard Gauge		65	65
3	Superelevation ramp rate			E_r		
			Narrow Gauge		1:1000	1:400
			Standard Gauge		1:750	1:300
4	Superelevation deficiency			D (mm)		
		Plain track:	Narrow Gauge		55	55
			Standard Gauge		75	80
			Optimal [1]		20	NA
		Horizontal bend (calculated) [2]			NA [3]	40
5	Superelevation excess (negative deficiency) [4]			D (mm)		
			Narrow Gauge		-35	-55
			Standard Gauge		-75	-75
6	Rate of change of superelevation deficiency / excess			D_{roc} (mm/s)		
			Narrow Gauge		35	55
			Standard Gauge		35	55
		Diverging track in conventional turnouts:				
			Narrow Gauge		35	55
			Standard Gauge		85	110
		Diverging track in tangential turnouts:				
			Narrow Gauge		35	55
			Standard Gauge		110	135
7	Rate of change of superelevation			E_{aroc} (mm/s)		
			Narrow Gauge		35	55
			Standard Gauge		35	55
8	Horizontal bend angle			B (degrees)	Nil	1º
9	Horizontal curve radius [5]			R (m)	300	160
10	Vertical curve radius			R_v (m)		
			Summit		7200	6670
			Sag		14400	13300
11	Grade (compensated) [6] [7]			G	1 in 100	1 in 80
12	Nominal spacing of vehicle bogies			B_c (m)	25	13
13	Max Vertical Acceleration			a (m/s^2)	0.2	0.4

Notes:

1. *Calculated from the minimum of:*
   - *the radius calculated from a versine at the point toe using a chord of length Bc, and*
   - *the radius in the body of the turnout curve.*
2. *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 Bc.*
3. *Not applicable as "desirable" limit for horizontal bends is nil.*
4. *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.*
5. *Where feasible the design of new track alignments should provide for a minimum horizontal curve radius of 800 m.*
6. *Grade should be calculated over the length of the train. Characteristics of the traffic should be considered when selecting grading. Curve compensation shall be added to the grade for assessment to these values.*

   Curve compensation can be calculated by an amount:

   $n = 1.65R$

   Where R is the curve radius in metres and n is the equivalent gradient 1 in "n"
7. *The Inland Rail Program has a special dispensation to design grades in accordance with the Inland Rail Program Requirements Specification (PRS).*

5.2.3.2 Guidelines

In an ideal environment the applied superelevation will be 20mm deficient for the typical operating speed, with the remainder of the deficiency limit used to determine the maximum posted speed.

Typical operating speeds should be determined by train operation modelling where actual speeds are not known.

Where the two gauges vary in operating speed, one gauge will require restriction to ensure safe operation.

Table 5-6 provides a worked example of superelevation values for various radii. This table has been configured for an average speed of 35km/h (at 0mm deficiency). When using a 20mm deficiency target the optimised speed for standard gauge varies as showed in the table below. The maximum speed has been determine using the appropriate superelevation deficiency limits from Table 5-5.

Table 5-6 - Suggested superelevation values for mixed use dual gauge track.

RADIUS	NARROW GAUGE	STANDARD GAUGE	SPEED	
	E_a	E_a	OPTIMISED	MAXIMUM
600	19	25	47	70
700	11	15	45	75
800	11	15	48	75
900	7	10	47	80
1000	7	10	50	85
1100	7	10	52	90
1200	7	10	54	90
1300	7	10	57	95
1400	7	10	59	100
1500	7	10	61	100
1600	7	10	63	105

Notes:

Superelevation has been rounded for Standard Gauge with the corresponding Narrow Gauge value calculated pro-rata.

The above example avoids the use of superelevation excess, where Vmax is required to be increased this superelevation excess may applied to achieve the desired max speed.

Departure from these guidelines should be approved by the responsible asset management authority.

5.2.4 Broad Gauge Track Design

Any new broad gauge track design shall be as per AS 7635 – Track Geometry.

For Dual Standard/Broad Gauge the track shall be designed for the standard gauge as per this standard.

5.2.5 Siding Track Design

5.2.5.1 General

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

5.2.5.1.1 Circular Curves

The designed minimum radius for sidings shall be

Connected to Heavy Haul and Interstate tracks 160m

Connected to Intrastate and Light Weight tracks 160m

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 standard 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 5-7 - Gauge widening on curves in sidings

RADIUS (M)		GAUGE (mm)
Standard Gauge	200 - 160	1441
	160 - 140	1445
	140 - 120	1450
	120 - 100	1455
Narrow Gauge	300 -160	1073
	160 - 100	1079

5.2.5.1.2 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.

5.2.5.1.3 Transitions

Transitions are not required on curves in sidings.

5.2.5.1.4 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.

5.2.5.1.5 Vertical Curves

Vertical curves are to be provided wherever there is a grade difference equal to or greater than 1 in 500. 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.

5.2.5.1.6 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.

5.3 Construction and Maintenance

5.3.1 Construction Requirements

Construction consists of any significant track alignment or realignment works. These activities include:

- New Construction
- Where track is reconstructed using existing rails
- Where major sections of formation or sleepers are replaced

5.3.1.1 Construction Track Geometry

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:

1. The maximum speed allowed should be 20km/h. These operations would normally require the operation of trains to be piloted from trackside.
2. The track geometry at any measured point should not exceed that of a Band C defect as per Table 5-16
3. The limitations on working in hot weather specified in Section 6 Track Lateral Stability should apply.

5.3.1.2 Track Alignment

Survey of track alignment should be undertaken in compliance with AS 7634. Monument frequency shall be as per Table 5-8.

Table 5-8 – Monument Frequency

GEOMETRY	FREQUENCY
Tangents	Even 20m intervals for first 100m of straight from TP then even 100m intervals
Curves >R400m	Even 20m intervals
Curves ≤R400m	Even 10m intervals
Transitions	Even 10m intervals
Monuments shall be located at all frame points of all elements (TP, CTP, TRS, CTRS, BEND etc).	

Track Alignment shall be as per Table 5-9

Table 5-9 – Construction Track Tolerance to Design Requirements

PARAMETER		LIMIT (mm)
Horizontal Alignment	Variation from design (Open Track)	± 10
	Variation from design (Restricted Locations) [1]	± 5
	Variation between locations 20m apart	± 10
Vertical Alignment	Variation from design (Open Track)	± 25
	Variation from design (Restricted Locations) [1]	+ 10
	Variation between locations20m apart	± 10
Superelevation		± 5
Ramp Rate		≤ 1:1000

Note

1. *Restricted locations include any area of reduced clearance, e.g. Platforms, Tunnels and Overbridges*

5.3.1.3 **Track Quality**

Track Quality for completed works should be as per Table 5-10.

Table 5-10 – Construction Track Quality Requirements

PARAMETER		LIMIT (mm)
Line	10m chord	5
Top	10m chord	5
Twist Rate		≤ 1:1000
Gauge	Concrete Sleepers complying with ETD-02-05	≥ 0
	All other locations	± 4

5.3.1.4 **Non-Conformances**

Acceptance of track alignment and quality outside of the tolerances in this section shall be at the discretion of the Corridor Manager. If any parameters are measured to be defects as per Table 5-16 they must be treated as such.

5.3.2 Maintenance Requirements

The following represents the minimum standard of track geometry of to be achieved following maintenance tamping. These values may be used for other maintenance activities such as manual surfacing where desired by the asset management authority.

Track measurements may be carried out using manual measuring methods or continuous track recording.

It recognises:

- construction and upgrading tolerances in some cases are not achievable because existing worn infrastructure is being used
- works on track should be performed to standard that creates some buffer from defect limits This allows deterioration of condition with usage before the defect thresholds are reached.

The maintainer may accept a lower standard where circumstances warrant, however defect criteria as per Table 5-16 still applies.

5.3.2.1 Track Quality following maintenance

Where maintenance work is undertaken to improve track geometry the following levels of track quality should be achieved.

Ideally these tolerances should be maintained, and restorative work undertaken when they are exceeded.

Where track monuments or design is known (e.g at platforms) the requirements of 5.3.3 shall be assessed.

Table 5-11 – Desirable limits track geometry after corrective maintenance

PARAMETER		DESIRABLE LIMIT (mm)
Line	10m chord	10
	Variation between overlapping chords	3
Top	10m chord	10
Twist	2m	6
	14m	12
Ramp Rate		≤ 1:1000

5.3.3 Variation from Design or Last Known Position

For open track where there are track monuments or a last known position, the track should be maintained to the tolerances in Table 5-12

Where track is found to be outside of the values below clearances shall be checked and action should be taken to restore track alignment.

Table 5-12 Open Track Tolerances for Clearances

PARAMETER	TOLERANCE (mm)
Superelevation/Cross Level from Design	± 15
Rail Level	± 75
Horizontal Alignment	+30

Track at restricted locations shall be maintained to the tolerances in Table 5-13. Where these values are exceeded a clearance, assessment is required.

Table 5-13 Platform Track Tolerances for Clearances

PARAMETER	TOLERANCE (mm)
Gauge (from 1435 mm)	± 5
Track alignment (from design)	± 15
Cross-level (from design)	± 10
Rail Level	± 25

Notes *Restricted locations include any area of reduced clearance, e.g. Platforms, Tunnels and Overbridges*

Rail Level may be checked as a variation from either a monument or as the platform height from the low rail

Areas of known infringement may have alternate tolerances that the track must be maintained to, these can be found in the infringement record.

5.4 Inspection and Assessment

5.4.1 Inspection

The guidelines for the inspection of track geometry including inspection intervals are set out in Table 5-14. 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:

5.4.1.1 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:

1. Track geometry defects including those that may indicate problems with the underlying track and civil structure.
2. Locations where the deterioration in track geometry is abnormal since last inspected.
3. 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 (e.g. a sudden change in curve radius).
4. Obvious variations in track alignment that may for example, affect clearances or track stability.
5. Alignment defects and signs of movement that could cause excessive vibration of track-mounted signalling equipment.
6. Alignment defects and signs of movement that could affect the operation and/or reliability of switches, crossings and associated equipment.
7. 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 5-14 - 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. 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 24 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 (e.g. 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. *Loops with track speeds over 60 km/h are to be inspected at the same frequency as main line.*

5.4.1.2 On-train inspection

Arrangements shall be made to inspect the track by riding in the cab of locomotives or passenger trains. These inspections should be carried out from the driver's cab or compartment of the leading vehicle 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:

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

4. 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, this may include further assessment of track or rollingstock.

5.4.1.3 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 5-16 and Table 5-17. 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.

Defect measurements produced by the AK Car shall not be reassessed and reduced in severity through a static measurement.

5.4.1.4 Detailed Inspection

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

1. Identification of track geometry defects in a way which will allow priorities for remedial action to be assessed.
2. Provision of statistical measurements of the quality of track geometry which can be used as a predictive or planning tool.
3. Recording of the main line leg of the turnout when recording the main line and the loop leg of the turnout when recording the loop line.

A local area representative (Track Geometry Recording Car Inspector) 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:

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

5.4.1.4.1 Missed Detailed Inspections

Where a section of track has been missed by the AK car the following controls may be put in place until the section is able to be tested by the AK Car either via a special run to pick up that which was missed or via the next scheduled test run. The use of these controls must be reviewed and accepted by the corridor manager and recorded in the Asset Management System.

1. Track Patrol with a specific focus and awareness looking for geometry defects, deterioration and historical known problem areas and issues in particular locations where defects were reported from previous AK Car run.
2. Evaluation of the ride of a train over locations of manual assessment to detect changes under load
3. Geometry to be considered at all restricted locations (Overbridges, tunnels, platforms etc) with respect to clearance requirements.
4. Review of VTI or ICW Exceptions

These controls should be repeated at a frequency appropriate to the factors which may lead to an increase in geometry deterioration occurring prior to the return of the AK Car such as:

- Frequency of rail traffic
- Type of rail traffic
- History of defects
- Condition of track including fastening system

These controls shall not be kept in place past the timeframe when the AK Car was next scheduled to run without approval from the Manager Standards.

5.4.2 Assessment

The assessment of track geometry condition should incorporate the following:

5.4.2.1 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 5-16. 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 5-17 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. Use of a TSR to moderate the response as per Table 5-16 does not require CER approval.

A defect that is re-inspected and found to have not increased in size may be re-issued to the same response as previous.

The responses defined in Table 5-16 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.

A CER may assess a defect and may provide approval to apply a less stringent response.

Note: Only the application of a less stringent response requires CER approval

5.4.2.2 Geometry defect categories

Limits have been specified in Table 5-16 for the following geometry defect categories:

Table 5-15 - Description of geometry defects

TRACK GEOMETRY DEFECT CATEGORY		DESCRIPTION	ROAMES PARAMETER NAME
Gauge	Wide	Gauge is measured between points on the gauge (or inside) face of the rails 16 mm below the top.	xGauge
	Tight	Measurement of tight gauge includes the effect of any rail head flow present.	
Horizontal alignment		Horizontal alignment is measured using the mid-ordinate offset (versine) of a 10 m chord. Limits in Table 5-16 have been set based on the variation from the actual design versine. For defect bands A and B in Table 5-16, the minimum radius negotiable by rolling stock is used as the limiting criterion.	versineLeft/ versineRight
Top (vertical alignment)	20m Inertial	20m inertial wavelength of the vertical surface	xL_Surface20m/ xR_Surface20m
	Short 6m Chord	Vertical alignment is assessed using a mid-ordinate of a 6m chord	topLeft_3_6m topRight_3_6m
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.	N/A
Absolute superelevation		Measurement of the actual superelevation (cross level)	SuperElevationFloat
Twist	Long	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 (i.e. tangent and circular curves), where the long twist may be primarily the result of a designed cross level variation	Twist14Xtn
	Short		Twist2

5.4.2.3 Application

Measured geometry conditions are set out by parameter band widths in Table 5-16.

Table 5-17 (which details the response categories and actions) is to be used for all types of locomotives and rolling stock in operation on the ARTC 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 5-16 sets out the required geometry conditions for safe train operations on running lines managed by ARTC.

Table 5-16 nominates the default speed of trains appropriate to these geometry conditions. It is in the form of geometry exceedances at given speeds with response categories.

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

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

Table 5-16 - Geometry Defects – Response Category Maintenance Limits see note 6, 7 and 8

MEASURED PARAMETERS IN mm UNDER LOADED TRACK										**MAX. SPEED (F/P) [1] f/p refers to Freight/Passenger speed bands**						**DEFECT BAND**
Gauge [10]		Horizontal Alignment [2]		Top [2]		Twist										
Wide	Tight	10m chord [2] [3]		20m Inertial [4]	6m Chord	Long 14m		Short [9]								
		A	B			Transition	Non-Transition	2 m A	2 m B	20/ 20	40/ 40	60/ 65	80/ 90	100/115	115/160	
>38	>20	>124	>108	>42	>40	>74	>70	>24	>20	E1	E1	E1	E1	E1	E1	A
35-38	19-20	90-124	83-108	40-42	36-40	65-74	61-70	23-24	19-20	E2	E2	E2	E1	E1	E1	B
29-34	17-18	>45	>34	36-39	33-35	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	30-32	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	27-29	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	24-26	38-42	36-40	15-16	11-12	N	N	N	N	P2	P1	F
21-22		15-18	11-14	24-26	21-23	33-37	31-35	12-14	9-10	N	N	N	N	N	P2	G

Cross level-Variation from design [11]						
Tangent track and curve track radii ≥2000m		Curved track including transitions (Radii <2000 m)				
		Insufficient superelevation based on maximum design speed		Excess superelevation based on maximum design speed		
>75	E1	>75	E1	>75	E1	A
51-75	P2	51-75	E2 plus restrict 40km/h below posted speed	51-75	P1	B
41-50	P2	41-50	E2 plus restrict 30km/h below posted speed	41-50	P2	C
		15-40	P1 plus restrict 20km/h below posted speed	15-40	P2	D

Absolute superelevation	
> 170mm requires E1 response (Band A)	160mm to 170mm no response required (record as PN defect to indicate superelevation is approaching emergency response levels)

Notes:

1. *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. *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 exceedances – i.e. Defect Bands C to G - are variations from design. The design versine can be calculated using the radius if known by (Versine (mm)= 12500/ (Radius (m))) or by using an average of 3 measurements on a section of the curve with the same radius unaffected by the line defect.*
4. *These figures are calculated from a 20m wavelength inertial output from the system.*
5. *All 6m chord defects reported before 01/10/2022 may be treated as PN. After this date they must be re-assessed classified as per this table.*
6. *All geometry parameters used are based on the loaded conditions. Where static or unloaded measurements are taken a competent worker must assess for additional dynamic loading movement and determine if void or play indications need to be quantified and incorporated.*
7. *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.*
8. *Actual defects shall be rounded down to the nearest mm when using this table.*
9. *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 superelevation deficiency. These limits apply to the transition as well as the curve. Limits in Column A - apply to all other ARTC tracks.
10. *In areas of concrete sleepers, measured side wear may be subtracted from the wide gauge defect value for defects with a P1 response and below.*
11. *Insufficient and Excess Superelevation refers to variation from design applied superelevation (E_a).*

    To determine the variation, knowledge of the design superelevation 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.

    The relevant asset management authority may alter the design and therefore apply an alternate Ea to remove the need for a speed restriction by applying an alternate superelevation deficiency value.

    Refer to 5.2.1.1.2 and Table 5-2 item 4 for details

Table 5-17 - Defect response and action

RESPONSE CATEGORY	INSPECT	RESPONSE	
E1 (Emergency Class 1)	Prior to next train	Repair	prior to next train
E2 (Emergency Class 2)	Within 2 hours or prior to the next train, whichever is greatest	Repair	within 24 hours
P1 (Priority Class 1)	Within 24 hrs	Repair	within 7 days
P2 (Priority Class 2)	Within 7 days	Repair or Re-assess	within 28 days
N	Normal scheduled inspection regime.		

Notes:

1. *Where it is not practical to respond within the specified time a speed restriction should be applied to reduce the priority of the defect. The response timeframe for both inspection and repair for the reduced priority may then be used whilst that speed remains in place.*
2. *If a Band A defect cannot be repaired within the specified time, trains may only pass the site following assessment by a Track Certifier, at a maximum speed of 10km/h and under the direction of a pilot. See section 5.4.3 for a dispensation.*
3. *If a Band B defect cannot be repaired within the specified time, trains may only pass the site following assessment by a Track Certifier and at a maximum speed of 20km/h. See section 5.4.3 for a dispensation.*
4. *For wide gauge normal operations may be permitted for defect bands C to G if the gauge widening is confirmed to be due to causes not expected to be prone to rapid deterioration, for instance curve wear or loss of insulating spacers. Check the track is secure against further widening due to lateral movement of the rail and the rail side wear limits are not exceeded.*

5.4.3 Dispensation for Track Geometry Defects

5.4.3.1 General

This clause is to be used to manage occasional temporary dispensation to the maximum allowable response times for inspect and repair of track geometry defects in Table 5-17.where there is a justifiable reason for the inability to achieve the mandated response times.

The following are examples where a dispensation may be justified:

- Trains are closely following that will prevent responding staff from safely attending the fault.
- The lighting or the weather conditions when the defect is found do not allow responding staff to correctly locate and attend to the defect.
- The short notice diversion of the required maintenance resource would require the deferment of other planned work with equal or higher risk/consequences.

The following risk factors should be considered when considering dispensation:

- Frequency of rail traffic.

- Type of rail traffic.
- Condition of track including fastening system.
- Track alignment (curve or tangent).
- Multiple lines.
- Location of the defect.
- How the track geometry car rode as it passed over the defect.

5.4.3.2 **Track Geometry Recording Car Inspector**

Track Geometry Recording Car Inspector on board the Track Recording Car considering section 5.4.3.1, may authorise extending of the response to defects found by the Track Recording Car as follows:

1. Band A

   The inspect or repair times may be extended once, up to 24 hours from the time of discovery with a temporary speed restriction of no more than 20km/h.

2. Band B

   The inspect or repair times may be extended once, up to 24 hours from the time of discovery with a temporary speed restriction of no more than 20km/h.

The extension is to consider how the car rode as it passed over the fault, the track recording car output indicated for all parameters and the configuration of the track at the location.

A record of evidence for extending the response time should be maintained. AK Cars Generated – Emergency E1 or E2 exceedances shall be annotated to document at a minimum the following information;

- Why has an extension been authorised (give reasons for decision),
- Time of dispensation, name, signature and RIW number of who provided the dispensation (competent person CER/ TGRCI).

5.4.3.3 **Civil Engineering Representative (CER)**

5.4.3.3.1 Track Geometry Defects

If the cause of a defect is known and it is known that it will not deteriorate rapidly an alternate response to that allowed for the response category is permitted with appropriate documentation and approval by the CER.

5.4.3.3.2 Track Geometry Recording Car Faults

There are times when the Track Geometry Recording Car reports faults that are considered spurious. In that case, alternative response time to that shown for either inspection or repair, or both inspection and repair, are permitted with the appropriate documentation and approval by the CER. The CER, or alternatively the Track Geometry Recording Car Inspector, is required to be present on the Track Geometry Recording Car to prepare the appropriate documentation. The appropriate documentation should include a description of the spurious reading, a description of the suspected cause of the spurious reading (if known), observation of the ride of the car, knowledge of the track and any discussion with the operators on the car. The defect can only be “signed off” after it has been verified by inspection.

5.4.4 Vehicle Track Interaction (VTI) Data

5.4.4.1 Overview

VTI is a system of accelerometers mounted onto ARTC customer's locomotives that are constantly traversing the ARTC Defined Interstate Rail Network. However, the VTI recordings do not take place at a regular scheduled time intervals as they are dependent upon the train paths of ARTC customers. Not all sections of track will be covered in each and every "VTI Exception Report" period.

The system provides ARTC with a method of obtaining regular track ride quality or feel data to assist with regular maintenance and performance tracking of track infrastructure.

The system provides different track geometry related condition exceptions:

- MCO – Mid Chord Offset (3m) – e.g. pumping track, mudholes
- CBR – Car Body Roll – e.g. Twist
- CBV – Car Body Vertical – e.g., top
- CBL – Car Body Lateral – e.g. Line

The system provides real time data on how the locomotives are riding or feeling the track.

At the location where the train "ride quality or feel" is not as expected, then an "exception" is registered and uploaded automatically to ENSCO using the mobile network.

These exceptions are then downloaded by ARTC periodically and a VTI exception report produced. The VTI exception reports are then distributed to the maintainer.

5.4.4.2 Application

Where VTI exceptions are produced they shall be managed in accordance with EGW-10-07.