Government of South Australia
Department for Infrastructure and Transport

Track Geometry – Tram System

Engineering Standard

Asset Management

TC1-DOC-003459

Document Amendment record

REV	CHANGE DESCRIPTION	DATE	COMMENTS
1	Initial Issue	14/06/2023	Supersedes Track Geometry CP-TS-976 (Sections 1, 2, 3 and 6)
Document Review Schedule:		3 yearly	

TABLE OF CONTENTS

1. Introduction

This standard supersedes Sections 1, 2, 3 and 6 of CP-TS-976: TransAdelaide Code of Practice Volume 3 – Tram System Track Geometry.

2. Purpose

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

4. Compliance

There are 3 types of provisions contained within this standard:

1. Requirements
2. Recommendations
3. Permissions

Requirements – it is mandatory to follow all requirements to claim full compliance with the standard. Requirements are identified within the text by the term '**must**'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term '**should**'. Recommendations recognise that there could be limitations to the universal application of the control, i.e., the identified control is not able to be applied or other controls are more appropriate or better.

Permissions **–** conveys consent by providing an allowable option. Permissions are identified within the text by the term '**may**'.

Deviation from a mandatory requirement noted within this standard is only permitted when an Engineering Waiver has been approved.

5. References

5.1. DIT Standards

DOCUMENT NAME	DOCUMENT NUMBER
Track and Civil Infrastructure Code of Practice, Volume 3 – Tram System, Track Geometry	CP-TS-976
Guard/Checkrails and Buffer Stops	CP-TS-982

5.2. DIT Documents

DOCUMENT NAME	DOCUMENT NUMBER
Identification and Numbering of Technical Documents and Drawings	FR-AM-GE-806
Drafting Standard for AutoCAD Drawings	AM4-DOC-000364
Naming and Numbering Conventions for DPTI Rail Assets and Infrastructure	AM4-DOC-000936
Development and Approval of Engineering Waivers	PR-AM-GE-807

5.3. DIT Standard Drawings

DOCUMENT NAME	DOCUMENT NUMBER
Standard Drawing – Non-Operational Signage – Track Monument – Platform Coping	TC2-DRG-201538
Standard Drawing – Non-Operational Signage – Track Monument – Sleeper Placement	TC2-DRG-201539
Standard Drawing – Non-Operational Signage – Track Monument – Horizontal Alignment Details	TC1-DRG-201408

5.4. Rail Industry and Australian Standards

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

6. Definitions

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

Rating - In the context of this standard, ‘rating’ is the compliance review of track geometry that has been designed and installed prior to this standard being published.

7. Horizontal and Vertical Alignment

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

7.1. Horizontal Alignment Components

Horizontal alignments must 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.
Various combinations of circular and transition curves are used, with the most desirable being a circular curve with identical transition curves at each end.

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) must 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 must 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 must 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 must have a unique co-ordinate set (E, N).

7.1.3. Circular Curves

A circular curve must 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 must 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 must be defined as a series of straight grades connected by vertical curves (VCs) or intersection points.

The parameters which define the components must 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 must be defined by a pair of terminal points called intersection points (IP), which should be located at whole 20m kilometrage points.

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

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

This percentage should 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 must be defined by the length (Lv) and should be a multiple of 20m.

The vertical curve must be based on the quadratic parabola.

8. Geometry Design – General

8.1. Design Abbreviations

Table 8.1 Table Abbreviations

TERM	SYMBOL	UNIT
Speed	V	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 must be to allow trams 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 must 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 engineering practices which allow for low maintenance track.

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.

8.5. Maximum or Minimum Design Limits

The Maximum or Minimum Design Limits allow for the track to be maintained within the safety limits (where relevant), however 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.

8.6. Track Gauge

The nominal track gauge of DIT tram tracks must be 1435mm (commonly referred to as standard gauge).
Gauge must be measured between the inside face of the rails (9mm below the top surface) and must consider any rail head flow.
Gauge widening must not be provided, other than as specified for special trackworks.

8.7. Tangent Track

Tangent track must be laid and measured between the tangent points of curves, points and crossings or the ends of the line. Tangent track must be as long as is reasonably practicable.
In general, tangent track must 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 Gradient

a) Gradients may be expressed in the form '1 in x' or as a percentage.
b) Gradient parameters are noted in Table :
c) Gradients should be as near level as possible.
d) The following must be considered in the selection of design gradient:
    a) Braking and traction performance of vehicles likely to use the line;
    a) Position of signals and operational regime;
    b) Projected rail adhesion conditions, including the effect of the weather;
    c) Clearances to structures;
    d) The combined effect of gradient and horizontal curvature where the gradient coincides with a small radius horizontal curve; and
    e) Sighting requirements.

8.9. Curve Compensation

In order to achieve a uniform resistance to tram movement, the gradients must be reduced on curves to compensate for the extra curve resistance.
The compensated gradient must be:

$$Gc = G - C \qquad \text{Equation (1)}$$

where:
Gc is the compensated design gradient
G is the uncompensated gradient
C is the degree of compensation

$$C = \frac{60}{R}\% \qquad \text{Equation (2)}$$

a) For new work, in order to achieve a uniform resistance to tram movement, gradients must be reduced on curves to compensate for the curve resistance by reducing the gradient percentage by $C = \frac{60}{R}\%$.
EXAMPLE: to achieve a 1 in 40 (2.5%) compensated gradient, on a curve of 200m radius the gradient would be reduced to 1 in 45.5 (2.2%).

b) On existing lines, to determine the equivalent gradient on curves which are not compensated, the gradient percentage must be increased by $C = \frac{60}{R}\%$
EXAMPLE: on a 1 in 40 (2.5%) uncompensated gradient, the equivalent gradient on a 200m radius curve would be 1 in 35.7 (2.8%).

8.10. Vertical Curves in Hogs and Sags

At changes of gradient greater than 0.200%, a vertical curve must be used between the two gradients of parabolic form and of length in accordance with the below equations:

$$L_v = \frac{R_v \Delta G}{100}$$ ……………………………………..Equation (3)

where:

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

ΔG = The difference in grade, where:
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 down grade negative.

R_v = The equivalent radius of the vertical curve, in meters

$$R_v = \frac{V^2}{12.96 \times a_v}$$ ………………………………...Equation (4)

where:

V is the speed in km/h

a_v is the vertical acceleration, with $g = \frac{9.81\text{m}}{\text{s}^2}$

The desirable minimum length of vertical curves and constant grades is 20m, with preferred increments of 20m. Longer grades are preferred with frequent changes of grade and use of vertical curves being avoided.

8.11. Lengths of Horizontal Straights and Curves

The alignment must be optimised, ensuring that straights are as long as possible, whilst maximising the radius of curves. Combinations of short straights and tight curves must not be used where a single larger radius curve can be used.

For all new design work:

a) The length of individual straight, transition, or circular curve elements should be equal to or greater than 20m. The absolute minimum length must be 12m. This minimum length may be reduced for a straight within a crossover.
b) Between contraflexure curves, a straight of minimum 20m must be provided. The absolute minimum length must be 12m.
c) Between similar flexure curves an adequate transition should be provided in accordance with Section 9.4.
d) Cant gradients must be not less than 20m long, including those between curves in a compound curve.

8.12. Cant and Speed – Explanation

a) When a tram 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, however, may 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 tram 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) The risk of derailment is increased if the Excess Cant appreciably exceeds one tenth of the gauge, i.e., 140mm. By considering a near stationary tram 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. As a result, well-maintained track may safely take a higher Applied Cant than poorly maintained track.

d) 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).

e) For passenger comfort:
   1) Cant Deficiency should not exceed 80mm; and
   2) The Rate of Change of Cant or Cant Deficiency should not exceed 35mm/s, however where space is restricted a rate of up to 55mm/s may be used in accordance with Section 9.4.2 (a) – Transitions of Restricted Length.

8.13. Cant related definitions/descriptions

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 during construction.

8.13.4. Actual Cant

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

8.13.5. Cross Level Variation

The Cross Level Variation is the unintended difference between the Design Cant and the Applied or Actual Cant at a discrete location.

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 tram.

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 tram is towards the outside of the curve.

$$E_q = E_a + E_d \qquad \text{Equation (5)}$$

Except as provided for in Section 9.4.2, Cant Deficiency must 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 tram 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 tram 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 must 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).

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).

8.13.14. Twist

The variation in the Cant between two track locations separated by a nominal distance interval.

9. Geometry Design

9.1. Limit Values of Track Parameters

Except as provided for elsewhere in this document, the parameters given in Table must be adopted (refer to Section 8 for Parameter descriptions):

Table 9.1: Limit values for Track Parameters

PARAMETER	DESIRABLE	RECOMMENDED	MINIMUM	MAXIMUM
HORIZONTAL GEOMETRY				
Radius – Existing Main Line realignment	500m	250m	25m	4000m [0]
Radius – New Main Line works	1000m	500m	25m	4000m [0]
Radius – Existing siding realignment			25m	4000m [0]
Radius – New siding works			25m	4000m [0]
Radius – Platforms [1]	Straight			
Maximum Design Cant:				
Where rails are continuously welded, and curves are properly transitioned				100mm
Where rails are not continuously welded, or curves are not properly transitioned				70mm
At Platforms and Level Crossings (LX)	0mm			20mm (LX)
On diverging route of tangential turnouts				0mm
Maximum Negative Cant				0mm
Maximum Cant Deficiency (refer to Sections 8.13.7 and 9.2.3):				

PARAMETER	DESIRABLE	RECOMMENDED	MINIMUM	MAXIMUM
Where rails are continuously welded, and curves are properly transitioned				80mm
Where rails are not continuously welded, or curves are not properly transitioned				50mm
On diverging route of tangential turnouts				40mm
Horizontal bend				40mm
Maximum Excess Cant (negative Deficiency)				70mm
Cant Gradient	1:1500	1:1000		1:400
Rate of change of Cant, Cant Deficiency, or Excess Cant [see Section 8.12(e)(2)]:				
Plain track	35mm/s			[3]
On diverging route of tangential turnouts	35mm/s			[3]
Horizontal Bend Angle				0° 15´ 00''
VERTICAL GEOMETRY				
Vertical curve radius (refer to Section 8.10)			1500m	
Vertical curve length		35m	20m	
Length between vertical curves	50m	35m	30m	
Vertical Acceleration	1% g (0.1m/s^2)	2% g (0.2m/s^2)		3% g (0.3m/s^2)
Grade length		35m	20m	
Maximum grade (compensated):				
Ballasted track	1 in 100 (1%)	1 in 50 (2%)		1 in 40 (2.5%)
Slab track	1 in 100 (1%)	1 in 33.3 (3%)		1 in 22.2 (4.5%)
Maximum grade (compensated) through a platform:				
Ballasted track and slab track	1 in 200 (0.5%)			1 in 100 (1%)
Maximum grade (compensated) at a Turnback and Depot:				
Ballasted track and slab track	1 in 200 (0.5%)			1 in 100 (1%)
GENERAL				
Spacing of Vehicle Bogies	12m			

Notes:
[1] Refer to Section 12
[2] This excludes instantaneous radii in transitions
[3] Refer to Section 8.12(e)(2)
Design speeds are to be rounded down to the nearest 5km/h

9.2. Horizontal Curves

9.2.1. Radius

a) Refer to Table for the limit values for radii.
b) On all curves on main lines where the radius is less than 325m the low leg (inside leg) of the curve must be fitted with a continuous check rail in accordance with CP-TS-982 (Guard/check rails and buffer stops).
c) Use of curve radii of less than 100m must be carefully considered as they are likely to cause rail squeal.
d) For further detail refer to Section 12 - Geometry Design Requirements for Alignments at Platforms

9.2.2. Cant and Speed Requirements

Tests show that for passenger comfort:

a) Cant Deficiency must not exceed 80mm; and
b) Rate of Change of Cant or Cant Deficiency must not exceed 35mm/s. However, where space is restricted a Rate of Change of Cant or Cant Deficiency of up to 55mm/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 .

9.2.4. Cant/Speed Relationship

a) The design speed must be the maximum speed that trams are not to exceed.
b) The maximum allowable vehicle speed for any curve must be determined by Equation 6. Where “V” exceeds the maximum allowable line speed, the line speed must be used and Cants recalculated accordingly.

<u>Determination of Speed:</u>

$$V = \sqrt{(R.Eq)/GF} \quad \text{Equation (6)}$$

where:
GF = Gauge Factor = 11.82

c) The Cant that may be applied to a curve must be determined by Equation 7:

<u>Determination of Cant – Using Equilibrium Cant Formulae:</u>

$$E_q = GF(\frac{V^2}{R}) \quad \text{Equation (7)}$$

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 for the location, then determine the maximum allowable Equilibrium Cant and then calculate the maximum allowable vehicle speed as in Equation 6.

9.3. Bends

9.3.1. Occurrence of Bends

Bends occur where two tangent tracks meet at near 180° without an intermediate curve.
Horizontal bends should be avoided where possible as they are not desirable.

9.3.2. Maximum Allowable Speed through Bends

The maximum allowable speed through a bend must be as shown in Equation 8:

$$V_m = 2.20\sqrt{\frac{\beta_d B_c}{\beta}} \quad \text{Equation (8)}$$

On AMPRN track, β_d = 40mm and B_c = 12m, and therefore that:

$$V_m = \frac{48}{\sqrt{\beta}} \quad \text{Equation (9)}$$

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 must be in clothoid form.
b) The centreline of the track on the true curve must 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 must be limited to 35mm/s and the Cant Gradient to no steeper than 1 in 400.
Thus, the minimum lengths of transitions must be calculated as shown in Equations 10, 11 and 12:

<u>Length of Transitions:</u>

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

$1)\ Lt = 0.0079.Ea.V$ ……………………….Equation (10)

$2)\ Lt = 0.0079.Ed.V$ …………………….... Equation (11)

$3)\ Lt = 0.4.Ea$ ………………………………Equation (12)

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(c). 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 (c). Under no circumstances must this value exceed 55mm/s [see Section **Error! Reference source not found.**(b)], and by adopting it, the formulae in Section 9.4.1 are modified as follows:

1) $Lt = 0.005.Ea.V$ …………………… Equation (13)

1) $Lt = 0005.Ed.V$ ……………………. Equation (14)

2) $Lt = 0.4.Ea$ ………………………..… Equation (15)

b) Adopt a higher Cant Deficiency than that specified in Section 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 Section 9.4.1 (c) or Section 9.4.2 (b) until the full Cant is applied. The distance over which the cant is increasing must be symmetrical with the distance over which the track is transitioned.

If the use of one of the above results in undesirable conditions, then the design speed must 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 must 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 must be 12m long.
By considering the transition as 12m 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 must be applied over a length that is symmetrical about the PT/PC/PCC.
The Cant must be increased in accordance with the maximum Rate of Change of Cant or Cant Deficiency or Cant Gradient until the maximum Cant is reached at the end of the virtual transition.
The maximum vehicle design speed will be attained if the Actual Cant equals the Cant Deficiency.

b) Curve un-canted and not transitioned

If the curve is un-canted and without transition, the maximum allowable vehicle speed must be determined using the maximum allowable Cant Deficiency for the curve.
The Cant Deficiency is assumed to build up over the virtual transition and must need to be checked to ensure that it does not exceed the allowable Cant Gradient.

9.4.4. Compound Curves

It is preferred to have constant/consistent Cant through compound curves except where this impacts upon the curve speed.
In compound curves, transitions between different radii of the compound curve must use the same criteria as for a simple curve, with the following variations:

a) Calculations involving Cant must use the difference in Cant between the two radii.
b) Calculations involving Cant Deficiency must use the difference in Cant Deficiency between the two radii.
c) The cant and speed must be determined for each curve individually.
d) The length of transition between the two curves must be the highest value of L_t as derived from the following three equations (derived from 9.4.1):

$$L_t = 0.0079.(\mathrm{Ea1} - \mathrm{Ea2}).\mathrm{V} \quad \text{Equation (16)}$$

$$L_t = 0.0079.(\mathrm{Ed1} - \mathrm{Ed2}).\mathrm{V} \quad \text{Equation (17)}$$

$$L_t = 0.4.(\mathrm{Ea1} - \mathrm{Ea2}) \quad \text{Equation (18)}$$

9.4.5. Reverse Curve

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

a) Calculations involving Cant must use the sum of the Cants for the two radii.
b) Calculations involving Cant Deficiency must use the sum of the Cant Deficiencies for the two radii.
c) The length of transition between the two curves must be the highest value of L_t as derived from the following three equations (derived from 9.4.1):

$$L_t = 0.0079.(Ea1 - Ea2).V$$ .... Equation (19)

$$L_t = 0.0079.(Ed1 - Ed2).V$$ .... Equation (20)

$$L_t = 0.4.(Ea1 - Ea2).V$$ .... Equation (21)

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 must not be exceeded.

9.5. Speed Through Points and Crossings

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

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

Points and crossings must:

a) be located on tangent track;
b) not contain vertical curves; and
c) be designed through a constant vertical grade (0% preferred) and horizontal alignment.

10. Track Geometry Requirements for Construction

10.1. New Construction Tolerances – Ballasted Track

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

10.2. Re-used Material Construction Tolerances – Ballasted Track

Use of any re-used material must be approved by and subject to tolerance limits nominated by the SAPTA Asset Manager - Train and Tram Assets.

Where track is to be constructed by re-using materials, in particular worn rail, the geometric tolerances must comply with the tolerances as shown in Table

Re-used rail must 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, must comply with the tolerances as shown in Table .

Table 10.1: Tolerances for track construction

GEOMETRIC MEASURE	NEW BALLASTED TRACK	REUSED BALLASTED TRACK	NEW FIXED TRACK
Gauge:			
Tangent and curved track	+3mm, -3mm		+3mm, -3mm
Tangent – worn rail		+7mm, -3mm	
Curve – worn rail		+9mm, -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	±3mm
Track Alignment:			
Tangent and Curve	±10mm	±10mm	±3mm
Variation between adjacent survey monuments	±10mm	±10mm	±5mm
At platforms (+ is away from platform)	+10mm, -5mm	+10mm, -5mm	+3mm, -0mm
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	±3mm	±3mm	±2mm
Top Surface:			
Defects in 10m chord	±5mm	±5mm	±3mm
Track Level [1]			
Plain track	±20mm	±20mm	±3mm
Through platform	+10mm, -0mm	+10mm, -0mm	±3mm
Overbridges with minimum ballast depth	+10mm, -10mm	+10mm, -10mm	
Concrete sleepers [2]			
Plain track spacing	±20mm	±20mm	±10mm
Skew	±10mm	±10mm	±10mm
Verticality of Ri57A rail (measured relative to vertical			+- 1 degree

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
3. The tolerances noted above must be considered in alignment with other relevant tolerance.

11. Track Monumenting

To allow for monitoring of the track alignment and track position at critical locations, regular Track monuments must be provided.
As a minimum, the track monuments must be located as shown in Table :

Table 11.1: Required locations for Track Monuments

ELEMENT/STRUCTURE	LOCATION	SPACING	DRAWING
Tangents, Circular Curves and Transitions	*Ballasted Track:* Sleeper *Slab Track:* Slab	Start and end points	TC2-DRG-201538 TC1-DRG-201408
Tram Stops	*Ballasted Track:* Platform coping	Either end (commencing 100mm in) and every 10m.	TC2-DRG-201539

Notes:

1. SAPTA reserves the right to instruct the installation of plaques outside of the circumstances noted in Table should the new infrastructure not align with the Element/Structure type noted.
2. Each Track Monument must be referenced by a Survey Plaque containing, at least, the following information (if applicable) for the referenced track/location:
   a) Unique identifier
   b) Track referenced
   c) Kilometrage to 1m (value not to be nominated until Tram Track Master Chainage has been developed
   d) Design curve radius
   e) Design transition length
   f) Design track centres from reference track to adjacent track
   g) Design Cant
   h) Horizontal offset from the track monument to the design running face of the nearest rail
   i) Vertical offset from the track monument to the design level of the nearest rail

12. Geometry Design Requirements for Alignments at Platforms

This section details the minimum requirements to be achieved in relation to track geometry alignment and track structure through, and on the approach/departure to tram stop platforms. These requirements have been defined in order to increase safety, maximise maintenance outcomes and future proof tram stop infrastructure.
New platforms must be a minimum of 45m long (excluding access ramps).

New platforms must allow for the future capability to:

- operate wide-bodied trams (static width of 2650mm); and
- provide 70m platform lengths (without significant alteration of infrastructure).

The current AMPRN trams have a static width of 2400mm and have the capability to couple and operate revenue services together (Flexity to Flexity and Citadis to Citadis).

12.1. New Corridor Design

A New Corridor is defined as a location where there is currently no existing track.
New grade separations are not classified as existing track.
The following requirements must apply for trackwork at new platforms (inclusive of future platform extension limits) that are within new corridors:

a) Refer to Table 9.1 for items not noted here.
b) Turnouts must not be provided within the platform.
c) Turnouts must not be provided within 20m of the end of platforms.
d) The vertical element must be constant within the platform.
e) A vertical curve element must not be provided within the platform.
f) On slab tracks, change of vertical elements may be located at the platform ends.
g) On ballasted track, change of vertical elements must be located a minimum of 20m away from platform ends (Desirable = 35m, Recommended = 25m).

h) The horizontal element must be constant within the platform.
i) On slab track, change of horizontal elements must be located away from platform ends so as not to affect the clearance requirements through platforms.
j) On ballasted track, change of horizontal elements must be located a minimum of 15m away from platform ends (Desirable = 35m, Recommended = 20m).
k) Track structure: new concrete sleepers (and ballast) or slab track with new AS50kg/Ri57 rail and new rail formation must be provided.

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

An Existing Corridor is defined as a location where there is currently existing track.
The following requirements must apply for trackwork at new platforms (or significant alternations to existing platforms - to be determined by the SAPTA Asset Manager - Train and Tram Assets) that are within existing corridors:

a) New Corridor Design requirements are preferred.
b) Refer to Table 9.1 for items not noted here.
c) Turnouts must not be provided within the platform.
d) Turnouts must not be provided within 20m of the ends of the platform.
e) A vertical curve element must not be provided within the platform.
f) On slab tracks, change of vertical elements may be located at the platform ends.
g) On ballasted track, change of vertical elements must be located a minimum of 15m away from platform ends (Desirable = 30m, Recommended = 20m).
h) The horizontal element must be constant within the platform.
i) On slab track, change of horizontal elements must be located away from platform ends so as not to affect the clearance requirements through platforms.
j) On ballasted track, change of horizontal elements must be located a minimum of 10m away from platform ends (Desirable = 30m, Recommended = 15m).
k) Track structure: new concrete sleepers (and ballast) or slab track with new AS50kg/Ri57 rail. Rail formation treatment must be proposed for approval.

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

An Existing Corridor is defined as a location where there is currently existing track.
The following requirements must apply for trackwork at new platforms (or significant alternations to existing platforms - to be determined by the SAPTA Asset Manager - Train and Tram Assets) that are within existing corridors:

a) New Corridor Design or Existing Corridor – Normal Limits requirements are preferred.
b) Refer to Table 9.1 for items not noted here.
c) Turnouts must not be provided within the platform.
d) Turnouts must not be provided within 15m of the ends of the platform.
e) A vertical curve element must not be provided within the platform.
f) On slab tracks, change of vertical elements may be located at the platform ends.
g) On ballasted track, change of vertical elements must be located a minimum of 10m away from platform ends (Desirable = 25m, Recommended = 15m).
h) The horizontal element must be constant within the platform.
i) On slab track, change of horizontal elements must be located away from platform ends so as not to affect the clearance requirements through platforms.
j) On ballasted track, change of horizontal elements must be located a minimum of 5m away from platform ends (Desirable = 25m, Recommended = 10m).
k) Track structure: new concrete sleepers (and ballast) or slab track with new AS50kg/Ri57 rail. Rail formation treatment must be proposed for approval.

12.4. Temporary Platforms

A temporary platform is a platform that must 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 must be met.

13. Design Documentation

13.1. General

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

a) FR-AM-GE-806: Identification and Numbering of SAPTA Technical Documents, Records and Drawings
b) AM5-DOC-003408: Drafting Requirements for SAPTA Drawings

13.2. Geometric Design Documentation

Design details, as a minimum, must include:

a) Survey co-ordinates and datums if available
b) Location details (benchmarks, frame points, vertical curves, changes in grade)
c) Curvature
d) Length of curve
e) Length of tangent
f) Length of transition
g) Gradient
h) Cant and Cant Deficiency
i) Maximum allowable speed
j) Cant Gradient
k) Rate of Change of Cant
l) Rate of Change of Cant Deficiency
m) Vertical curve K value