Track Geometry – Train System

Engineering Standard

Rail Commissioner

TC1-DOC0000448

Government of South Australia
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1. Introduction

The Department of Planning, Transport and Infrastructure (DPTI) operates and maintains the Adelaide Metropolitan Passenger Rail Network (AMPRN) under the Rail Accreditation assigned to the Rail Commissioner.

This standard supersedes Sections 1, 2, 3, 4 and 6 of CP-TS-956: *TransAdelaide Code of Practice Volume 2 – Train System Track Geometry*.

2. Purpose

This standard specifies the track geometry requirements for the design and construction of rail track on the AMPRN train system.

This standard:

- defines track geometry parameters used in design of new track and rating of existing track;
- defines track geometry limits for construction;
- provides for passenger comfort;
- defines the requirements for track geometry that does not subject train movements to traction requirements beyond their capacity (i.e. by limiting grades); and
- defines the requirements that must be met in order to limit the frequency and magnitude of track forces which may cause excessive track maintenance requirements.

3. Scope

This standard applies to new and existing broad gauge track geometry.

This standard specifies general procedures for the design/rating of track geometry, including track gauge, tangent track, bends, horizontal curves, gauge widening, Cant, maximum vehicle line speed, transitions, gradients and vertical curves.

This standard specifies general procedures for the determination of allowable track condition and limiting vehicle speeds during construction and re-construction of tracks.

4. References

4.1. DPTI Standards

DOCUMENT NAME	DOCUMENT NUMBER
Track and Civil Infrastructure Code of Practice, Volume 2 – Train System, Track Geometry	CP-TS-956 (KNet# 7117746)

4.2. DPTI Documents

DOCUMENT NAME	DOCUMENT NUMBER
Design Decision Record – Reverse Curve Impacts to 4000 Class Rail Cars, including Adelaide Yard South Rationalisation Proposal and Proposed Track and Rolling Stock Modifications	AR-PW-PM-DDR-00110001 (KNet#7558267)
Identification and Numbering of Technical Documents and Drawings	FR-AM-GE-806 (KNet# 6900682)
Drafting Standard for AutoCAD Drawings	AM4-DOC-000364 (KNet# 7636432)
Naming and Numbering Conventions for DPTI Rail Assets and Infrastructure	AM4-DOC-000936 (KNet# 7481083)

4.3. DPTI Standard Drawings

DOCUMENT NAME	DOCUMENT NUMBER
Design Standard – Roundings	TC4-DRG-201405 (KNet# 15619878)

Maximum Outline for Metropolitan Railway Rollingstock & Equipment – 1600 Gauge	200-A3-82-1658 (KNet# 9480611)
System Drawing – Adelaide Electrification Project – Traction Overhead Structure Number – Labelling Layout and Location	AR-SN-21750007 (KNet #9085637)
Standard Drawing – Non-Operational Signage –OHWS / Lineside Track Monument General Layout	TC1-DRG-201406 (KNet #15572658)
Standard Drawing – Non-Operational Signage – Horizontal Frame Point Track Monument General Layout	TC1-DRG-201407 (KNet #15572650)
Standard Drawing – Non-Operational Signage – Horizontal Frame Point Example Track Monument Layout	TC1-DRG-201408 (KNet #15572655)

4.4. Rail Industry and Australian Standards

DOCUMENT NAME
AS 7635 Track Geometry
RISSB Glossary National Guideline: Glossary of Railway Technology

5. Acronyms

ACRONYM	FULL NAME
AMPRN	Adelaide Metropolitan Passenger Rail Network
CC	Centre of Circle
CS	Curve to Spiral
DPTI	Department of Planning, Transport and Infrastructure
IP	Intersection Point
IPRL	Intersection Point, Reduced Level
PC	Point of Curve
PCC	Point of Change of Curvature
PT	Point of Tangent
RISSB	Rail Industry Safety and Standards Board
RL	Reduced Level
SC	Spiral to Curve
ST	Spiral to Tangent
TM	Track Monument
TS	Tangent to Spiral
VC	Vertical Curve

6. Definitions

General railway technical terms extracted from the RISSB National Guideline – Glossary of Railway Terminology, unless noted otherwise in this standard.

7. Horizontal and Vertical Alignment

Horizontal and vertical alignment shall be designed to meet the requirements specified in Section 8, using a combination of the following components.

7.1. Horizontal Alignment Components

Horizontal alignments shall be defined by a combination of tangents, transitions and circular and/or compound curves.
Horizontal track geometry primarily consists of tangents and circular curves, with transitions commonly used to join them.

The horizontal alignment defines the centreline of the track.

Horizontal alignment frame points are to be named in accordance with AM4-DOC-000936 – *Naming and Numbering Conventions for DPTI Rail Assets and Infrastructure*.

7.1.1. Tangents

A tangent (straight) shall be defined by two tangent points (Point of Tangent (PT), Point of Curve (PC), Spiral to Tangent (ST), or Tangent to Spiral (TS)), two bends, or one of each.
Each of these two points shall have a unique co-ordinate set (Easting (E), Northing (N)).

7.1.2. Transitions

A transition is the component that joins a tangent to a circular curve and is based on a clothoid spiral. Transitions can also occur between two circular curves within a compound curve, being in this case called *compound transitions*.
A transition shall be defined by three co-ordinated points, being the tangent point (TS or ST), transition point (Curve-Spiral (CS) or Spiral-Curve (SC) and Centre of Circle (CC).
Each of the points shall have a unique co-ordinate set (E, N).

7.1.3. Circular Curves

A circular curve shall be defined by three co-ordinated points, being the two transition points or tangent points (PC, PT, SC, CS or Point of Change in Curvature (PCC) and the centre of circle (CC).
Each of the three points shall have a unique co-ordinate set (E, N).

7.1.4. Compound Curves

Compound curves are used where curves of similar hand are required and are not separated by a tangent (PCC).

7.2. Vertical Alignment Components

Vertical alignment shall be defined as a series of straight grades connected by vertical curves (VCs) or intersection points.
The parameters which define the components shall be:

- Intersection Point reduced level (IPRL)
- Vertical curve length (L_v)

IPRL includes km and level.
Vertical alignment defines the elevation of the low rail of each track.

7.2.1. Vertical Grades

Each straight grade shall be defined by a pair of terminal points called intersection points (IP), which shall preferably be located at whole 20m kilometrage points.

Each IP shall have a defined reduced level (RL).

The 'grade' of each straight grade shall be expressed either in the form ‘1 in X’ or as a percentage.

This percentage shall be an exact increment of 0.005% to give an exact number of millimetre changes per 20m, except where kilometrage adjustments or other similar constraints occur.

7.2.2. Vertical Curves

The vertical curve shall be defined by the length (L_v) and shall preferably be a multiple of 20m.
The vertical curve shall be based on the quadratic parabola.

8. Geometry Design and Rating – General

8.1. Design Abbreviations

Table 8.1: Design abbreviations

TERM	SYMBOL	UNIT
Speed	V	km/h
Maximum allowable speed	V_m	km/h
Radius	R	m
Bend angle	β	Degrees, minutes, seconds
Cant	E_a	mm
Difference in Cant	$\triangle E_a$	mm
Equilibrium Cant	E_q	mm
Cant Gradient	E_g	1 in X
Cant Deficiency	E_d	mm
Cant Deficiency in Bend	β_d	mm
Rate of Change of Cant	E_{aroc}	mm/s
Rate of Change of Cant Deficiency	E_{droc}	mm/s
Difference in Cant Deficiency	$\triangle E_d$	mm
Length of Transition	L_t	m
Grade	G	% or 1 in X
Difference between two adjacent grades	$\triangle G$	%
Length of vertical curve	L_v	m
Normal Spacing of Vehicle Bogies	B_c	m

8.2. General

The aim of the track alignment design shall be to allow trains to maintain the maximum speed for the traffic operating. This is generally best achieved by minimising the grade and curvature of the track.

Track geometry for track in all mainline and siding tracks shall be designed in accordance with this standard.

8.3. Desirable Design Limits

Target for all new track design and existing track realignment.
The Desirable Design Limits represent preferred engineering practice which allow for low maintenance track.

Track geometry design shall conform to the Desirable Design Limits unless otherwise approved by the DPTI Unit Manager Track and Civil Engineering.

8.4. Recommended Design Limits

Target for all new track design and existing track realignment within a constrained corridor.

Recommended Design Limits are acceptable if Desirable Design Limits are not achievable due to significant physical constraints and are subject to approval by the DPTI Unit Manager Track and Civil Engineering.

8.5. Maximum (or Minimum) Design Limits

The Maximum (or Minimum) Design Limits allow for the track to be maintained within the safety limits, but may result in higher maintenance costs.

Maximum (or Minimum) Design Limits are acceptable if neither Desirable nor Recommended Design Limits are achievable due to significant physical constraints and are subject to approval by the DPTI Unit Manager Track and Civil Engineering.

8.6. Track Gauge

a) Gauge shall be measured (in mm) between the inside face of the rails, 16mm below the top surface.
b) The nominal track gauge of DPTI rail tracks shall be 1600mm (broad gauge).
c) Gauge widening shall not be permitted on curves of $R \geq 200$m.

8.7. Tangent Track

Tangent track shall be laid and measured between the tangent points of curves, points and crossings or the ends of the line.

In general, tangent track shall be laid and maintained level across the rails.

Exceptions to this rule occur at the approach to un-transitioned curves, where half the Cant is applied on the tangent track and the other half on the curve.

8.8. Vertical Gradients

a) Gradients may be expressed in the form '1 in x' or as a percentage.
b) The maximum gradients shall be:
   - 1 in 45 (2.222%) for ballasted track; and
   - 1 in 33 (3.000%) for slab track.
c) Gradients should be as near level as possible.
d) The following shall be considered in the selection of design gradient:
   a) Braking and traciton performance of vehicles likely to use the line;
   b) Position of signals and operational regime;
   c) Projected rail adhesion conditions, including the effect of the weather;
   d) Clearances to structures

8.9. Curve Compensation

In order to achieve a uniform resistance to train movement, gradients shall be reduced on curves to compensate for the extra curve resistance.

The compensated gradient shall be:

$$G_c = G - C$$

Where:
G_c is the compensated design gradient
G is the uncompensated gradient
C is the degree of compensation

$$C = \frac{60}{R}\%$$

a) For new work, in order to achieve a uniform resistance to train movement, gradients shall be reduced on curves to compensate for the curve resistance.

   The gradient percentage shall be reduced by $\frac{60}{R}\%$.

   EXAMPLE: to achieve a 1 in 45 (2.222%) compensated gradient, on a curve of 200m radius the gradient would be reduced to 1 in 52.0 (1.922%).

b) On existing lines, to determine the equivalent gradient on curves which are not compensated, the gradient percentage shall be increased by $\frac{60}{R}$%.

EXAMPLE: on a 1 in 45 (2.222%) uncompensated gradient, the equivalent gradient on a 200m radius curve would be 1 in 39.6 (2.522%).

8.10. Vertical Curves in Hogs and Sags

At changes of gradient greater than 0.200%, a vertical curve shall be used between the two gradients of parabolic form and of length in accordance with Equations 1, 2 and 3:

$$L_v = K\ \Delta G \quad (1)$$

Or

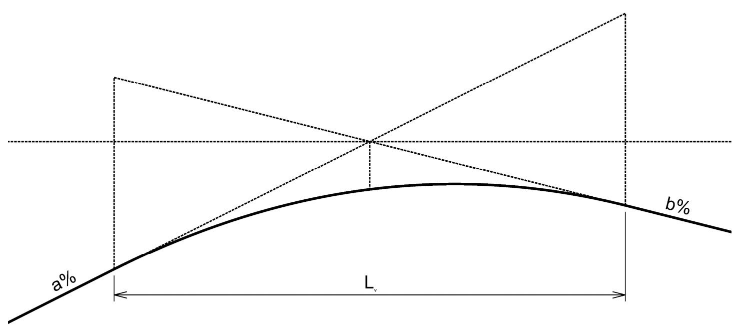
$$L_v = K(b - a) \text{ for sag curves} \quad (2)$$
$$L_v = K(a - b) \text{ for hog curves} \quad (3)$$

Where:
ΔG is the difference in grade
ΔG = b – a for sag curves or a – b for hog curves
a and b are the two gradients expressed as a percentage with rising grades positive and falling grades negative.

L_v is the length of the vertical curve in the horizontal plane, in metres.

For reference, Figure 8.1 shows a hog curve, in which a is positive and b is negative:

Figure 8.1: Vertical curve diagram



The default minimum K value is 75. A lower K value, in accordance with Table 8.2, may be used where the ultimate maximum speed at a specific location is less than 110km/h and physical restraints limit the length of the vertical curve.

Table 8.2: Track speed relative to minimum K values

POTENTIAL TRACK SPEED (KM/H)	K-VALUE
110	75
100	60
90	50
80	40
70	30
60	20
50	15
40	10
35	10

The actual value of K used shall not be less than that applicable to the ultimate line speed for the location.

The length of vertical grades and curves shall be a minimum of 20m, with preferred length increments of 20m. Longer grades are preferred with frequent changes of grade and use of vertical curves being avoided.

Refer to drawing TC4-DRG-201405 for further details on vertical curves.

8.11. Lengths of Horizontal Straights and Curves

For all new design work:

a) The length of individual straight, transition, or circular curve elements shall be equal to or greater than 20m.
b) Cant gradients shall be not less than 20m long, including those between curves in a compound curve.
c) Between contra flexure curves a straight of minimum 20m shall be provided. The minimum length of straight may be reduced at crossovers.

For all renewal design work:

a) Between contra flexure curves a straight shall be provided of length at least equal to the longest bogie centres approved for the AMPRN (18.3m). However, the length of straight may be reduced at crossovers.
b) Circular curves and transitions shall have a minimum length of 18.3m, and should preferably have a length of at least 20m.
c) Cant gradients should be not less than 20m long, including those between circular curves in a compound curve. The minimum allowable length of Cant gradients shall be 18.3m.

8.12. Cant and Speed - Explanation

a) When a rail passenger vehicle enters a curve, centripetal force acts on the vehicle and any passengers inside. Passengers experience it as an apparent force towards the outside of the curve. The centripetal force is proportional to the square of the speed of the vehicle and inversely proportional to the radius of the curve. At moderate levels of operation this force has no effect on safety, but can affect the comfort of passengers. To counter the effects of the force on passengers, Cant is applied to the curve by raising the outside rail.
b) For a given curve radius and Cant, there is one speed at which the centripetal force is perfectly balanced by the Cant. At this speed, passengers would not experience any lateral force. When a train travels at a speed that is lower than this "equilibrium" speed, there is "Excess Cant", in which the passengers experience a net lateral force towards the inside of the curve. If the speed is higher than the

equilibrium speed, there is “Cant Deficiency”, in which the net lateral force is towards the outside of the curve.

c) Overseas tests reveal that risk of derailment is increased if the Excess Cant appreciably exceeds one tenth of the gauge, i.e. 160mm. By considering a near stationary train on a curve (for example, at a “stop” signal), this effectively sets an upper limit for the (total) Cant. I.e., the original deliberately applied (nominal) Cant plus any further Cant accidentally applied because of track settlement should not exceed 160mm. As a result, well-maintained track may safely take a higher Applied Cant than poorly maintained track.

The prime reason for canting curved track is for passenger comfort, not safety. Excessive Cant may jeopardize safety; lack of Cant will not (except near the speed at which overturning may occur, but Cant would only have a marginal effect at such an excessive speed).

The design speed shall be the maximum speed that trains are not to exceed.

8.13. Cant Related Definitions

8.13.1. Cant

On a curved track the level of the outside rail is typically raised higher than the inside rail.
This difference in level between the two rails, taken on the top of the rails at a single point along the track, is known as ‘Cant’.

8.13.2. Design Cant

Design Cant is the calculated Cant for a section of track and which should be the Applied Cant in construction.

8.13.3. Applied Cant

Applied Cant is that applied to the curve in construction.

8.13.4. Actual Cant

Actual Cant is the Cant as measured in the field (due to track irregularity over time).

8.13.5. Cross Level

The Cross Level is the unintended difference between the Design Cant and the Actual Cant at a discrete location.
The variation in Cross Level at two longitudinally separated positions along the track determines track twist.

8.13.6. Equilibrium Cant

Equilibrium Cant is the theoretical Cant at which the resultant of the centrifugal force and the vertical force due to gravity is perpendicular to the plane taken across the tops of rails at a given speed. In this situation there is no net lateral force on the train.

In practice the Design Cant is normally less than the Equilibrium Cant.

8.13.7. Cant Deficiency

Cant Deficiency is the amount by which the Cant would have to be increased to equal the Equilibrium Cant. In this situation the net lateral force on the train is towards the outside of the curve.

$$E_q = E_a + E_d$$

Except as provided for in Section 9.4.2, Cant Deficiency shall not exceed 80% of the Design Cant.

8.13.8. Excess Cant

Excess Cant occurs when the Cant is greater than the Equilibrium Cant. When a train is travelling on a curve at a speed for which the Equilibrium Cant is lower than the Actual Cant, Excess Cant is achieved. In this situation the net lateral force on the train is towards the inside of the curve.

8.13.9. Negative Cant

Negative Cant is where the inside rail on a curve is higher than the outside rail. This shall not be provided by design on the AMPRN.

8.13.10. Cant Ramp

A Cant Ramp is the length of track over which the Cant is designed to change, which should normally be coincident with a transition.

8.13.11. Cant Gradient

Cant Gradient is the rate at which the Cant changes through the Cant Ramp, expressed as ‘1 in x’.

8.13.12. Rate of Change of Cant

The Rate of Change of Cant is similar to the Cant Gradient, being a measure of how the Cant changes.
Unlike the Cant Gradient, however, it measures how quickly the Cant varies over time (expressed as mm/s).
For example, a transition of length 35m, connecting a tangent and a curve with 1600m radius and 35mm Cant, at a 90km/h design speed, would have a Rate of Change of Cant of 25mm/s.

8.13.13. Rate of Change of Cant Deficiency

The Rate of Change of Cant Deficiency is the rate at which Cant Deficiency changes over time (expressed as mm/s).
For example, the curve described in 8.13.12 would have a Cant Deficiency of 31.5mm, and the transition would have a Rate of Change of Deficiency of 22.5mm/s.

9. Geometry Design and Rating

9.1. Limit Values of Track Parameters

Except as provided for elsewhere in this document, the parameters given in Table 9.1 shall be adopted:

Table 9.1: Limit values for Track Parameters – Broad Gauge

PARAMETER	DESIRABLE	RECOMMENDED	MINIMUM	MAXIMUM
HORIZONTAL GEOMETRY				
Radius – Existing Main Line realignment	1600m	1000m	200m	4000m [2]
Radius – New Main Line works			1600m	4000m [2]
Radius – Existing siding realignment			160m	4000m [2]
Radius – New siding works			180m	4000m [2]
Radius – Platforms [1]	Straight	1000m		

PARAMETER	DESIRABLE	RECOMMENDED	MINIMUM	MAXIMUM
Maximum Design Cant: • Where rails are continuously welded and curves are properly transitioned • Where rails are not continuously welded or curves are not properly transitioned • At Platforms and Level Crossings • On diverging route of conventional/tangential turnouts	110mm 50mm 0mm	25mm		130mm 90mm 50mm 0mm
Maximum Negative Cant				0mm
Maximum Cant Deficiency (see Sections 8.13.7 and 9.2.3: • Where rails are continuously welded and curves are properly transitioned • Where rails are not continuously welded or curves are not properly transitioned • At Platforms and Level Crossings • On diverging route of conventional/tangential turnouts • Horizontal bend				100mm 70mm 40mm 100mm 40mm
Maximum Excess Cant (negative Deficiency)				80mm
Cant Gradient	1:1500	1:1000		1:400
Rate of change of Cant, Cant Deficiency, or Excess Cant (see Section 9.2.2): • Plain track • On diverging route of conventional/tangential turnouts • Virtual transitions	39mm/s 39mm/s			[3] [3] 37mm/s
Horizontal Bend Angle				1° 50´
VERTICAL GEOMETRY				
Vertical curve radius (see Section 8.10)				
Length between vertical curves	50m		20m	
Grade length			20m	
Vertical curve length			20m	
Maximum grade (compensated) • Ballasted track • Slab track	1 in 100 1 in 100	1 in 50 1 in 50		1 in 45 1 in 33
Maximum grade (compensated) through a platform • Ballasted track • Slab track	1 in 200 1 in 200	1 in 100 1 in 100		
GENERAL				
Spacing of Vehicle Bogies [5]			16.8m [6]	18.3m [7]

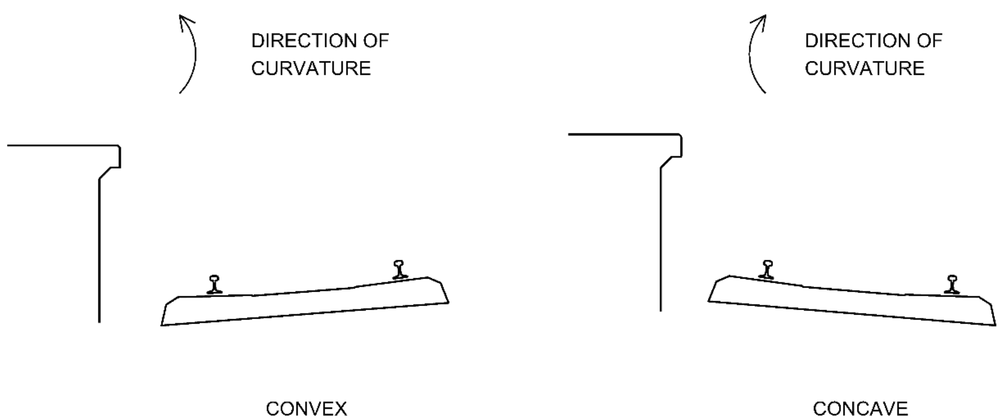
Notes:
1. Refer to Sections 9.2 and 12
2. This excludes instantaneous radii in transitions
3. Refer to Section 9.4.2
4. Design speeds are to be rounded down to the nearest 5km/h
5. All calculations involving B_c shall use either the Minimum or Maximum value, whichever is more conservative (e.g. virtual transitions shall have a length of 16.8m).
6. Bogie spacing of 4000 Class railcar.
7. Maximum bogie spacing allowable by rolling stock outline. Refer to drawing 200-A3-82-1658.

9.2. Horizontal Curves

9.2.1. Minimum Radius - Platforms

a) It is desirable to have tangent track through platforms. Approval shall be provided by the Unit Manager Track and Civil Engineering; based on sufficient justification provided; for non-tangent alignments through platforms.
b) Convex curves, in which the track curves (and is Canted) ‘towards’ the platform (e.g. left-hand curve, left-hand platform. See Figure 9.1), are undesirable due to the induced variances of stepping distances (platform gaps), the increased maintenance requirements between the track and platform interface and the reduction in proximity between station infrastructure and the rollingstock.
c) Concave curves, in which the track curves (and is Canted) ‘away’ from the platform (e.g. right-hand curve, right-hand platform. See Figure 9.1), are not permitted as they increase the stepping distance and sight lines along the platforms are restricted.
d) For further detail refer to Section 12.

Figure 9.1: Definition of convex and concave curves within a platform



9.2.2. Cant and Speed Requirements

Tests show that for passenger comfort:
1. Cant Deficiency should not exceed 100mm (refer to Table 9.1); and
2. Rate of Change of Cant or Cant Deficiency should not exceed 39mm/s.

However, where space is restricted a rate of up to 60mm/s may be used in accordance with Section 9.4.2 (Transitions of restricted length).

9.2.3. Maximum allowable Applied Cant and Cant Deficiency

Except as provided for in Section 9.4.2, the maximum allowable Applied Cants and Cant Deficiencies are as shown in Table 9.1.

9.2.4. Cant/Speed Relationship

a) The design speed shall be the maximum speed that trains are not to exceed.
b) The maximum allowable vehicle speed for any curve shall be determined by Equation 4. Where “V” exceeds the maximum allowable line speed, the line speed shall be used and Cants recalculated accordingly.

$$V = 0.276\sqrt{E_q R} \quad (4)$$

Where:
V = Maximum allowable vehicle speed (km/h)
E_q = Equilibrium Cant (mm)
$E_q = E_a + E_d$

c) R = Radius of curve (m)The Cant that may be applied to a curve shall be determined by Equation 5:

$$E_q = 13.14\frac{V^2}{R} \quad (5)$$

Where:
E_q = Equilibrium Cant (mm)
V = Maximum allowable vehicle speed (km/h)
R = Radius of curve (m)

1. The Cant should preferably be as close as possible to 55% of the Equilibrium Cant.
2. If this exceeds the value shown in Table 9.1 for the location, then determine the maximum allowable Equilibrium Cant and then calculate the maximum allowable vehicle speed as in Equation 4.

9.3. Bends

9.3.1. Occurrence of Bends

Bends occur where two tangent tracks meet at near 0° without an intermediate curve. Mostly they occur at the toe of straight switches but can occur in plain track.
Except at the toe of conventional points, horizontal bends shall be avoided where possible as they are not desirable.

9.3.2. Maximum Allowable Speed through Bends

The maximum allowable speed through a bend shall be as shown in Equation 6:

$$V_m = 2.09\sqrt{\frac{\beta_d B_c}{\beta}} \quad (6)$$

Where:
V_m = Maximum allowable vehicle speed (km/h)
β_d = Cant Deficiency (mm)
B_c = Bogie centres of rolling stock (m)
β = Angle between two tangent tracks (degrees)

On AMPRN track it may be assumed that β_d = 40mm and B_c = 16.8m, and therefore that:

$$V_m = \frac{54}{\sqrt{\beta}}$$

Example: For a straight 6.095m switch (angle = 1°17’0”), maximum allowable speed = 45 km/h (rounded down from 47.7km/h).
Note, however, that the speed through the turnout may be dependent on its radius.

9.4. Transitions

Transitions should be provided between circular curves and tangents, and compound transitions provided between circular curves within a compound curve.

9.4.1. Standard Transitions

a) All standard curve transitions shall be in clothoid form.
b) The centreline of the track on the true curve shall be moved towards the centre of the curve by a “shift” to facilitate the construction of the transition.
c) The Rate of Change of Cant or Cant Deficiency shall be limited to 39mm/s and the Cant Gradient to no steeper than 1 in 400. Thus, the minimum lengths of transitions shall be calculated as shown in Equations 7, 8 and 9:

The minimum length of transition on any curve shall be the highest value of L_t as derived from the following three equations:

$$L_t = \frac{E_a V}{3.6 E_{aroc}} \quad (7)$$

$$L_t = \frac{E_d V}{3.6 E_{droc}} \quad (8)$$

$$L_t = \frac{E_a}{1000 E_g} \quad (9)$$

Where:
E_a = Cant (mm)
E_{aroc} = Rate of Change of Cant (mm/s)
E_d = Cant Deficiency (mm)
E_{droc} = Rate of Change of Cant Deficiency (mm/s)
E_g = Cant Gradient (converted from ‘1 in X’ to a dimensionless value; i.e. 1 in 200 = 0.005)
V = Design speed (km/h)

If the theoretical transition length is less than 20m, or the shift is less than 10mm (may be calculated using a cubic parabola as an approximation of a clothoid), no transition need be applied.

9.4.2. Transitions of Restricted Lengths

In certain circumstances it may not be possible to apply the standard transition lengths as calculated in Section 9.4.1. If so the alternative solutions, in descending order, may be:

a) Adopt a greater Rate of Change of Cant than that specified in Section 9.4.1. Under no circumstances shall this value exceed 60mm/s [see Section 9.2.2].
b) Adopt a higher Cant Deficiency than that specified in Sections 9.2.3 and 9.2.4, but not exceeding the applied Cant.
c) Adopt a shorter transition than calculated, but commence canting the track before the commencement of the transition and increase the Cant in accordance with paragraphs 9.4.1(c) or 9.4.2(b) until the full Cant is applied.

If the use of one of the above results in undesirable conditions, then the design speed shall be reviewed.

9.4.3. Curves Without Transitions and Virtual Transitions

If it is not possible to apply any transition at all, the following action shall be considered. Between when the first bogie of a bogie vehicle enters a curve and the second bogie enters the curve, the vehicle gradually takes up circular motion.
This is the “virtual transition” and is equal in length to the bogie centres.
On AMPRN track, the virtual transition shall be 16.8m long.
By considering the transition as 16.8m long (symmetrical about the tangent point) the alternatives shown in clauses (a) or (b) may be used.

a) Curve canted but not transitioned

If the curve is canted without a transition, the Cant shall be applied over a length that is symmetrical about the PT/PC/PCC. The length of this Cant Ramp may be determined independently of the virtual transition, and may even be shorter than the 18.3m required for other Cant Ramps, but shall not be shorter than the virtual transition (16.8m).

A canted curve without a transition shall:

1. have a Rate of Change of Cant not exceeding 37mm/s, determined by substituting the length of the Cant Ramp for L_t in Equation 7 (or Equation 11 if between two radii of a compound curve);
2. have a Rate of Change of Deficiency not exceeding 37mm/s, determined by substituting the length of the virtual transition (16.8m) for L_t in Equation 8 (or Equation 12); and
3. have a Cant Gradient complying with the limits in Table 9.1, determined by substituting the length of the Cant Ramp for L_t in Equation 9 (or Equation 13).

The solutions detailed in Section 9.4.2 shall not be used for any virtual transition, with or without Cant.

If the proposed Cant Ramp is longer than 30m, or the Applied Cant is more than 58% of the Equilibrium Cant, a detailed analysis shall be undertaken to demonstrate the behaviour of E_{roc} and D_{roc} through the different sections of the Cant Ramp, and to prove that the relevant limits are not exceeded.

b) Curve un-canted and not transitioned

If the curve is un-canted and without transition, the maximum allowable vehicle speed shall be determined using the maximum allowable Cant Deficiency for the curve.

The Cant Deficiency is assumed to build up over the virtual transition. The virtual transition needs to be checked to ensure that it does not exceed the allowable Rate of Change of Cant Deficiency. The solutions detailed in Section 9.4.2 shall not be used for any virtual transition, with or without Cant. The calculation of the Cant and speed shall be as per Equation 10:

From Equation 4:

$$V = 0.276\sqrt{E_q R}$$

From Equation 8:

$$L_t = \frac{E_d V}{3.6 E_{droc}} = \frac{E_d V}{3.6 \times 37} = \frac{E_d V}{133.2} \approx 0.0075 E_d V$$

and $L_t = 16.8\text{m}$, so therefore:

$$0.0075 E_d V \approx 16.8$$

$$V \approx \frac{2238}{E_d}$$

Equating V from the two formulae:

$$0.276\sqrt{E_q R} \approx \frac{2238}{E_d}$$

In this case $E_q = E_d$ so therefore:

$$0.276\sqrt{E_d R} \approx \frac{2238}{E_d}$$

$$E_d \approx \frac{403.6}{\sqrt[3]{R}}$$

Then, substituting this value of E_d into Equation 4:

$$V = 0.276\sqrt{E_d R}$$

$$V = 0.276\sqrt{\frac{403.6}{\sqrt[3]{R}} \times R}$$

$$V = 0.276\sqrt{403.6 R^{\frac{2}{3}}}$$

$$V \approx 5.544\sqrt[3]{R} \quad (10)$$

EXAMPLE: If R = 200m:

$$V \approx 5.544\sqrt[3]{200} \approx 32\text{km/h}$$

9.4.4. Compound Curves

It is preferred to have constant applied Cant through compound curves except where this impacts upon the curve speed.

In compound curves, transitions between different radii of the compound curve shall use the same criteria as for a simple curve, with the following variations:

a) The Cant and Cant Deficiency together with the allowable speed shall be determined for each curve individually. It is preferable that a compound curve has a constant design speed throughout the curve.
b) Calculations involving Cant shall use the difference in Cant between the two radii.
c) Calculations involving Cant Deficiency shall use the difference in Cant Deficiency between the two radii.
d) The length of transition between the two curves shall be derived from Equations 11, 12 and 13:

$$L_t = \frac{\Delta E_a V}{3.6 E_{aroc}} \quad (11)$$

$$L_t = \frac{\Delta E_d V}{3.6 E_{droc}} \quad (12)$$

$$L_t = \frac{\Delta E_a}{1000 E_g} \quad (13)$$

9.4.5. Reverse Curve

Transitions directly connecting reverse curves shall not be designed for the AMPRN, unless approved by the Unit Manager Track and Civil Engineering. If approved, they shall comply with the following.

In reverse curves, transitions between different radii of the reverse curve shall use the same criteria as for a simple curve with the following variations:

a) The Cant and Cant Deficiency together with the allowable speed shall be determined for each curve individually. It is preferable that a reverse curve has a constant design speed throughout the reverse.
b) Calculations involving Cant shall use the sum of the Cants for the two radii.
c) Calculations involving Cant Deficiency shall use the sum of the Cant Deficiencies for the two radii.
d) The length of transition between the two curves shall be derived from Equations 14, 15 and 16:

$$L_t = \frac{(E_{a1}+E_{a2})V}{3.6 E_{aroc}} \quad (14)$$

$$L_t = \frac{(E_{d1}+E_{d2})V}{3.6 E_{droc}} \quad (15)$$

$$L_t = \frac{E_{a1}+E_{a2}}{1000 E_g} \quad (16)$$

9.4.6. Curves of Restricted Cant

Through some curves the applied Cant is restricted, such as at level crossings, platforms and some compound curves. In these circumstances the Cant may be less than 55% of the Equilibrium Cant, however the maximum allowable Cant Deficiencies as noted in this standard shall not be exceeded.

9.5. Points and Crossings

The determination of the maximum allowable vehicle speed through curves in points and crossings shall be made using the standards specified in Sections 9.2 and 9.3.

Where straight switches are used, the standards in Section 9.3 shall be used.

For curves in points and crossings without Cant or transitions the standards in Section 9.4.3 (b) shall be used.

Points and crossings shall:
a) be located on tangent track.
b) not contain vertical curves.
c) be designed through a constant vertical grade and horizontal alignment.

10. Track Geometry Requirements for Construction

All track shall be constructed within the limits specified in Section 10.1, 10.2 or 10.3, whichever is relevant.

10.1. New Construction Tolerances – Ballasted Track

Construction of new works, where new sleepers and rail are installed, shall comply with the tolerances as shown in Table 10.1.

10.2. Re-used Material Construction Tolerances – Ballasted Track

Use of any re-used material shall be approved by and subject to tolerance limits nominated by the Unit Manager Track and Civil Engineering.

Where track is to be constructed by re-using materials, in particular worn rail, the geometric tolerances are to be as shown in Table 10.1.

Re-used rail shall not be transposed.

10.3. New Construction Tolerances – Fixed Track

Construction of new fixed tracks (e.g. track slabs and other non-ballasted track forms), where new track support systems are installed, shall comply with the tolerances as shown in Table 10.1.

Table 10.1: Tolerances for track construction

GEOMETRIC MEASURE	NEW BALLASTED TRACK	REUSED BALLASTED TRACK	NEW FIXED TRACK
Gauge			
Tangent and curved track	+4mm, -2mm		+3mm, -0mm
Tangent – worn rail		+7mm, -3mm	
Curve – worn rail		+15mm, -3mm	
Variation in 2m	±4mm	±5mm	±3mm
Line – tangents and curves (excluding transitions) Mid ordinate deviation from design in a 10m chord length	±5mm	±5mm	±5mm
Alignment			
Tangent and Curve	±10mm	±10mm	±8mm
Variation between adjacent survey monuments	±10mm	±10mm	±8mm
At platforms (+ is away from platform)	+10mm, -5mm	+10mm, -5mm	±5mm
Twist - Rate of Change of Cant (excluding transitions)	1 in 800	1 in 800	1 in 1000
Twist (Rate of Change of Cant) variation from design In 10m	±4mm	±4mm	±3mm
Cant			
Maximum difference to design	±5mm	±5mm	±3mm
Top Surface			
Defects in 10m chord	±5mm	±5mm	±5mm
Track Level [1]			
Plain track	±20mm	±20mm	±10mm
Through platform	+20mm, -0mm	+20mm, -0mm	±5mm
Overbridges with minimum ballast depth	+20mm, -10mm	+20mm, -10mm	
Concrete sleepers [2]			
Plain track spacing	±10mm	±10mm	±10mm
Skew	±10mm	±10mm	±10mm

Notes:

1. Measurement convention:
   + means track is higher than design level
   - means track is lower than design level
2. These tolerances are to be met for the entire length of the sleeper

11. Track Monumenting

To allow for monitoring of the track alignment and track position, regular Track Monuments (TMs) shall be provided. TMs shall comply with TC1-DRG-201406, TC1-DRG-201407 and TC1-DRG-201408 depending on the type of track monument required.
As a minimum, the Track Monuments shall be located as shown in Table 11.1:

Table 11.1: Required spacing for Track Monuments

ELEMENT/STRUCTURE	LOCATION	SPACING	DRAWING
Straights - Non Electrified Lines	Sleeper	Start and end points	TC1-DRG-201407
Straights - Non Electrified Lines	Lineside post	Every 100m	TC1-DRG-201406
Straights - Electrified Lines	Overhead wiring structure	On overhead wiring structures adjacent each track	TC1-DRG-201406
Circular curves and Transitions	Sleeper	Start and end points	TC1-DRG-201407
Platforms	Platform wall	Either end (commencing 100mm in) and: • every 20m through tangent alignments • every 10m through curve with R≤1000m	
Overbridge Abutments	Abutments	Either end (commencing 100mm in from abutment end) and every 10m through the structure	TC1-DRG-201406
Tunnels	Tunnel walls	Either end (commencing 100mm inside of tunnel portal) and every 10m through the structure	TC1-DRG-201406

Notes:

1) The Unit Manager Track and Civil Engineering reserves the right to instruct the installation of plaques outside of the circumstances noted in Table 11.1 should the new infrastructure not align with the Element/Structure type noted.
2) Track Monuments shall be placed nominally 200mm above design rail level of the nearest rail.

Each Track Monument shall be referenced by a Survey Plaque containing, at least, the following information:

a) Unique identifier (if applicable)
b) OHWS Identification (if applicable)
c) Track referenced
d) Kilometrage of TM to 1m
e) Curve radius (if applicable)
f) Transition Length (if applicable)
g) Design Track Centres from referenced track to adjacent track (if applicable)
h) Design Cant of referenced track (mm)
i) Horizontal offset from TM to Design running face of nearest rail of referenced track (mm)
j) Vertical offset from TM to top of nearest rail of referenced track (mm)

12. Geometry Design Requirements for Alignments at Platforms

12.1. New Corridor Design

A New Corridor is defined as a location where there is currently no existing track. The following minimum requirements shall apply for trackwork at platforms that are within new corridors:

a) Desirable Limits requirements noted in Table 9.1.
b) Turnouts are prohibited in or within 50m of the platform.
c) Changes of curvature within 50m of a platform prohibited.
d) Track grade shall be constant through the platform and for 50m beyond each end of the platform.
e) Track horizontal alignment shall be constant through the platform and for 50m beyond each end of the platform.
f) Track structure: new concrete sleepers (and ballast) or slab track with new AS50kg rail. New rail formation shall be provided.

12.2. New Platform or Trackwork within an Existing Corridor – Desirable Limits

An Existing Corridor is defined as a location where there is currently existing track. If approved by the Unit Manager Track and Civil Engineering, the following minimum requirements shall apply for the design of new platforms (or significant alternations to an existing platform – to be determined by the Unit Manager Track and Civil Engineering) and/or new trackwork at platforms that are in an existing corridor:

a) New Corridor requirements are preferred.
b) Desirable Limits requirements noted in Table 9.1.
c) Turnouts are prohibited in or within 30m of the platform.
d) Changes of curvature within 30m of a platform prohibited.
e) Track grade shall be constant through the platform and for 30m beyond each end of the platform.
f) Track horizontal alignment shall be constant through the platform and for 30m beyond each end of the platform.
g) Track structure: new concrete sleepers (and ballast) or slab track with new AS50kg rail. Rail formation treatment shall be proposed for approval.

12.3. New Platform or Trackwork within an Existing Corridor – Maximum (or Minimum) Limits

If approved by the Unit Manager Track and Civil Engineering, the following minimum requirements shall apply for the design of new platforms and/or new trackwork at platforms that are in an existing corridor:

a) Recommended requirements noted in Table 9.1. Maximum/Minimum requirements may be proposed for approval.
b) Turnouts are prohibited in or within 20m of the platform.
c) Changes of curvature within 20m of a platform prohibited.
d) Track grade shall be constant through the platform and for 20m beyond each end of the platform.
e) Track horizontal alignment shall be constant through the platform and for 20m beyond each end of the platform.
f) Track structure: new concrete sleepers (and ballast) or slab track with new AS50kg rail. Rail formation treatment shall be proposed for approval.

12.4. Temporary Platforms

A temporary platform is a platform that shall be used for a period of no more than six months (including construction time).

Where a temporary platform is provided, the requirements of Section 12.3 shall be met.

13. Design Documentation

13.1. General

Preparation, content and presentation of track design documentation shall be undertaken in accordance with the requirements of the following DPTI standards:

1. FR-AM-GE-806: Identification and Numbering of Technical Documents and Drawings
2. AM4-DOC-000364: Drafting Standard for AutoCAD Drawings

13.2. Geometric Design Documentation

Design details, as a minimum, shall include:

1. Survey co-ordinates and datums if available
2. Location details (bench marks, frame points, vertical curves, changes in grade)
3. Curvature
4. Length of curve
5. Length of tangent
6. Length of transition
7. Gradient
8. Cant and Cant Deficiency

9. Maximum allowable speed
10. Cant Gradient
11. Rate of Change of Cant
12. Rate of Change of Cant Deficiency
13. Vertical curve K value