California High-Speed Train Project

TECHNICAL MEMORANDUM

Turnouts and Station Tracks
TM 2.1.3

Prepared by: *Signed document on file*_____ 24 June 09
George Harris Date

Checked by: *Signed document on file*_____ 29 June 09
John Chirco Date

Approved by: *Signed document on file*_____ 29 June 09
Ken Jong, PE, Engineering Manager Date

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Anthony Daniels, Program Director Date

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for the California High-Speed Rail Authority

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.

System Level Technical Reviews by Subsystem:

Systems:	*Signed document on file* Eric Scotson	25 Jun 09 Date
Infrastructure:	*Signed document on file* John Chirco	25 Jun 09 Date
Operations:	*Signed document on file* Paul Mosier	25 Jun 09 Date
Maintenance:	*Signed document on file* Paul Mosier	25 Jun 09 Date
Rolling Stock:	*Signed document on file* Frank Banko	27 May 09 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.

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.

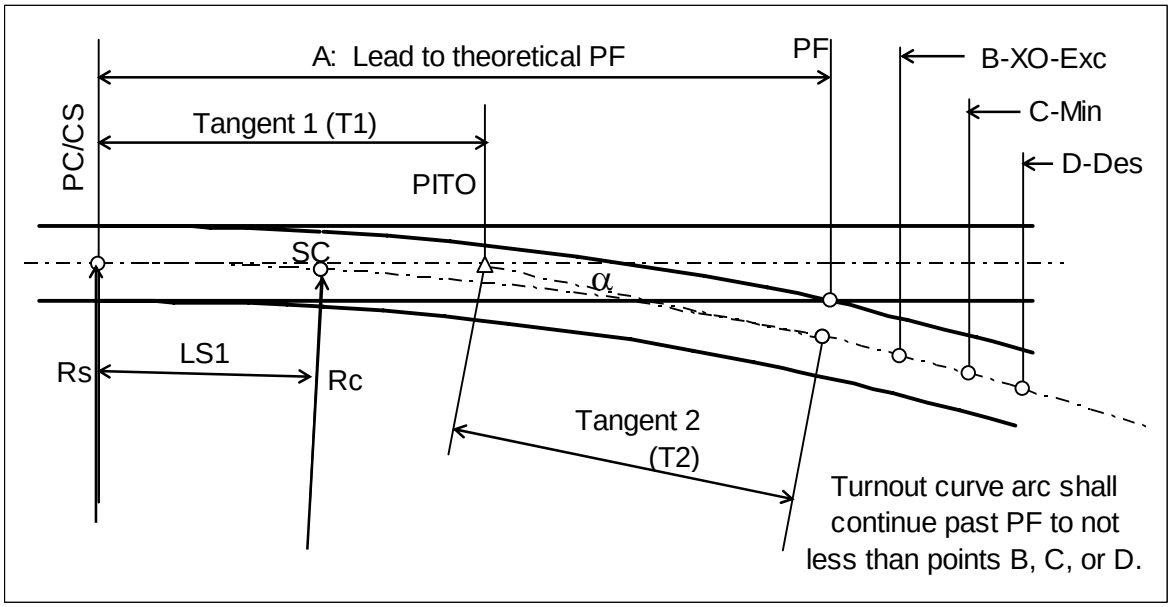
It is assumed that these high-speed turnouts will normally be built on some form of concrete based track, not on ties and ballast.

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

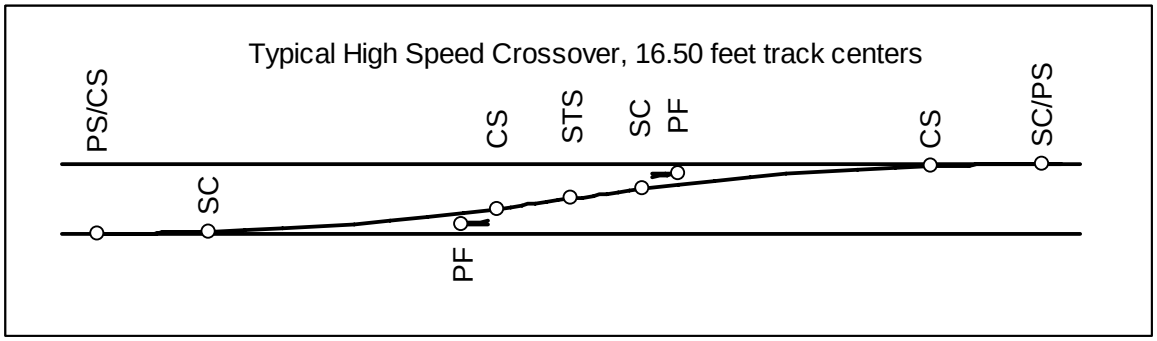


Table 6.1.2: High-Speed Crossovers

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

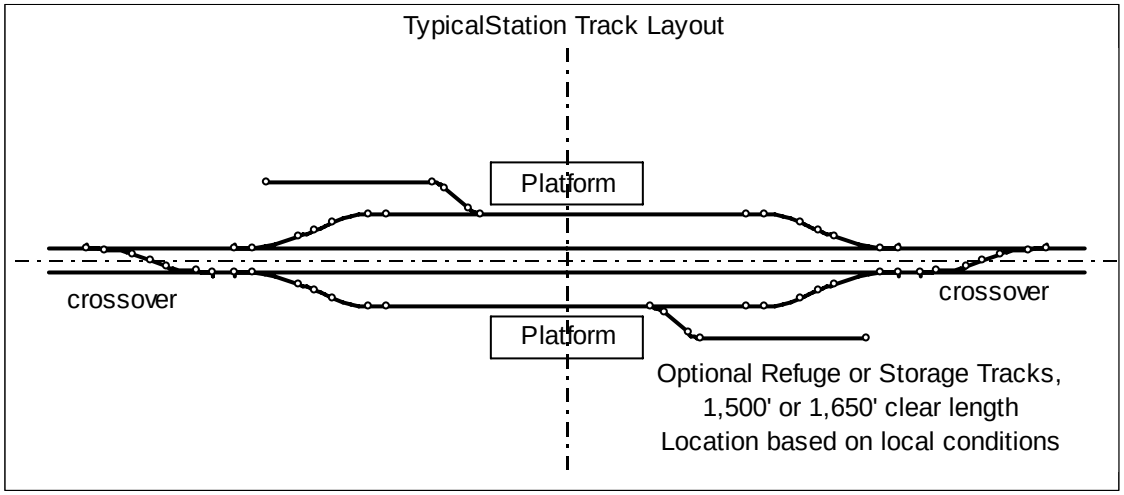
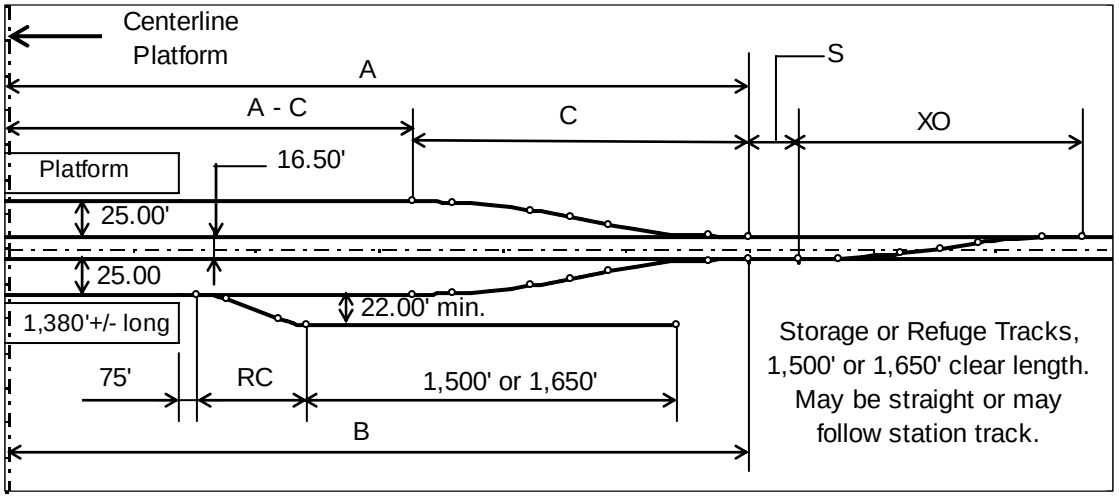


Figure 6.1.4: Detail of Intermediate Station Track Layout



Explanation of undimensioned data in Figure 6.1.4:

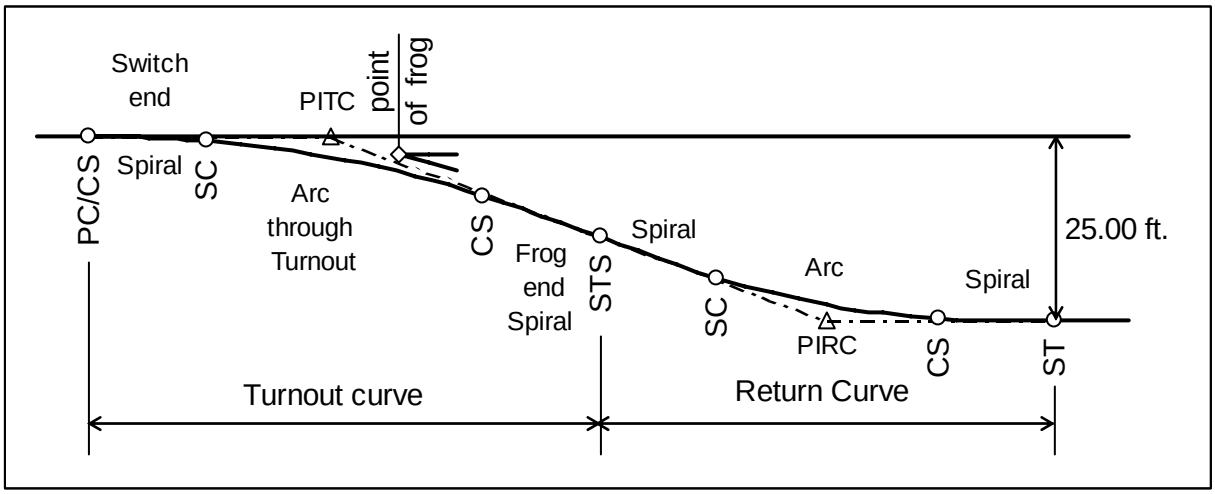
- A: Distance from center of platform to approach turnout, normal arrival direction. Set by operational requirement, but with a minimum distance of C plus half platform length plus 85 feet without refuge/storage track, or C plus half platform plus length of refuge turnout plus 75 feet with refuge/storage 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

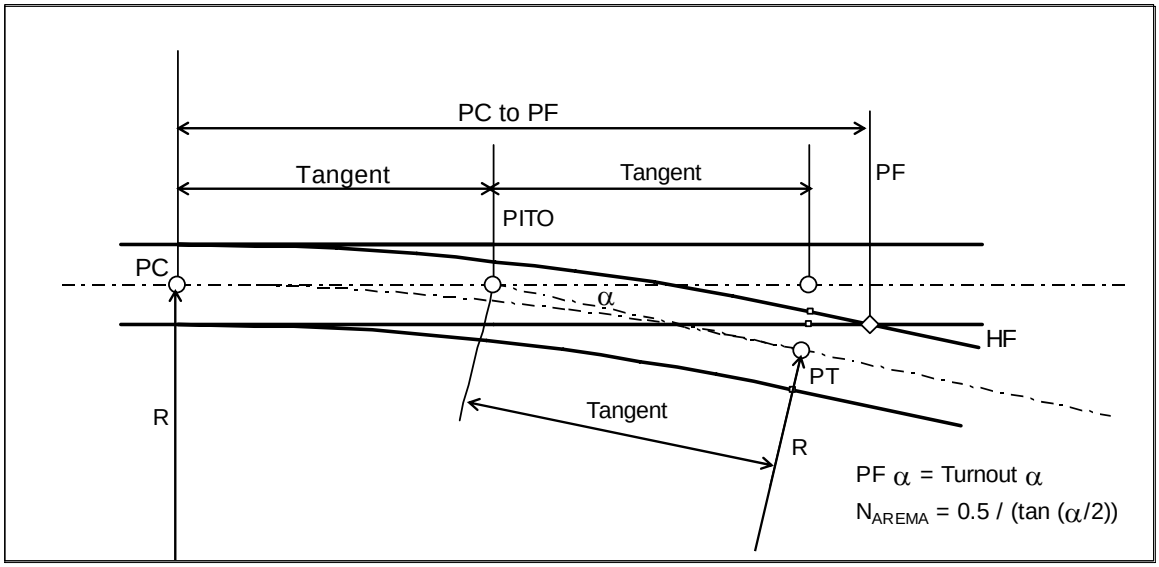


Table 6.1.4: Low and Medium Speed Turnouts

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