California High-Speed Train Project

TECHNICAL MEMORANDUM

Turnouts and Station Tracks
TM 2.1.3

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System Level Technical and Integration Reviews

The purpose of the review is to ensure:
- Technical consistency and appropriateness
- Check for integration issues and conflicts

System level reviews are required for all technical memoranda. Technical Leads for each subsystem are responsible for completing the reviews in a timely manner and identifying appropriate senior staff to perform the review. Exemption to the System Level technical and integration review by any Subsystem must be approved by the Engineering Manager.

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Paul Mosier Date

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Frank Banko Date

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ABSTRACT

This technical memorandum presents guidance for the geometric design of turnouts, crossovers, and station connection tracks with turnouts and return curves to be used in the basic design in order to achieve a safe and reliable operating railway that meet applicable regulatory requirements and achieve the operational and performance requirements for equipment traveling on California High-Speed Train (CHST) rail lines.

- This technical memorandum presents the theoretical basis for the geometric design for turnouts.
- This technical memorandum presents a summary of turnout designs used in the US and on high speed train systems in France, Japan, Germany, Italy, and Austria for purposes of examples, foundation and substantiation of the designs developed in this technical memorandum.
- This technical memorandum develops and presents the specific geometric designs to be used in turnouts, crossovers and station connection tracks.
- This technical memorandum is not a specification for track materials or track construction but is the guideline for the development of those specifications.
- This technical memorandum will not include analysis or discussion of the operation of turnouts, including such things as the nature and spacing of drive points or the usage of switch machines and additional drives.

The information presented in this technical memorandum will be included in the CHSTP Design Manual.

1.0 INTRODUCTION

This Technical Memorandum presents the basis of design for turnout geometry. The geometric design will be the same regardless of the track form on which it is constructed. It also includes standardized station track layouts, high-speed crossovers between main lines and preliminary information on development of other track layouts that involve turnouts and crossovers. Components and track material will be discussed only as relevant to geometric issues.

This Technical Memorandum will not discuss such issues as nature of frogs, whether fixed, spring, or movable point, nor the operation of movable point frogs. The long switch points inherent in high speed turnouts will require drives at multiple points. The spacing and nature of these drives will not be discussed in this Technical Memorandum.

This Technical Memorandum is not intended to be a specification for track materials or track construction. It is intended to be the basis for the development of the specification for those items. General track information on such items as basic track materials, fastenings, and supports, will bee the subject of another Technical Memorandum. .

Following review, specific guidance in this technical memorandum will be excerpted for inclusion in the CHSTP Design Manual.

1.1 PURPOSE OF TECHNICAL MEMORANDUM

The purpose of this technical memorandum is to develop the turnout, crossover, and station connection track geometries to be used in the CHSTP system.

1.2 STATEMENT OF TECHNICAL ISSUE

The objective is to develop turnout geometries appropriate to the nature and speed of the trains to be operated.

1.3 CONCEPTS AND DEFINITIONS

1.3.1 Definition of Terms

Technical terms and acronyms will use common American terminology. A number of common terms are different between American and European terminology. European term will be noted in the following definitions and as appropriate elsewhere, but otherwise will not normally be used.

Unless otherwise noted, definitions are either identical to or closely based on the definitions found in either AREMA's <u>Manual for Railway Engineering</u> (AREMA Manual) or <u>The Dictionary of Railway Track Terms</u> by Christopher F. Schulte, Simmons Boardman Publishing, 1990.

<u>Acronyms:</u>

- CHSTP: California High Speed Train Project
- CFR: Code of Federal Regulations
- FRA: Federal Railroad Administration
- AREMA: American Railway Engineering and Maintenance of Way Association
- UIC: International Union of Railways. Acronym is from the French original, Union Internationale des Chemins de Fer.
- TSI: The European Union's Technical Specification for Interoperability.

<u>Parts of a turnout:</u>

- Frog: Commonly called a Crossing in European terminology.
    - Fixed Frog: Term essentially synonymous with Frog. "Fixed" is sometimes used as part of the name on railroad systems that also use spring frogs and swing nose frogs in order to clarify the type of frog used in a given situation.

    - Spring Frog: A frog without a fixed open flangeway on one side between the frog point and wing rail that has springs holding that wing rail up against the frog point on that side so as to provide unbroken wheel support for the main track. The other wing rail is fixed. Main track traffic travels on the fixed wing side of the frog, not moving the frog. The wheels of diverging side traffic opens the sprung wing rail which is then forced closed by the spring after the wheel has passed. Spring frogs are either right handed or left handed. These devices are normally used only where the traffic on the side springing the wing rail is 20% or less of the total traffic over the frog. These devices are generally unknown outside North America.
    - Swing Nose Frog: A frog in a turnout with a movable frog point connected to a switch machine for manipulation relative to the switch position.
    - Point of Frog: In American terminology, the point where the gauge lines are ½ inch apart, or the point located one-half the distance in inches from the intersection of the gauge lines of the rails through the frog. In European terminology, the theoretical point of intersections of the gauge lines of the rails through the frog. The point as defined in European terminology is usually called the theoretical point of frog in American terminology.
    - Heel of Frog: End of rails that are part of the frog assembly on the end away from the switch
    - Toe of Frog: End of rails that are part of the frog assembly on the end toward the switch.
- Lead: American definition: The distance from the actual point of switch to the ½ inch point of frog. European definition: The nearest European equivalent is the distance from the switch end theoretical beginning of the turnout curve to the theoretical point of frog.
- Switch: The component of a Turnout consisting of switch rails and connecting parts providing a means for making a path over which to transfer rolling stock from one track to another.
    - Split Switch: Synonymous with Switch on modern railroads.
    - Secant Point Switch: A switch point in which the arc of the radius of the switch rail or the turnout itself crosses the gauge line of the stock rail. American standard switch rails are Secant Point Switches.
    - Tangent Point Switch: A switch point in which the arc of the radius of the switch rail or the turnout itself matches the gauge line of the stock rail. European and most other turnouts are designed to be Tangent Point Switches.

1.3.2 Units

The California High-Speed Train Project is based on U.S. Customary Units consistent with guidelines prepared by the California Department of Transportation and defined by the National Institute of Standards and Technology (NIST). U.S. Customary Units are officially used in the United States, and are also known in the US as “English” or “Imperial” units. In order to avoid any confusion, all formal references to units of measure should be made in terms of U.S. Customary Units.

Guidance for units of measure terminology, values, and conversions can be found in the Caltrans Metric Program Transitional Plan, Appendice B U.S. Customary General Primer (http://www.dot.ca.gov/hq/oppd/metric/TransitionPlan/Appendice-B-US-Customary-General-Primer.pdf). Caltrans Metric Program Transitional Plan, Appendice B can also be found as an attachment to the CHSTP Mapping and Survey Technical Memorandum.

2.0 DEFINITION OF TECHNICAL TOPIC

2.1 GENERAL

The general basis for materials standards shall be the AREMA Manual. Some reference and use will be made of UIC and other European standards where appropriate.

2.2 LAWS AND CODES

Various codes and standards referenced herein include but are not necessarily limited to the following:

Certain requirements of the Federal Railroad Administration (FRA), among them:

- CFR Part 213, Track Safety Standards, generally and also in particular Subpart G -Train Operations at Track Classes 6 and Higher.

Other Design Guidelines:

- The Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA Manual), in particular the following chapters:
  - Chapter 4: Rail
  - Chapter 5: Track
- The AREMA Portfolio of Trackwork Plans, commonly referenced as the AREMA Portfolio.
- UIC Leaflet 703, Layout Characteristics for Lines Used by Fast Passenger Trains
- UIC Leaflet 711, Geometry of Points and Crossings with UIC Rails Permitting Speeds of 100 km/h or more on the Diverging Track
- The European Union's Technical Specification for Interoperability (TSI), Infrastructure Sub-System.
- Deutsche Bahn's publication 800.0120, Netzinfrastruktur Technik Entwerfen; Weichen und Kreuzungen. (Translated: Infrastructure Technical Information, Switches and Crossings).
- Taiwan High Speed Rail Corporation (THSRC), Volume 9, Design Specifications, Section 2, Alignment Design Specification

The latest version of the above standards shall be the one applicable.

There is no one single law or code or design standard currently in existence that can be followed to produce a high speed railroad appropriate to the intended purpose and use anticipated. In discussion on track, reference is frequently made to FRA Track Safety Standards. However, these are not design standard in the normal sense. While they do have some requirements that could affect the design, their primary purpose is track safety.

UIC 711 has a specific set of standard high speed turnout geometries, but it appears that most European countries use their own standard geometric layouts which in a number of cases are not even similar to the UIC layouts.

The Infrastructure TSI offers limited guidance in development of turnout designs, primarily related to limitations on change in lateral acceleration, use of movable frogs, and flangeway and locking requirements.

In case of differing values or conflicts among the various design requirements and between any of them and the following design guidelines, the standard followed shall be that which results in the highest level of satisfaction of all requirements or that deemed the most appropriate.

2.3 STANDARDS

2.3.1 Design Standards for Construction

These are the minimum standards of alignment deviation that should appear in the construction specification. Meeting or exceeding these standards shall also be required for the track condition following any adjustments or maintenance work. Allowance for defective materials and components should be very low or nil.

2.3.2 Maintenance Standards

These are the minimum standards to which the track may be allowed to deteriorate without either the speed being reduced or traffic halted altogether. These standards shall include both geometric deviations and component wear / deterioration / degradation considerations. The worst-case for these standards should be no more than half way toward the limits that are determined to be safety standards. Geometric deviation maintenance limits should be based on ride quality considerations, not safety considerations and are therefore likely to be well under half-way toward the geometric deviation safety limits.

2.3.3 Safety Standards

Safety standards define the standards below which the track is regarded as unable to perform its function at the design speed. Safety standards are subject to determination by the FRA. These are the minimum standards to which the track may be allowed to deteriorate with either the speed being reduced or traffic halted altogether. These standards shall include both geometric deviations and component wear / deterioration / degradation considerations.

3.0 ASSESSMENT / ANALYSIS

3.1 TERMINOLOGY AND CALCULATION METHODS

There are a few significant differences between the normal European and the normal American way of describing various facets of turnouts and design processes. These differences may lead to confusion if not understood.

3.1.1 Differences in Method of Description and Analysis

In American terminology, a turnout is defined by its frog number and all other aspects of the turnout design are related to that frog number, though with some variations. The frog number definition is also used by the British and Japanese. In American, British, and Japanese calculations, the frog number – frog angle relationship is:

Angle = 2 * atan(0.5/number)

The value is normally rounded to the nearest second of angle and all further calculations based on that derived dms angle.

In European calculations the radius is defined and all values calculated from that radius. The frog may be either straight or curved. Therefore quite frequently there will be two and sometimes more angles for a single defined radius, or multiple and significantly different radii for the same angle. In European calculations the frog number – frog angle relationship is Number = 1/tan(angle), and is normally written as the ratio 1:N. For curved frogs, the location at which this angle is measured and the "N" determined is not the point, but the angle between the ends of the rails on the heel end of the frog. Examples that may be seen in European turnout lists are such things as a 190-1:9 and a 300-1:9. In the 190-1:9, the curve radius is 190 meters and ends short of the frog. The frog is straight with a 1:9 ratio, angle 6d 20m 25s. In the 300-1:9, the curve radius is 300 meters and carries completely through the frog. The 1:9 ratio is defined as being at the end of the heel of the frog. At the point (nose) of the frog, the angle is 5d 35m 59s, which is equivalent to a No. 10.22 in American terminology. For the same 300 meter radius there is also a straight frog version, commonly at a ratio of 1:12, angle 4d 45m 49s, which is called a 300-1:12.

The beginning point of an American turnout is the actual point of switch. In European turnouts, the beginning point is defined as the theoretical beginning point of the curve through the turnout. The actual point of switch is cut back a short distance beyond that point.

The point of frog as defined in American turnouts is referred to as the ½ inch point of frog. It is not at the location where the gauge lines of the rails actually meet. It is defined variously as the point where the gauge lines are ½ inch apart or as one-half the distance in inches from the theoretical point of the frog. To add to the confusion, the actual physical point of frog on modern American frogs is not at the ½ inch point. It is located where the gauge lines of the rails reach $^5/_8$ inch separation. The point of frog as defined in European terminology and calculations is the theoretical point of intersection of the gauge lines of the rails.

3.2 TYPES OF TURNOUT GEOMETRY

3.2.1 Simple Circular Curve (Tangent Point Geometry)

The standard turnout geometry in most of the world is a single simple curve beginning at or ahead of the actual point of switch and continuing either completely through the frog or else stopping at a point short of the frog unit. In most of the world this type of geometry has no particular name. Since it is not standard in the US and other locations using AREMA based turnout geometry, it is referred to as either a Tangent Point Turnout or a Tangent Geometry Turnout. For these turnouts the radius of the switch point and the radius of the curved closure rail are identical. These turnouts will always be longer than secant point turnouts with the same frog angle.

Generally, turnouts of this geometry are defined by radius or a combination of radius and frog number. When frog number is used as part of the definition, if the frog is curved, normally the number and angle given in European descriptions are those at the heel of frog, not at the point, as is the norm in American descriptions.

3.2.2 Secant Point Geometry (AREMA Geometry)

The name for this type of turnout is based on the nature of the switch point. Switch points are either straight or curved. The straight points have large point angles and are normally used only in low speed turnouts. The curved points also have a relatively large entry angles with the extended arc of the switch point curve always crossing the gauge of the stock rail. For some, but not all designs the extended arc of the closure rail curve between the heel of switch and toe of frog also crosses the gauge line of the stock rail. Due to the nature of the geometry of these turnouts, high lateral forces occur at the point of switch. The resulting relatively short switch point lengths compensates, in part, for the increased effort required to maintain the alignment of the switch point.

3.2.3 Spiral or Transition Geometry Turnouts

With increased speed the entry and exit forces to turnouts become more pronounced. To reduce this effect, transitions in the internal curve radius of the turnouts are used. There are several variations in the nature of these transitions that will be discussed more fully in Section 3.4 in the description of specific turnout designs. These variations are:

- **Full radius at the switch point with a single transition through the frog end:** Geometries of this nature are found primarily in 160 km/h (100 mph) and higher speed UIC and SNCF turnouts used in crossovers or connections to a parallel track. The SNCF versions of some of these turnout designs have a short length of arc of constant radius at the switch end and others are a single spiral only with a zero length arc. Turnouts of this geometric type reduce the change in lateral forces to about the same as that in normal spiral curves for the crossover, but do not reduce the sudden change in lateral force at the switch point at all. Turnouts of this geometry type have very long low angle frogs for their design speed compared to turnouts with other forms of geometry. Since frogs on these designs are in the spirals, their geometry is complex.
- **Switch end Spirals on Turnouts:** Reduction in switch point entry forces may be accomplished by use of a spiral on the switch point end. To avoid an extremely long very thin switch point, the switch end spiral is normally not a complete spiral but effectively a combining spiral as would be used at the point of compounding in a compound curve. The nominal point radius is set at a value that provides for an acceptable lateral jerk rate (see 3.3.2). This curve is normally of zero length and is the beginning point for a spiral to the radius for the central portion of the turnout. Systems that use spiral switch points usually apply them to turnouts with design speeds of 100 km/h to 120 km/h) (60 to 75 mph) and higher. Even with the compound curve nature of the spiral, switch points on these turnouts are quite long for the given central radius, but the maintenance required for this extra length is mitigated by their lower wear rate.
- **Turnouts with two Spirals:** Turnouts with spirals on both ends are used where turnouts with switch end spirals are to be part of crossovers between close track centers. The smaller center radius of some turnout designs of this nature has a zero length. Other turnout designs have center radii length equal to or greater than the spiral length, which results in a shorter overall turnout length for a given central radius. Again, a spiral through the frog results in a long and complex frog.

3.3 GEOMETRIC THEORY – LATERAL ACCELERATION AND TRANSITIONS

3.3.1 Lateral Acceleration – Unbalanced Superelevation

Lateral Acceleration is the name for what is commonly called centrifugal force. It can be very simply calculated by $LA = V^2 / R$, providing the units are consistent throughout the equation. That is, if V is in feet/second and R is in feet, then the result is in feet/second/second, or ft/sec^2. (To convert mph to ft/sec, multiply by 44/30.) If it is desired to have lateral acceleration as a percentage of gravity, then divide by 32.174 ft/sec^2. If metric units are used, then the units of the results are m/s^2, and gravity is 9.80665 m/s^2. (To convert km/h to m/s, divide by 3.6.) Simply using 32.2 ft/s^2 or 9.8 m/s^2 as appropriate provides sufficient precision for the purposes of these calculations. The advantage in using lateral acceleration instead of superelevation is that track gauge is not part of the formula.

When track gauge and gravity are included, along with use of convenient units of inches for superelevation and miles per hour for speed, the formula, SE = 4.0 V^2 / R, is derived. Since much of the basic theory of the forces in turnouts is European in origin, note that in metric units this formula becomes SE = 11.8 V^2 / R, where SE is in millimeters, V is in km/h, and R is in meters. Since for very practical constructability reasons turnouts are always built without any superelevation in their curves, the formula as applied to turnouts is for unbalanced superelevation and is usually written as EU or E_{unb} = 4.0 V^2 / R, or in metric units as EU or E_{unb} = 11.8 V^2 / R.

UIC 711: 1 – Switch with Simple Diverging Track states in part:

> It is known that on a curved track the running speed causes a centrifugal acceleration γ (m/s^2) linked with the speed and radius, and is also expressed in terms of cant deficiency **I** (mm).
>
> Because of the sudden change of curvature when passing from straight track to the curve of the diverging route, cant deficiency should be limited. The can deficiency value to be adopted consequently lies between 80 and 100 mm (100 mm being the maximum).

Further discussion equates the values for unbalanced superelevation (cant deficiency) to lateral acceleration as follows: 80 mm = 0.523 m/s^2 through 100 mm = 0.654 m/s^2. In US Customary units these relationships become $3^1/_8$ inches = 1.72 ft/sec^2 and 4 inches = 2.15 ft/sec^2 which are higher than the values normally used in US practice and a number of other locations outside Europe. In the Taiwan High Speed Railway, turnout speed limits were based on not exceeding 80 mm ($3^1/_8$ inches) of cant deficiency, and the ride quality through the turnouts indicates that this level of deficiency is a reasonable limit in high-speed train service.

AREMA Manual Chapter 5: Section 3.4, Speeds of Trains Through Level Turnouts (1956) states in part:

> b. Speeds through turnouts with either straight or curved switch points are calculated from the equation E = 0.0007 V^2D-3 . . ., where D equals the degree of curvature of the closure curve or the switch curve, whichever is sharper; for turnouts with straight switch points, D of the switch point curve is the degree of curvature of a curve having a central angle equal to the switch angle and a chord length equal to the length of the switch points.

Despite this statement, most US railroad companies set their turnout speeds at lower limits, with unbalanced superelevation seldom exceeding about 2½ inches which is a lateral acceleration of 1.4 ft/sec^2. There are two reasons behind these lower limits: First due to the use of switch points with relatively large entry angles there is a significant jerk at the point. Even the AREMA curved switch points have significantly larger entry angles at the point than is normal for European and Japanese switch points. Second, ride quality is better and the turnout components will last longer with lower speed traffic on the curved side.

3.3.2 Transition Rate – Lateral Jerk – Pull-In Jerk

The change in lateral acceleration per unit of time is the lateral jerk, called the pull-in jerk in some publications. Thus, LJ = LA / t, where "t" is the time it takes for the transition to occur, giving Lateral Jerk units of feet/second/second/second or ft/sec^3. If metric units are used, then the units of the results are m/s^3.

When it is desired to express this factor as a transition rate in superelevation or unbalanced superelevation, then either actual superelevation (SE) or unbalanced superelevation (EU) is substituted for LA in the formula in the preceding paragraph. Given that the subject is turnouts which have no superelevation, the formula becomes LJ = EU / t, with units of inches per second or millimeters per second, depending upon the measuring system used.

3.3.3 Virtual Transition Rate

The time in the Lateral Jerk formula is the elapsed time over the transition spiral. For turnouts which normally have no spiral and for unspiraled curves, the length of spiral would be zero, giving a time of zero and therefore a transition rate of infinity. To avoid this obvious impossibility and develop a number that could be used in design, the concept of the "Virtual Transition" was developed. This concept may also be called the "Virtual Lateral Jerk", but when applied to turnout design is normally simply called "Lateral Jerk" or "Pull-in Jerk" without modifiers.

UIC 711 does not address the limits on Virtual Transition Rates for turnouts but only for the reversing direction of curvature occurring in crossovers. For the crossover case, the limits are give as, "For an ordinary vehicle, the variation rate must, for example, be less than 125 mm/s (exceptionally 150 mm/s). It is calculated in relation to the time taken to pass over the length of the straight track, plus the length of the vehicle wheelbase." Nominally, 125 mm/s equals 5 inches/second and 150 mm/s equals 6 inches/second. The "vehicle wheelbase" is referred to elsewhere in UIC 711 as being nominally 19 meters (62'-4") and appears to be considered as the truck centers, not the total wheelbase of truck centers plus the axle spacing on the trucks. This distance is somewhat long for the anticipated vehicles to be operated in California. Standard truck centers are 18.7 meters (61'-4¼") for TGV coaches, 17.5 meters (57'-5") for Shinkansen coaches, and 59'-6" for Amtrak coaches.

UIC 711 does not apply the virtual transition rate concept to the switch end of the turnout. Why this is so is not stated. One possibility that becomes clear after these turnouts analyzed: The higher speed UIC turnouts have virtual transition rates at the switch points that are much higher than the recommended limits.

DB (Germany), SBB (Switzerland), and OEBB (Austria) does apply virtual transition rate limits to both the entry and exit of turnouts. For high speed turnouts they have developed modified turnout designs to reduce the transition rate, called Pull-In Jerk in their standards, to values they consider acceptable.

The virtual Transition Rate values are quite high in relation to the Transition Rates for Spirals given in either the AREMA Manual or UIC 703. In UIC 703, (Layout Characteristics for Lines Used by Fast Passenger Trains) the values are generally in the range of 25 mm/s to 36 mm/s "Standard" and 70 mm/s to 75 mm/s "Maximum", that is between 1.0 and 1.4 in/sec Standard to not more than 3.0 in/sec Maximum. The standard values are slightly higher than the AREMA normal of 0.90 to 1.25 in/sec.

This Virtual Transition Rate / Lateral Jerk effect must be applied judiciously. Since the calculation is applied to the actual spiral length where spirals exist and to the "Virtual Transition" length where spirals do not exist, it can be seen that where spirals are short the calculation could give the completely fallacious result that the track would ride better with no spiral at all than with a short spiral.

A summary of these various factors and the formulae used to calculate them is as follows:

Superelevation: (Cant in European terminology): The difference in the elevation of the two rails in a curve applied to reduce perceived lateral acceleration. Balancing Superelevation (SE_{bal}) is the amount of superelevation required to achieve a zero perceived lateral acceleration. The difference between the Actual Superelevation (SE) applied to a curve and the Balancing Superelevation is the Unbalanced Superelevation (EU).

$SE_{bal} = 4.0\ V^2 / R$ (with SE_{bal} in inches, V in mph, R in feet) or

$11.8\ V^2 / R$ (with SE_{bal} in mm, V in km/h, R in meters)

For turnouts where applied SE normally = 0, SE_{bal} = EU

Transition Rate (with distance): The rate at which superelevation or unbalanced superelevation is placed in track, usually stated as feet per inch, or a ratio.

Transition Rate (with time): The rate at which superelevation or unbalanced superelevation is experienced with time at a defined speed, usually the design speed. Units are normally inches per second or millimeters per second.

TR = SE * V * 44/30 / L (with TR in inch/sec., SE in inches, V in mph, L in feet) or

SE * V / (L * 3.6) (with TR in mm/s, SE in mm, V in km/h, L in meters)

For the case of unbalance, substitute EU for SE in the formula.

Virtual Transition: An imaginary transition imputed as being of the length of the truck centers (TC) of the passenger carrying vehicle being operated into the curve or turnout. At the start of a curve with no spiral, the virtual transition is presumed as being located ½ in the straight and ½ in the curve. For crossovers or reverse curves where the straight distance between them is less than the truck centers of the vehicle, the distance is shorter, since the portions presumed as being in the tangent would overlap. Therefore the virtual transition rate in such a reversing curve situation is considered as occurring over a length defined as one truck center plus length of straight ($TC+L_{st}$), with ½ half the truck center distance presumed located in each curve and the remainder in the straight.

Virtual Transition Rate (with time): The transition rate with time into a curve or turnout with no actual transition, or a transition only to a larger radius, not to infinity. Calculated by the Transition Rate (with time) formula with truck centers or truck centers plus length of straight substituted for length of transition.

VTR = EU * V * 44/30 / TC (with VTR in inch/sec., EU in inches, V in mph, L in feet) or

EU * V / (TC * 3.6) (with VTR in mm/s, EU in mm, V in km/h, L in meters)

A valuable result of the Virtual Transition Rate calculation is that it does illustrate that as speed goes up the turnout entry/exit effects become more pronounced. The significance of this issue and turnout designs to ameliorate it are discussed in 3.4.5.

It is interesting to note, given a set unbalance, how the Virtual Transition Rate goes up with speed. The data is based on using truck centers of 57'-5", the truck centers of the Shinkansen equipment, which is slightly less than that of European or American equipment.

Table 3.3.1: Virtual Transition Rates

Metric Units (mm/second)				**US Customary Units** (inches/second)			
Speed km/h	65 mm unbalance	80 mm unbalance	100 mm unbalance	Speed mph	2.5" unbalance	3" unbalance	4" unbalance
25	25.8	31.7	39.7	15	0.96	1.15	1.53
40	41.3	50.8	63.5	25	1.60	1.92	2.55
60	61.9	76.2	95.2	40	2.55	3.07	4.09
80	82.5	101.6	127.0	50	3,39	3.83	5.11
100	103,3	127.0	*158.7*	60	3.83	4.60	*6.13*
130	134.1	*165.1*	*206.3*	80	5.11	*6.13*	*8.17*
160	*165.1*	*203,3*	*254.0*	100	*6.39*	*7.66*	*10.22*
200	*206.3*	*254.0*	*317.5*	125	*7.98*	*9.58*	*12.77*
240	*247.6*	*304.8*	*381.0*	150	*9.58*	*11.49*	*15.33*

It is readily seen that at higher speeds the Virtual Transition Rate becomes unacceptably high for turnouts having normal unbalanced superelevations.

3.4 EXAMPLES OF COMMONLY USED HIGH-SPEED TURNOUT GEOMETRIES

3.4.1 AREMA Turnout Geometry – Overview

AREMA and predecessor organizations have long been dominated by freight railroads far more interested in robust turnout designs with low maintenance requirements than with high-speed or low entry force turnouts. Consequently, the largest standard turnout in the AREMA Manual is the Number 20. Speed over this turnout is normally limited to 50 mph or less. There are high-speed turnouts on the Northeast Corridor, but these are all special designs. Union Pacific uses a 70 mph turnout of their own design. Therefore, AREMA turnouts will not be discussed within the context of high-speed turnouts, but will be discussed in the context of medium-speed and low-speed turnouts which will be required in lower speed areas in major cities and in yards.

3.4.2 UIC and SNCF Turnout Geometry – Simple Arc Turnouts

UIC 711 and SNCF high-speed turnout geometries are identical for turnouts of the type having simple arc curves and curved frogs. The following table in UIC 711 presents the allowed speeds for various limits of unbalanced superelevation through these turnouts:

Table 3.4.1A: UIC 711 Turnouts – Unbalance and Allowed Speed – as given in UIC 711

I / γ / R	80 mm 0.523 m/s^2	85 mm 0.556 m/s^2	90 mm 0.589 m/s^2	95 mm 0.621 m/s^2	100 mm 0.654 m/s^2
1,200 m	90 km/h	93 km/h	95 km/h	98 km/h	100 km/h
1,540 m	102 km/h	105 km/h	108 km/h	111 km/h	114 km/h
2,000 m	116 km/h	120 km/h	123 km/h	127 km/h	130 km/h
2,500 m	130 km/h	134 km/h	138 km/h	142 km/h	145 km/h
3,000 m	142 km/h	147 km/h	151 km/h	155 km/h	160 km/h

Table 3.4.1B: UIC 711 Turnouts – Unbalance and Allowed Speed – US Customary Units

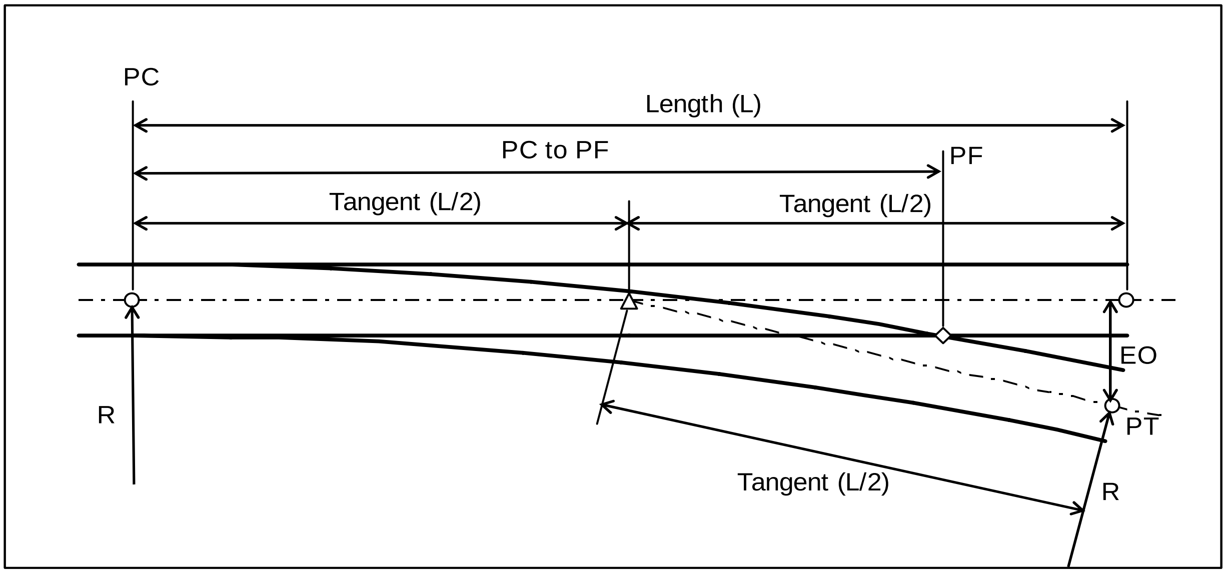
I / γ / R	3.15 inch 1.716 ft/s^2	3.35 inch 1.824 ft/s^2	3.54 inch 1.932 ft/s^2	3.74 inch 2.037 ft/s^2	3.94 inch 2.146 ft/s^2
3,937.01 ft	56 mph	58 mph	59 mph	61 mph	63 mph
5,052.49 ft	63 mph	65 mph	67 mph	69 mph	71 mph
6,561.68 ft	72 mph	75 mph	77 mph	79 mph	81 mph
8,202.10 ft	81 mph	83 mph	86 mph	88 mph	145 mph
9,842.52 ft	89 mph	91 mph	94 mph	97 mph	99 mph

Geometry of these Turnouts: All these turnouts are “tangent point design” in American terminology. That is, the theoretical switch point angle is zero. These all have one single radius that goes from the beginning point to beyond the frog. Thus, frogs in these turnouts are also all curved. Note the typical end of curve location in Figure 3.4.1.

There is a slight cut back from a true zero point angle, as under normal conditions there would be no contact between wheel and rail or switch point at the entry location. The nature of this cut back is shown in UIC 711 Figure 1. When looking at the various standard designs of turnouts used in Europe, it is seen that the recommendations of this figure are not generally followed. Generally, the cut back distance is shorter than that shown in the figure. The cut back to be used in CHSTP turnouts of this type is beyond the scope of this Technical Memorandum.

UIC 711 presents geometric figures for these turnouts, but without the analysis of the entry and exit virtual transition rates. When these entry and exit virtual transition rates are calculated, it becomes clear why these forces are not addressed in UIC 711. At higher speeds, all these turnouts have virtual transition rates that are higher than the recommended limits for these forces given in this same document.

Figure 3.4.1: UIC 711 Recommended Turnouts Layouts



The lower speed for the turnout labeled “SNCF” is taken from a Cogifer document.

Table 3.4.2A: UIC 711 Circular Arc Turnouts – Geometric Arrangement – as given

UIC 711 Fig.	Data in UIC 711 Figures								Derived Data	
	ratio 1/N	R (m)	speed (km/h)	EU (mm)	L (m)	T = L/2 (m)	PC to PF (m)	EO (m)	*PF angle, deg min sec*	*Virtual transition Rate (mm/s)*
2	18.5	1200	100	98	64.818	32.409	58.686	1.749	*2^o 48’ 05”*	*144*
3	21	1540	100	77	73.292	36.646	66.482	1.743	*2^o 28’ 23”*	*112*
4	26.85	2500	130	80	93.078	46.539	84.705	1.732	*1^o 56’ 28”*	*152*
5	26.5	2500	130	80	94.306	47.153	84.705	1.778	*1^o 56’ 28”*	*152*
6	29.74	3000	160	101	100.846	50.423	92.790	1.694	*1^o 46’ 19”*	*236*
SNCF	29.74	3000	130	66	100.846	50.423	92.790	1.694	*1^o 46’ 19”*	*126*

1. Figure 1 is not a turnout geometry, but relates to the point detail.
2. End offset (EO) is measured perpendicular to the straight side.
3. UIC 711 Virtual Transition Rate Limits: 125 mm/s, exceptional 150 mm/s. Note that some of these turnouts have transition rates in excess of these limits.
4. Virtual Transition Rate is based on the UIC 711 truck center distance of 19.00 m. If based on the shortest high speed vehicle truck centers of 17.50 m, the values become **156**, 122, **165, 165, 256,** and 137 mm/s, 8.7% further above the allowable limits.

Table 3.4.2B: UIC 711 Circular Arc Turnouts – Geometric Arrangement – US Customary Units

UIC 711 Fig.	Data in UIC 711 Figures, units converted								Derived Data	
	ratio 1/N	R (feet)	speed (mph)	EU (inch)	L (feet)	T = L/2 (feet)	PC to PF (ft)	EO (feet)	*PF angle, deg min sec*	*Virtual transition Rate (in/s)*
2	18.5	3,937.01	62.1	3.92	212.66	106.33	192.54	5.74	*2^o 48' 05"*	*5.74*
3	21	5,052.49	62.1	3.06	240.46	120.23	218.12	5.72	*2^o 28' 23"*	*4.47*
4	26.85	8,202.10	80.8	3.18	305.37	152.69	277.91	5.68	*1^o 56' 28"*	***6.05***
5	26.5	8,202.10	80.8	3.18	309.40	154.70	277.91	5.83	*1^o 56' 28"*	***6.05***
6	29.74	9,842.52	99.4	4.02	330.86	165.43	304.44	5.56	*1^o 46' 19"*	***9.40***
SNCF	29.74	9,842.52	80.8	2.65	330.86	165.43	304.44	5.56	*1^o 46' 19"*	*5.04*

1. Figure 1 is not a turnout geometry, but relates to the point detail.
2. End offset (EO) is measured perpendicular to the straight side.
3. UIC 711 Virtual Transition Rate Limits: 5 inches/second, exceptional 6 inches/second. Note that some of these turnouts have transition rates in excess of these limits.
4. Virtual Transition Rate is based on the UIC 711 truck center distance of 62'-4". If based on the shortest high speed vehicle truck centers of 57'-5" the values become 6.23, 4.85, 6.57, 6.57, 10.20, and 5.47 in/s, 8.7% further above the allowable limits.

Forces in these turnouts: While the forces, unbalanced superelevation and virtual transition rate are very easy to see in table 3.4.2 for these simple turnouts, as arrangements get more complex, it is desirable to show these relationships graphically. Since for these simple turnouts there is no need to show all of them graphically, only UIC 711 Figures 3 and 6 and the SNCF 29.74 turnout will be shown. Only the US Customary Unit analysis will be shown. Rather than use the odd speeds that the direct Metric to US Customary unit conversions give, set the speeds at commonly used US limits as follows:

Table 3.4.2C: UIC 711 Circular Arc Turnouts – Geometric Arrangement – US Customary Speeds

UIC 711 Fig.	Selected UIC Turnouts with US Customary Speed Limits								Derived Data	
	ratio 1/N	R (feet)	speed (mph)	EU (inch)	L (feet)	T = L/2 (feet)	PC to PF (ft)	EO (feet)	PF angle, deg min sec	Virtual transition Rate (in/s)
3	21	5,052.49	60	2.85	240.46	120.23	218.12	5.72	2^o 28' 23"	4.02
6	29.74	9,842.52	100	4.06	330.86	165.43	304.44	5.56	1^o 46' 19"	**9.56**
SNCF	29.74	9,842.52	80	2.60	330.86	165.43	304.44	5.56	1^o 46' 19"	4.90

1. End offset is measured perpendicular to the straight side.
2. UIC 711 Virtual Transition Rate Limits: 5 inches/second, exceptional 6 inches/second. Note that the Figure 6 turnout switch end virtual transition rate is far in excess of these values.
3. Virtual Transition Rate is based on the UIC 711 truck center distance of 62'-4". If based on vehicle truck centers of 57'-5" the values become 4.37, 10.38, and 5.32 in/s.

Plots of Forces in these turnouts: The following plots for UIC 711 Figures 3 and 6 and the SNCF 29.74 turnout are shown primarily for the purpose of illustrating the variations that speed and unbalance make in the Transition Rate under simple situation. Only the US Customary Unit analysis is shown. Of particular interest is to see how increase in speed results in increase in the transition rate due to the decrease in time since the Virtual Transition is defined on the basis of a fixed distance. Speeds are set at US mph rounded limits appropriate to the radius of the turnout curve.

Figure 3.4.2: UIC 711 Fig.3, Unbalance and Transition Rate versus Distance

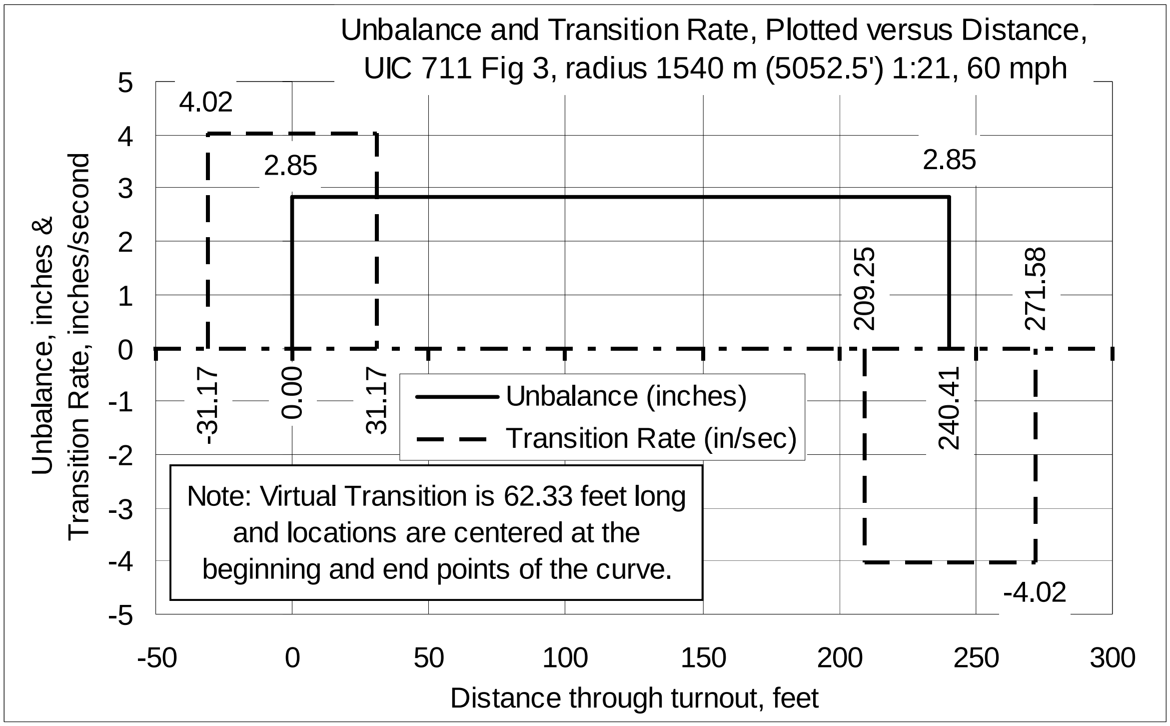


Figure 3.4.3: UIC 711 Fig.3, Unbalance and Transition Rate versus Time

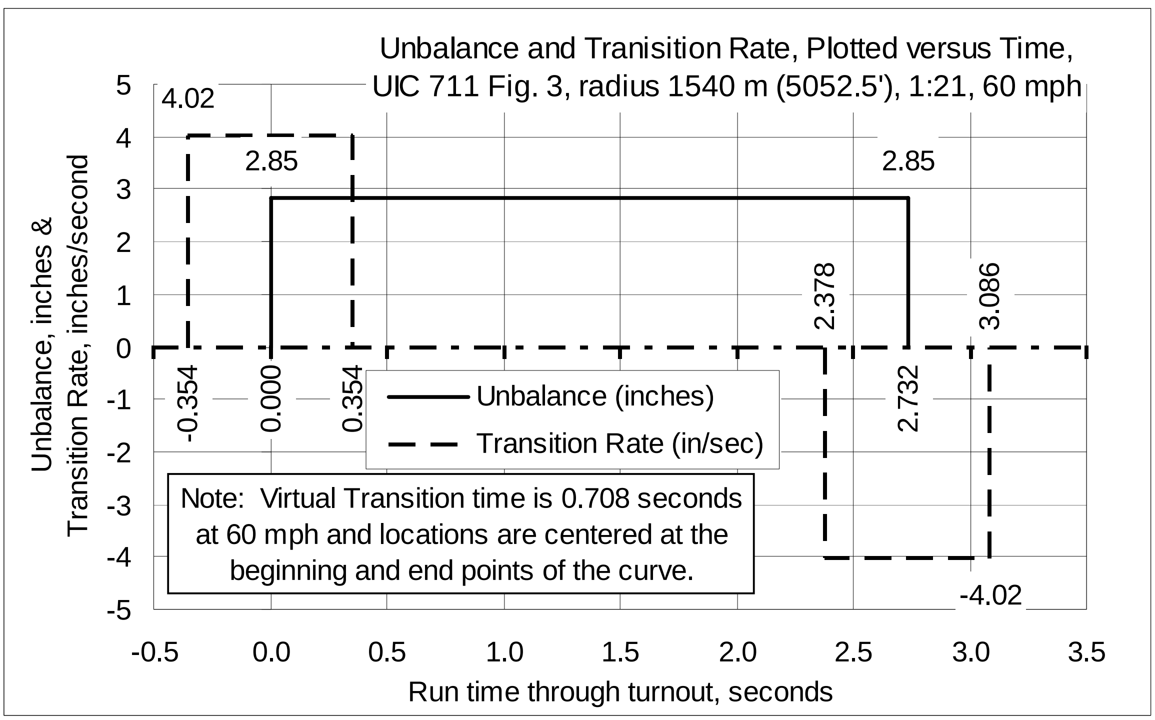


Figure 3.4.4: UIC 711 Fig.6, Unbalance and Transition Rate versus Distance

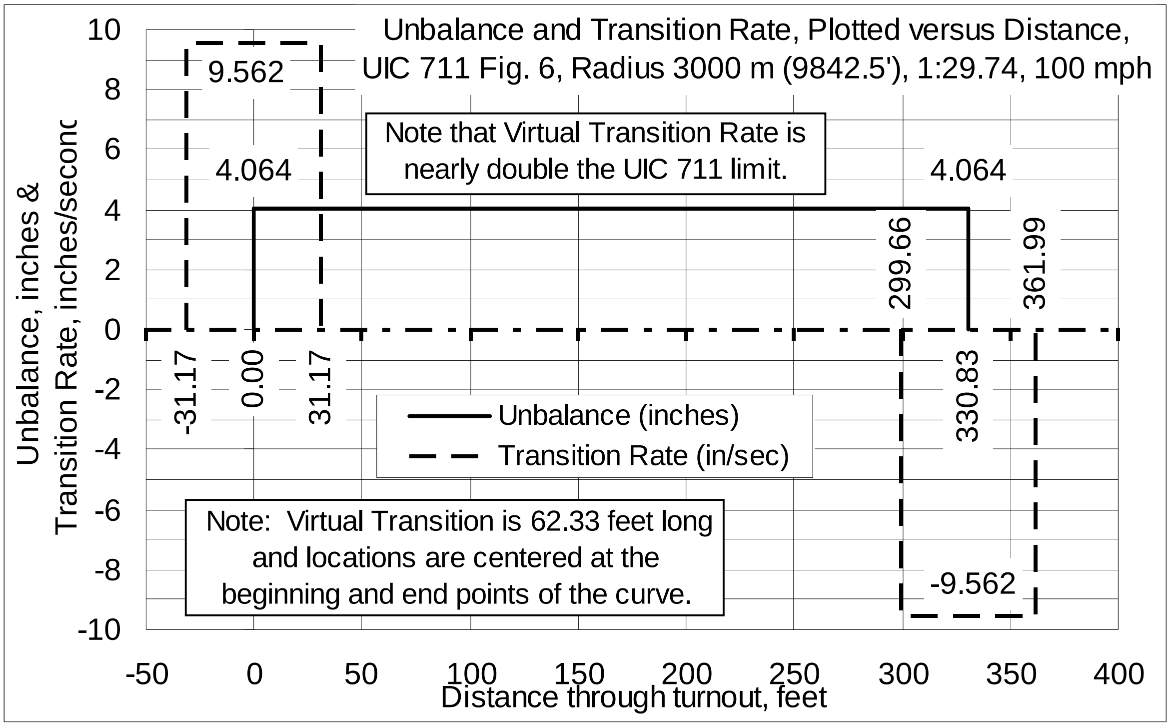


Figure 3.4.5: UIC 711 Fig.6 Unbalance and Transition Rate versus Time

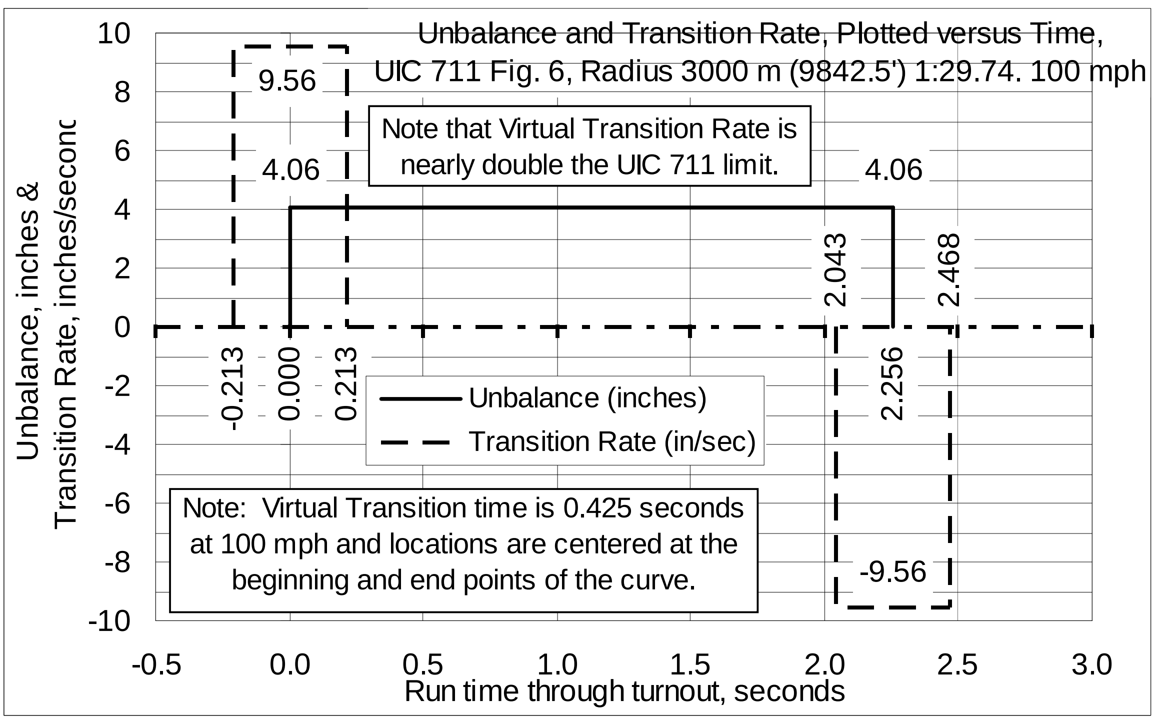


Figure 3.4.6: SNCF 130 km/h turnout, Unbalance and Transition Rate versus Distance

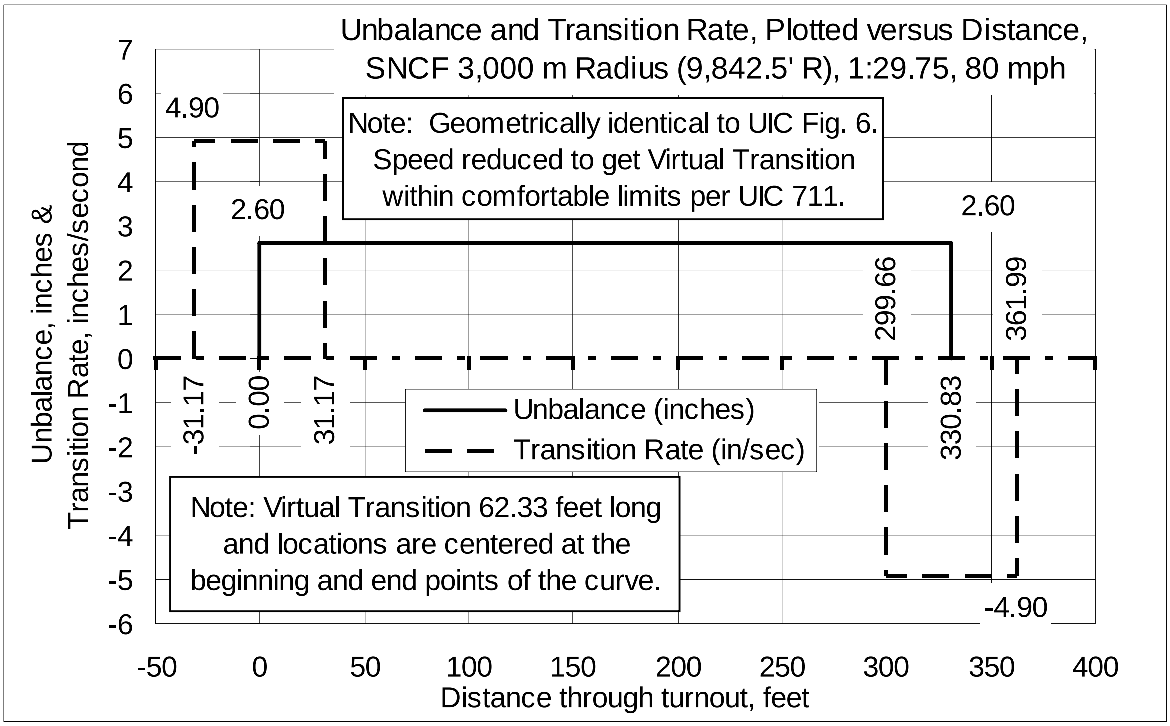
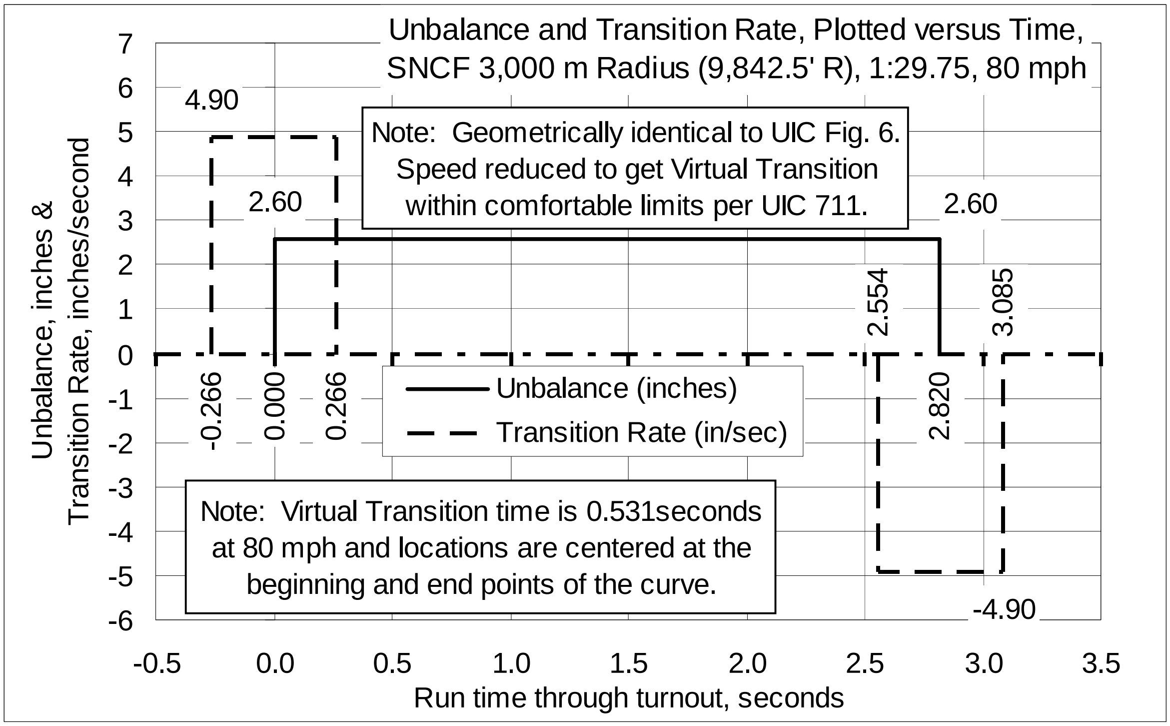


Figure 3.4.7: SNCF 130 km/h turnout, Unbalance and Transition Rate versus Time



3.4.3 UIC Transitioned Turnouts

UIC 711 Figures 7 and 8 have a zero length curve at the switch end with a spiral out to tangent beyond the frog on the frog end. These turnouts are labeled as being for crossovers and are based on track centers of 4.20 meter (13'-9 $^3/_8$"). The spiral curve with full radius on the switch point end keeps the real reversal transition rate less than half the limit given in UIC 711 but leaves the switch point end virtual transition around twice the limit given in UIC 711.

Figure 3.4.8: UIC 711 Recommended Transitioned Turnout Layouts

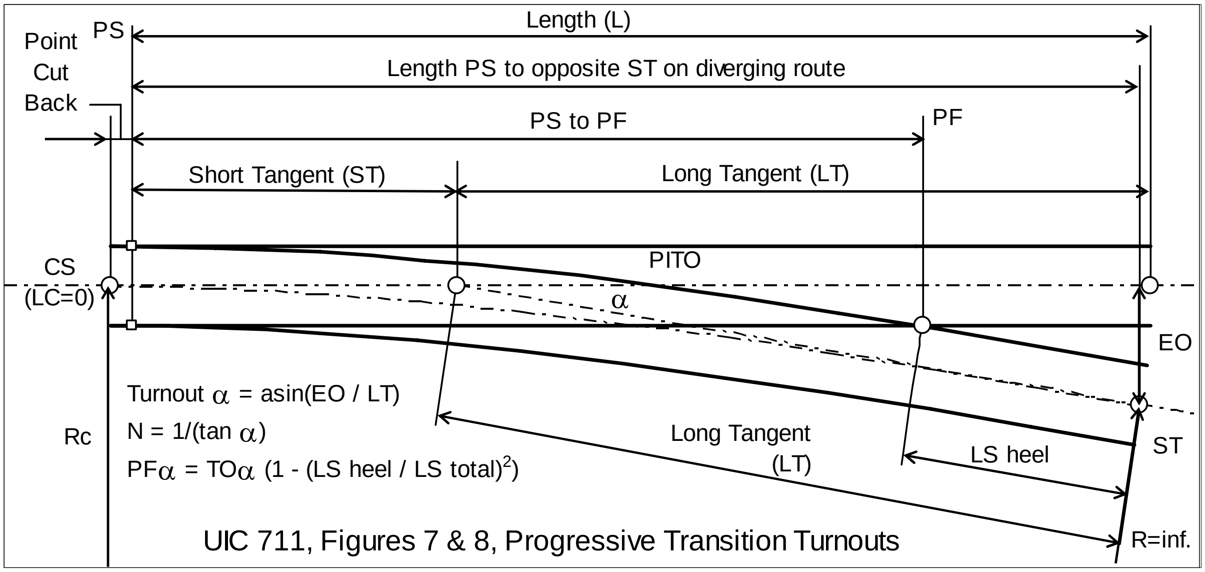


Table 3.4.3A: UIC 711 Spiral Turnouts for Crossovers, Geometric Arrangement – as given

UIC 711 Fig. No.	Data in UIC 711 Figures 7 & 8							Derived Data			
	frog ratio 1/N	end ratio 1/N	radius (m)	speed (km/h)	EU (mm)	total length (m)	PC to PF (m)	*point of frog angle, deg min sec*	*end turnout angle, deg min sec*	*Virtual transition Rate (mm/s)*	*Spiral transition Rate (mm/s)*
7	46	43.65	3,000	160	101	137.493	108.013	*1° 14’ 43”*	*1° 18’ 46”*	*236*	32.5
8	65	61.68	6,720	220	85	195.445	153.784	*0° 52’ 53”*	*0° 55’ 44”*	*273*	26.6

1. Lengths are distances from start of full radius for UIC turnouts, not from joint as shown on plan.
2. End offset is measured perpendicular to the straight line and is 2.100 m on all figures.
3. Virtual Transition Rate based on 19.00 m truck centers. If based on the shortest high speed vehicle truck centers of 17.50 m, the values become 256, and 297 mm/s, respectively, 8.6% higher.
4. Spiral transition rate based on run time over total length at the defined speed.

Table 3.4.3B: UIC 711 Spiral Turnouts for Crossovers
Geometric Arrangement – US Customary Units

UIC 711, Fig. No.	Data in UIC 711 Figures 7 & 8, units converted							Derived Data			
	frog ratio 1/N	end ratio 1/N	radius (feet)	speed (mph)	EU (in)	total length (feet)	PC to PF (feet)	*point of frog angle, deg min sec*	*end turnout angle, deg min sec*	*Virtual transition Rate (in/s)*	*Spiral transition Rate (in/s)*
7	46	43.65	9,842.52	99.4	4.02	451.09	354.37	*1° 14’ 43”*	*1° 18’ 46”*	*9.40*	1.30
8	65	61.68	22,047.24	136.7	3.39	641.22	504.54	*0° 52’ 53”*	*0° 55’ 44”*	*10.91*	1.06

1. Lengths are distances from start of full radius for UIC turnouts, not from joint as shown on plan
2. End offset is measured perpendicular to the straight line and is 6’-10 $^{11}/_{16}$” on all figures.
3. Virtual Transition Rate based on 62’-4” truck centers. If based on the shortest high speed vehicle truck centers of 57’-5”, the values become 10.20, and 11.84inch/s, respectively, 8.6% higher.
4. Spiral transition rate based on run time over total length at the defined speed.

Table 3.4.3C: UIC 711 Spiral Turnouts for Crossovers
Geometric Arrangement – US Customary Speeds

UIC 711, Fig. No.	Data in UIC 711 Figures 7 & 8, units converted							Derived Data			
	frog ratio 1/N	end ratio 1/N	radius (feet)	Set speed (mph)	EU (in)	total length (feet)	PC to PF (feet)	*point of frog angle, deg min sec*	*end turnout angle, deg min sec*	*Virtual transition Rate (in/s)*	*Spiral transition Rate (in/s)*
7	46	43.65	9,842.52	**100**	4.06	451.09	354.37	*1° 14' 43"*	*1° 18' 46"*	9.56	1.32
8	65	61.68	22,047.24	**135**	3.31	641.22	504.54	*0° 52' 53"*	*0° 55' 44"*	10.50	1.02

1. Lengths are distances from start of full radius for UIC turnouts, not from joint as shown on plan.
2. End offset is measured perpendicular to the straight line and is 6'-10 $^{11}/_{16}$" on all figures.
3. Virtual Transition Rate based on 62'-4" truck centers. If based on the shortest high speed vehicle truck centers of 57'-5", the values become 10.20, and 11.84inch/s, respectively, 8.6% higher.
4. Spiral transition rate based on run time over total length at the defined speed.

Plots of Forces in these turnouts: The following plots for UIC 711 Figure 7 illustrate the variation of forces that occur in these transitioned turnouts.

- **Unbalanced Superelevation:** Since the internal curve is a Clothoid type spiral, the unbalance superelevation decreases linearly from beginning point to end point of turnout.
- **Transition Rate through the Turnout:** Since the internal curve is a Clothoid type spiral, the Transition Rate of the unbalanced superelevation is a constant.
- **Virtual Transition Rate at the Switch End:** The common standard for showing the Virtual Transition Rate is to illustrate the virtual transition at a point 9.5 meters (31'-2") ahead of the point for which the rate is given, apparently based on the normal usage of showing the virtual transition as being half each side of the point of transition. The value is based on the radius at the beginning of the curve and 19 meters (62'-4") into the spiral.

Only the US Customary Unit analysis is shown with speeds are set at US mph rounded limits appropriate to the radius of the turnout curve. Note that the Virtual Transition Rate at the switch end is extremely high, approximately twice the limits recommended in UIC 711.

Figure 3.4.9: UIC 711 Fig. 7, Unbalance and Transition Rate versus Distance

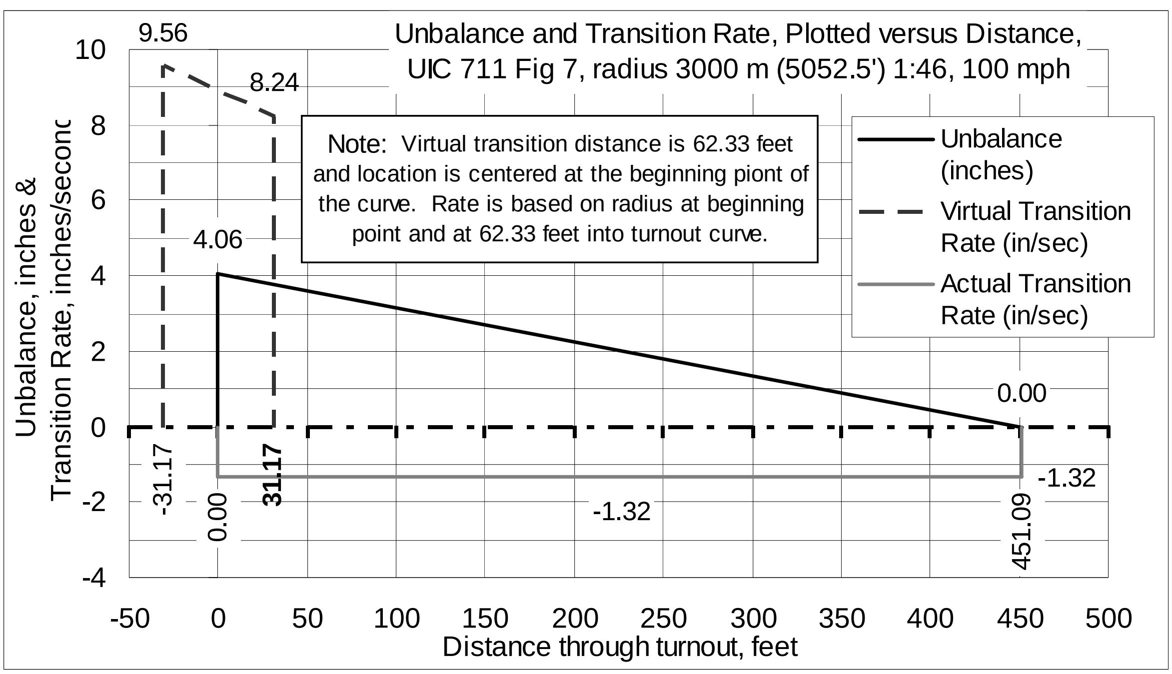
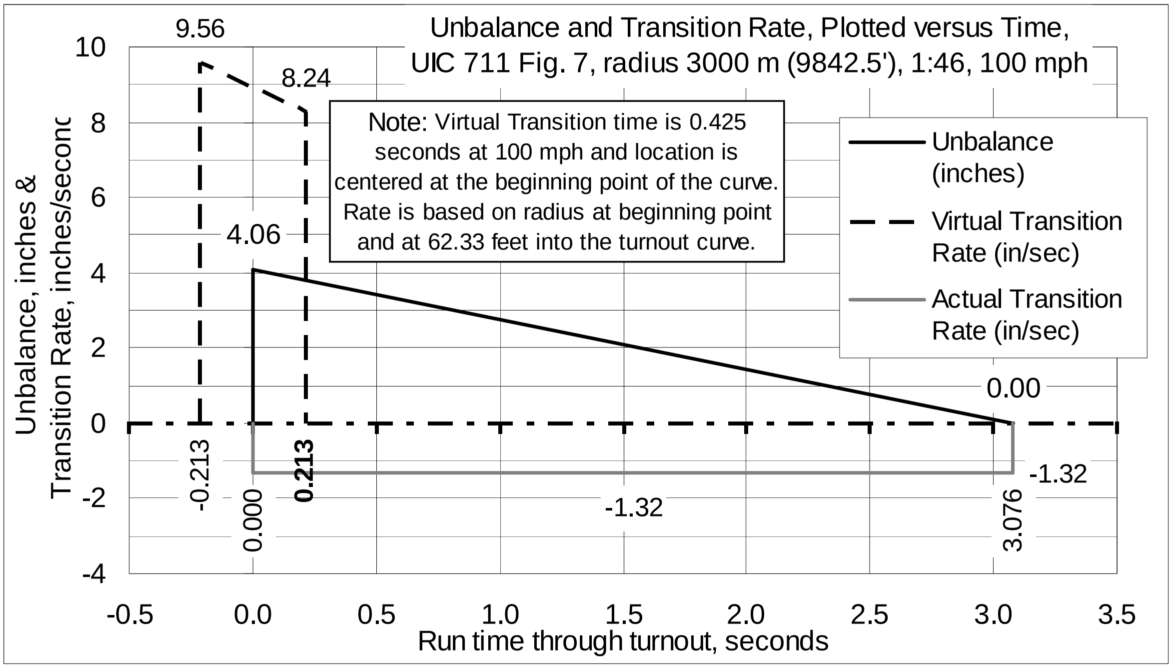


Figure 3.4.10: UIC 711 Fig. 7, Unbalance and Transition Rate versus Time



3.4.4 SNCF Transitioned Turnouts

The SNCF transitioned turnouts appear to be an improved version of the UIC transitioned turnouts. These turnouts have a length of constant radius at the switch end then followed by a spiral out to tangent beyond the frog on the frog end. These turnouts are labeled as being for crossovers.

As with the UIC transitioned turnouts, the spiral curve with full radius on the switch point end keeps the reversal transition rate well below the UIC 711 limits, but the radius at the switch point end still leaves a virtual transition that is roughly twice the limit recommended in UIC 711.

Figure 3.4.11: SNCF Transitioned Turnout Layouts

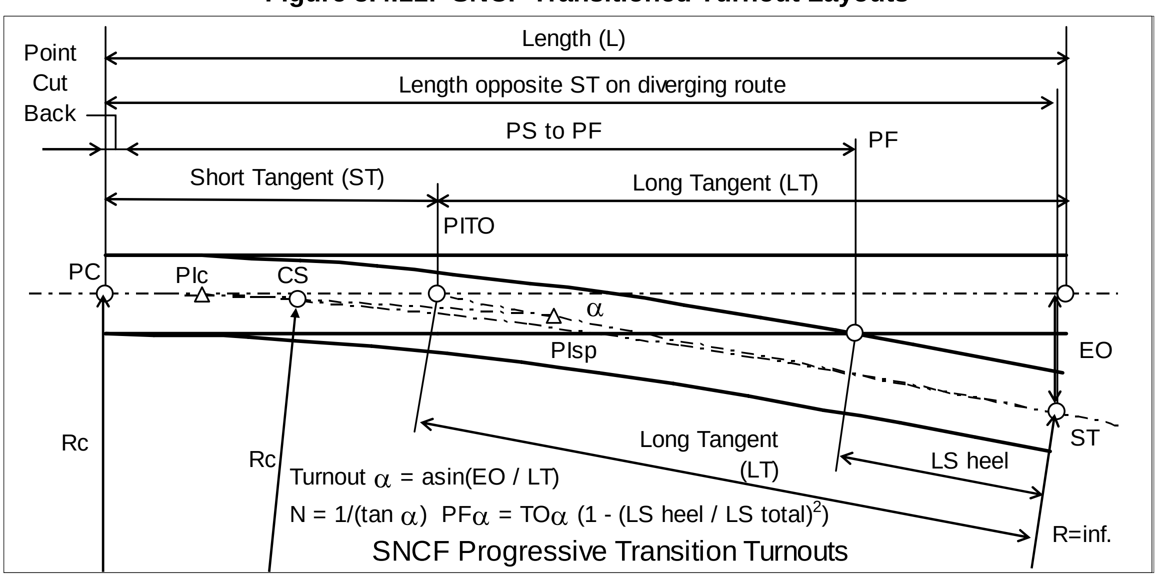


Table 3.4.4A: SNCF Spiral Turnouts for Crossovers
Geometric Arrangement – as given in Metric units

Source of Data: Cogifer								Derived Data			
frog ratio 1/N	end ratio 1/N	radius (m)	speed (km/h)	EU (mm)	arc length (m)	spiral length (m)	total length (m)	*point of frog angle, deg min sec*	*end turnout angle, deg min sec*	*Virtual transition Rate (mm/s)*	*Spiral transition Rate (mm/s)*
46	43.63	3,550	170	96	21.488	115.260	136.743	*1° 14' 43"*	*1° 18' 46"*	*239*	39.4
65	61.67	6,720	220	85	20.488	172.977	193.425	*0° 52' 53"*	*0° 55' 44"*	*273*	30.0
65	61.67	7,350	230	85	37.376	156.340	193.716	*0° 52' 53"*	*0° 55' 44"*	*286*	34.7

1. Virtual Transition Rate based on 19.00 m truck centers. If based on the shortest high speed vehicle truck centers of 17.50 m, the values become 259, 297, and 310 mm/s, respectively, 8.6% higher.
2. Spiral transition rate based on run time over total spiral length at the defined speed.

Table 3.4.4B: SNCF Spiral Turnouts for Crossovers
Geometric Arrangement – US Customary Units

Source of Data: Cogifer								Derived Data			
frog ratio 1/N	end ratio 1/N	radius (feet)	speed (mph)	EU (inch)	arc length (feet)	spiral length (feet)	total length (feet)	*point of frog angle, deg min sec*	*end turnout angle, deg min sec*	*Virtual transition Rate (in/s)*	*Spiral transition Rate (in/s)*
46	43.63	11,646.98	105.6	3.83	70.50	378.15	448.63	*1° 14' 43"*	*1° 18' 46"*	*9.52*	1.57
65	61.67	22,047.24	136.7	3.39	67.09	567.51	634.60	*0° 52' 53"*	*0° 55' 44"*	*10.91*	1.20
65	61.67	24,114.17	142.9	3.39	122.62	512.93	635.55	*0° 52' 53"*	*0° 55' 44"*	*11.39*	1.38

1. Virtual Transition Rate based on 62'-4" truck centers. If based on the shortest high speed vehicle truck centers of 57'-5", the values become 10.34, 11.84, and 12.37 inch/s, respectively, 8.6% higher.
2. Spiral transition rate based on run time over total spiral length at the defined speed.

Table 3.4.4C: SNCF Spiral Turnouts for Crossovers
Geometric Arrangement – US Customary Speeds

Source of Data: Cogifer								Derived Data			
frog ratio 1/N	end ratio 1/N	radius (feet)	Set speed (mph)	EU (inch)	arc length (feet)	spiral length (feet)	total length (feet)	*point of frog angle, deg min sec*	*end turnout angle, deg min sec*	*Virtual transition Rate (in/s)*	*Spiral transition Rate (in/s)*
46	43.63	11,646.98	105	3.43	70.50	378.15	448.63	*1° 14' 43"*	*1° 18' 46"*	*9.36*	1.54
65	61.67	22,047.24	135	3.31	67.09	567.51	634.60	*0° 52' 53"*	*0° 55' 44"*	*10.50*	1.15
65	61.67	24,114.17	140	3.25	122.62	512.93	635.55	*0° 52' 53"*	*0° 55' 44"*	*10.71*	1.30

1. Virtual Transition Rate based on 62'-4" truck centers. If based on the shortest high speed vehicle truck centers of 57'-5", the values become 10.15, 11.40, and 11.62 inch/s, respectively, 8.6% higher.
2. Spiral transition rate based on run time over total spiral length at the defined speed.

Figure 3.4.12: SNCF 1:46: Unbalance and Transition Rate versus Distance

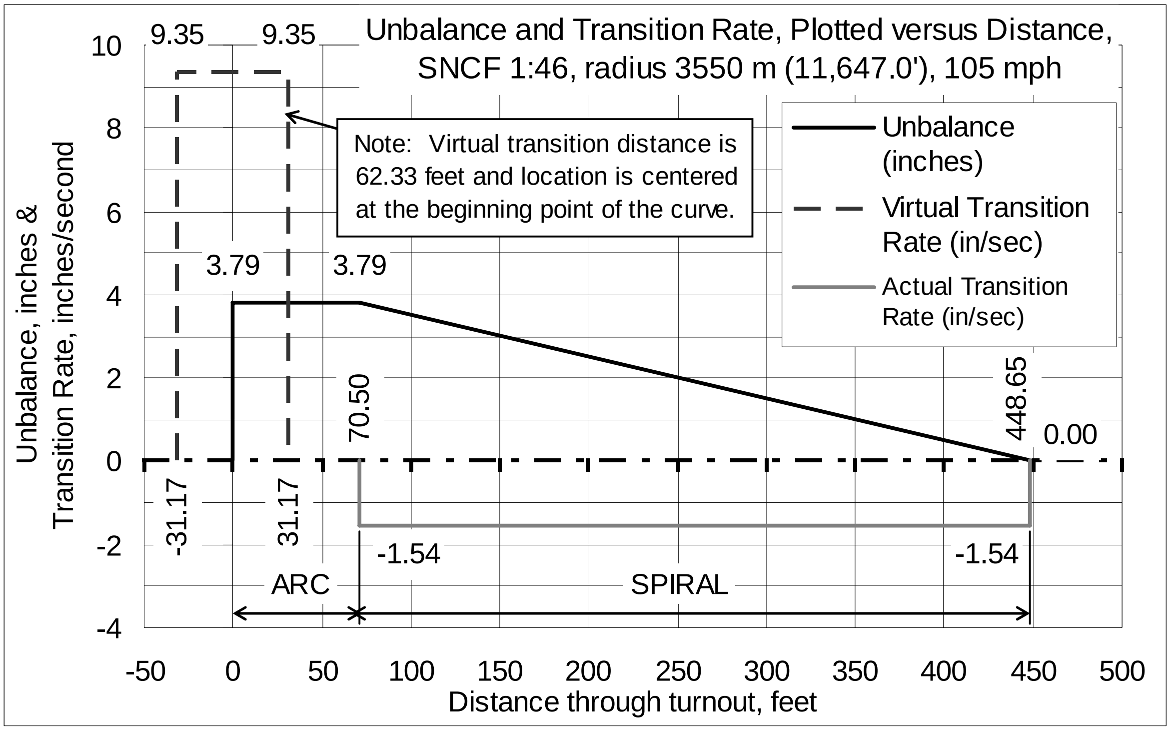
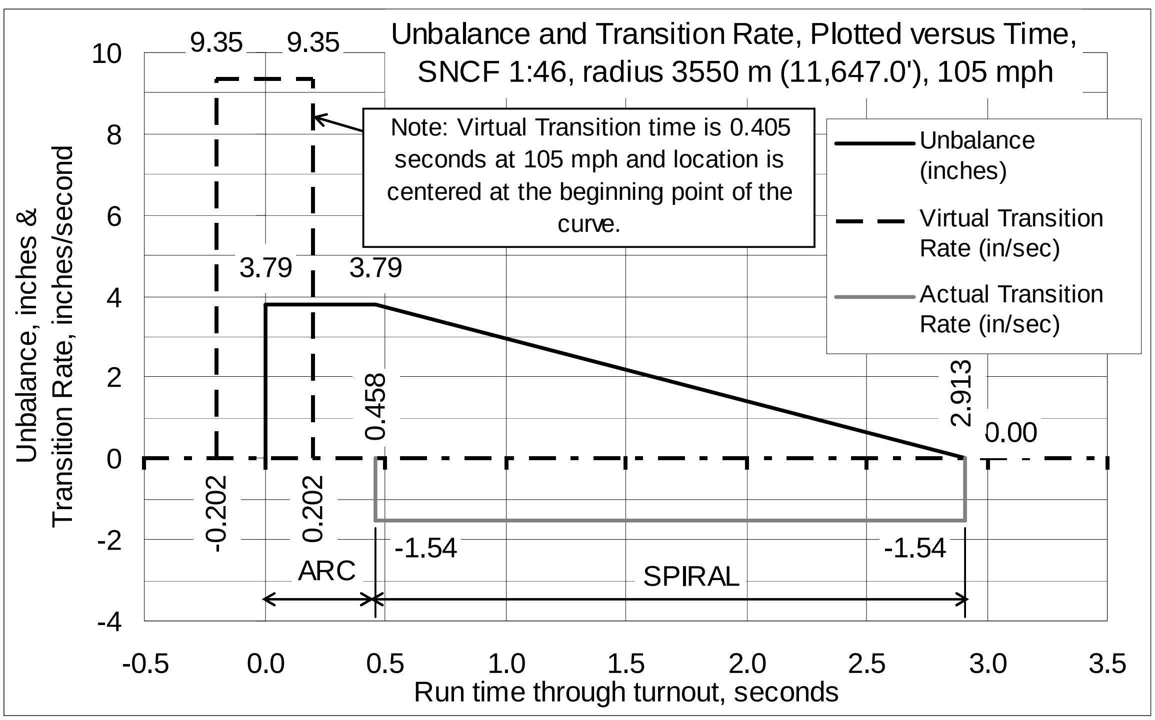


Figure 3.4.13: SNCF 1:46: Unbalance and Transition Rate versus Time



The forces in only the 1:46 turnout are being plotted, as the purpose of these plots is primarily illustrative.

3.4.5 DB Turnout Geometry

Deutsche Bahn (DB) high-speed turnouts all use spiral transitions to reduce the entry and exit forces in order to keep the Lateral Jerk to reasonable limits. There are two high speed turnout designs: One design has a spiral at the switch end only for use where the track beyond the turnout will continue on the same radius. The other design has a spiral on both ends for use in crossovers or where the diverging track will be straight or return to an alignment parallel to the main track. The switch end transition is not a full spiral to a tangent, but, in effect, a combining spiral between two curves of differing radii, with the curve at the switch end having a zero arc length. For the turnouts that also have a transition at the frog end, the frog end spiral is to a straight alignment at a point 2.000 m (13.12 ft) offset from the centerline of the through track.

There are four standard turnouts for each type in the Deutsche Bahn's publication 800.0120, Netzinfrastruktur Technik Entwerfen; Weichen und Kreuzungen. (Translation: Infrastructure Technical Information, Switches and Crossings). The four turnouts and their design speeds are:

Table 3.4.5A: DB Klotoidenweichen (German Clothoid Turnouts)

Speed (km/h)	Single Spiral for Branch line Connection	Spiral both ends (for crossovers)
100	3,000 / 1,500 – 1:18.132	3,000 / 1,500 / infinity
130	4,800 / 2,450 – 1:24.257	4,800 / 2,450 / infinity
160	10,000 / 4,000 – 1:32.050	10,000 / 4,000 / infinity
200	16,000 / 6,100 – 1:40.154	16,000 / 6,100 / infinity

Table 3.4.5B: German Clothoid Turnouts – US Customary Units

Speed (mph)	Single Spiral for Branch line Connection	Spiral both ends (for crossovers)
62	9,842.52 / 4,921.26 – 1:18.132	9,842.52 / 4,921.26 / infinity
80	15,748.03 / 8,038.06 – 1:24.257	15,748.03 / 8,038.06 / infinity
100	32,808.40 / 13,123.36 – 1:32.050	32,808.40 / 13,123.36 / infinity
124	52,493.44 / 20,013.12 – 1:40.154	52,493.44 / 20,013.12 / infinity

Both types of turnouts are identical on the switch end and use the same central radius. The overall unit length, tangents, total angle and offsets and frog point angle and offsets are different between the two types. Sketches and geometric characteristics of these turnouts are as follows:

Figure 3.4.14: German High Speed Turnouts with a Spiral only on the Switch End (Klotoidenweichen fur Abzweigstellwn)

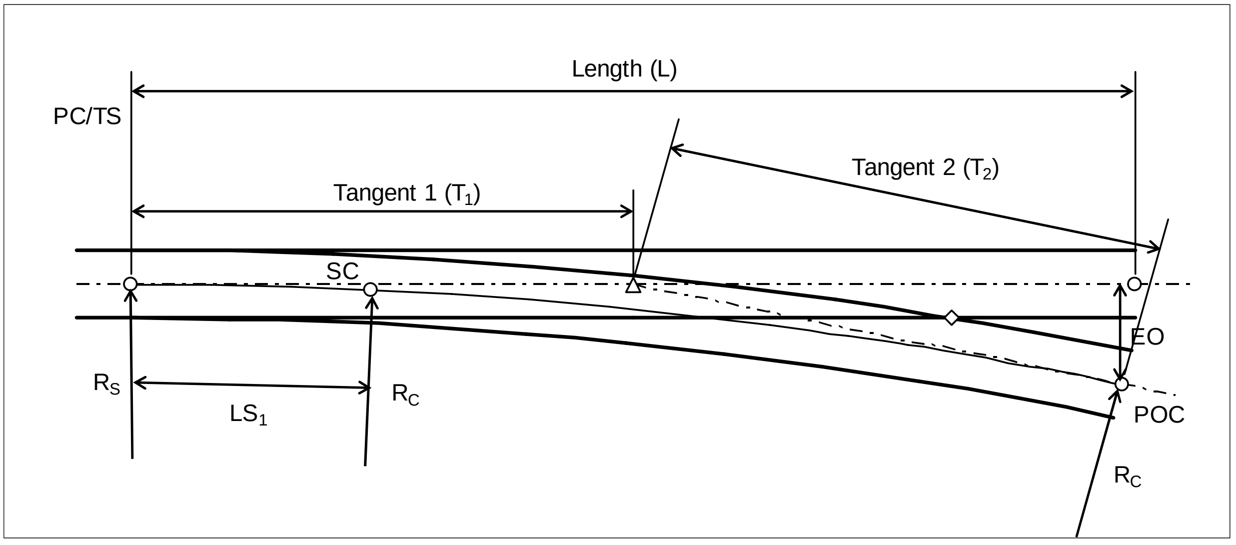


Figure 3.4.15: German High Speed Turnouts with Spirals on Both Ends for use in Crossovers (Klotoidenweichen fur Gleisverbindungen bei Gleisabstand e>4.00m)

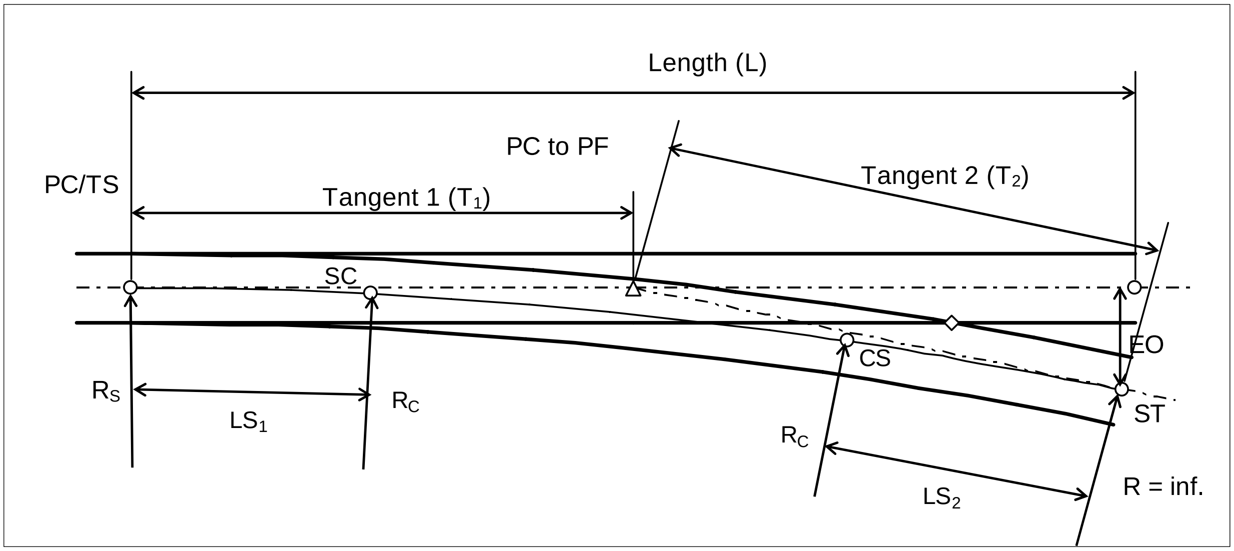


Table 3.4.6 provides the dimensions of these turnouts as extracted from DB publication 800.0120. The left side of the table provides the dimensions as given. The right side provides US Customary unit conversions of these dimensions.

Table 3.4.6: Geometry of German Clothoid Turnouts

Factor	Metric Units, dimensions in meters				US Customary Units, dimensions in feet			
Speed	100	130	160	200	62	80	100	124
	Values common to both turnout types				Values common to both turnout types			
R_S	3,000	4,800	10,000	16,000	9,842.52	15,748.03	32,808.40	52,493.44
R_C	1,500	2,450	4,000	6,100	4,921.26	8,038.06	13,123.36	20,013.12
LS_1	27.000	41.075	37.500	56.000	88.583	134.760	123.031	183.727
	Turnouts with switch end spiral, only				**Turnouts with switch end spiral, only**			
L	89.416	111.016	136.026	169.216	293.360	364.226	446.280	555.171
T_1	47.624	59.672	73.018	92.129	156.247	195.774	239.560	302.260
T_2	41.792	51.344	63.008	77.087	137.113	168.451	206.719	252.910
EO	2.302	2.115	1.965	1.919	7.552	6.939	6.447	6.296
Ratio	18.132	24.257	32.050	40.154	18.132	24.257	32.050	40.154
Angle	not given	not given	not given	not given	3° 09’ 24”	2° 21’ 38”	1° 47’ 14”	1° 25’ 36”
PF Ratio	not given	not given	not given	not given	23.180	29.797	37.726	46.813
PF angle	not given	not given	not given	not given	2° 28’ 13”	1° 55’ 20”	1° 31’ 06”	1° 13’ 25”
	Turnouts with spirals on both ends				**Turnouts with spirals on both ends**			
LS_2	32.000	42.700	55.225	62.500	104.987	140.092	181.184	205.052
L	85.879	111.229	141.114	176.568	281.755	364.925	462.972	579.291
T_1	38.41	49.827	62.862	81.239	126.017	163.474	206.240	266.532
T_2	47.469	61.402	78.252	95.329	155.738	201.450	256.732	312.759
EO	2.150	1.981	1.894	1.838	7.054	6.499	6.214	6.030
Ratio	not given	not given	not given	not given	22.079	30.995	41.316	51.866
Angle	not given	not given	not given	not given	2° 28’ 13”	1° 55’ 20”	1° 31’ 06”	1° 13’ 25”

Table 3.4.7 repeats certain of the information in Table 3.4.6 to aid in reference, but its primary purpose is to provide information on the train operating characteristics when passing through these units at their design speed. This information is not provided in DB publication 800.0120,

but is calculated from it. The Virtual Transition Rate (VTR_{19}) is based on the passage of a vehicle with 19 meter (62'-4") truck centers in accordance with normal European concepts. The time and derived transition rates (TR) are calculated for both entry and exit spirals. The transition rate given for the entry spiral is based on the difference between the unbalanced superelevation at the entry point of the switch end spiral and the unbalance of the central radius of the turnout body. The left side of the table provides the dimensions as given or calculated in Metric units. The right side provides US Customary unit conversions of these dimensions. Note that the speed given is set to a commonly used US Customary value rather than exactly converted from the metric unit. Factors such as unbalance and transition rates are then calculated for this set US Customary speed. Thus, they are not exact conversions of the values given on the left side of the table.

Table 3.4.7: German Clothoid Turnouts – Calculated Values and Operational Characteristics

Factor	Metric Units, dimensions in meters				US Customary Units, dimensions in feet			
Speed	100 km/h	130	160	200	60 mph	80	100	125
	Values common to both turnout types				Values common to both turnout types			
R_S	3,000 m	4,800	10,000	16,000	9,842.52 ft	15,748.03	32,808.40	52,493.44
EU	39.3 mm	41.6	30.2	29.5	1.46 in	1.63	1.22	1.19
VTR_{19}	57.5mm/s	79.0	70.7	86.3	2.07in/sec	3.06	2.87	3.50
LS_1	27.000 m	41.075	37.500	56.000	88.583 ft	134.760	123.031	183.727
time	0.97 s	1.14	0.84	1.01	1.01 sec	1.15	0.84	1.00
TR	40.5mm/s	35.0	53.7	47.5	1.45in/sec	1.36	2.18	1.93
R_C	1,500 m	2,450	4,000	6,100	4,921.26 ft	8,038.06	13,123.36	20,013.12
EU	78.7 mm	81.4	75.5	77.4	2.93 in	3.18	3.05	3.12
	Turnouts with switch end spiral, only				**Turnouts with switch end spiral, only**			
L_{arc}	89.416m	111.016	136.026	169.216	293.36 ft	364.23	446.28	555.17
time	3.21 s	3.07	3.06	3.05	3.33 sec	3.10	3.04	3.03
	Turnouts with spirals on both ends				**Turnouts with spirals on both ends**			
L_{arc}	85.879m	111.229	141.114	176.568	281.76 ft	364.92	462.97	579.29
time	3.09 s	3.08	3.18	3.18	3.20 sec	3.11	3.16	3.16
LS_2	32.000m	42.700	55.225	62.500	104.99 ft	140.09	181.18	205.05
time	1.15 s	1.18	1.24	1.12	1.19 sec	1.19	1.24	1.12
TR	68.3mm/s	68.8	60.8	68.8	2.45 in/sec	2.67	2.47	2.79

The additional complexity of these turnouts is easier to understand when the force arrangement is plotted. Therefore, plots for the extreme cases are given: The 3,000/1,500 turnout, both with one spiral and with two spirals will be plotted for forces at 60 mph, and the 16,000/6,100 turnout will be plotted for forces at 125 mph, again both for the one spiral and the two spiral layouts.

Figure 3.4.16: DB 3000/1500 double spiral, Unbalance and Transition Rate versus Distance

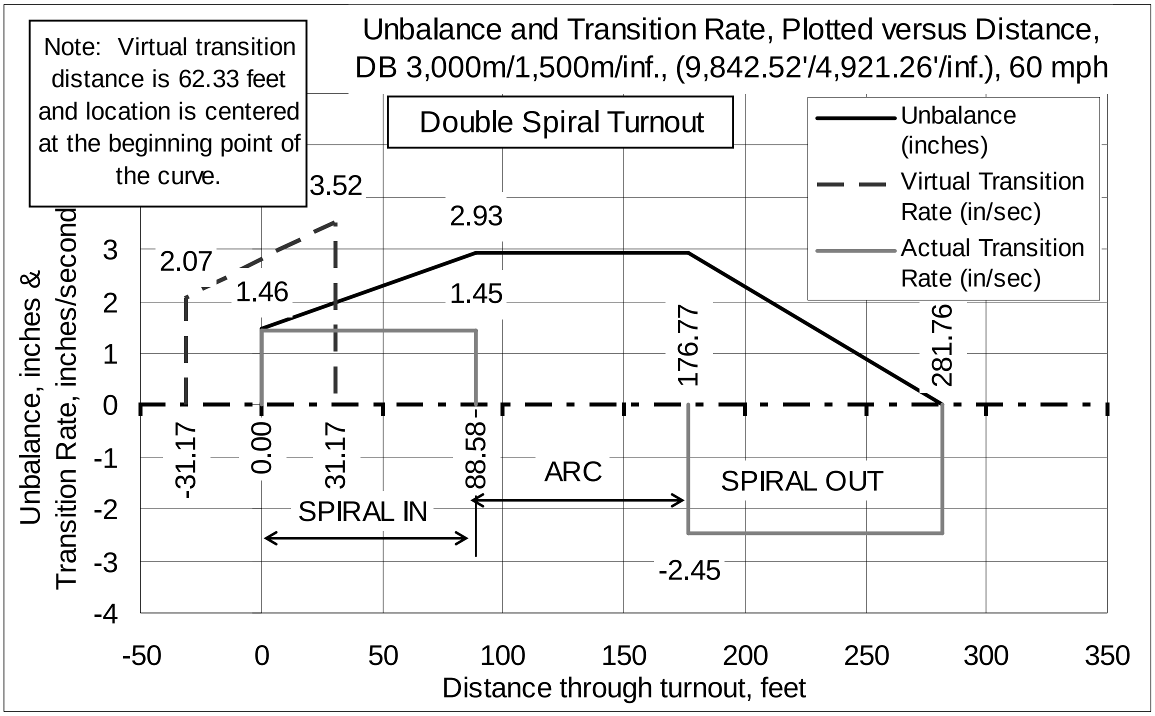


Figure 3.4.17: DB 3000/1500 double spiral, Unbalance and Transition Rate versus Time

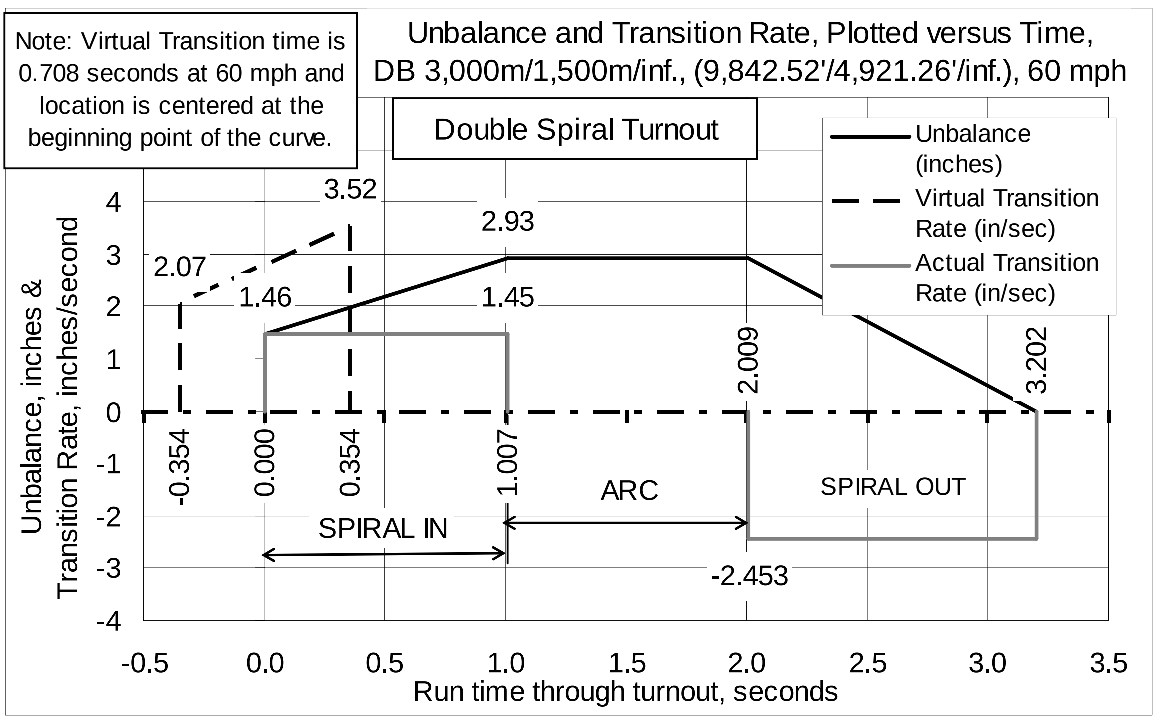


Figure 3.4.18: DB 3000/1500 single spiral, Unbalance and Transition Rate versus Distance

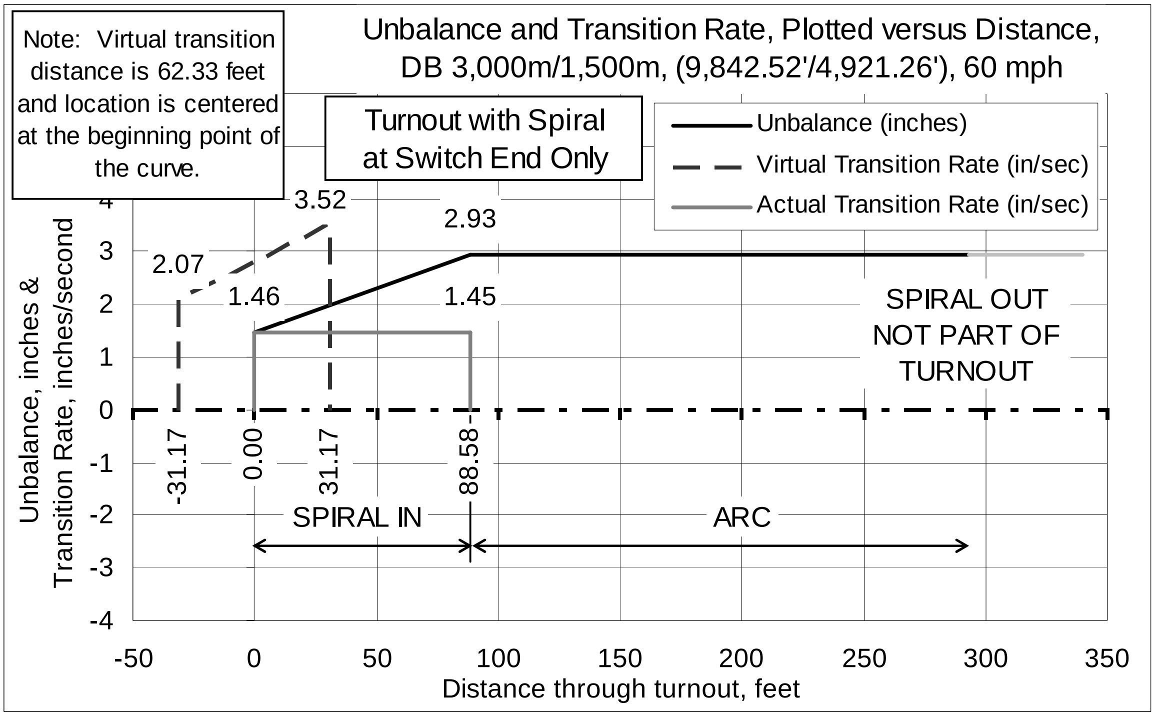


Figure 3.4.19: DB 3000/1500 single spiral, Unbalance and Transition Rate versus Time

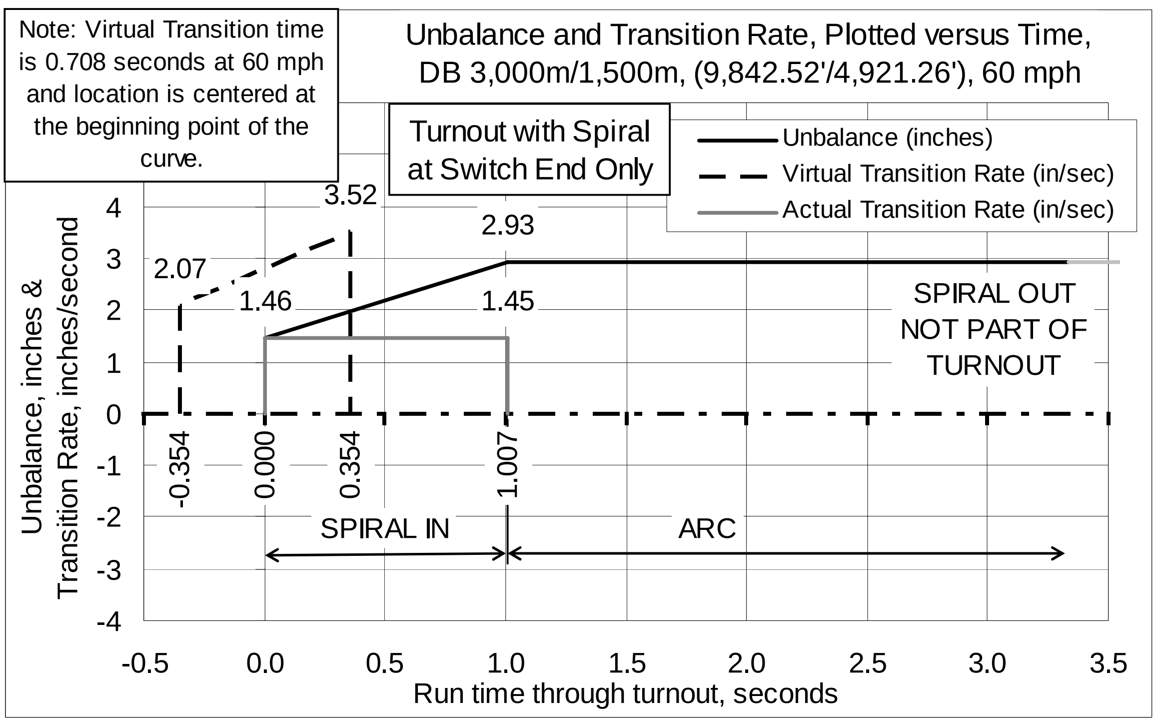


Figure 3.4.20: DB 16000/6100 double spiral, Unbalance and Transition Rate versus Distance

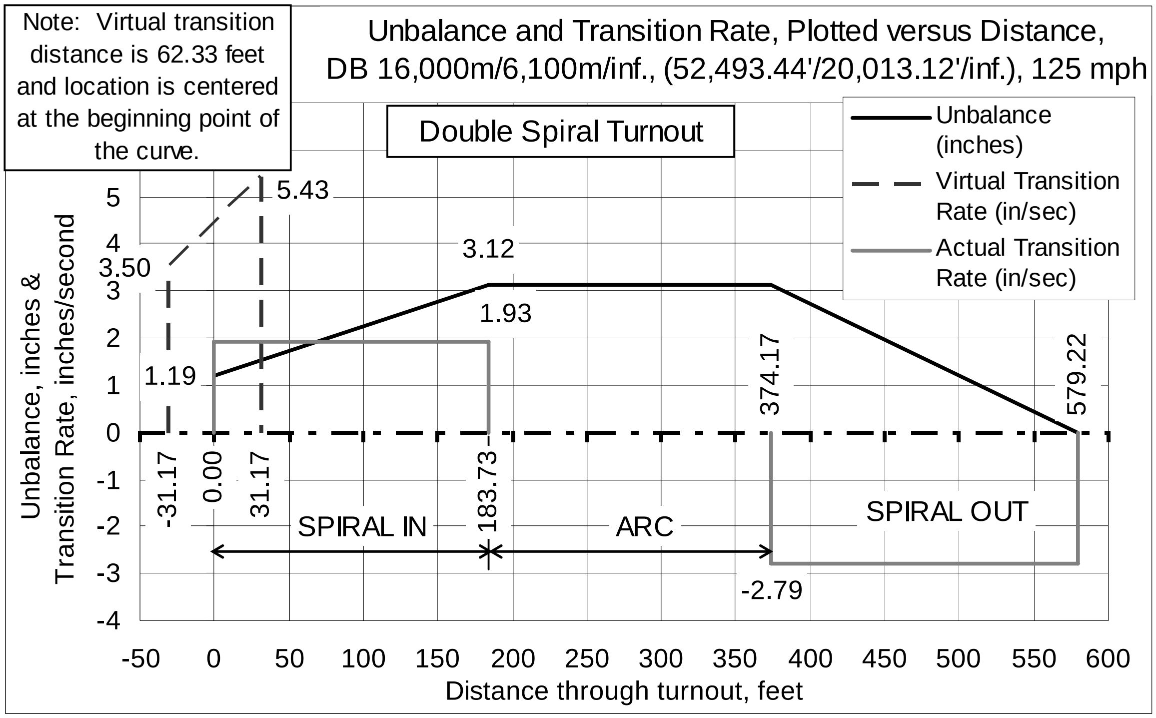


Figure 3.4.21: DB 16000/6100 double spiral, Unbalance and Transition Rate versus Time

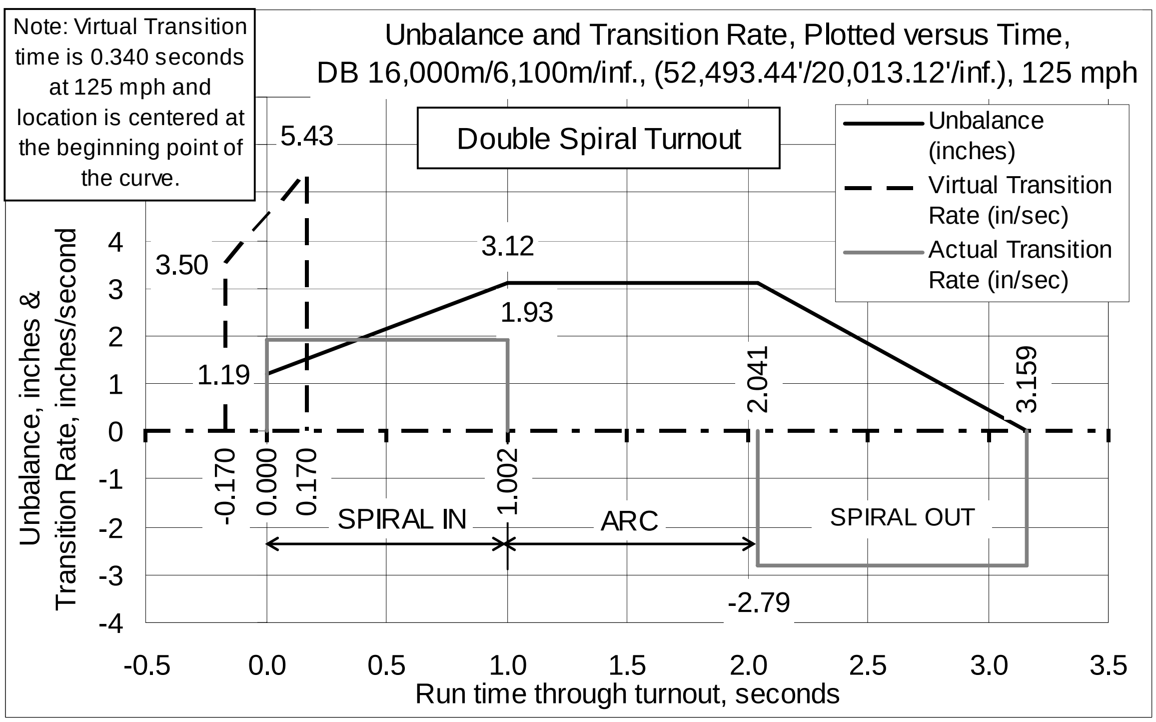


Figure 3.4.22: DB 16000/6100 single spiral, Unbalance and Transition Rate versus Distance

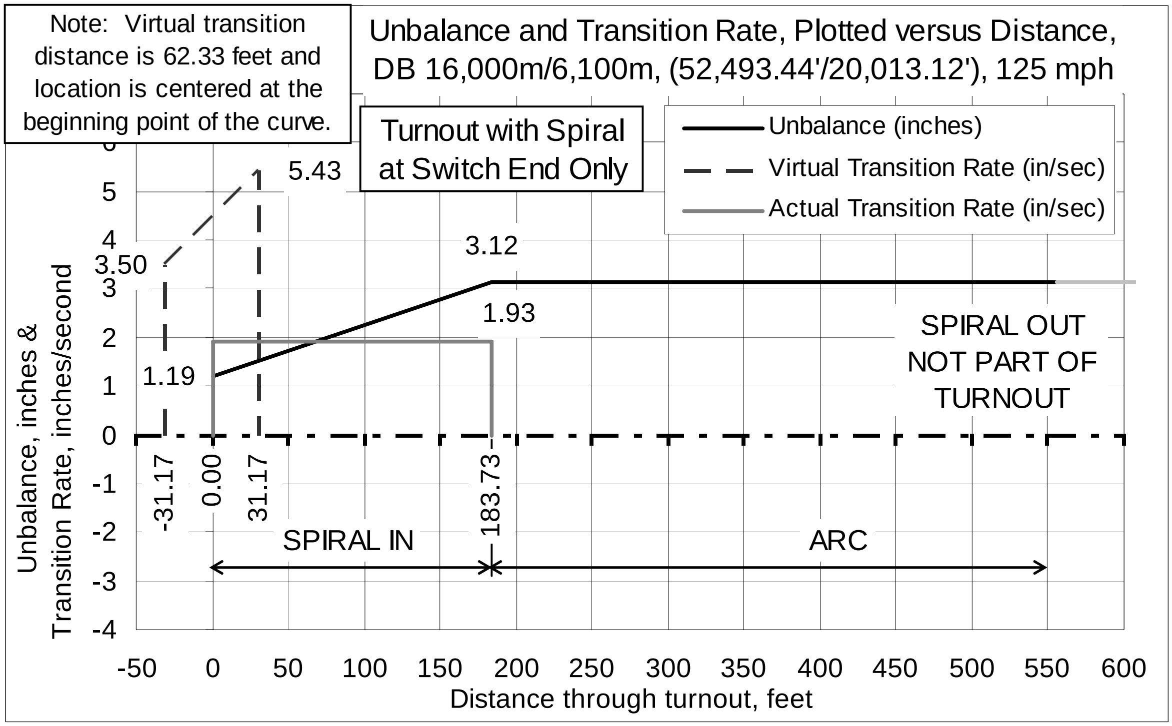
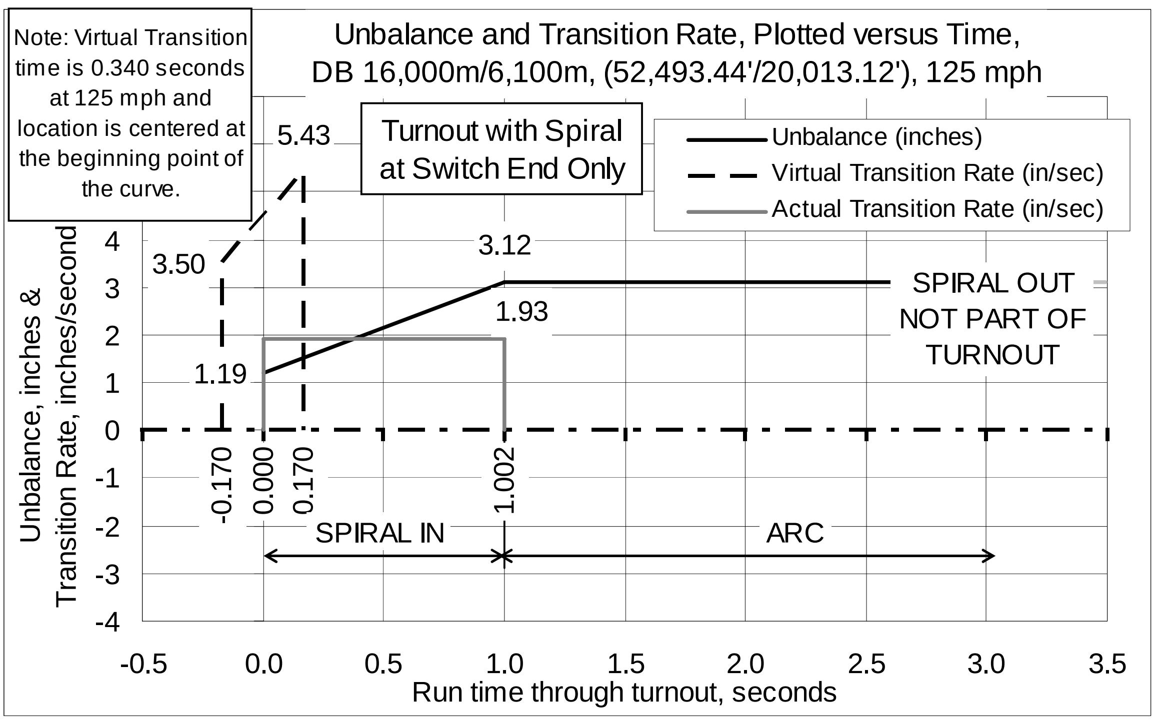


Figure 3.4.23: DB 16000/6100 single spiral, Unbalance and Transition Rate versus Time



The DB high speed turnouts with transitions at the switch end only were the basis of the Taiwan High Speed Railway turnouts, as the closest track centers for high speed turnouts connecting to parallel tracks were at 6.600 m (21.65 ft) centers. Transitioned turnouts were not used for main line crossovers.

3.4.6 Double Spiral Turnout Geometry

Three designs of double spiral turnouts have been developed either by or for the Austrian Federal Railways for high speed crossovers. The objective is to minimize entry and exit forces for the turnouts. These designs are developed using the following forces:

- Lateral acceleration in the deviation: 0.654 m/s^2
- Jerk at entry into the Deviation: 1.0 m/s^3
- Continuous change in Lateral Acceleration: 0.25 m/s^3

When these requirements are placed in more familiar terms, they are:

- Maximum unbalanced superelevation: 100 mm = 3.94 inches
- Virtual Transition Rate: 153 mm/s = 6.02 inches/second
- Transition Rate in Spiral: 38 mm/s = 1.50 inches/second

The three turnouts developed using these force limits are described as follows:

Table 3.4.8A: VAE Double Spiral Turnouts – Defined Values and Speeds – Metric Units

Ratio	Unit Length (m)	Radii (meters)	Allowed Speed km/h	*Unbalanced Superelevation (mm)*	*Virtual Transition Rate mm/s)*
1:24	82.500	2,600 / 1,600 / 2,600	116	*61.1 / 99.2 / 61.1*	*104*
1:45	147.300	6,000 / 3,700 / 12,107 / inf.	175	*60.2 / 97.7 / 29.8*	*154*
1:66	197.115	12,080 / 6,580 / 12,080	220	*47.3 / 86.8 / 47.3*	*152*

Table 3.4.8B: VAE Double Spiral Turnouts – Defined Values and Speeds – US Customary Units

Ratio	Unit Length (feet)	Radii (feet)	Allowed Speed mph	*Unbalanced Superelevation (inches)*	*Virtual Transition Rate (in/sec)*
1:24	270.67	8,530.18 / 5,249.34 / 8,530.18	72.1	*2.44 / 3.96 / 2.44*	*4.13*
1:45	483.27	19,685.04 / 12,139.11 / 39,721.13 / inf.	108.7	*2.40 / 3.90 / 1.19*	*6.15*
1:66	646.70	39,632.55 / 21,587.93 / 39,632.55	136.7	*1.89 / 3.46 / 1.89*	*6.07*

All these turnouts have a defined radius with an arc length of zero at the switch point end in a similar manner to that used on the DB standard turnouts. But, unlike the DB turnouts, two of these turnouts do not have a full spiral on the frog end. Only the 1:45 unit has a full spiral to a tangent on the frog end of the turnout. The 1:24 and 1:66 units have two equal length spirals such that the frog end has the same radius as the point of switch end, and therefore a Virtual Transition Rate out that is the same as the Virtual Transition Rate in. Note that for the 1:45 and 1:66 turnouts, the Virtual Transition Rate is higher than the limits allowed in UIC 711.

Note that the entry/exit radii are at lower multiples of the central radii than those used in the DB turnouts. Thus, the virtual transition rates are higher than those for DB turnouts with the same central radius and unbalanced superelevation on that central radius.

Lower speed limits than the designated speed limits shown in Table 3.4.8 are set by some users of these turnouts. For example: The 1:45 turnout is used by the FS (Italian State Railway). On their system, it is defined as a 160 km/h turnout. For this speed, the unbalanced superelevations are 50.3 / 81.6 / 25.0 / 0.0 mm (2.10 / 3.26 / 1.00 / 0.00 inches). At this speed, the entry Virtual Transition Rate is 118 mm/s (4.70 in/sec), which is under the recommended UIC 711 limit.

3.4.7 Shinkansen Turnout Geometry

The normal operating concept on the Shinkansen is to have the station track turnouts located very close to the end of the platform and to move past the platform at a relatively slow speed. Therefore they do not use high speed turnouts. On the Nogano Shinkansen there is one 160 km/h (100 mph) No. 38 turnout that was installed in 1998. Otherwise, the largest turnouts used on the Shinkansen are No. 18 turnouts with an internal radius of 1106 m (3628.61 ft) measured on the curved closure rail.

3.4.8 Taiwan High Speed Railway Turnout Geometry

The primary application of high speed turnouts in the Taiwan High Speed Railway is at eight intermediate stations having platforms on bypass tracks connected to the main tracks with high speed entry and exit turnouts. Even though the system has bi-directional signaling, the design of the station layouts was based on the normal direction of operation. These station tracks were set 6.60 meters (21.65 feet) offset and parallel to the main tracks.

Initially the turnouts proposed for this application were those illustrated in UIC 711. For the station connection tracks the plan was to combine these turnouts with return curves (reversing curves beyond these turnouts bringing the turnout track to an alignment parallel to the main track. The return curves were initially designed with spiral lengths developed in accordance with the requirements of UIC 703, Layout Characteristics for Lines Used by Fast Passenger Trains.

In the final study phase pre-construction the alignment and track engineers of the Taiwan system decided to follow the DB concepts of spiraled switch points for the station connection tracks because use of these spiraled switch point resulted in a considerable reduction in the entrance forces (the virtual transition rate). Reduced forces are more than simply a ride quality concern. High forces between train and track also mean reduced component life. As part of this decision, it was also decided to shorten the spirals on the return curves so that the transition forces were similar to those in the turnouts.

In all these analyses and calculations, the truck centers used were 17.5 meters (57'-5") instead of the 19 meters used in UIC 711, because 17.5 meters was the truck centers of the passenger equipment operated on the system.

Use of the UIC 711 Figure 2 turnout (1200 meter radius 1:18.5) was retained for one application, the turnouts set between main tracks to permit single line operation for two reasons.

- Anticipated infrequent use
- Larger turnouts on viaducts would require one or more sets of rail expansion joints

First a look at these remaining UIC style turnouts in their crossover application:

Figure 3.4.24: THSRC Main Track Crossover – 1:18.5 Simple Arc Turnouts

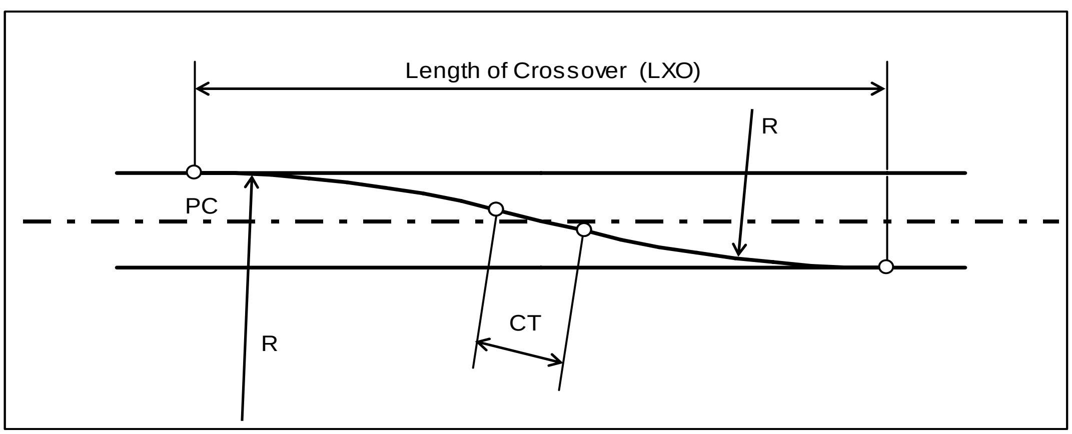


Table 3.4.9: THSRC 100 km/h 1:18.5 Crossover, in 4.5 meter Track Centers

	Metric Units	US Customary Units	
Geometric Properties			
Track Centers	4.5 m	14.76 ft	
Central Angle of Turnouts	3d05m38.6s	3d05m38.6s	
Turnout Curve Radius	1,200	3,937.01	
Length on Tangent	148.068	485.79	
Length through Crossover	148.158	486.08	
Length of Curve	64.802	212.60	
Tangent Between Curves	18.554	60.87	
Operating Characteristics			
Design Speed	100 km/h	62.14 mph	60 mph
Unbalance	98.3 mm	3.92 inches	3.66 inches
Virtual Transition Distance (Truck centers of Shinkansen)	17.500 m	57.42 ft	57.42 ft
Virtual Transition Time	0.630 s	0.653 sec	0.676 sec
Virtual Transition Rate	156 mm/s	6.01 in/sec	5.61 in/sec

Figure 3.4.25: THSRC Main Track Crossovers Unbalance and Transition Rate versus Distance

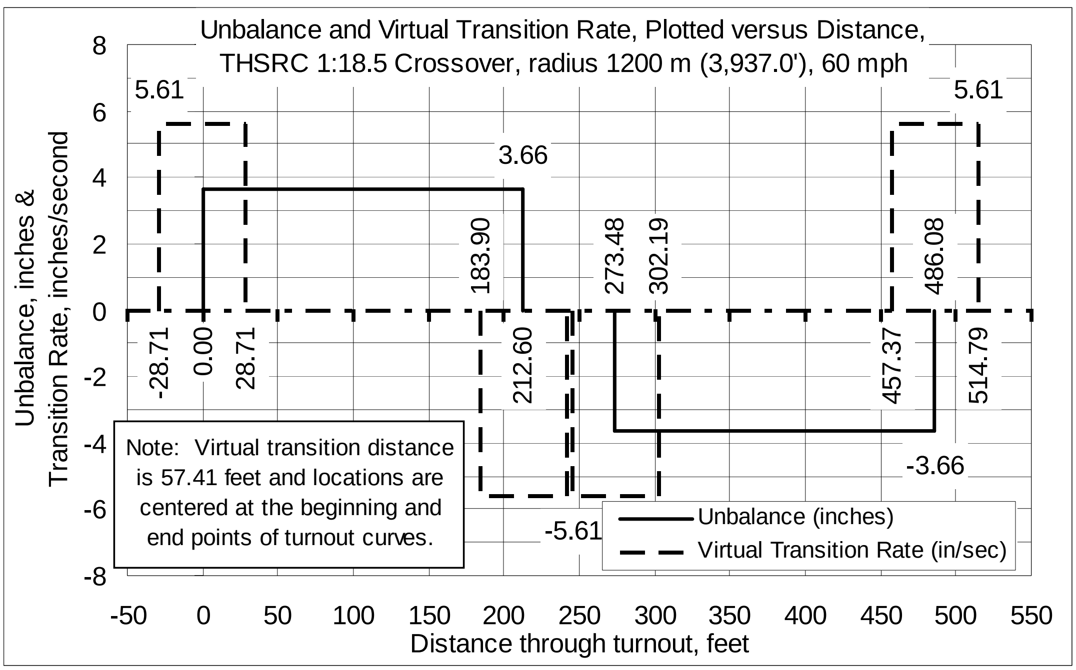
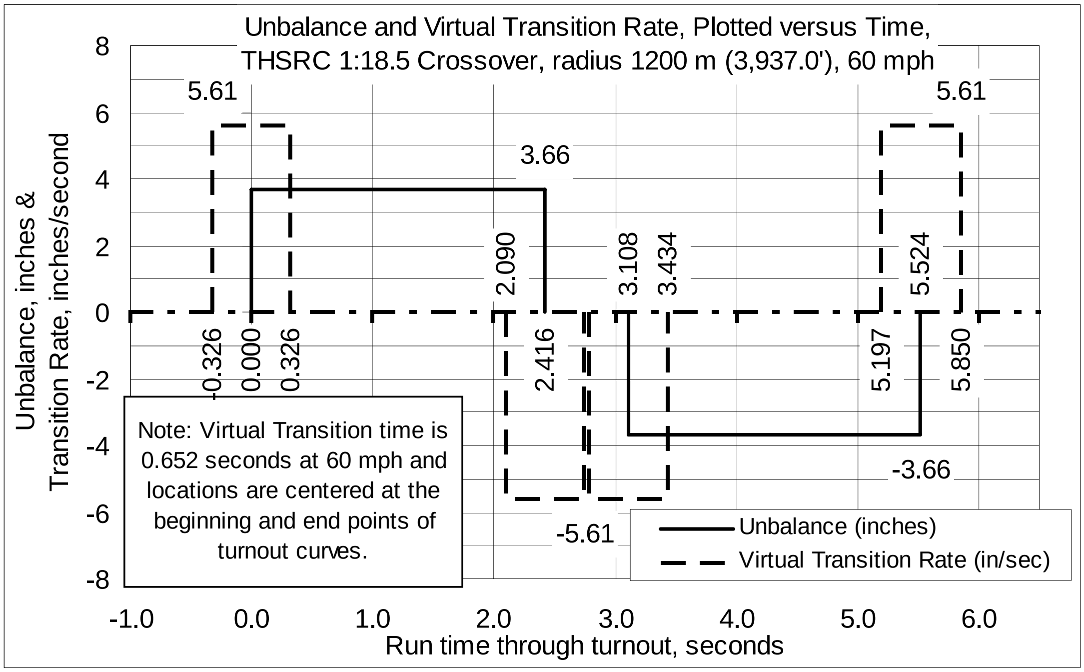


Figure 3.4.26: THSRC Main Track Crossover, Unbalance and Transition Rate versus Time



Despite this turnout being a typical European “tangent point” design turnout, it has high entry and exit forces due to the high speed and high unbalanced superelevation. These high unbalanced superelevation and virtual transition rates clearly illustrate why use of this turnout in regular service at its nominal design speed of 100 km/h (62 mph) was determined to be undesirable. Therefore all these turnouts are place where they are used only in emergencies or abnormal operating conditions.

Final Selected Geometry of Station Connection Tracks: Following the determination to use spiral point turnouts, the initial geometry of the station connections was set so that the segment run times and forces in the turnouts and the return curves were similar, using the DB design concepts, but not the exact DB designs. The DB designs were known to include some compromises necessary to fit existing situations in Germany that would not need to be considered in a new system. This initial design combination resulted in a theoretical smooth riding connection. However, based on the thought at the time that these units would be built with the UIC 60 rail section, is was decided to follow the DB turnout designs exactly on the switch point ends for the sake of procurement of a previously used standard design to reduce or eliminate potential problems in fabrication. As the situation developed, the Taiwan system track did not use the UIC 60 rail section in which these turnouts were normally fabricated. Instead, it was built in Japanese 60 kg/m rail, a section very close in shape and properties to 119RE. By this time it was too late to modify the turnout internal geometry so as to rationalize the switch entry characteristics.

The selected turnout-curve combinations were applied based on the calculated maximum speed of any part of the train over the switch point with the objective being that the train speed would not be affected by the speed limit of the turnout. The speed-distance relationship used to determine the needed turnout speed was based on that shown in the following figures.

Figure 3.4.27: Train Braking and Acceleration – Metric Units

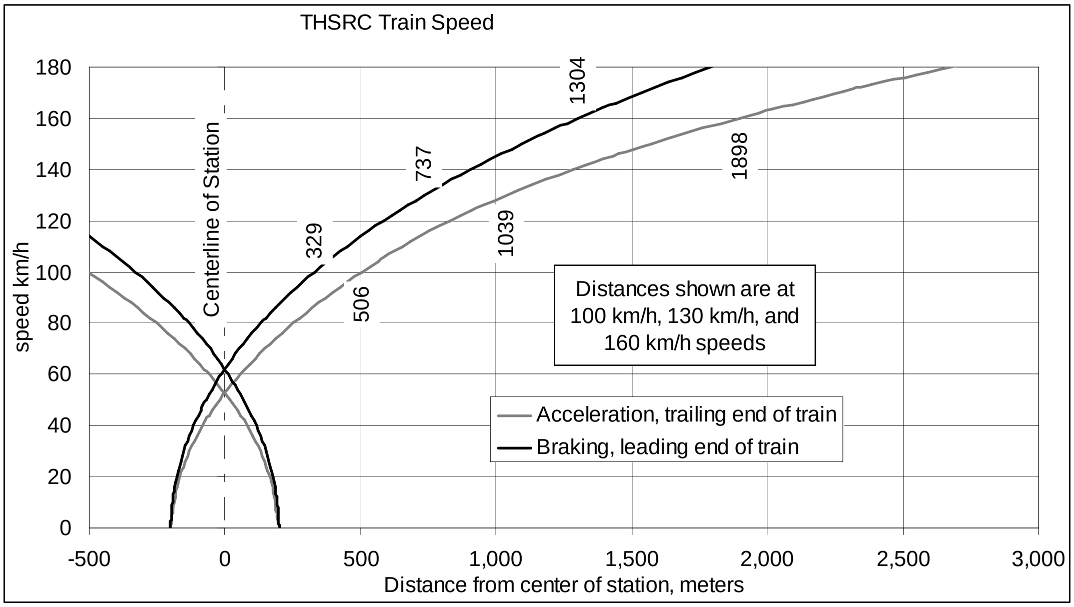
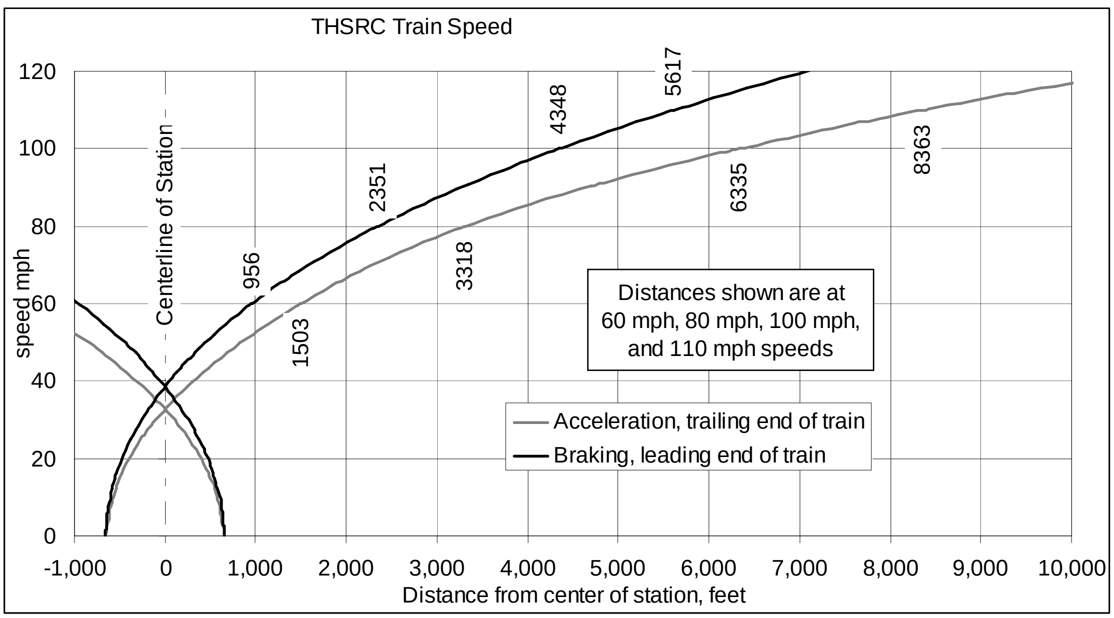


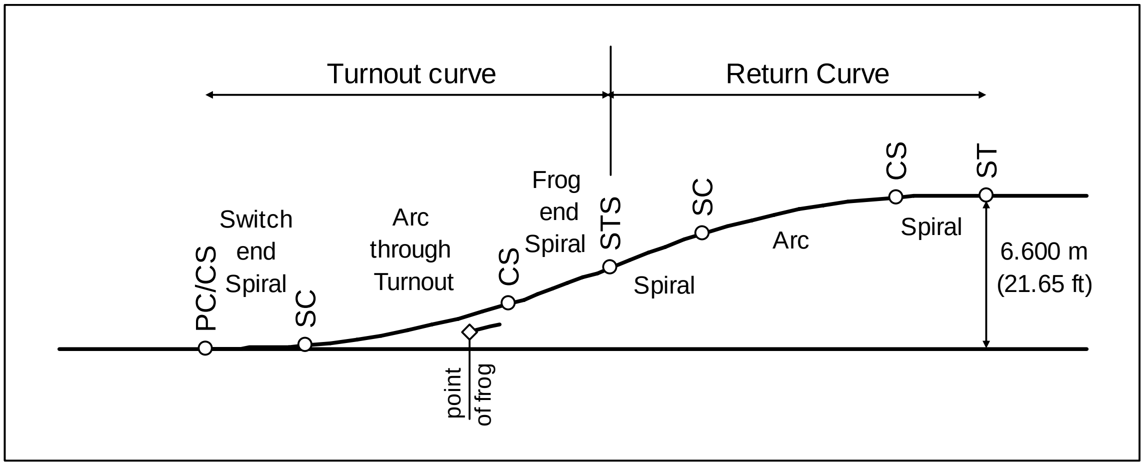
Figure 3.4.28: Train Braking and Acceleration – US Customary Units



The distance between switch point and platform center on the designated arrival end varied from 550 meters to 1,367 meters (1,804 feet to 4,485 feet), and on the designated departure end from 443 meters to 911 meters (1,453 feet to 2,989 feet). Four standard designs were developed, for speeds of 100, 130, 160 and 200 km/h (60, 80, 100, and 125 mph). The highest speed design was not necessary at any location, and therefore was not used. The predominant exit connection design was the 100 km/h arrangement with only three 130 km/h exit tracks. The predominant entry design was the 130 km/h arrangement with only four 160 km/h entrance tracks.

The curve used to bring the alignment off the end of the turnout curve back to parallel was set as a true reversing curve, with the spiral off the turnout curve meeting the spiral into the return curve at an STS point. The curve radius was set slightly smaller than the turnout curve radius, as it was set with 30 mm (1.18 inches) of superelevation. Bringing these spiral ends together provided one single smooth transition in direction rather than two with a short break in between. Since both these curves had spirals of sufficient length to prevent any adverse effects, there was no need, either for ride quality or track issues, to provide any tangent between them.

Figure 3.4.29: Taiwan High Speed Railway Typical Station Connection Turnout and Curve

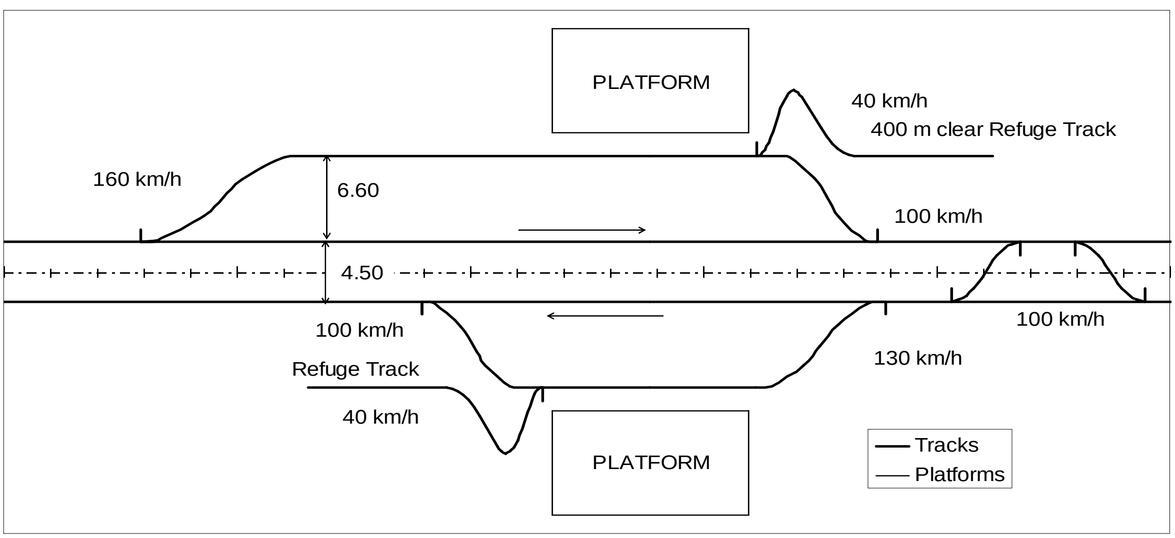


The distance between turnout and station was determined by a practical compromise between:

- The distance required in the operation plan
- the structural layout and
- the alignment geometry.

Generally, the distance required in the operation plan was increased rather than decreased where structural and alignment considerations required a different turnout placement. The arrangement shown in Figure 3.4.29 is used for all mainline connections shown in Figure 3.4.30.

Figure 3.4.30: Taiwan High Speed Railway Track Layout for Typical Intermediate Stations



Note that the operation of trains in Taiwan is normally left handed. This standard is normal practice on the previously existing Taiwan Railroad network and the Shinkansen System.

The design speed of the entry and exit connections to station tracks depended upon their distance from the station platform. Since the operating plan permitted the exit turnouts to be as close as practical to the end of the platform, most exit connections used the 100 km/h arrangement, which required 238 meters (781 ft) beyond platform end without a refuge track. With allowance for the refuge track turnout, the normal distance from center of platform to switch point of exit end turnout was set at 480 meters (1575 feet) beyond platform center. Since the back end of the train could not achieve 100 km/h (62 mph) in less than 506 meters (1660 feet) beyond platform center, a 100 km/h arrangement had no affect on train speed. Due to the faster braking rate, the front end of the stopping train could still be moving faster than 100 km/h when it passed the point 438 meters from platform end. Therefore, the minimum design speed of the approach connection was that for 130 km/h (81 mph).If the operating plan needed an approach track that extended over 720 meters (2362 feet) from the platform center, a 160 km/h (99 mph) connection layout was used.

Table 3.4.10A: Taiwan High Speed Rail Standard Station Connection Turnouts and Curves Metric Units

Station Connection Tracks with Spiral Point Turnouts				
Part 1: Geometry of Connection and its Segments, in meters unless stated otherwise				
Design Speed	100 km/h	130 km/h	160 km/h	200 km/h
Platform Track Offset	6.600 m	6.600 m	6.600 m	6.600 m
Turnout Entry Radius	3,000.000	4,800.000	10,000.000	16,000.000
Turnout Body Radius	1,500.000	2,450.000	4,000.000	6,100.000
Switch Spiral Length	27.000	41.075	37.500	56.000
Frog Spiral Length	28.000	36.000	42.000	55.000
Return Curve Radius	1,300.000	2,300.000	3,600.000	5,400.000
Curve Spiral Length	25.000	33.000	40.000	52.000
Total Length along main track	213.156	278.981	350.536	436.315
Total Length along Platform Track	213.301	279.092	350.624	436.386
Minimum straight distance beyond platform end	25.000	25.000	25.000	25.000
Angle at STS	3d25m43s	2d 37m48s	2d05m55s	1d41m30s
Length of Entry Curve	0.000	0.000	0.000	0.000
Length of Turnout Body Curve	55.509	63.441	99.263	113.940
Length of Return Curve	52.791	72.576	91.861	107.446
Part 2: Unbalanced Superelevation and Transition Rates in mm or mm/s as applicable				
Unbalance at Turnout Entry	39.3	41.5	30.2	29.5
Unbalance in Turnout Body	78.7	81.4	75.5	77.4
Superelevation in Return Curve	30.0	30.0	30.0	30.0
Unbalance in Return Curve	60.8	56.7	53.9	57.4
Virtual Transition Time	0.630	0.485	0.394	0.315
Virtual Transition Rate at Entry	62.4	85.7	76.7	93.7
Virtual Transition Rate 17.5 m in	102.9	120.8	130.4	141.1
Actual Transition Rate in Switch	40.5	35.0	53.7	47.5
Transition Rate at Frog End	78.0	81.6	79.9	78.2
Transition Rate in Curve Spirals	67.5	62.1	59.9	61.3
Part 3: Run Time of Segments and Connection in Total, in seconds				
Switch Spiral	0.97	1.14	0.84	1.01
Turnout arc	2.00	1.76	2.23	2.05
Frog spiral	1.01	1.00	0.95	0.99
Curve Spiral	0.90	0.91	0.90	0.94
Curve Arc	1.90	2.01	2.07	1.93
Curve Spiral	0.90	0.91	0.90	0.94
Sum through Divergence	7.68	7.73	7.89	7.85

Table 3.4.10B: Taiwan High Speed Rail Standard Station Connection Turnouts and Curves US Customary Units and Speeds

Station Connection Tracks with Spiral Point Turnouts				
Part 1: Geometry of Connection and its Segments, in feet unless stated otherwise				
Design Speed	60 mph	80 mph	100 mph	125 mph
Platform Track Offset	21.65	21.65	21.65	21.65
Turnout Entry Radius	9,842.52	15,748.03	32,808.40	52,493.44
Turnout Body Radius	4,921.26	8,038.06	13,123.36	20,013.12
Switch Spiral Length	88.58	134.76	123.03	183.73
Frog Spiral Length	91.86	118.11	137.80	180.45
Return Curve Radius	4,265.09	7,545.93	11,811.02	17,716.54
Curve Spiral Length	82.02	108.27	131.23	170.60
Total Length along main track	699.33	915.29	1,150.05	1,431.48
Total Length along Platform Track	699.81	915.66	1,150.34	1,431.71
Minimum straight distance beyond platform end	82.02	82.02	82.02	82.02
Angle at STS	3d25m43s	2d 37m48s	2d05m55s	1d41m30s
Length of Entry Curve	0.000	0.000	0.000	0.000
Length of Turnout Body Curve	182.12	208.14	325.66	373.82
Length of Return Curve	173.20	238.11	301.38	352.51
Part 2: Unbalanced Superelevation and Transition Rates, inches or inches/sec as applicable				
Unbalance at Turnout Entry	1.46	1.63	1.22	1.19
Unbalance in Turnout Body	2.93	3.18	3.05	3.12
Superelevation in Return Curve	1.18	1.18	1.18	1.18
Unbalance in Return Curve	2.20	2.21	2.21	2.35
Virtual Transition Time	0.652	0.489	0.391	0.313
Virtual Transition Rate at Entry	2.24	3.32	3.11	3.80
Virtual Transition Rate 57.42 ft in	3.70	4.68	5.29	5.73
Actual Transition Rate in Switch	1.45	1.36	2.18	1.93
Transition Rate at Frog End	2.80	3.16	3.24	3.17
Transition Rate in Curve Spirals	2.36	2.40	2.46	2.52
Part 3: Run Time of Segments and Connection in Total, in seconds				
Switch Spiral	1.01	1.15	0.84	1.00
Turnout arc	2.07	1.77	2.22	2.04
Frog spiral	1.04	1.01	0.94	0.98
Curve Spiral	0.93	0.92	0.89	0.93
Curve Arc	1.97	2.03	2.05	1.92
Curve Spiral	0.93	0.92	0.89	0.93
Sum through Divergence	7.95	7.80	7.84	7.81

The following figures illustrate the values and forces for the conditions as given in Table 3.4.10B. Note that there is very little difference in the time over these segments, despite the large increase in distance required as speed increases.

Figure 3.4.31: Taiwan High Speed Railway: Forces Relative to Distance in 60 mph Station Connection Turnout and Curve

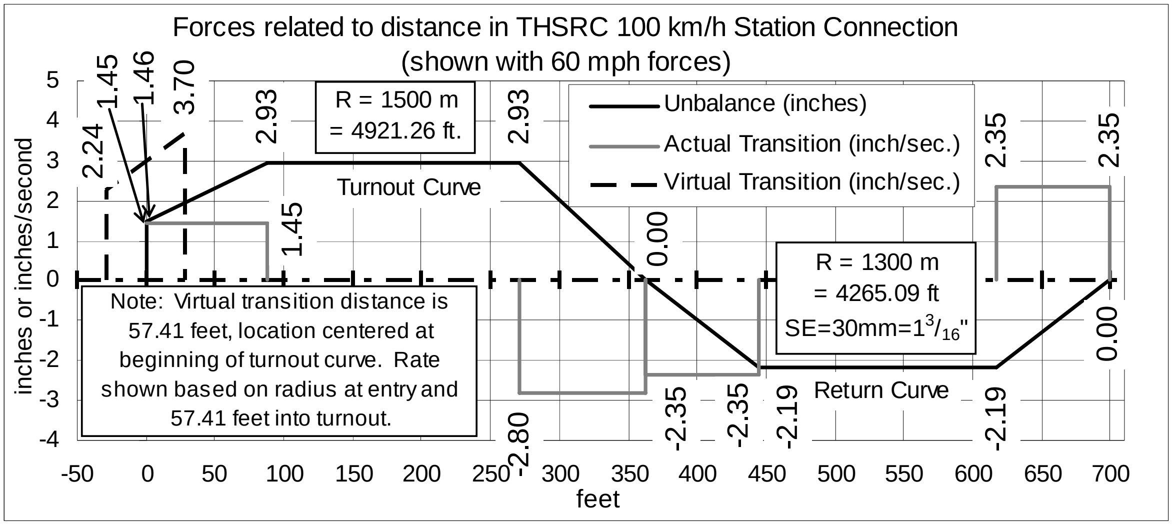


Figure 3.4.32: Taiwan High Speed Railway: Forces Relative to Time in 60 mph Station Connection Turnout and Curve

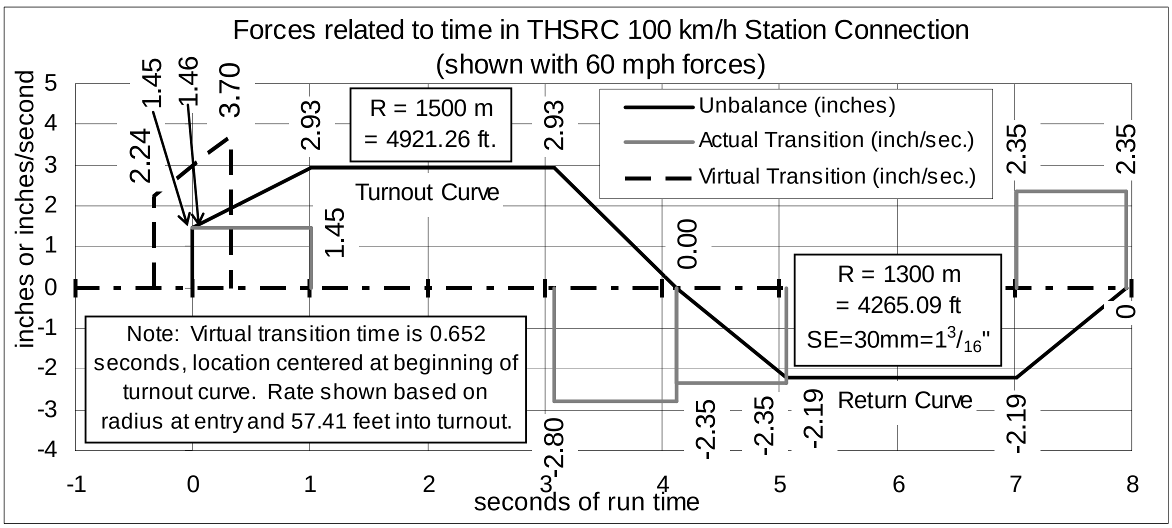


Figure 3.4.33: Taiwan High Speed Railway: Forces Relative to Distance in 80 mph Station Connection Turnout and Curve

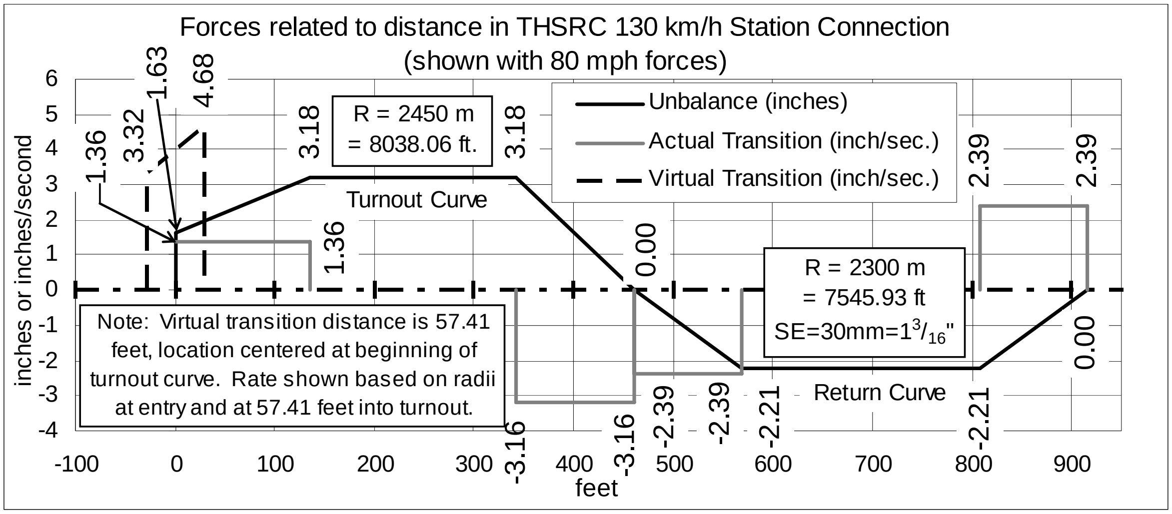


Figure 3.4.34: Taiwan High Speed Railway: Forces Relative to Time in 80 mph Station Connection Turnout and Curve

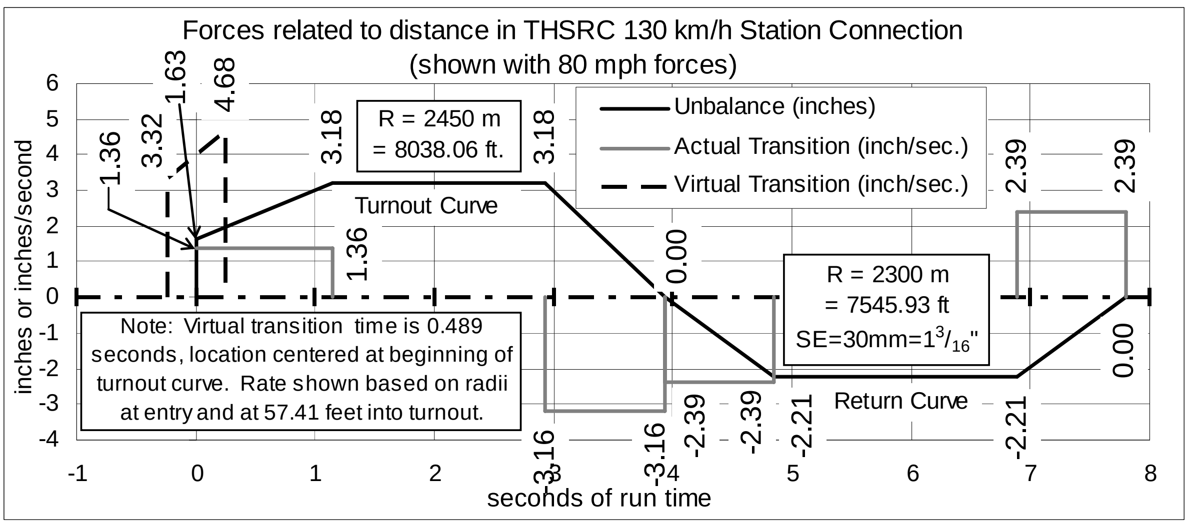


Figure 3.4.35: Taiwan High Speed Railway: Forces Relative to Distance in 100 mph Station Connection Turnout and Curve

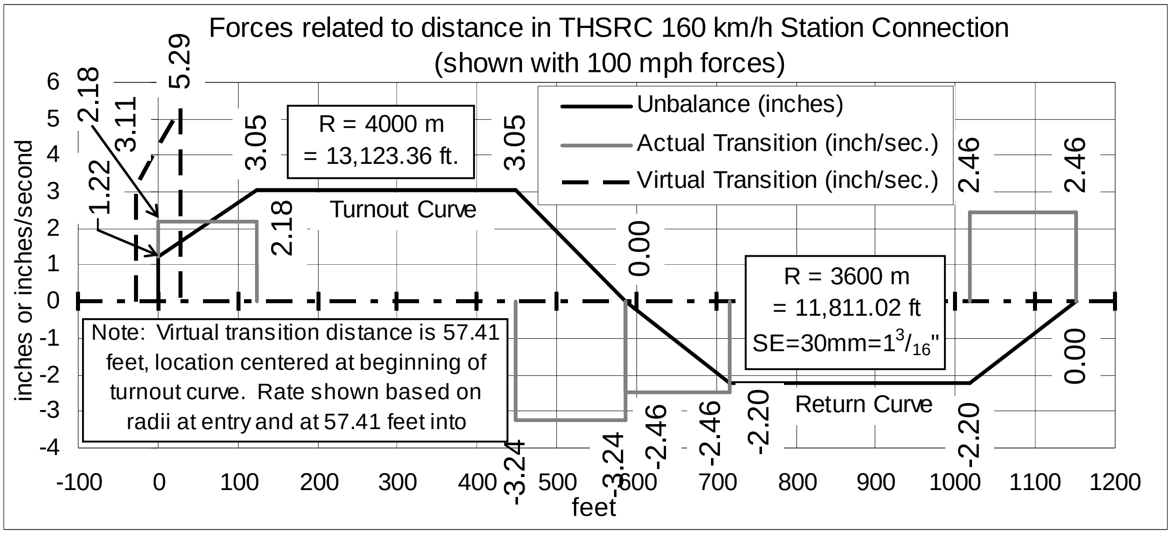


Figure 3.4.36: Taiwan High Speed Railway: Forces Relative to Time in 100 mph Station Connection Turnout and Curve

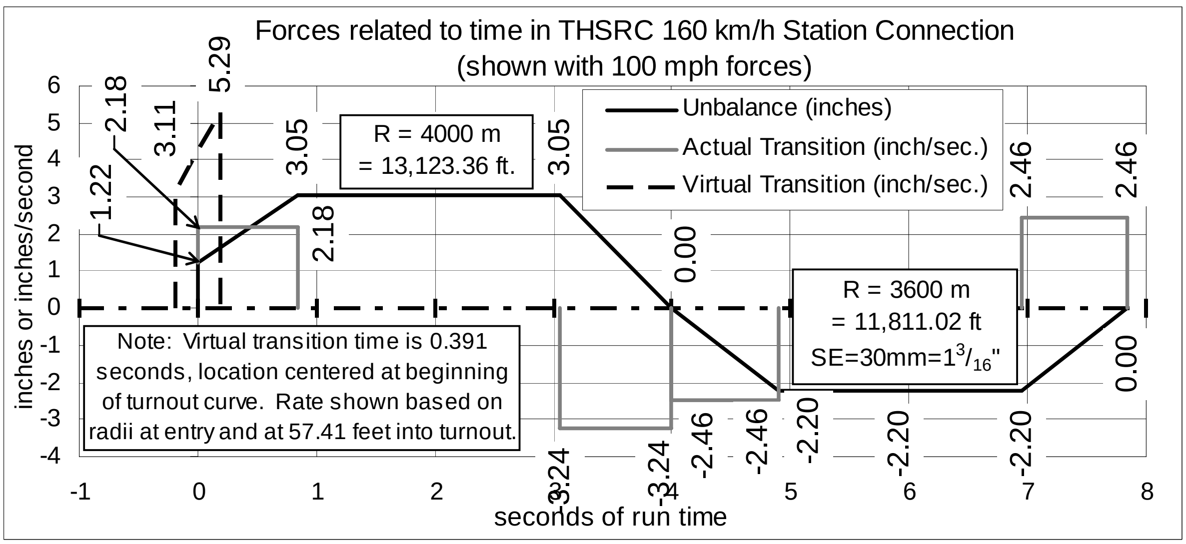
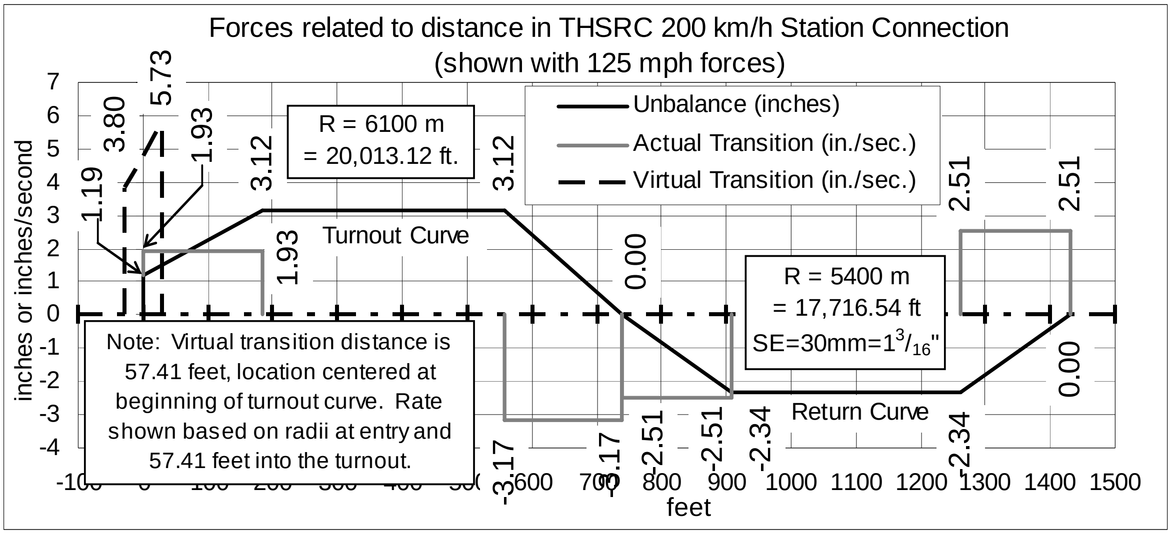
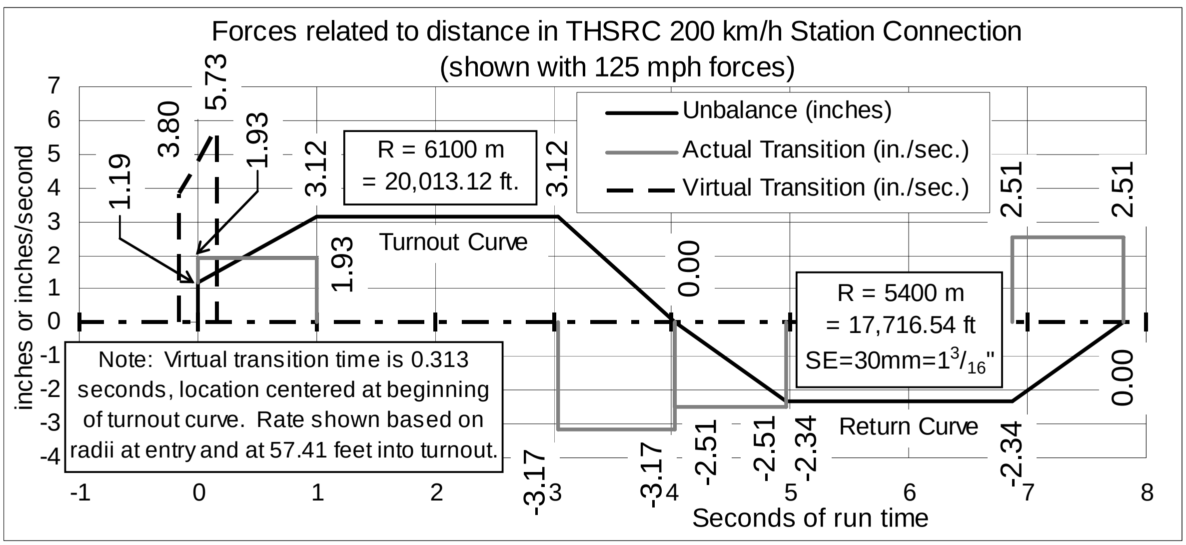


Figure 3.4.37: Taiwan High Speed Railway: Forces Relative to Distance in 125 mph Station Connection Turnout and Curve



(None of these were built in Taiwan)

Figure 3.4.38: Taiwan High Speed Railway: Forces Relative to Time in 125 mph Station Connection Turnout and Curve



(None of these were built in Taiwan)

These concepts derived from these turnouts and return curves are one of the primary sources used in development of the high-speed turnouts and high-speed station track connections for the California High Speed Train project. These arrangements are known to provide a very good ride quality through the connection, and are relatively consistent throughout the connection.

The following major parameters may be gleaned from these arrangements:

- Actual transition lengths should be set with a length equivalent to about 1.0 to 1.1 seconds of run time at the design speed.
- The radius at the beginning of the switch end transition curve should be roughly twice the radius of the turnout body curve, unless the virtual transition rate exceeds the limits given in UIC 711.
- Connection to the return curve should be with reversing spirals so that the transition forces are relatively constant through the reversal.

- The return curve radius may and should be slightly smaller than the turnout body curve as some superelevation may and should be placed in this curve.

3.5 LOW AND MEDIUM SPEED TURNOUT GEOMETRIES

3.5.1 American Turnout Geometry – Overview

A number of American practices are at considerable variance from those used in most of the rest of the world. Table 3.4.1 gives the list of commonly used AREMA style turnouts. Those listed as "Recommended Practice" are shown in bold. Frog numbers that have been used by major railroad companies but are not in the AREMA listing on Plans 910 and 920 are shown in italics. Use of curved frogs is rare in American practice as it results in there being two versions for each given number, right hand and left hand, which complicates parts inventory in maintenance. Only spring frogs are truly handed, and even these are usually straight.

These frogs are then mated with a set of standard switch lengths, straight switch points on Plan 910, commonly 16'-6", 22'-0" and 30'-0" or curved switch points on Plan 920, commonly 19'-6", 26'-0" and 39'-0". Unlike most standards elsewhere, the curved points do not come down to a nominal zero angle at the point, but instead have an entry angle of about half that for the straight point version of the same frog number turnout. The longer straight points have fallen out of use, and are no longer part of AREMA's recommended practice.

The other dimension commonly given in discussion of American turnouts is the Lead, which is the distance from the actual point of switch to the ½ inch point of frog, and is normally given in feet and inch values rather than decimal feet. A curve radius is then calculated to fit with the distance between the ends of the switch rails and the beginning point of the frog rails. Since each railroad company has historically developed their own designs, not all turnout designs with the same given frog number and switch type will be of the same length and internal radius, although variation are normally within a relatively small range of values.

The length of track occupied by switch ties is of interest for installation purposes, but this distance is not part of the geometric design of the turnout, and again varies from railroad company to railroad company.

AREMA Geometry and modified AREMA Geometry turnouts have historically been primarily slow speed devices. The geometric layouts shown in the AREMA Portfolio of Trackwork Plans, Plans 910 and 920 (see Table 3.4.1) are the basis for the turnout designs used by most railroad companies following AREMA practices. Turnout frogs are normally set at angles defined by their ratio using whole number ratios. Most US railroad companies limit themselves to the use of three to five different turnouts, but frequently not the same three to five as other companies. Since each company has historically developed their own designs, even with the use of standard frog numbers and angles the internal geometry of the turnout and the selection of switch point to be used with the turnout may differ from that shown in the AREMA Portfolio. The AREMA has recommended that the numbers of turnouts be limited to only five, but this has not been followed by all the railroad companies operating in North America.

Table 3.5.1: AREMA Standards and Other Commonly Used North American Turnouts

Frog No.	Frog Angle	Straight Point			Curved Point			
		Length	Angle	Closure Radius	Length	Entry Angle	Point Radius	Closure Radius
5	11° 25’ 16”	11’-0”	2° 39’ 34”	177.80	13’-0”	1° 41’ 31”	616.55	188.10
6	**9° 35’ 38”**	**11’-0”**	**2° 39’ 34”**	**258.57**	13’-0”	1° 41’ 31”	616.55	283.88
7	8° 10’ 16”	16’-6”	1° 46’ 22”	365.59	13’-0”	1° 41’ 31”	616.55	409.77
8	**7° 09’ 10”**	**16’-6”**	**1° 46’ 22”**	**487.28**	13’-0”	1° 41’ 31”	616.55	550.75
8½	*6° 43’ 59”*	*16’-6”*	*1° 46’ 22”*	*603.28*	*unk.*	*unknown*	*unk.*	*unknown*
9	6° 21’ 35”	16’-6”	1° 46’ 22”	615.12	19’-6”	1° 04’ 24”	1,222.17	632.15
10	**5° 43’ 29”**	**16’-6”**	**1° 46’ 22”**	**779.39**	19’-6”	1° 04’ 24”	1,222.17	806.09
11	5° 12’ 18”	22’-0”	1° 19’ 46”	927.27	19’-6”	1° 04’ 24”	1,222.17	1,009.34
12	4° 46’ 19”	22’-0”	1° 19’ 46”	1,104.63	19’-6”	1° 04’ 24”	1,222.17	1,205.02
13	*4° 24’ 19”*	*22’-0”*	*1° 19’ 46”*	*unknown*	*unk.*	*unknown*	*unk*	*unknown*
14	4° 05’ 29”	22’-0”	1° 19’ 13”	1,581.20	26’-0”	0° 50’ 44”	2,464.55	1,576.40
15	**3° 49’ 06”**	30’-0”	0° 58’ 30”	1,720.77	**26’-0”**	**0° 50’ 44”**	**2,464.55**	**1,8872.90**
16	3° 34’ 47”	30’-0”	0° 58’ 30”	2,007.12	26’-0”	0° 50’ 44”	2,464.55	2,240.84
18	3° 10’ 56”	30’-0”	0° 58’ 30”	2,578.83	39’-0”	0° 27’ 19”	3,605.70	2,622.45
20	**2° 51’ 51”**	30’-0”	0° 58’ 30”	3,289.29	**39’-0”**	**0° 27’ 19”**	**3,605.70**	**3,329.91**
24	*2° 23’ 13”*	*unk.*	*unknown*	*unknown*	39’-0”	0° 32’ 45”	5,105.62	5103.26

Union Pacific and BNSF have developed a set of Common Standards for turnouts. The following table provides the basic characteristics of these turnouts along with a comparison to the closest equivalent standard design in AREMA Plan 910 or 920.

Table 3.5.2: BNSF / UPRR Common Standard Turnouts compared to AREMA

Frog No	Frog Angle deg, min, sec	Type	Lead (PS to ½” PF), feet[4]	Closure Radius, feet	Switch Length, feet	Switch Type	point angle deg, min, sec	Extended Curve Offset, inches[5]
24	2° 23’ 13”	CS[1]	177.25	5,103.26	39.00	curved	0° 32’ 45”	**-0.233**
20	2° 51’ 51”	CS[1]	156.057	3,329.66	39.00	curved	0° 32’ 45”	**-0.030**
		RE-cv[2]	156.042	3,329.91	39.00	curved	0° 27’ 19”	**-0.791**
15	3° 49’ 06”	CS	111.229	1,853.42	26.00	curved	0° 44’ 47”	**-0.159**
		RE-cv	113.417	1,872.90	26.00	curved	0° 50’ 44”	**-0.941**
11	5° 12’ 18”	CS	83.500	1,011.69	19.50	curved	1° 00’ 40”	**-1.200**
		RE-cv	83.500	1,009.34	19.50	curved	1° 04’ 25”	**-1.033**
9	6° 21’ 35”	CS	72.917	614.00	16.50	straight	1° 46’ 22”	3.010
		RE-st[3]	72.297	615.12	16.50	straight	1° 46’ 22”	2.702
		RE-cv	74.104	632.15	19.50	curved	1° 04’ 25”	1.669

1. Type CS is the BNSF-UP Common Standard as shown on their drawings:
   341000: No. 9 Turnout 16’-6” Straight Switch Turnout Geometry;
   343000: No. 11 Turnout 19’-6” Curved Switch Turnout Geometry;
   345000: No. 15 Turnout 26’-0” Curved Switch Turnout Geometry;
   346000: No. 20 Turnout 39’-0” Curved Switch Turnout Geometry.
   347000: No. 24 Turnout 39’-0” Curved Switch Turnout Geometry.
2. Type RE-cv from AREMA Plan No. 920, Turnout and Crossover Data for Curved Split Switches.
3. Type RE-st from AREMA Plan No. 910, Turnout and Crossover Data for Straight Split Switches.
4. Lead distances are normally nominated in feet and inches.
5. Extended Curve Offset shows whether the extended arc of the curved closure rail crosses the straight rail, and by how far. A negative value indicates that the arc crosses the rail.

For many years, the largest AREMA standard design has been the No. 20 turnout with a 39’-0” curved switch which is usually limited to 40 or 45 mph over the curved side, although the AREMA Manual states that 50 mph is permissible. Caltrain allows 50 mph for passenger trains and 40 mph for freight trains over their No. 20 turnouts, but their turnouts have a longer switch point with a smaller entry angle than the AREMA standard. Even with that, there is a significant jerk in the ride over these points.

Turnouts having the frog numbers currently used in the Union Pacific BNSF Common Standards will be used for the yard turnouts and low and medium speed turnouts on the CHSTP. The internal geometry will be the “tangent point” design so as to provide a small switch point entry angle and smooth curve.

3.5.2 Shinkansen Turnout Geometry

The normal operating concept on the Shinkansen is to have the station track turnouts located very close to the end of the platform and to move past the platform at a relatively slow speed. For this situation, the turnouts used are No. 18 turnouts with an internal radius of 1106 m (3628.61 ft) measured on the curved closure rail. Other than the No. 9, which is their standard turnout for yards on the Shinkansen system, all Japanese standard turnouts are curved frog turnouts, with the defined angle being at the end of the unit. Turnout numbers are defined the same as US standard, but the angle is then rounded to the nearest minute or half minute.

The No. 9 radius, 202.109 m (663.09 ft) at the closure rail, which gives 201.392 m (660.73 ft) at track centerline is regarded as the smallest practical radius through which Shinkansen equipment should be operated. However, the Shinkansen equipment had no apparent difficulty traveling through the 190 m (623.36 ft) radius yard turnouts in Taiwan. The more heavily used of these turnouts did show early indications of a high rate of side wear on the rails, but this is understood to also be true for the Japanese standard No. 9 turnouts.

3.5.4 Low and Medium Speed Turnouts used on the Taiwan High Speed Rail

Lower speed turnouts were based on European practices, with the following being used:

Table 3.5.3A: Taiwan High Speed Rail Low and Medium Speed Turnouts, Metric Units

Design Speed	100 km/h	90 km/h	80 km/h	60 km/h	40 km/h	25 km/h
Ratio	1:18.5		1:16	1:12	1:9	1:9S
Origin of Design	UIC		SBB	original	numerous	numerous
Ratio	1:18.5		1:16	1:12	1:9	1:9S
Radius	1,200 m		900 m	600 m	300 m	190 m
Lead, PC to theoretical PF	58.686 m		50.823 m	41.500 m	29.343 m	23.478 m
Unbalanced Superelevation	98.3 mm	79.7 mm	83.9 mm	70.8 mm	62.9 mm	38.8 mm
Transition Rate,	144 mm/s	105 mm/s	98 mm/s	62 mm/s	--	--

Table 3.5.3B: Taiwan High Speed Rail Low and Medium Speed Turnouts, US Customary Units

Design Speed	60 mph	55 mph	50mph	35 mph	25 mph	15 mph
Ratio	1:18.5		1:16	1:12	1:9	1:9S
Origin of Design	UIC		SBB	none	numerous	numerous
Ratio	1:18.5		1:16	1:12	1:9	1:9S
Radius	3,937.01 ft		2,952.76’	1,968.50’	984.25’	623.36’
Lead, PC to theoretical PF	192.54 ft		166.74’	136.14’	96.27’	77.03’
Unbalanced Superelevation	3.66 in	3.07 in	3.39”	2.49”	2.54”	1.44”
Transition Rate,	5.61 in/s	4.32 in/s	4.33 in/s	2.23 in/s	--	--

All these turnouts have curved frogs except the 190 meter radius yard turnout, which has a straight frog.

3.6 DEFINED TURNOUT, CROSSOVER AND STATION CONNECTION TRACK GEOMETRIES

The following is a summary of the concepts used to develop the turnout and crossover designs. It is intended that the turnouts used in high speed turnouts, crossovers, and station connections shall be the same to the greatest extent practical.

The DB design concept for turnouts significantly reduces the entry and exit forces in high speed turnouts. The Taiwan High Speed Railway versions of these turnouts proved to provide a very smooth ride into and out of station tracks, which is the primary usage of high speed turnouts.

The High Speed Turnouts and crossovers for the CHSTP shall be based on the following criteria.

- Unbalanced Superelevation not to exceed 3 inches
- Minimum time over any turnout segment or curve connected to a turnout, including spirals on the frog end of turnouts and spirals into a curve on the diverging track that is adjacent to the turnout, about 1.0 second
- Maximum Virtual Transition Rate at switch point: 5.0 inches/second
- Ratio of entry radius to turnout body radius: Not less than 2:1.
- Superelevation in curve off of a turnout: 1.25 inches or less.
- Use curved frogs

- Keep Spirals out of frogs
  - Minimum/Exceptional: In order to avoid a special design swing nose frog, the frog end spiral shall begin at or beyond the point where track centerline spacing exceeds 5.85 feet, even if this means that the transition length in a crossover will have a run time of less than 1.0 seconds.
  - Desirable: Start frog end spiral beyond the point where the track centerline spacing exceeds 7.00 feet, if spiral is to a tangent or followed by a reversing curve. If the spiral is to a compound curve, it shall start beyond the point where the track centerline spacing exceeds 8.00 feet.

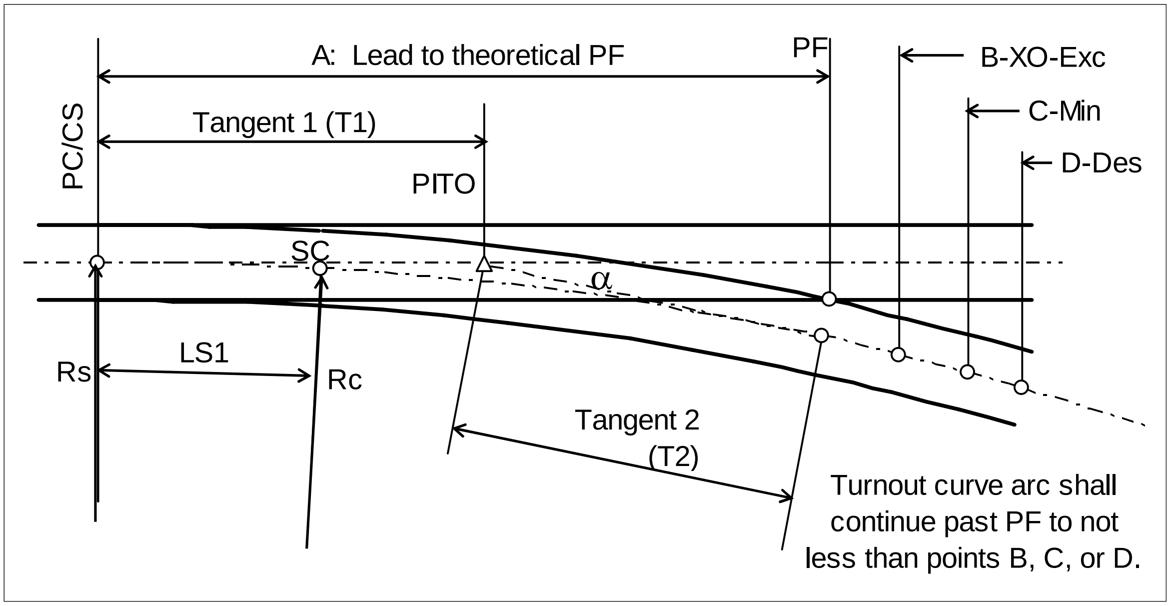
It is assumed that these high speed turnouts will normally be build on some form of concrete based track, not on ties and ballast.

3.6.1 High-Speed Turnouts

Using the criteria stated above, turnout geometries are developed for the following speeds: 60 mph, 80, mph, 110 mph, and 150 mph. If it is determined that a design speed of 145 mph will be used in some locations, the 150 mph design shall be used for that application. Should higher speed turnouts be required, the same design principles may be used to develop those designs.

This Technical Memorandum is limited to geometric considerations only. These designs are within the range of turnout designs built and in use in other parts of the world, and therefore are practical to build, operate, and maintain. It is assumed that all these turnouts will have movable point frogs and will required a combination of multiple switch machines and rod and crank additional drives on the switch points. The determination of the nature and location of these drives will be the subject of another Technical Memorandum. The type of switch rail, point shape, and other mechanical components will also be covered in another Technical Memorandum.

Figure 3.6.1: High-Speed Turnouts



Force diagrams for these turnouts will be shown with the application of these turnouts to crossovers and station entry tracks.

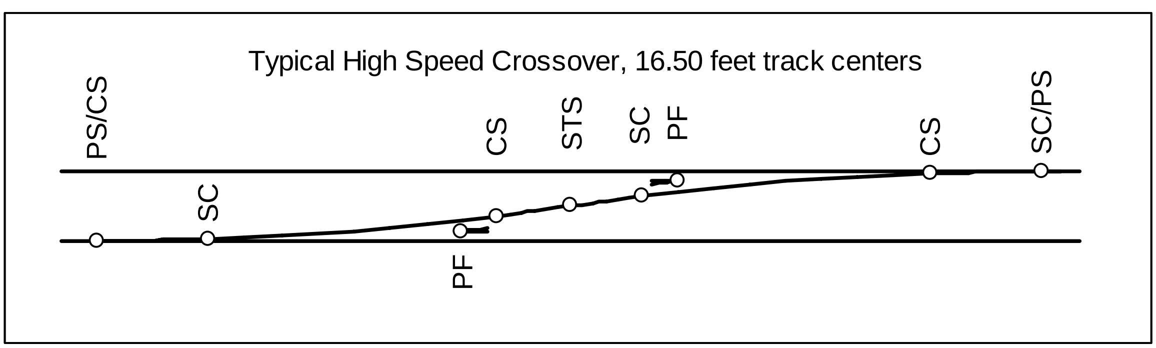
Table 3.6.1: High Speed Turnouts

Part 1: Geometry of Turnout and its Segments, in feet unless stated otherwise				
Design Speed	60 mph	80 mph	110 mph	150 mph
Turnout Entry Radius	10,000.00	18,000.00	34,000.00	80,000.00
Turnout Body Radius	5,000.00	9,000.00	17,000.00	32,000.00
Switch Spiral Length and Desirable Frog End Spiral Length	90.00	120.00	160.00	220.00
A. Distance to Theoretical Point of Frog	237.53	318.53	436.76	610.07
Angle at Theoretical Point of Frog	2d27m49s	1d 50m12s	1d20m14s	0d58m27s
Derived Frog Number (AREMA method)	23.25	31.2	42.8	58.8
Turnout Body Curve Arc Length, SC to PF	147.50	198.51	276.74	375.18
B. Distance to point of 5.85 ft. separation	262.62	352.18	482.98	673.52
C. Distance to point of 7.00 ft. separation	285.48	382.85	525.11	731.34
D. Distance to point of 8.00 ft. separation	303.85	407.49	558.97	777.81
Part 2: Unbalanced Superelevation and Transition Rates, inches or in./sec as applicable				
Unbalance at Turnout Entry	1.44	1.42	1.42	1.13
Unbalance in Turnout Body	2.88	2.84	2.85	2.81
Virtual Transition Time	0.676	0.507	0.369	0.270
Virtual Transition Rate at Entry	2.13	2.80	3.86	4.16
Virtual Transition Rate 59.50 feet in	3.54	4.20	5.30	5.85
Actual Transition Rate in Switch	1.41	1.39	1.44	1.69
Part 3: Run Time of Segments, in seconds				
Switch Spiral	1.02	1.02	0.99	1.00
Turnout arc to point of frog	1.67	1.69	1.72	1.71

3.6.2 Crossovers Between Main Tracks

Where these high speed turnouts are put together to form crossovers between the main tracks, a transition between them is necessary to reduce the transition forces in the reversal of the direction of curvature. Where the track centers are 21.50 feet or greater, a full length spiral as shown in the tabulation for Station Connection tracks may be used. Where the track centers are less, the spirals must be shorter, or the spiral will be, at least partially, in the frog unit. A spiral frog introduces complexity that should be avoided. Figure 3.6.2 shows the normal relationship between crossover components in a crossover between 16.50 feet track centers. Use of high speed crossovers in tracks with centers of under 16.50 feet shall be an Exceptional condition.

Figure 3.6.2: High Speed Crossovers



If these crossovers are applied to tracks at track centers of under 16.50 feet, the transition forces in the reversal shall be calculated to determine the amount of required reduction in speed through the crossover necessary to keep the transition force in the reversal to an acceptable level. Track centers for track with high speed crossovers shall not be less than 15.00 feet.

Table 3.6.2: High Speed Crossovers

Main Track Crossovers – 16’50 feet track centers				
Part 1: Geometry of Turnout and its Segments, in feet unless stated otherwise				
Design Speed	60 mph	80 mph	110 mph	150 mph
Track Centers	16.50	16.50	16.50	16.50
Turnout Entry Radius	10,000.00	18,000.00	34,000.00	80,000.00
Turnout Body Radius	5,000.00	9,000.00	17,000.00	32,000.00
Switch Spiral Length	90.00	120.00	160.00	220.00
Frog Spiral Length	45.00	62.00	85.00	115.00
Total Length along main track	618.74	829.97	1,138.63	1,583.92
Total Length along Crossover Track	619.05	830.20	1,138.80	1,584.04
Angle at STS	3d01m31s	2d 15m15s	1d38m28s	1d11m49s
Length of Entry Curve	0.00	0.00	0.00	0.00
Length of Turnout Body Curve	173.52	233.10	324.40	457.02
Part 2: Unbalanced Superelevation and Transition Rates, inches or inches/sec as applicable				
Unbalance at Turnout Entry	1.44	1.42	1.42	1.13
Unbalance in Turnout Body	2.88	2.84	2.85	2.81
Virtual Transition Time	0.676	0.507	0.369	0.270
Virtual Transition Rate at Entry	2.13	2.80	3.86	4.16
Virtual Transition Rate 59.50 feet in	3.54	4.20	5.30	5.85
Transition Rate in Switch	1.41	1.39	1.44	1.69
Transition Rate at Frog End	5.51	5.38	5.40	5.38
Part 3: Run Time of Segments, in seconds				
Switch Spiral	1.02	1.02	0.99	1.00
Turnout arc to reversing spiral	1.98	1.99	2.01	2.08
Reversing Spirals between turnouts	1.02	1.06	1.06	1.04
Turnout arc to switch spiral	1.98	1.99	2.01	2.08
Switch Spiral	1.02	1.02	0.99	1.00
Total time through crossover	7.03	7.08	7.06	7.20

The use of high speed crossovers between tracks set at 15.00 feet track centers should be avoided, as the spirals will be very short. If these crossovers are applied to tracks at track centers of under 16.50 feet, the transition forces in the reversal shall be calculated to determine the amount of required reduction in speed through the crossover necessary to keep the transition force in the reversal to an acceptable level. Track centers for track with high speed crossovers shall be not less than 15.00 feet.

Figures 3.6.3 and 3.6.4 illustrate the unbalanced superelevation and transition forces in these crossovers. Only the 110 mph case is shown. Other cases are similar. Note that the transition rate in the reversal is somewhat high when compared to the transition rates at the switch end and the reversals in station connection tracks. This rate can be lowered only by increasing track centers.

Figure 3.6.3: Forces in 110 mph High Speed Crossovers, versus Distance

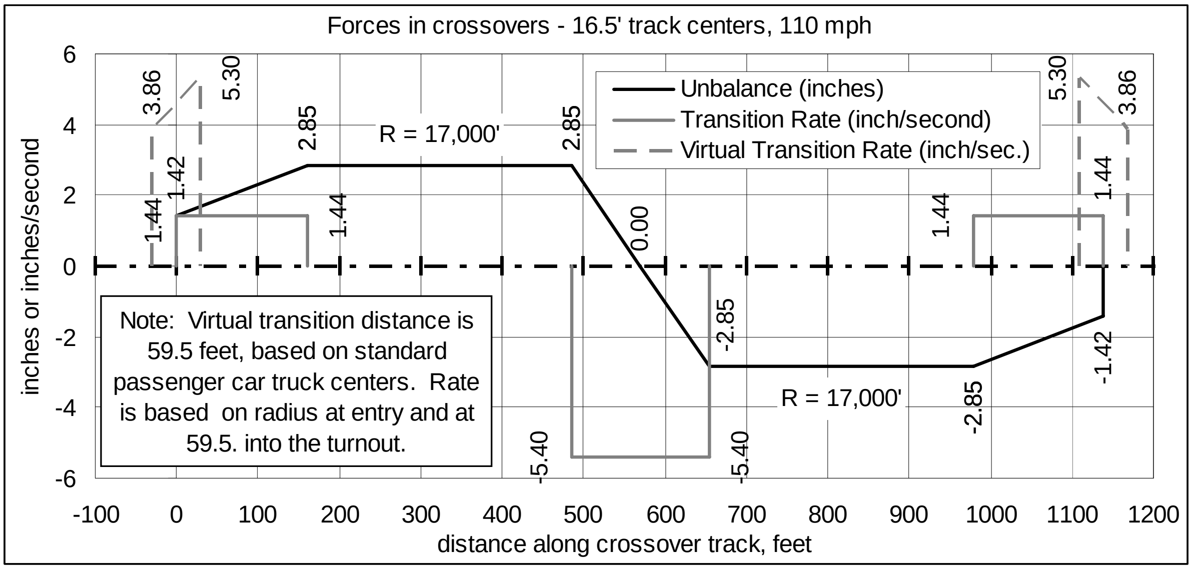
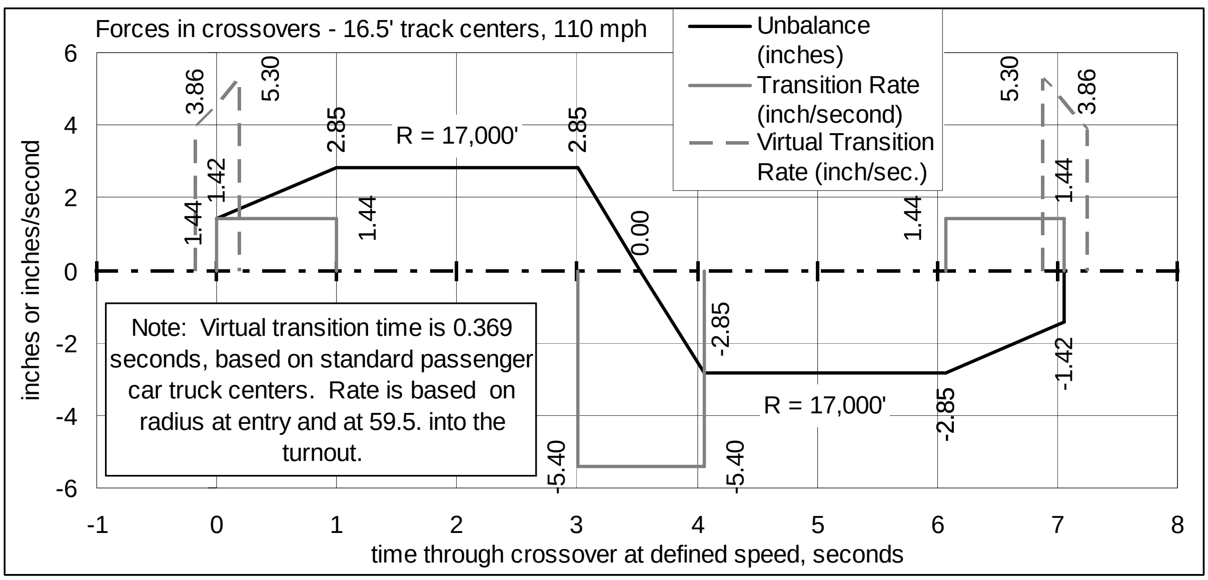


Figure 3.6.4: Forces in 110 mph High Speed Crossovers, versus Time



3.6.3 Station Connection Tracks

Station connection tracks will use the turnouts above in combination with a return curve that gives similar forces in the train. For the normal 25.00 feet track spacing, the connecting curve radius, spirals, and overall length of connection are as follows.

Figure 3.6.5: Typical Track Layout, Intermediate Station with High Speed Turnouts

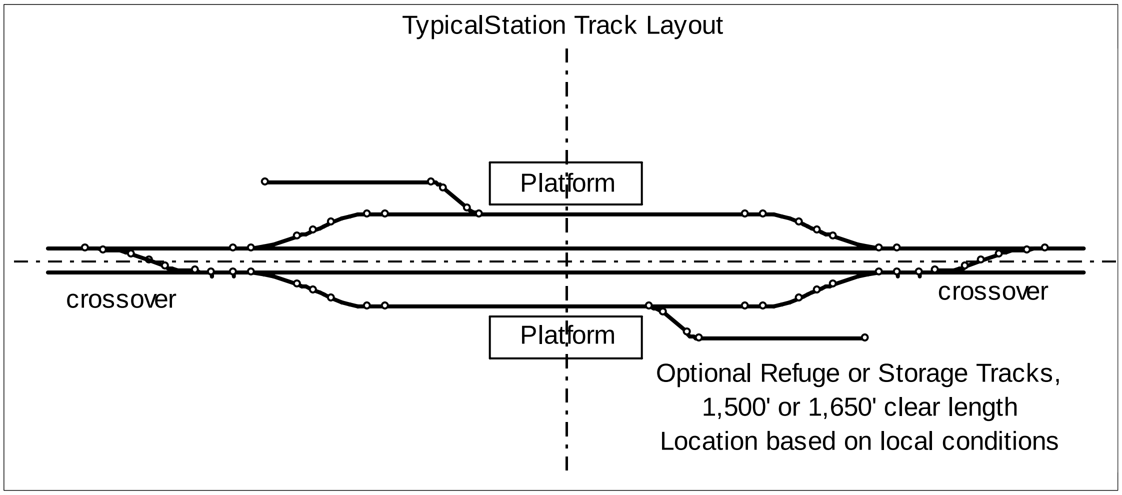
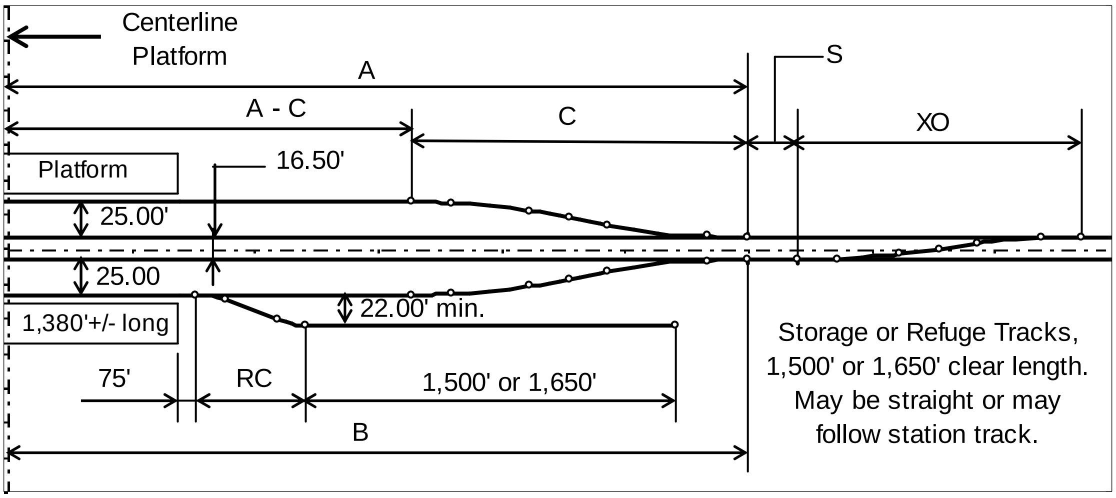


Figure 3.6.6: Detail of Intermediate Station Track Layout



Explanation of undimensioned data in Figure 3.6.6:

- A: Distance from center of platform to approach turnout, normal arrival direction. Set by operational requirement, but with a minimum distance of C plus half platform length plus 85 feet without refuge/storage track, or C plus half platform plus length of refuge turnout plus 75 feet with refuge/storage track.
- B: Distance from center of platform to approach turnout, normal departure direction. Set by operational requirement, but with a minimum distance of C plus half platform length plus 85 feet without refuge/storage track, or C plus half platform plus length of refuge turnout plus 75 feet with refuge/storage track.
- C: Distance required by geometry of the connection. See distance labeled “Total length along main tracks” in Table 3.6.3.
- S: Minimum distance between end of station turnout and crossover turnout where they are in the same track. 1.5 seconds run time Desirable, 1.0 seconds minimum.
- XO: Length of crossover. See “Total Length along main track” in Table 3.6.2.
- RC: Length required to achieve offset for Storage/Refuge Track. Determined by medium/low speed turnout selected from Table 3.6.5.

Table 3.6.3: Standard Station Connection Turnouts and Curves, 25 feet Track Centers

Station Connection Tracks with Spiral Point Turnouts				
Part 1: Geometry of Connection and its Segments, in feet unless stated otherwise				
Design Speed	60 mph	80 mph	110 mph	150 mph
Platform Track Offset	25.00	25.00	25.00	25.00
Turnout Entry Radius	10,000.00	18,000.00	34,000.00	80,000.00
Turnout Body Radius	5,000.00	9,000.00	17,000.00	32,000.00
Switch Spiral Length	90.00	120.00	160.00	220.00
Frog Spiral Length	90.00	120.00	160.00	220.00
Return Curve Radius	4,000.00	7,000.00	13,500.00	24,000.00
Curve Spiral Length	90.00	120.00	160.00	220.00
C. Total Length along main track	743.65	991.80	1,364.60	1,862.87
Total Length along Platform Track	744.25	992.25	1,364.92	1,863.11
Angle at STS	3d44m07s	2d 48m04s	2d02m17s	1d30m04s
Length of Entry Curve	0.000	0.000	0.000	0.000
Length of Turnout Body Curve	213.47	290.02	404.71	574.35
Length of Return Curve	170.78	222.24	320.21	408.76
Part 2: Unbalanced Superelevation and Transition Rates, inches or inches/sec as applicable				
Unbalance at Turnout Entry	1.44	1.42	1.42	1.13
Unbalance in Turnout Body	2.88	2.84	2.85	2.81
Superelevation in Return Curve	1.25	1.25	1.25	1.25
Unbalance in Return Curve	2.35	2.41	2.34	2.50
Virtual Transition Time	0.676	0.507	0.369	0.270
Virtual Transition Rate at Entry	2.13	2.80	3.86	4.16
Virtual Transition Rate 59.50 feet in	3.54	4.20	5.30	5.85
Actual Transition Rate in Switch	1.41	1.39	1.44	1.69
Transition Rate at Frog End	2.82	2.78	2.87	2.81
Transition Rate in Curve Spirals	2.30	2.35	2.35	2.50
Part 3: Run Time of Segments and Connection in Total, in seconds				
Switch Spiral	1.02	1.02	0.99	1.00
Turnout arc	2.43	2.47	2.51	2.61
Frog spiral	1.02	1.02	0.99	1.00
Curve Spiral	1.02	1.02	0.99	1.00
Curve Arc	1.94	1.89	1.98	1.86
Curve Spiral	1.02	1.02	0.99	1.00
Sum through Divergence	8.46	8.46	8.46	8.47

The speed of turnout and connection to be selected will depend upon the train speed at the point of the turnout. The intent is that the limitation of speed inherent in the turnout and its associated curve shall not cause the train to have to be running slower than it otherwise would need to in a normal acceleration from full speed to stop at the platform.

Figure 3.6.7: Detail of Station Entry/Exit High Speed Turnout and Return Curve

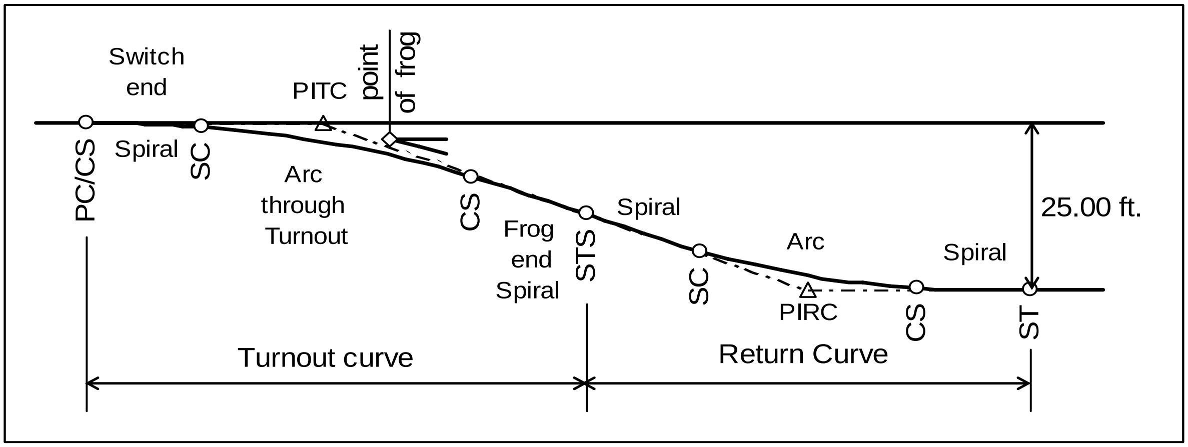


Figure 3.6.8: Forces in 110 mph Station Connection, versus Distance

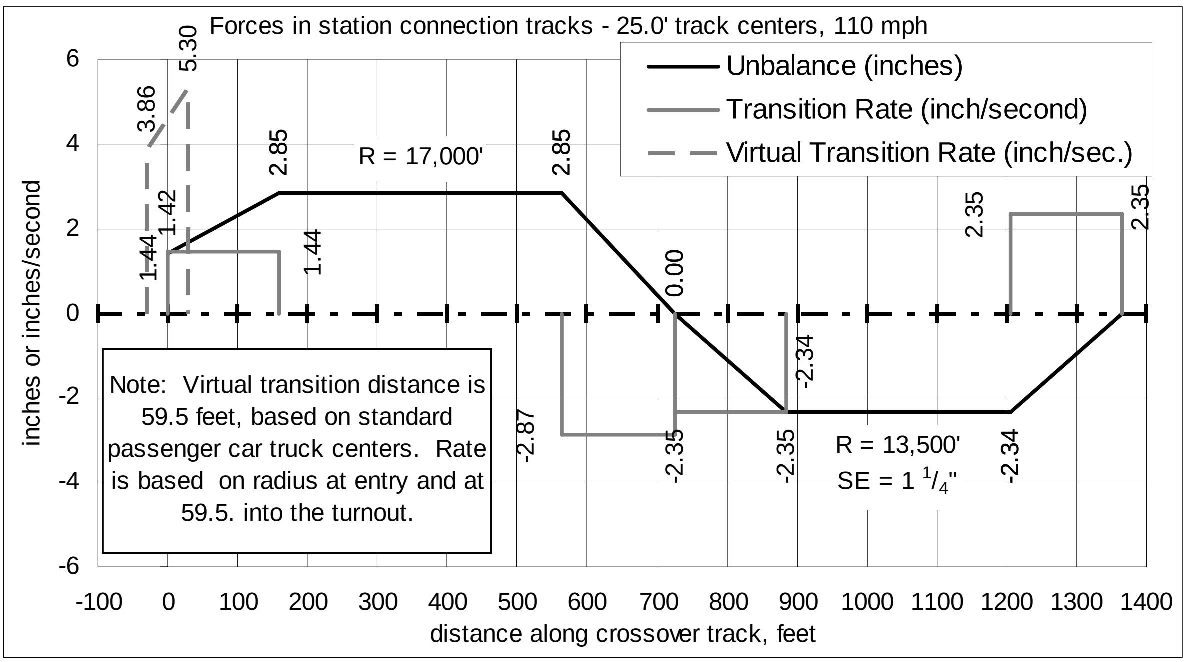
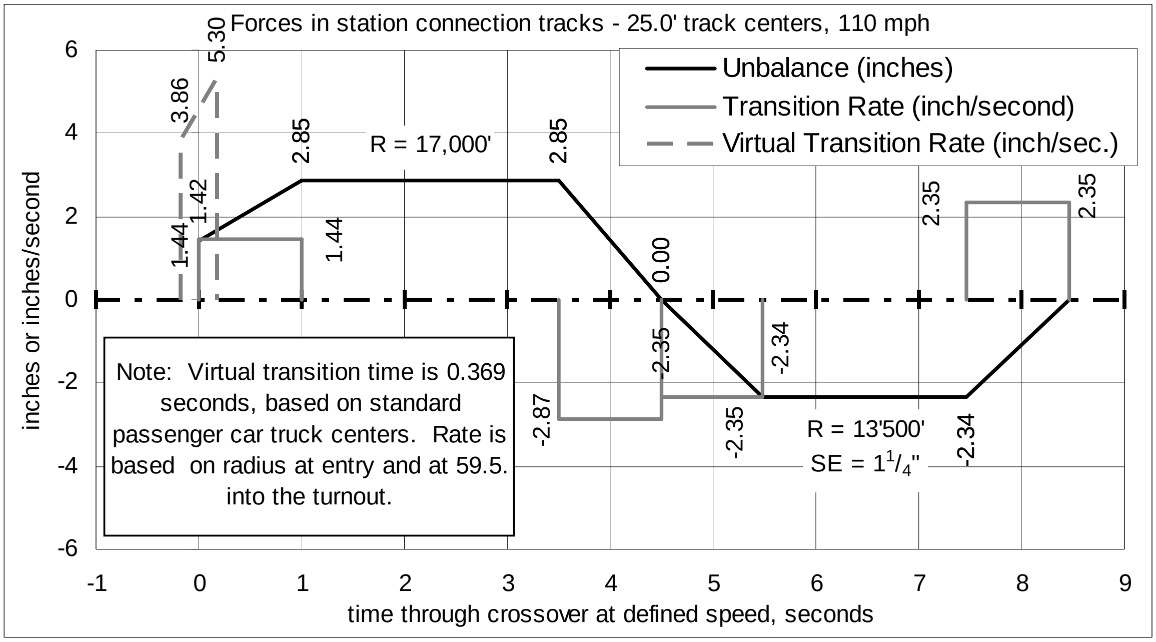


Figure 3.6.9: Forces in 110 mph Station Connection, versus Time



3.6.4 Low and Medium Speed Turnouts

The low and medium speed turnouts will have the same standard frog numbers as the current BNSF/UPRR standards. The internal curve will be of a "tangent point" design so as to give a small switch point entry angle.

The radii of all these turnouts are small enough that there is no need to consider the Virtual Transition Rate or to provide a switch point or frog end transition. All these are straight frog turnouts so that there is no need to consider the "hand" of the frog unless a spring frog is to be installed.

Figure 3.6.10: Low and Medium Speed Turnouts

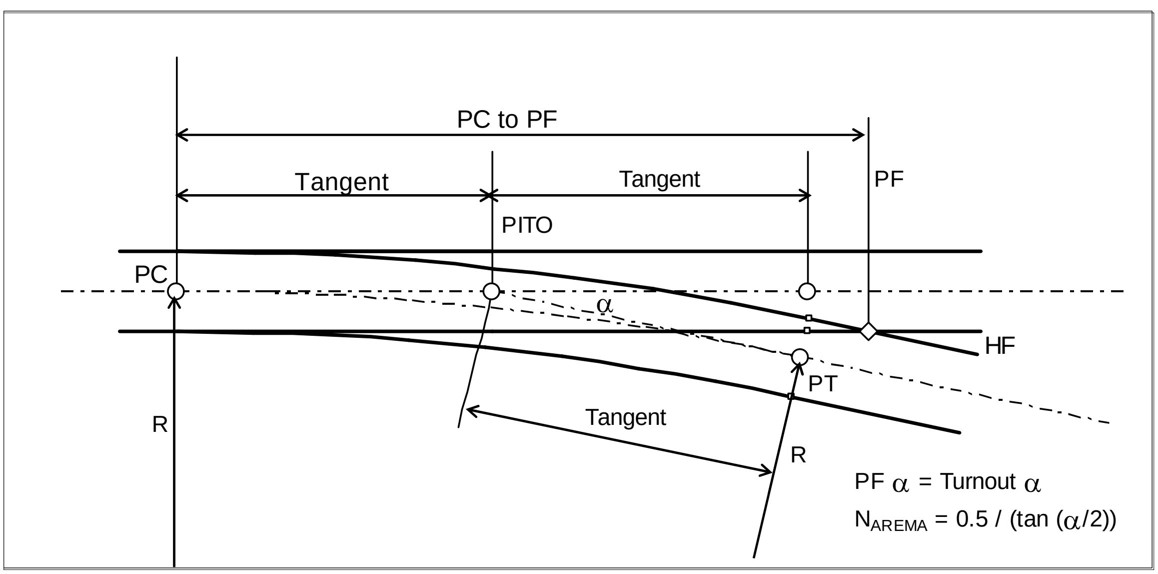


Table 3.6.4: Low and Medium Speed Turnouts

Number	9	11	15	20
Defined Angle	6d21m35s	5d12m18s	3d49m06s	2d51m51s
Radius	620 feet	950 feet	1750 feet	3275 feet
Tangent	34.44 feet	43.18 feet	58.33 feet	81.87 feet
Lead, PC to ½ inch PF	77.19 feet	95.43 feet	129.58 feet	176.87 feet
Tangent Rail, ½ inch PF to Curve PT	8.31 feet	9.07 feet	12.92 feet	13.13 feet
Set Speed	20 mph	25 mph	35 mph	50 mph
Unbalance	2.58 inches	2.63 inches	2.80 inches	3.05 inches

The switch points of these turnouts shall be treated in a manner similar to that described in UIC 711, but the exact shape and cutback of the switch point is beyond the scope of this Technical Memorandum.

Use of the Number 9 turnout should be treated as an "Exceptional" condition for any situation where the traffic volume is other than very low due to the know high rate of side wear of the rails that occurs in small radius turnouts under high speed equipment. Number 11 turnouts will be used as the standard yard turnout, and as the minimum size turnout to be installed in main tracks with speeds of 125 mph or less and in station tracks. Number 15 turnouts shall be the minimum turnouts out of main tracks for all other situation. Yard Lead or other tracks that will have traffic volume other than very low shall be no less than Number 20 turnouts if conditions permit.

3.6.5 Storage and Refuge Tracks at High Speed Stations

The turnout – return curve selected for this application will depend upon the operational needs. Turnouts smaller than the number 11 shall not be used for this application. For the 22.00 feet track offset the turnout – return curve selections shall be as defined in Table 3.6.5. Spirals need not be applied to the return curve for a stub end track. If the track is for yard access instead of to storage, a spiral appropriate to the design speed of the access track shall be applied.

Table 3.6.5: Connection to Storage and Refuge Tracks at High Speed Stations

Number	11	15	20
Set Speed	25 mph	35 mph	50 mph
Track Centers	22 feet	22	22
Return Curve Radius	950 feet	1750	3275
Curve Tangent	43.18 feet	58.33	81.87
Overall Length, PS to end Curve	327.87 feet	446.30	603.48

4.0 Summary and Recommendations

The recommended Turnout and Crossover Geometries are included in this document and summarized in Section 6.0

5.0 SOURCE INFORMATION AND REFERENCES

1. Manual for Railway Engineering of the American Railway Engineering and Maintenance of Way Association (AREMA Manual) and the AREMA Portfolio of Trackwork Plans
2. Certain publication of the UIC: (International Union of Railways) (Acronym is from the French original, Union Internationale des Chemins de Fer)
   - Leaflet 703, Layout Characteristics for Lines Used by Fast Passenger Trains
   - Leaflet 711, Geometry of Points and Crossings with UIC Rails Permitting Speeds of 100 km/h or more on the Diverging Track
3. Deutsche Bahn's publication 800.0120, Netzinfrastruktur Technik Entwerfen; Weichen und Kreuzungen. (Translated: Infrastructure Technical Information, Switches and Crossings).
4. Voest-Alpine Eisenbahnsysteme Ges.m.b.H, Turnouts Geometry and Max. Allowable Speed into the Deviation
5. Japanese Industrial Standards
   - JIS E 1303, Railway Turnouts and Crossings
   - JIS E 1304, Dimensions of Turnouts and Crossings
6. The European Union's Directive, Interoperability of the Trans-European High Speed Rail System, Technical Specification for Interoperability (TSI), Infrastructure Sub-System
7. Taiwan High Speed Rail Corporation (THSRC), Volume 9, Design Specifications, Section 2, Alignment Design Specification

6.0 DESIGN MANUAL CRITERIA

6.1 DEFINED TURNOUT, CROSSOVER AND STATION CONNECTION TRACK GEOMETRIES

The High Speed Turnouts and crossovers for the CHSTP shall be based on the following criteria.

- Unbalanced Superelevation not to exceed 3 inches
- Minimum time over any turnout segment or curve connected to a turnout, including spirals on the frog end of turnouts and spirals into a curve on the diverging track that is adjacent to the turnout, about 1.0 second
- Maximum Virtual Transition Rate at switch point: 5.0 inches/second
- Ratio of entry radius to turnout body radius: Not less than 2:1.
- Superelevation in curve off of a turnout: 1.25 inches or less.
- Use curved frogs
- Keep Spirals out of frogs
  - Minimum/Exceptional: In order to avoid a special design swing nose frog, the frog end spiral shall begin at or beyond the point where track centerline spacing exceeds 5.85 feet, even if this means that the transition length in a crossover will have a run time of less than 1.0 seconds.
  - Desirable: Start frog end spiral beyond the point where the track centerline spacing exceeds 7.00 feet, if spiral is to a tangent or followed by a reversing curve. If the spiral is to a compound curve, it shall start beyond the point where the track centerline spacing exceeds 8.00 feet.

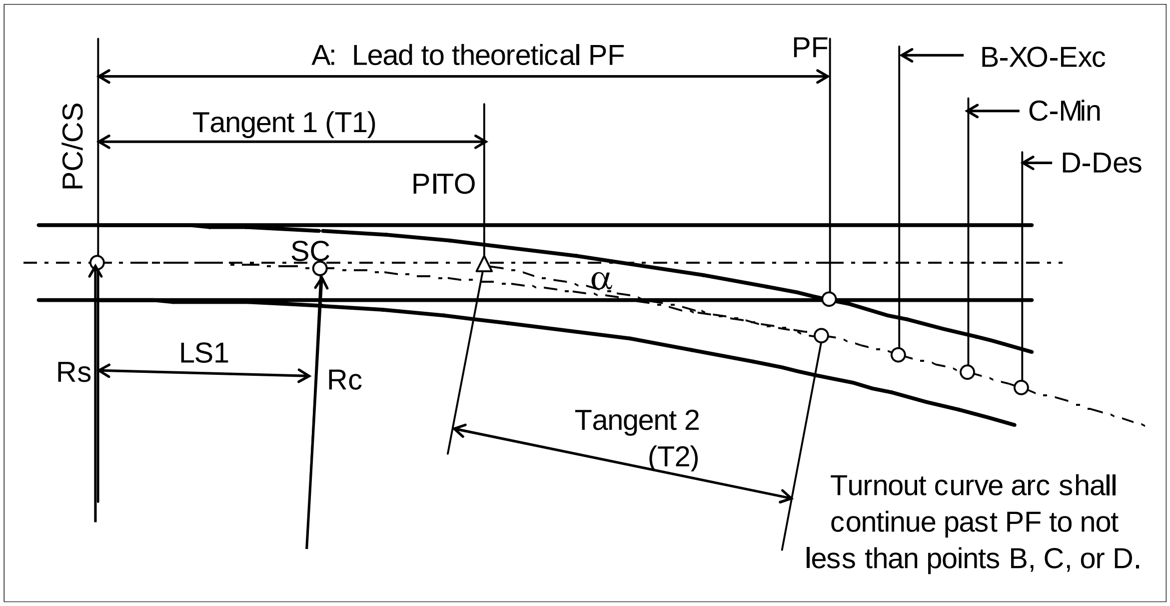
It is assumed that these high-speed turnouts will normally be built on some form of concrete based track, not on ties and ballast.

6.1.1 High Speed Turnouts

Using the criteria stated above, turnout geometries are developed for the following speeds: 60 mph, 80, mph, 110 mph, and 150 mph. If it is determined that a design speed of 145 mph will be used in some locations, the 150 mph design shall be used for that application. Should higher speed turnouts be required, the same design principles may be used to develop those designs.

The requirements of this section are limited to geometric considerations only. These turnouts will have movable point frogs and will require a combination of multiple switch machines and rod and crank additional drives on the switch points. .

Figure 6.1.1: High-Speed Turnouts



Force diagrams for these turnouts will be shown with the application of these turnouts to crossovers and station entry tracks.

Table 6.1.1: High-Speed Turnouts

Part 1: Geometry of Turnout and its Segments, in feet unless stated otherwise				
Design Speed	60 mph	80 mph	110 mph	150 mph
Turnout Entry Radius	10,000.00	18,000.00	34,000.00	80,000.00
Turnout Body Radius	5,000.00	9,000.00	17,000.00	32,000.00
Switch Spiral Length and Desirable Frog End Spiral Length	90.00	120.00	160.00	220.00
A. Distance to Theoretical Point of Frog	237.53	318.53	436.76	610.07
Angle at Theoretical Point of Frog	2d27m49s	1d 50m12s	1d20m14s	0d58m27s
Derived Frog Number (AREMA method)	23.25	31.2	42.8	58.8
Turnout Body Curve Arc Length, SC to PF	147.50	198.51	276.74	375.18
B. Distance to point of 5.85 ft. separation	262.62	352.18	482.98	673.52
C. Distance to point of 7.00 ft. separation	285.48	382.85	525.11	731.34
D. Distance to point of 8.00 ft. separation	303.85	407.49	558.97	777.81
Part 2: Unbalanced Superelevation and Transition Rates, inches or in./sec as applicable				
Unbalance at Turnout Entry	1.44	1.42	1.42	1.13
Unbalance in Turnout Body	2.88	2.84	2.85	2.81
Virtual Transition Time	0.676	0.507	0.369	0.270
Virtual Transition Rate at Entry	2.13	2.80	3.86	4.16
Virtual Transition Rate 59.50 feet in	3.54	4.20	5.30	5.85
Actual Transition Rate in Switch	1.41	1.39	1.44	1.69
Part 3: Run Time of Segments, in seconds				
Switch Spiral	1.02	1.02	0.99	1.00
Turnout arc to point of frog	1.67	1.69	1.72	1.71

6.1.2 Crossovers Between Main Tracks

Where these high-speed turnouts are put together to form crossovers between the main tracks, a transition between them is necessary to reduce the transition forces in the reversal of the direction of curvature. Where the track centers are 21.50 feet or greater, a full length spiral as shown in the tabulation for Station Connection tracks may be used. Where the track centers are less, the spirals must be shorter, or the spiral will be, at least partially, in the frog unit. A spiral frog introduces complexity that shall be avoided. Figure 6.1.2 shows the normal relationship between crossover components in a crossover between 16.50 feet track centers. Use of high-speed crossovers in tracks with centers of under 16.50 feet shall be an Exceptional condition.

If these crossovers are applied to tracks at track centers of under 16.50 feet, the transition forces in the reversal shall be calculated to determine the amount of required reduction in speed through the crossover necessary to keep the transition force in the reversal to an acceptable level. Track centers for track with high-speed crossovers shall not be less than 15.00 feet.

Figure 6.1.2: High-Speed Crossovers

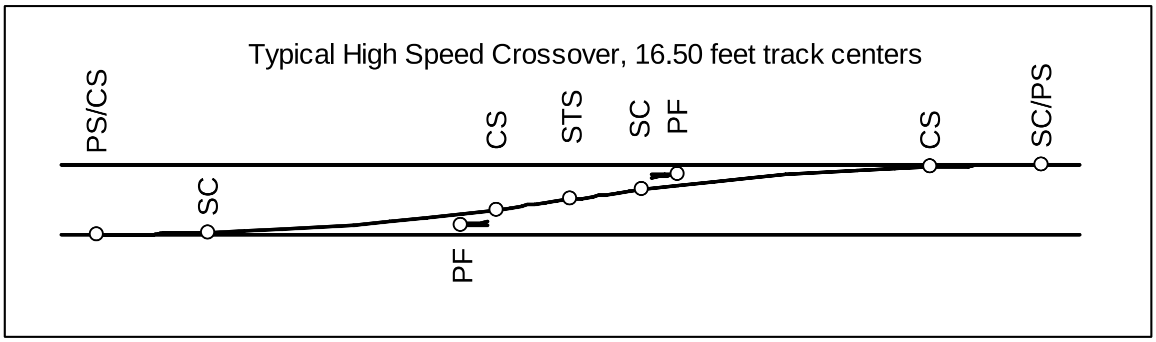


Table 6.1.2: High-Speed Crossovers

Main Track Crossovers – 16'50 feet Track Centers				
Part 1: Geometry of Turnout and its Segments, in feet unless stated otherwise				
Design Speed	60 mph	80 mph	110 mph	150 mph
Track Centers	16.50	16.50	16.50	16.50
Turnout Entry Radius	10,000.00	18,000.00	34,000.00	80,000.00
Turnout Body Radius	5,000.00	9,000.00	17,000.00	32,000.00
Switch Spiral Length	90.00	120.00	160.00	220.00
Frog Spiral Length	45.00	62.00	85.00	115.00
Total Length along main track	618.74	829.97	1,138.63	1,583.92
Total Length along Crossover Track	619.05	830.20	1,138.80	1,584.04
Angle at STS	3d01m31s	2d 15m15s	1d38m28s	1d11m49s
Length of Entry Curve	0.00	0.00	0.00	0.00
Length of Turnout Body Curve	173.52	233.10	324.40	457.02
Part 2: Unbalanced Superelevation and Transition Rates, inches or inches/sec as applicable				
Unbalance at Turnout Entry	1.44	1.42	1.42	1.13
Unbalance in Turnout Body	2.88	2.84	2.85	2.81
Virtual Transition Time	0.676	0.507	0.369	0.270
Virtual Transition Rate at Entry	2.13	2.80	3.86	4.16
Virtual Transition Rate 59.50 feet in	3.54	4.20	5.30	5.85
Transition Rate in Switch	1.41	1.39	1.44	1.69
Transition Rate at Frog End	5.51	5.38	5.40	5.38
Part 3: Run Time of Segments, in seconds				
Switch Spiral	1.02	1.02	0.99	1.00
Turnout arc to reversing spiral	1.98	1.99	2.01	2.08
Reversing Spirals between turnouts	1.02	1.06	1.06	1.04
Turnout arc to switch spiral	1.98	1.99	2.01	2.08
Switch Spiral	1.02	1.02	0.99	1.00
Total time through crossover	7.03	7.08	7.06	7.20

6.1.3 Station Connection Tracks

Station connection tracks will use the turnouts above in combination with a return curve that gives similar forces in the train. For the normal 25.00 feet track spacing, the connecting curve radius, spirals, and overall length of connection are as follows.

Figure 6.1.3: Typical Track Layout, Intermediate Station with High-Speed Turnouts

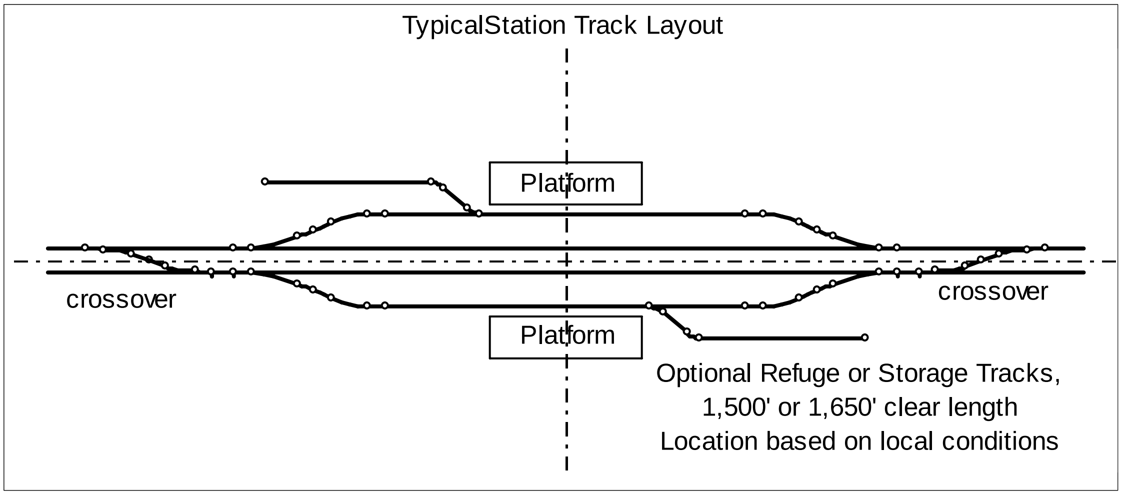
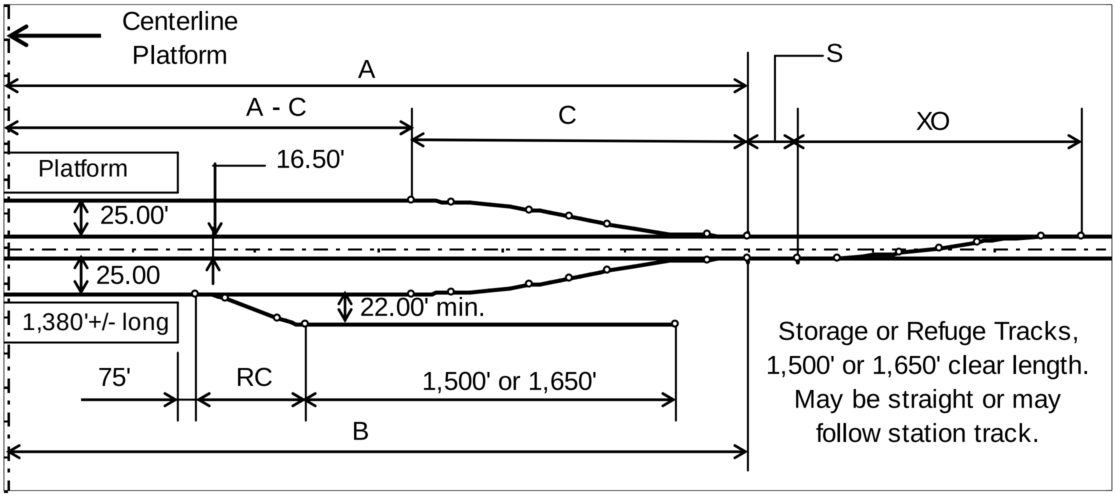


Figure 6.1.4: Detail of Intermediate Station Track Layout



Explanation of undimensioned data in Figure 6.1.4:

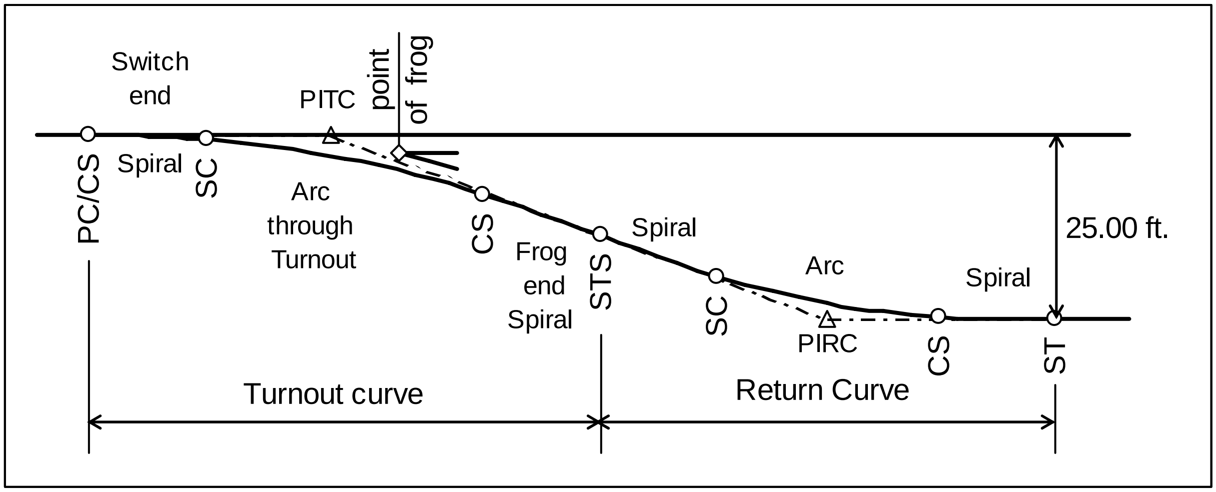
- A: Distance from center of platform to approach turnout, normal arrival direction. Set by operational requirement, but with a minimum distance of C plus half platform length plus 85 feet without refuge/storage track, or C plus half platform plus length of refuge turnout plus 75 feet with refuge/storage track.
- B: Distance from center of platform to approach turnout, normal departure direction. Set by operational requirement, but with a minimum distance of C plus half platform length plus 85 feet without refuge/storage track, or C plus half platform plus length of refuge turnout plus 75 feet with refuge/storage track.
- C: Distance required by geometry of the connection. See distance labeled “Total length along main tracks” in Table 6.1.3.
- S: Minimum distance between end of station turnout and crossover turnout where they are in the same track. 1.5 seconds run time Desirable, 1.0 seconds minimum.
- XO: Length of crossover. See “Total Length along main track” in Table 6.1.2.
- RC: Length required to achieve offset for Storage/Refuge Track. Determined by medium/low speed turnout selected from Table 6.1.5.

Table 6.1.3: Standard Station Connection Turnouts and Curves, 25 feet Track Centers

Station Connection Tracks with Spiral Point Turnouts				
Part 1: Geometry of Connection and its Segments, in feet unless stated otherwise				
Design Speed	60 mph	80 mph	110 mph	150 mph
Platform Track Offset	25.00	25.00	25.00	25.00
Turnout Entry Radius	10,000.00	18,000.00	34,000.00	80,000.00
Turnout Body Radius	5,000.00	9,000.00	17,000.00	32,000.00
Switch Spiral Length	90.00	120.00	160.00	220.00
Frog Spiral Length	90.00	120.00	160.00	220.00
Return Curve Radius	4,000.00	7,000.00	13,500.00	24,000.00
Curve Spiral Length	90.00	120.00	160.00	220.00
C. Total Length along main track	743.65	991.80	1,364.60	1,862.87
Total Length along Platform Track	744.25	992.25	1,364.92	1,863.11
Angle at STS	3d44m07s	2d 48m04s	2d02m17s	1d30m04s
Length of Entry Curve	0.000	0.000	0.000	0.000
Length of Turnout Body Curve	213.47	290.02	404.71	574.35
Length of Return Curve	170.78	222.24	320.21	408.76
Part 2: Unbalanced Superelevation and Transition Rates, inches or inches/sec as applicable				
Unbalance at Turnout Entry	1.44	1.42	1.42	1.13
Unbalance in Turnout Body	2.88	2.84	2.85	2.81
Superelevation in Return Curve	1.25	1.25	1.25	1.25
Unbalance in Return Curve	2.35	2.41	2.34	2.50
Virtual Transition Time	0.676	0.507	0.369	0.270
Virtual Transition Rate at Entry	2.13	2.80	3.86	4.16
Virtual Transition Rate 59.50 feet in	3.54	4.20	5.30	5.85
Actual Transition Rate in Switch	1.41	1.39	1.44	1.69
Transition Rate at Frog End	2.82	2.78	2.87	2.81
Transition Rate in Curve Spirals	2.30	2.35	2.35	2.50
Part 3: Run Time of Segments and Connection in Total, in seconds				
Switch Spiral	1.02	1.02	0.99	1.00
Turnout arc	2.43	2.47	2.51	2.61
Frog spiral	1.02	1.02	0.99	1.00
Curve Spiral	1.02	1.02	0.99	1.00
Curve Arc	1.94	1.89	1.98	1.86
Curve Spiral	1.02	1.02	0.99	1.00
Sum through Divergence	8.46	8.46	8.46	8.47

The speed of turnout and connection to be selected will depend upon the train speed at the point of the turnout. The intent is that the limitation of speed inherent in the turnout and its associated curve shall not cause the train to have to be running slower than it otherwise would need to in a normal acceleration from full speed to stop at the platform.

Figure 6.1.5: Detail of Station Entry/Exit High-Speed Turnout and Return Curve



6.1.4 Low and Medium Speed Turnouts

The radii of these turnouts are small enough that there is no need to consider the Virtual Transition Rate or to provide a switch point or frog end transition. All these are straight frog turnouts so that there is no need to consider the "hand" of the frog unless a spring frog is to be installed.

Figure 6.1.6: Low and Medium Speed Turnouts

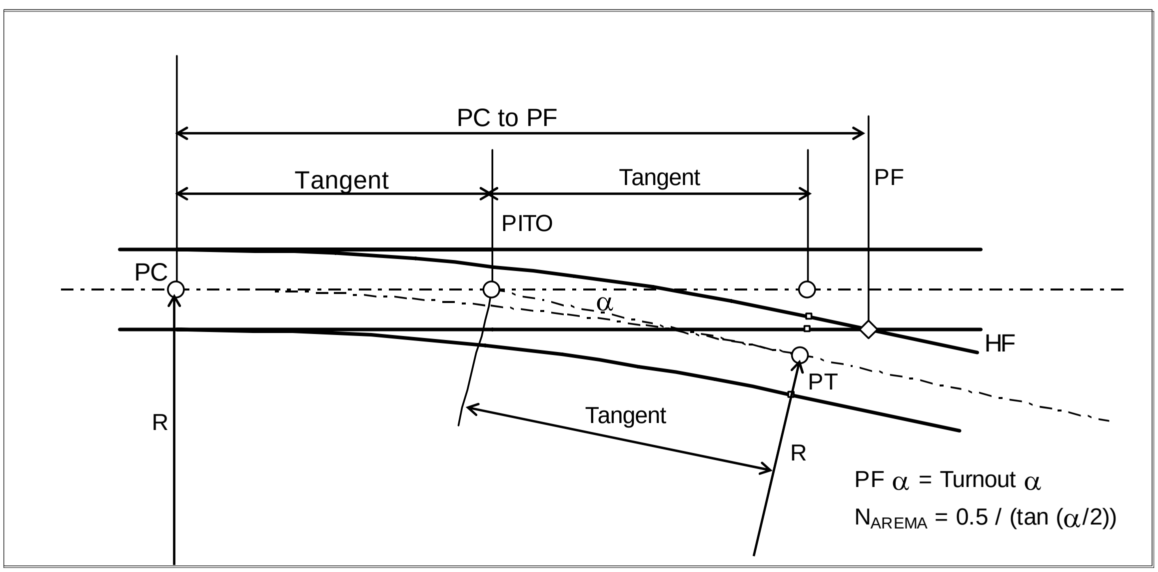


Table 6.1.4: Low and Medium Speed Turnouts

Number	9	11	15	20
Defined Angle	6d21m35s	5d12m18s	3d49m06s	2d51m51s
Radius	620 feet	950 feet	1750 feet	3275 feet
Tangent	34.44 feet	43.18 feet	58.33 feet	81.87 feet
Lead, PC to ½ inch PF	77.19 feet	95.43 feet	129.58 feet	176.87 feet
Tangent Rail, ½ inch PF to Curve PT	8.31 feet	9.07 feet	12.92 feet	13.13 feet
Set Speed	20 mph	25 mph	35 mph	50 mph
Unbalance	2.58 inches	2.63 inches	2.80 inches	3.05 inches

The requirements of this section are limited to geometric considerations only. The determination of the nature of the point and driving mechanism are described elsewhere.

Use of the Number 9 turnout shall be treated as an "Exceptional" condition for any situation where the traffic volume is other than very low due to the know high rate of side wear of the rails that occurs in small radius turnouts under high-speed equipment. Number 11 turnouts shall be used as the standard yard turnout, and as the minimum size turnout to be installed in main tracks with speeds of 125 mph or less and in station tracks. Number 15 turnouts shall be the minimum turnouts out of main tracks for all other situation. Yard Lead or other tracks that will have traffic volume other than very low shall be no less than Number 20 turnouts if conditions permit.

6.1.5 Storage and Refuge Tracks at High-Speed Stations

The turnout – return curve selected for this application will depend upon the operational needs. Turnouts smaller than the number 11 shall not be used for this application. For the 22.00 feet track offset the turnout – return curve selections shall be as defined in Table 6.1.5. Spirals need not be applied to the return curve for a stub end track. If the track is for yard access instead of to storage, a spiral appropriate to the design speed of the access track shall be applied.

Table 6.1.5: Connection to Storage and Refuge Tracks at High-Speed Stations

Number	11	15	20
Set Speed	25 mph	35 mph	50 mph
Track Centers	22 feet	22	22
Return Curve Radius	950 feet	1750	3275
Curve Tangent	43.18 feet	58.33	81.87
Overall Length, PS to end Curve	327.87 feet	446.30	603.48

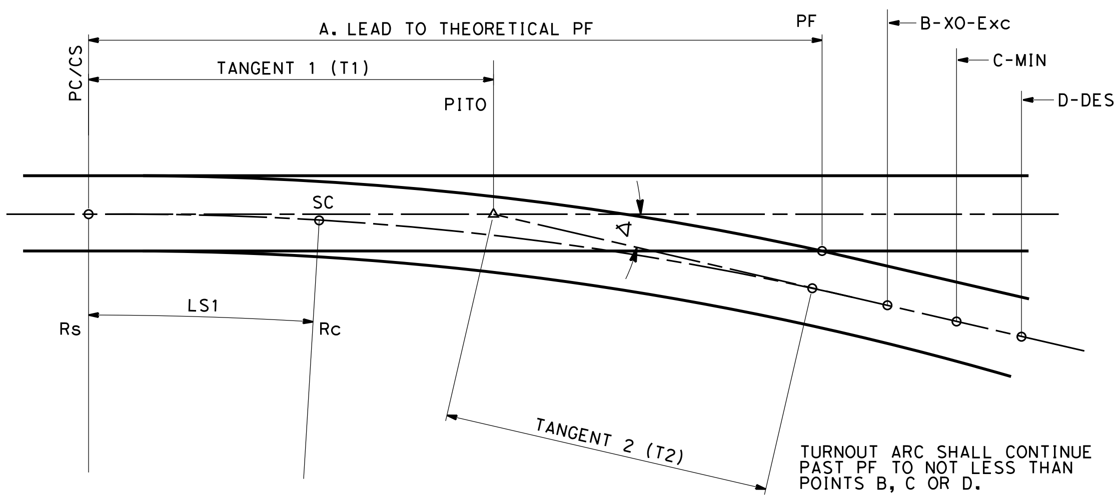


FIGURE 6.1.1: HIGH-SPEED TURNOUT LAYOUT

(SEE NOTE 2)

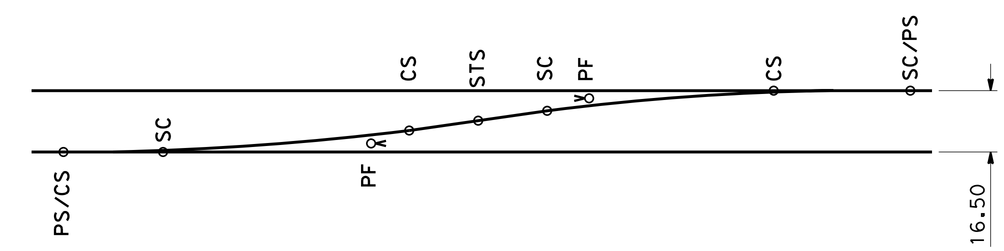


FIGURE 6.1.2: TYPICAL HIGH-SPEED CROSSOVER LAYOUT

NOTES:

1. BASIS OF DATA: TM 2.1.3, TURNOUTS AND STATION TRACK.
2. FORCE DIAGRAMS FOR THESE TURNOUTS SHALL BE SHOWN WITH THE APPLICATION OF THESE TURNOUTS TO CROSSOVERS AND STATION ENTRY TRACKS.

P-RT 1: GEOMETRY OF TURNOUT -ND ITS SEGMENTS, IN FEET UNLESS ST-TED OTHERWISE				
DESIGN SPEED	60 MPH	80 MPH	110 MPH	150 MPH
TURNOUT ENTRY R-DIUS	10,000.00	18,000.00	34,000.00	80,000.00
TURNOUT BODY R-DIUS	5,000.00	9,000.00	17,000.00	32,000.00
SWITCH SPIR-L LENGTH -ND DESIR-BLE FROG END SPIR-L LENGTH	90.00	120.00	160.00	220.00
-. DISTANCE TO THEORETICAL POINT OF FROG	237.53	318.53	436.76	610.07
-NGLE -T THEORETIC-L POINT OF FROG	2d27m49s	1d50m12s	1d20m14s	0d58m27s
DERIVED FROG NUMBER (-REM- METHOD)	23.25	31.2	42.8	58.8
TURNOUT BODY CURVE -RC LENGTH, SC TO PF	147.50	198.51	276.74	375.18
B. DIST-NCE TO POINT OF 5.85 FT. SEP-RATION	262.62	352.18	482.98	673.52
C. DIST-NCE TO POINT OF 7.00 FT. SEP-RATION	285.48	382.85	525.11	731.34
D. DIST-NCE TO POINT OF 8.00 FT. SEP-RATION	303.85	407.49	558.97	777.81
P-RT 2: UNB-L-NCED SUPERELEV-TION -ND TR-NSITION R-TES, INCHES OR IN./SEC -S -PPLIC-BLE				
UNB-L-NCE -T TURNOUT ENTRY	1.44	1.42	1.42	1.13
UNB-L-NCE IN TURNOUT BODY	2.88	2.84	2.85	2.81
VIRTUAL TRANSITION TIME	0.68	0.51	0.37	0.27
VIRTU-L TR-NSITION R-TE AT ENTRY	2.13	2.80	3.86	4.16
VIRTU-L TR-NSITION RATE 59.50 FEET IN	3.54	4.20	5.30	5.85
-CTU-L TRANSITION R-TE IN SWITCH	1.41	1.39	1.44	1.69
P-RT 3: RUN TIME OF SEGMENTS, IN SECONDS				
SWITCH SPIR-L	1.02	1.02	0.99	1.00
TURNOUT ARC TO POINT OF FROG	1.67	1.69	1.72	1.71

TABLE 6.1.1: HIGH-SPEED TURNOUTS

M-IN TR-CK CROSSOVERS 16.50 FEET TR-CK CENTERS				
P-RT 1: GEOMETRY OF TURNOUT -ND ITS SEGMENTS, IN FEET UNLESS ST-TED OTHERWISE				
DESIGN SPEED	60 MPH	80 MPH	110 MPH	150 MPH
TR-CK CENTERS	16.50	16.50	16.50	16.50
TURNOUT ENTRY R-DIUS	10,000.00	18,000.00	34,000.00	80,000.00
TURNOUT BODY RADIUS	5,000.00	9,000.00	17,000.00	32,000.00
SWITCH SPIR-L LENGTH	90.00	120.00	160.00	220.00
FROG SPIR-L LENGTH	45.00	62.00	85.00	115.00
TOT-L LENGTH -LONG M-IN TRACK	618.74	829.97	1,138.63	1,583.92
TOT-L LENGTH -LONG CROSSOVER TR-CK	619.05	830.20	1,138.80	1,584.04
ANGLE -T STS	3d01m31s	2d15m15s	1d38m28s	1d11m49s
LENGTH OF ENTRY CURVE	0.00	0.00	0.00	0.00
LENGTH OF TURNOUT BODY CURVE	173.52	233.10	324.40	457.02
P-RT 2: UNB-L-NCED SUPERELEV-TION -ND TR-NSITION R-TES, INCHES OR IN./SEC -S -PPLIC-BLE				
UNB-L-NCE -T TURNOUT ENTRY	1.44	1.42	1.42	1.13
UNB-L-NCE IN TURNOUT BODY	2.88	2.84	2.85	2.81
VIRTU-L TR-NSITION TIME	0.68	0.51	0.37	0.27
VIRTUAL TRANSITION R-TE -T ENTRY	2.13	2.80	3.86	4.16
VIRTU-L TR-NSITION R-TE 59.50 FEET IN	3.54	4.20	5.30	5.85
TRANSITION R-TE IN SWITCH	1.41	1.39	1.44	1.69
TR-NSITION RATE -T FROG END	5.51	5.38	5.40	5.38
P-RT 3: RUN TIME OF SEGMENTS, IN SECONDS				
SWITCH SPIR-L	1.02	1.02	0.99	1.00
TURNOUT -RC TO REVERSING SPIR-L	1.98	1.99	2.01	2.08
REVERSING SPIR-LS BETWEEN TURNOUTS	1.02	1.06	1.06	1.04
TURNOUT -RC TO SWITCH SPIR-L	1.98	1.99	2.01	2.08
SWITCH SPIR-L	1.02	1.02	0.99	1.00
TOT-L TIME THROUGH CROSSOVER	7.03	7.08	7.06	7.20

TABLE 6.1.2: HIGH-SPEED CROSSOVERS

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY D. MANITI
DRAWN BY D. SOLTERO
CHECKED BY G. HARRIS
IN CHARGE J. CHIRCO
DATE 04/09/10

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
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CALIFORNIA HIGH-SPEED TRAIN PROJECT

HIGH-SPEED
TURNOUTS AND CROSSOVER DATA

CONTRACT NO. 13259
DRAWING NO. TM 2.1.3-A
SCALE NTS
SHEET NO.

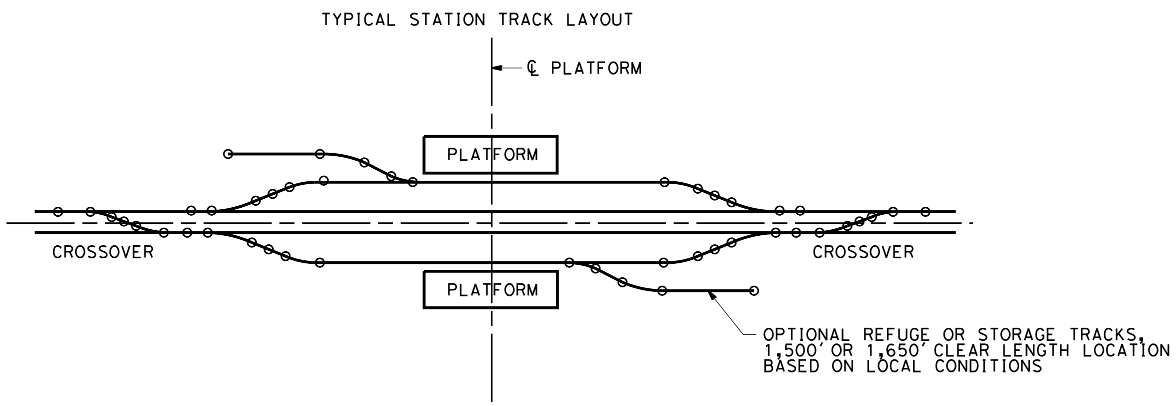

FIGURE 6.1.3: TYPICAL TRACK LAYOUT, INTERMEDIATE STATION WITH HIGH SPEED TURNOUTS

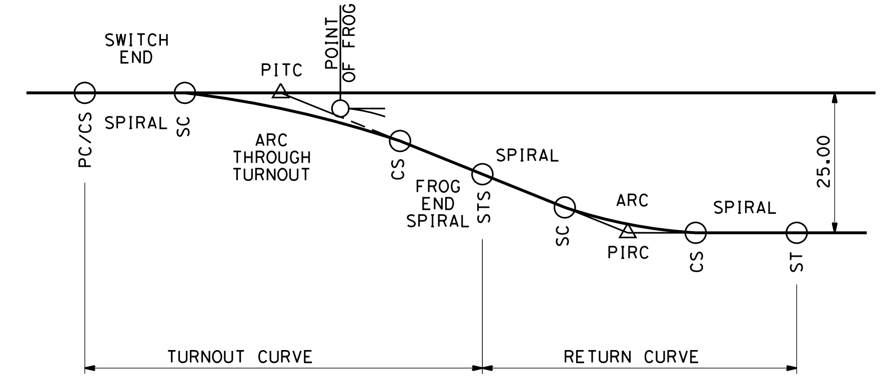

FIGURE 6.1.5: DETAIL OF STATION ENTRY/EXIT HIGH-SPEED TURNOUTS AND RETURN CURVE

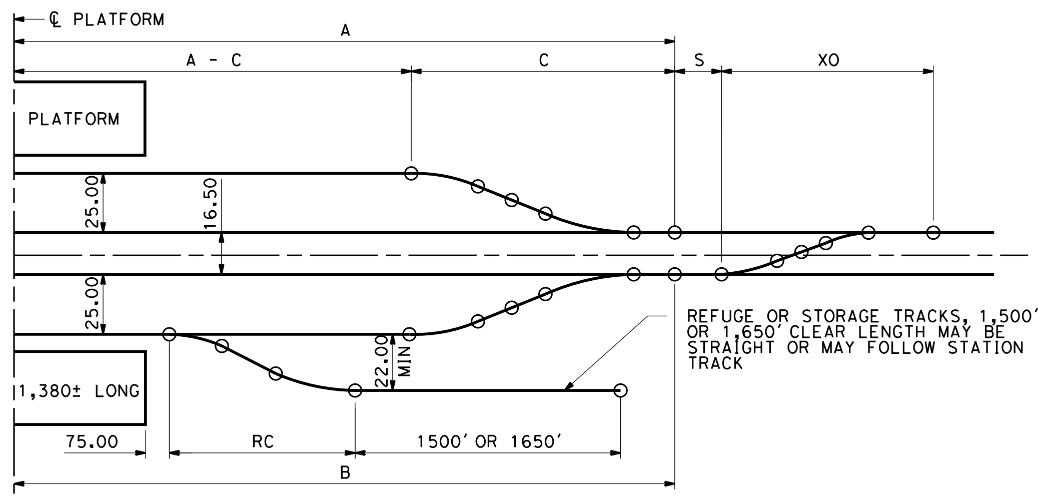

FIGURE 6.1.4: DETAIL OF INTERMEDIATE STATION TRACK LAYOUT

ST-TION CONNECTION TR-CKS WITH SPIR-L POINT TURNOUTS				
P-RT 1: GEOMETRY OF TURNOUT -ND ITS SEGMENTS, IN FEET UNLESS ST-TED OTHERWISE				
DESIGN SPEED	60 MPH	80 MPH	110 MPH	150 MPH
PL-TFORM TRACK OFFSET	25.00	25.00	25.00	25.00
TURNOUT ENTRY R-DIUS	10,000.00	18,000.00	34,000.00	80,000.00
TURNOUT BODY RADIUS	5,000.00	9,000.00	17,000.00	32,000.00
SWITCH SPIR-L LENGTH	90.00	120.00	160.00	220.00
FROG SPIR-L LENGTH	90.00	120.00	160.00	220.00
RETURN CURVE RADIUS	4,000.00	7,000.00	13,500.00	24,000.00
CURVE SPIRAL LENGTH	90.00	120.00	160.00	220.00
C. TOT-L LENGTH ALONG M-IN TR-CK	743.65	991.80	1,364.60	1,862.87
TOTAL LENGTH ALONG PLATFORM TR-CK	744.25	992.25	1,364.92	1,863.11
ANGLE -T STS	3d44m07s	2d48m04s	2d02m17s	1d30m04s
LENGTH OF ENTRY CURVE	0.00	0.00	0.00	0.00
LENGTH OF TURNOUT BODY CURVE	213.47	290.02	404.71	574.35
LENGTH OF RETURN CURVE	170.78	222.24	320.21	408.76
P-RT 2: UNB-L-NCED SUPERELEV-TION -ND TR-NSITION R-TES, INCHES OR IN./SEC -S -PPLIC-BLE				
UNB-L-NCE -T TURNOUT ENTRY	1.44	1.42	1.42	1.13
UNB-L-NCE IN TURNOUT BODY	2.88	2.84	2.85	2.81
SUPERELEV-TION IN RETURN CURVE	1.25	1.25	1.25	1.25
UNB-L-NCE IN RETURN CURVE	2.35	2.41	2.34	2.50
VIRTU-L TR-NSITION TIME	0.68	0.51	0.37	0.27
VIRTUAL TRANSITION R-TE -T ENTRY	2.13	2.80	3.86	4.16
VIRTU-L TR-NSITION R-TE 59.50 FEET IN	3.54	4.20	5.30	5.85
-CTU-L TR-NSITION RATE IN SWITCH	1.41	1.39	1.44	1.69
TR-NSITION R-TE -T FROG END	2.82	2.78	2.87	2.81
TR-NSITION R-TE IN CURVE SPIR-LS	2.30	2.35	2.35	2.50
P-RT 3: RUN TIME OF SEGMENTS, IN SECONDS				
SWITCH SPIR-L	1.02	1.02	0.99	1.00
TURNOUT -RC	2.43	2.47	2.51	2.61
FROG SPIR-L	1.02	1.02	0.99	1.00
CURVE SPIR-L	1.02	1.02	0.99	1.00
CURVE -RC	1.94	1.89	1.98	1.86
CURVE SPIR-L	1.02	1.02	0.99	1.00
SUM THROUGH DIVERGENCE	8.46	8.46	8.46	8.47

TABLE 6.1.3: STANDARD STATION CONNECTION TURNOUTS AND CURVES, 25 FEET TRACK CENTERS

EXPLANATION OF UNDIMENSIONED DATA IN FIGURE 6.1.4:

A: DISTANCE FROM CENTER OF PLATFORM TO APPROACH TURNOUT, NORMAL ARRIVAL DIRECTION. SET BY OPERATIONAL REQUIREMENT, BUT WITH A MINIMUM DISTANCE OF C PLUS HALF PLATFORM LENGTH PLUS 85 FEET WITHOUT REFUGE/STORAGE TRACK, OR C PLUS HALF PLATFORM PLUS LENGTH OF REFUGE TURNOUT PLUS 75 FEET WITH REFUGE/STORAGE TRACK.

B: DISTANCE FROM CENTER OF PLATFORM TO APPROACH TURNOUT, NORMAL DEPARTURE DIRECTION. SET BY OPERATIONAL REQUIREMENT, BUT WITH A MINIMUM DISTANCE OF C PLUS HALF PLATFORM LENGTH PLUS 85 FEET WITHOUT REFUGE/STORAGE TRACK, OR C PLUS HALF PLATFORM PLUS LENGTH OF REFUGE TURNOUT PLUS 75 FEET WITH REFUGE/STORAGE TRACK.

C: DISTANCE REQUIRED BY GEOMETRY OF THE CONNECTION. SEE DISTANCE LABELED "TOTAL LENGTH ALONG MAIN TRACKS" IN TABLE 6.1.3.

S: MINIMUM DISTANCE BETWEEN END OF STATION TURNOUT AND CROSSOVER TURNOUT WHERE THEY ARE IN THE SAME TRACK. 1.5 SECONDS RUN TIME DESIRABLE, 1.0 SECONDS MINIMUM.

XO: LENGTH OF CROSSOVER. SEE "TOTAL LENGTH ALONG MAIN TRACK" IN TABLE 6.1.2.

RC: LENGTH REQUIRED TO ACHIEVE OFFSET FOR STORAGE/REFUGE TRACK. DETERMINED BY MEDIUM/LOW SPEED TURNOUT SELECTED FROM TABLE 6.1.5.

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY D. MANTINI
DRAWN BY D. SOLTERO
CHECKED BY G. HARRIS
IN CHARGE J. CHIRCO
DATE 04/09/10

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
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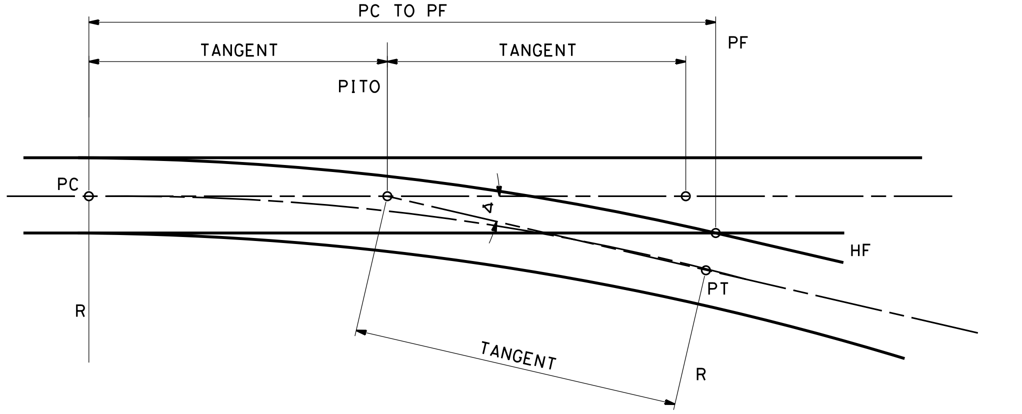
CALIFORNIA HIGH-SPEED TRAIN PROJECT

TYPICAL TRACK LAYOUT
INTERMEDIATE STATION
WITH HIGH-SPEED TURNOUTS

CONTRACT NO. 13259
DRAWING NO. TM 2.1.3-B
SCALE NTS
SHEET NO.



PF Δ = TURNOUT Δ

$N_{AREMA} = 0.5/(TAN(Δ/2))$

FIGURE 6.1.6: LOW AND MEDIUM SPEED TURNOUT LAYOUT

NUMBER	9	11	15	20
DEFINED -NGLE	6d21m35s	5d12m18s	3d49m06s	2d51m51s
R-DIUS	620 FEET	950 FEET	1750 FEET	3275 FEET
T-NGENT	34.44 FEET	43.18 FEET	58.33 FEET	81.87 FEET
LE-D, PC TO 1/2 INCH PF	77.19 FEET	95.43 FEET	129.58 FEET	176.87 FEET
TANGENT RAIL, 1/2 INCH PF TO CURVE PT	8.31 FEET	9.07 FEET	12.92 FEET	13.13 FEET
SET SPEED	20 MPH	25 MPH	35 MPH	50 MPH
UNBAL-NCE	2.58 INCHES	2.63 INCHES	2.80 INCHES	3.05 INCHES

TABLE 6.1.4: LOW AND MEDIUM SPEED TURNOUTS

1. THE REQUIREMENTS OF THIS SECTION ARE LIMITED TO GEOMETRIC CONSIDERATIONS ONLY. THE DETERMINATION OF THE NATURE OF THE POINT AND DRIVING MECHANISM ARE DESCRIBED ELSEWHERE IN THE DESIGN CRITERIA MANUAL.

2. USE OF THE NUMBER 9 TURNOUT SHALL BE TREATED AS AN "EXCEPTIONAL" CONDITION FOR ANY SITUATION WHERE THE TRAFFIC VOLUME IS OTHER THAN VERY LOW DUE TO THE KNOWN HIGH RATE OF SIDE WEAR OF THE RAILS THAT OCCURS IN SMALL RADIUS TURNOUTS UNDER HIGH-SPEED EQUIPMENT. NUMBER 11 TURNOUTS SHALL BE USED AS THE STANDARD YARD TURNOUT, AND AS THE MINIMUM SIZE TURNOUT TO BE INSTALLED IN MAIN TRACKS WITH SPEEDS OF 125 MPH OR LESS AND IN STATION TRACKS. NUMBER 15 TURNOUTS SHALL BE THE MINIMUM TURNOUTS OUT OF MAIN TRACKS FOR ALL OTHER SITUATION. YARD LEAD OR OTHER TRACKS THAT WILL HAVE TRAFFIC VOLUME OTHER THAN VERY LOW SHALL BE NO LESS THAN NUMBER 20 TURNOUTS IF CONDITIONS PERMIT.

NUMBER	11	15	20
SET SPEED	25 MPH	35 MPH	50 MPH
TR-CK CENTERS	22 FEET	22	22
RETURN CURVE R-DIUS	950 FEET	1750	3275
CURVE T-NGENT	43.18 FEET	58.33	81.87
OVER-LL LENGTH, PS TO END CURVE	327.87 FEET	446.30	603.48

TABLE 6.1.5: CONNECTION TO STORAGE AND REFUGE TRACKS AT HIGH-SPEED STATIONS

6.1.5: STORAGE AND REFUGE TRACKS AT HIGH-SPEED STATIONS

1. THE TURNOUT RETURN CURVE SELECTED FOR THIS APPLICATION WILL DEPEND UPON THE OPERATIONAL NEEDS. TURNOUTS SMALLER THAN THE NUMBER 11 SHALL NOT BE USED FOR THIS APPLICATION. FOR THE 22.00 FEET TRACK OFFSET THE TURNOUT RETURN CURVE SELECTIONS SHALL BE AS DEFINED IN TABLE 6.1.5. SPIRALS NEED NOT BE APPLIED TO THE RETURN CURVE FOR A STUB END TRACK. IF THE TRACK IS FOR YARD ACCESS INSTEAD OF TO STORAGE, A SPIRAL APPROPRIATE TO THE DESIGN SPEED OF THE ACCESS TRACK SHALL BE APPLIED.

NOTES:

1. NOT USED

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY D. MANTINI
DRAWN BY D. SOLTERO
CHECKED BY G. HARRIS
IN CHARGE J. CHIRCO
DATE 04/09/10

PB PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
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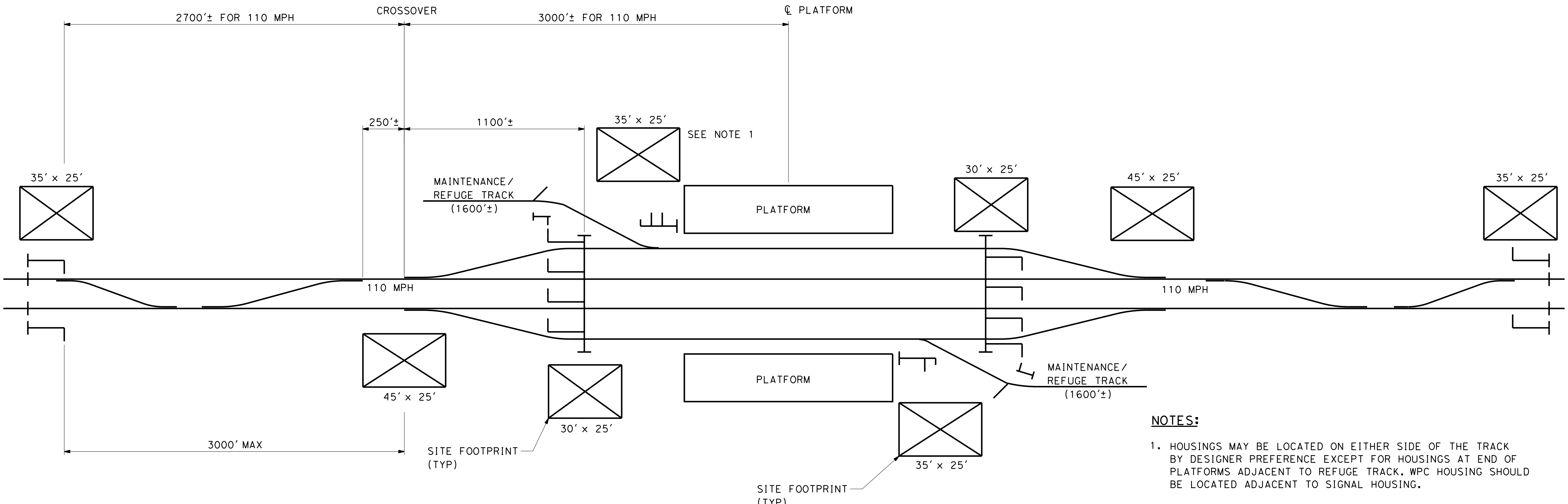
CALIFORNIA HIGH-SPEED TRAIN PROJECT

LOW AND MEDIUM SPEED TURNOUTS DATA

CONTRACT NO. 13259
DRAWING NO. TM 2.1.3-C
SCALE NTS
SHEET NO.



NOTES:

1. HOUSINGS MAY BE LOCATED ON EITHER SIDE OF THE TRACK BY DESIGNER PREFERENCE EXCEPT FOR HOUSINGS AT END OF PLATFORMS ADJACENT TO REFUGE TRACK. WPC HOUSING SHOULD BE LOCATED ADJACENT TO SIGNAL HOUSING.

2. COMMUNICATION EQUIPMENT NEEDED FOR SIGNALING WILL BE LOCATED WITHIN THE SIGNAL HOUSING.

3. WPC - WAYSIDE POWER CONTROL CABINET WILL HOUSE RTU (REMOTE TERMINAL UNIT) AND DC POWER SUPPLY UNIT FOR MOTOR OPERATED DISCONNECT SWITCHES.

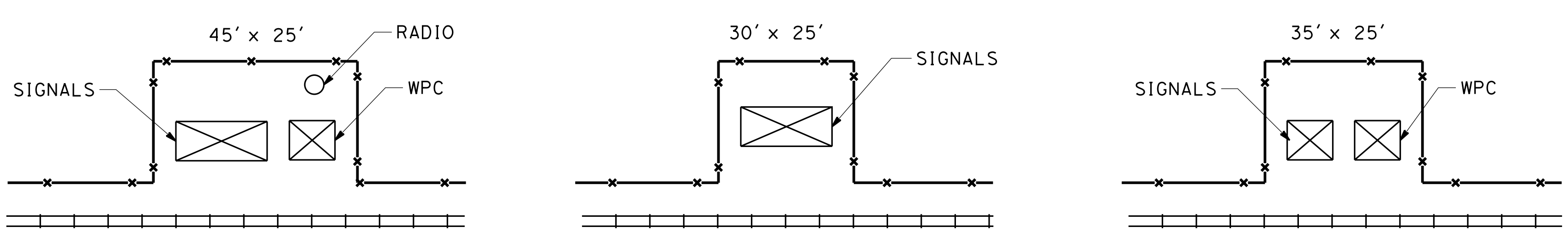
4. VEHICLE ACCESS TO ALL HOUSING VIA ACCESS ROADS @ 20 FOOT WIDE (MIN).

5. ALL FACILITIES WITHIN INTRUSION PROTECTED FENCE.

6. STAIR ACCESS TO/FROM AERIAL GUIDEWAY AND HOUSES. GUIDEWAY ACCESS CAN BE COMBINED WITHIN 1000 FEET.

7. 20 FOOT WIDE ACCESS ROAD FOR HI-RAIL ACCESS TO MAINTENANCE TRACK.

8. PROVIDE A MAINTENANCE OF WAY STORAGE AREA AT THE END OF THE REFUGE TRACK. STORAGE AREA TO BE APPROXIMATELY 70 FEET X 250 FEET WITH PERIMETER FENCING AND 20-FOOT-WIDE GATED OPENINGS AT BOTH ENDS.



HOUSING WITHIN SITES

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY H. GLICKENSTEIN
DRAWN BY D. SOLTERO
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE 02-25-10

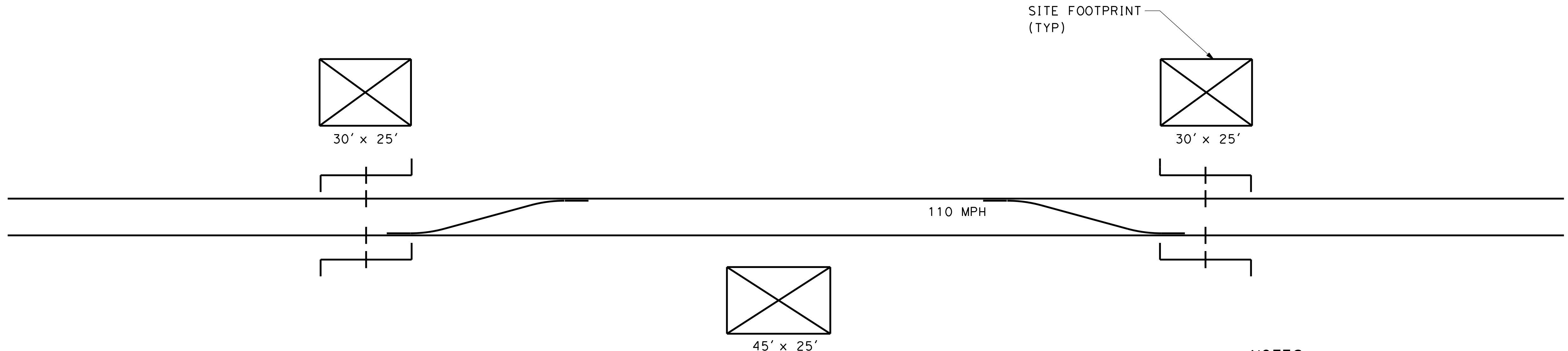
PARSONS BRINCKERHOFF

CALIFORNIA HIGH-SPEED RAIL AUTHORITY
FLY CALIFORNIA
Without ever leaving the ground.

CALIFORNIA HIGH-SPEED TRAIN PROJECT

TYPICAL INTERLOCKING SCHEMATIC AT STATIONS
ELEMENTS IN SITE FOOTPRINT

CONTRACT NO.
DRAWING NO. TM 2.1.3-INTERLOCK A
SCALE NO SCALE
SHEET NO.



NOTES:

1. HOUSINGS MAY BE LOCATED ON EITHER SIDE OF THE TRACK BY DESIGNER PREFERENCE EXCEPT FOR HOUSINGS AT END OF PLATFORMS ADJACENT TO REFUGE TRACK. WPC HOUSING SHOULD BE LOCATED ADJACENT TO SIGNAL HOUSING.

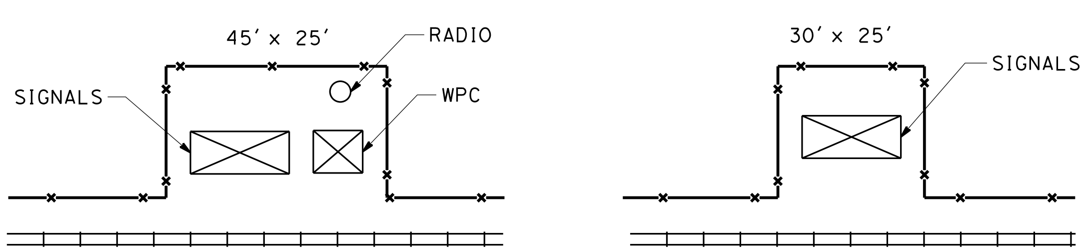
2. COMMUNICATION EQUIPMENT NEEDED FOR SIGNALING WILL BE LOCATED WITHIN THE SIGNAL HOUSING.

3. WPC - WAYSIDE POWER CONTROL CABINET WILL HOUSE RTU (REMOTE TERMINAL UNIT) AND DC POWER SUPPLY UNIT FOR MOTOR OPERATED DISCONNECT SWITCHES.

4. VEHICLE ACCESS TO ALL HOUSING VIA ACCESS ROADS @ 20 FOOT WIDE (MIN).

5. ALL FACILITIES WITHIN INTRUSION PROTECTED FENCE.

6. STAIR ACCESS TO/FROM AERIAL GUIDEWAY AND HOUSES. GUIDEWAY ACCESS CAN BE COMBINED WITHIN 1000 FEET.



HOUSING WITHIN SITES

REV	DATE	BY	CHK	APP	DESCRIPTION

DESIGNED BY H. GLICKENSTEIN
DRAWN BY D. SOLTERO
CHECKED BY R. SCHMEDES
IN CHARGE K. JONG
DATE 02-25-10

PB PARSONS BRINCKERHOFF

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CALIFORNIA HIGH-SPEED TRAIN PROJECT

TYPICAL INTERLOCKING SCHEMATIC
ELEMENTS IN SITE FOOTPRINT

CONTRACT NO.
DRAWING NO. TM 2.1.3-INTERLOCK B
SCALE NO SCALE
SHEET NO.