Welcome

Industry Collaboration

We are here in good form as “One” Railway industry. Today we will enter into a collaborative structured discussion centered around track alignment.

I encourage us all to open our minds, be attentive, share personal & professional experiences, and join us in open dialog as we strive towards eliminating alignment irregularity (track caused) derailments.

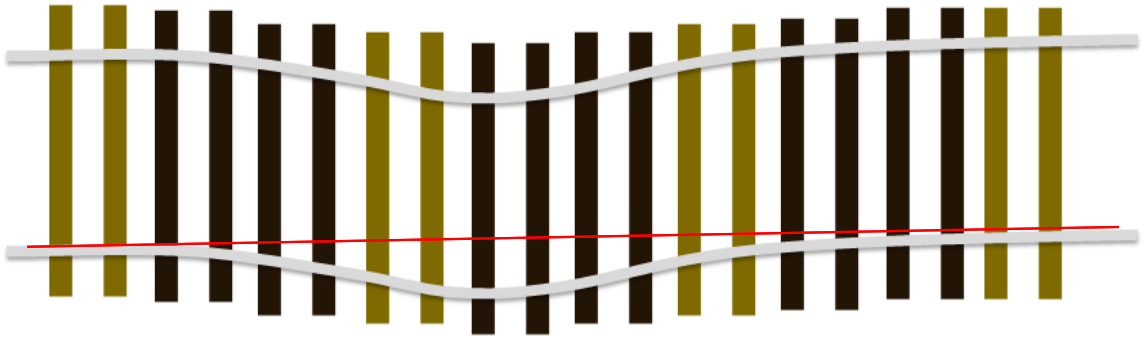
Our primary objective is to understand alignment rate of change in 31’. This includes curve spirals, connecting tracks, turnback curves, reverse curves, and turnouts. Due to time restraints we will not be addressing Rail Neutral Temperature/Track Buckle (Track Shift) type alignment conditions.

Opportunity

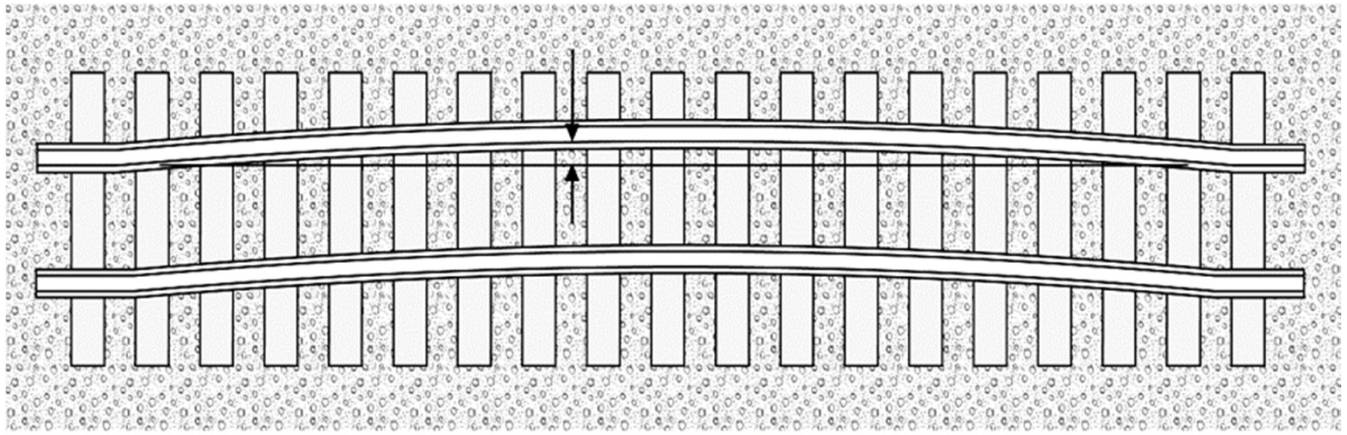
In most cases an extreme rate of change in alignment over 31’ is an Engineered track condition created during track installation & Maintenance. We must first know the difference between a track shift alignment and a spike line alignment.

Understanding Track Alignment

Track Shift - Alignment



Spike Line - Alignment



Alignment Rate of Change

Alignment Rate of Change

FRA Part 213.55

Track Alinement

Alinement is the variation in curvature of each rail of the track.

Alignment may not deviate from uniformity more than the amount prescribed in the following table:

On tangent track, the intended curvature is zero; thus, the alinement is measured as the variation or deviation from zero.

Class of Track	Tangent track	Curved track	
	The deviation of the mid-offset from a 62 foot line[1] may not be more than- (inches)	The deviation of the mid-ordinate from a 31 foot chord[2] may not be more than- (inches)	The deviation of the mid-ordinate from a 62 foot chord[2] may not be more than- (inches)
Class 1 track	5	[3] N/A	5
Class 2 track	3	[3] N/A	3
Class 3 track	1-¾	1-¼	1-¾
Class 4 track	1-½	1	1-½
Class 5 track	¾	½	5/8

1 The ends of the line shall be at points on the gage side of the line rail, five-eighths of an inch below the top of the railhead. Either rail may be used as the line rail, however, the same rail shall be used for the full length of that tangential segment of track.
2 The ends of the chord shall be at points on the gage side of the outer rail, five-eighths of an inch below the top of the railhead.
3 N/A - - Not Applicable.

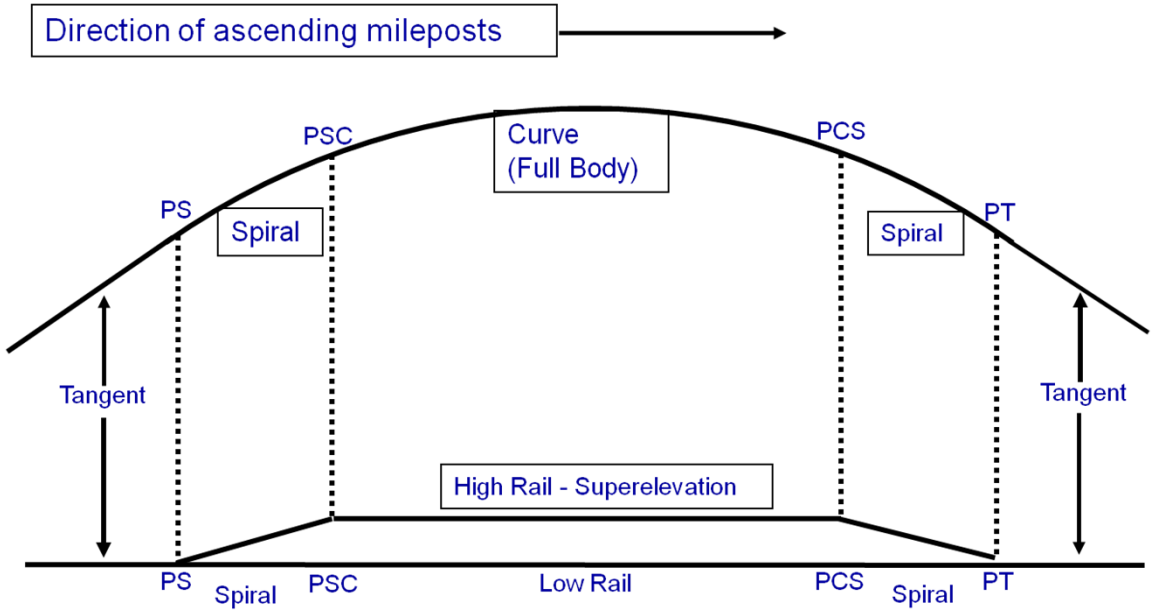
FRA Part 213.55

Measuring Curve Alignment

- Measure with 62’ chord, 9 stations @ 31’
- Measurements are taken along the gage side of the outer or high rail
- Measure 5/8” down on the side of the rail
- Alignement deviation is the difference between the average full body measurement, and the mid-ordinate measurement at the worst spot (point of concern or POC)

FRA Part 213.55

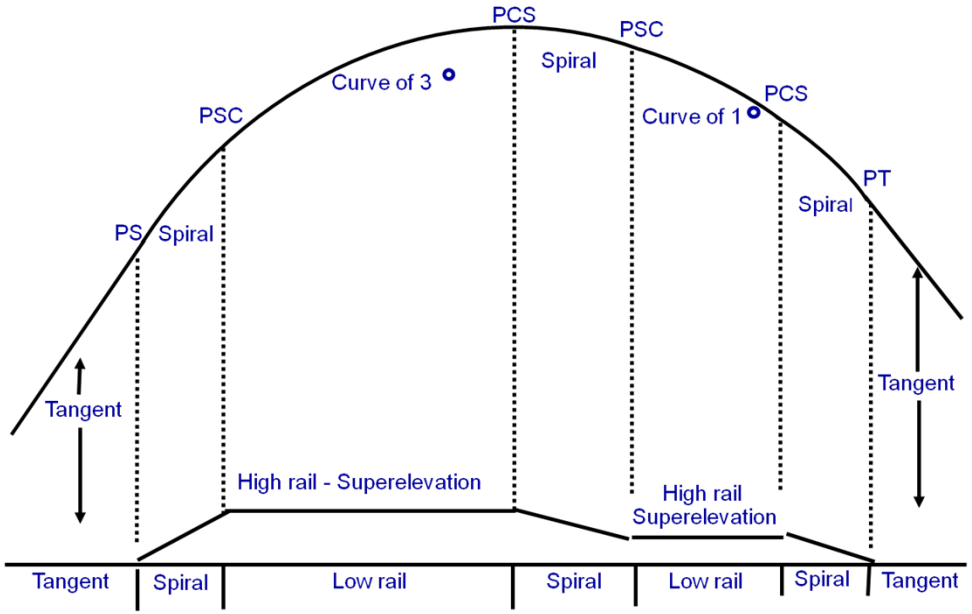
Alignment – Spiral Curve



The PS (Point of Spiral) is found at the low end milepost of the curve.

FRA Part 213.55

Alinement – Compound Curve



Change in degree of curvature and/or change in superelevation.

FRA Part 213.55

Alinement – Compound Curve

Curve Design Data:

Rec Nbr	Region	Service Unit	Subdivision	Segm	Bgng MP	Endg MP	Track Type	Dir	Delta	Unbal Factor	Max Frt Speed	Max Psgr Speed	Total Curve Length
1	Northern	DENVER	Moffat Tunnel	4745-0	16.73	17.20	SIMN	L	045-04-00	0.00	50	60	2523.30

Comp Type	Spiral Type	Comp Length	Deg Curv Dec	Curv Delt Deg Dec	Curve Delta	Curve Degree	Actl Supr Elev
Spiral	Unknown	260.00					
Curve		2003.30	2.00000	40.0660	040-03-58	02-00-00	2-0/0
Spiral	Unknown	260.00					

Compound Curve Design Data:

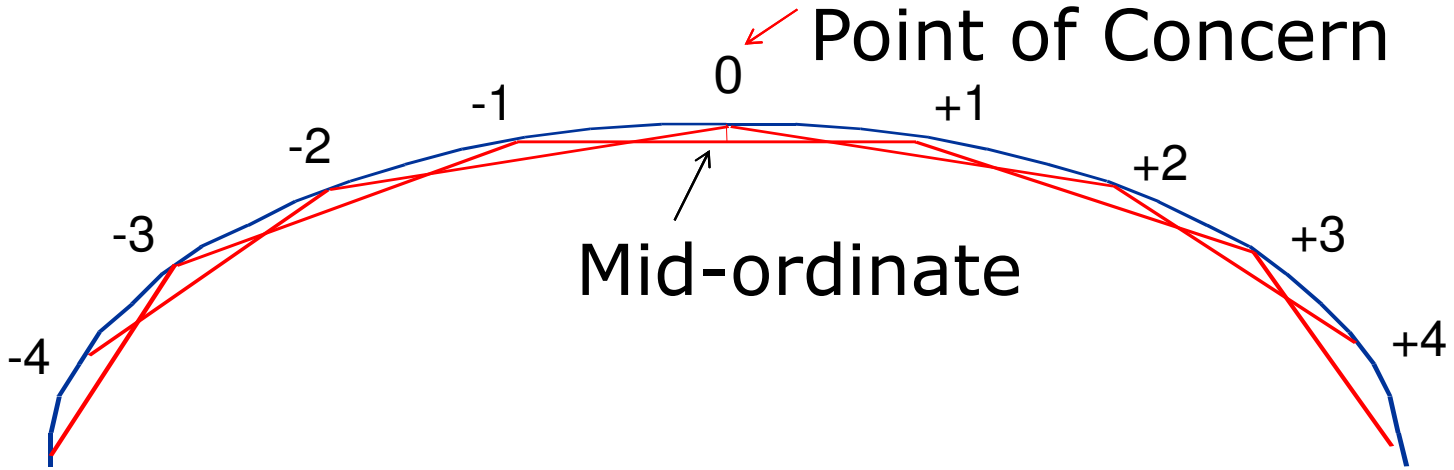
Rec Nbr	Region	Service Unit	Subdivision	Segm	Bgng MP	Endg MP	Track Type	Dir	Delta	Unbal Factor	Max Frt Speed	Max Psgr Speed	Total Curve Length
9	Northern	DENVER	Moffat Tunnel	4745-0	18.95	19.55	SIMN	L	026-18-30	1.00	25	30	3061.48

Comp Type	Spiral Type	Comp Length	Deg Curv Dec	Curv Delt Deg Dec	Curve Delta	Curve Degree	Actl Supr Elev
Spiral	Talbot	214.75					
Curve		548.50	2.60000	14.2610	014-15-40	02-36-00	0-3/4
Spiral	Talbot	110.00					
Curve		805.95	1.47917	11.9214	011-55-17	01-28-45	0-3/4
Spiral	Talbot	175.00					
Curve		148.41	7.16667	10.6361	010-38-10	07-10-00	2-0/0
Curve		863.36	8.00000	69.0688	069-04-08	08-00-00	2-1/4
Spiral	Talbot	195.51					

FRA Part 213.55

Measuring Curve Alignment – Classes 1 through 5

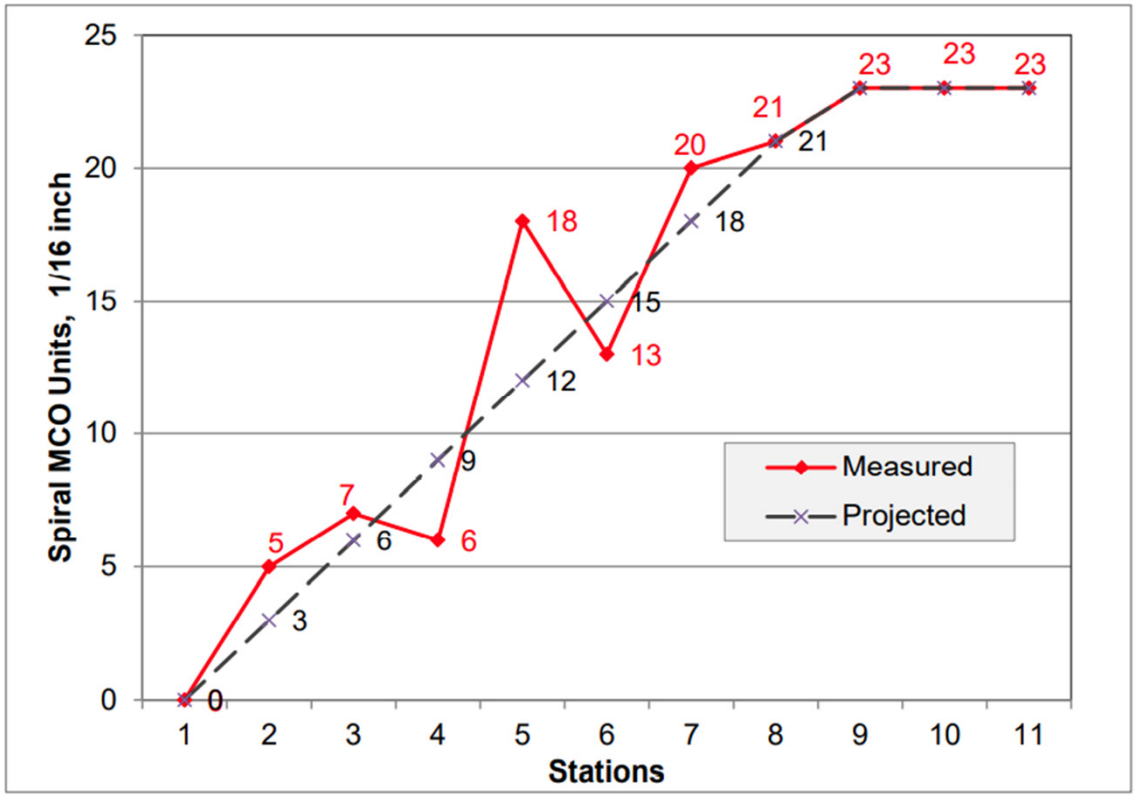
- Determine mid-ordinate for a 62’ chord at nine stations spaced 31’ apart
- Uniformity is the average of the measurements on each side of the point of concern
- The deviation from uniformity is the difference between the mid-ordinate reading at the point of concern and uniformity



FRA Part 213.55

Spiral Alignment

FRA Compliance Manual



The following figure represents a hypothetically case where the spiral length is 248 ft. (9 stations spaced at 31 ft).

The chart would approximate a 1.44 degree curve whose curvature is gradually increased from 0 (at TS) to 1.44 degrees (at SC).

The figure shows a spiral calculation for 62-foot chord with MCO units in 1/16-inch increments. A similar analysis is required for 31-foot chord for Classes 3 through 5. At Station 5, the measured value is 18 units (1-1/8 inches) and the projected value is 12 units (3/4 inch); therefore, the deviation from uniformity is 6 units (3/8 inch).

FRA Part 213.55

Alignment Limits - Uniformity

- Exceptions to determine uniformity:
  - If point of concern is near spiral, measure the stations in the curve body only
  - If curve body is short, reduce the number of stations accordingly
  - In compound curves, measure the mid-ordinates of the entire curve to determine where curve bodies exist. Then, treat each curve body as a separate curve.
- Spirals may require plotting a graph of projected and existing alignment to determine deviation from uniformity

Union Pacific has adopted the following methodology to measure and establish a uniform rate of change when considering alignment irregularities.

RATE OF CHANGE IN ALIGNMENT

Industry discussion

Industry Opportunity

According to industry standards, the question of rate of alinement change from a track standpoint is one that is not yet answered or at least not outlined in the compliance manual.

The only way a defect can be measured is against “uniformity”. The FRA also, does not publish a minimum spiral length concerning alinement. They only consider necessary length to achieve the appropriate superelevation without creating a variation in crosslevel (twist) condition.

Industry Opportunity

*Spirals applied to railroad layout must be long enough to permit an increase in superelevation not exceeding 1-1/4 inches per second for the maximum speed of train operation. Minimum spiral length is determined by an equation based on full theoretical superelevation of the curve in inches.

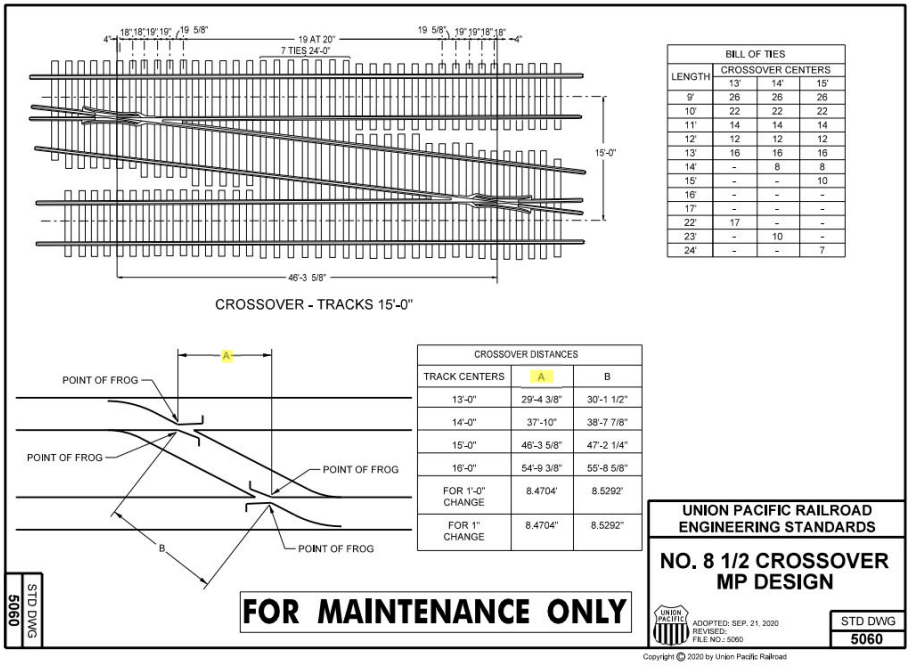
Curves are designed at a maximum rate of 2.45 inches per 100 feet (1 inch in 44 feet).

The proper spiral length provides the best riding conditions by maintaining the desired relationship between the amount of superelevation and the degree of curvature.

The degree of curvature increases uniformly throughout the length of the spiral. The same equation is used to compute the length of a spiral between the arcs of a compound curve. The difference between the superelevation's of the two circular arcs.

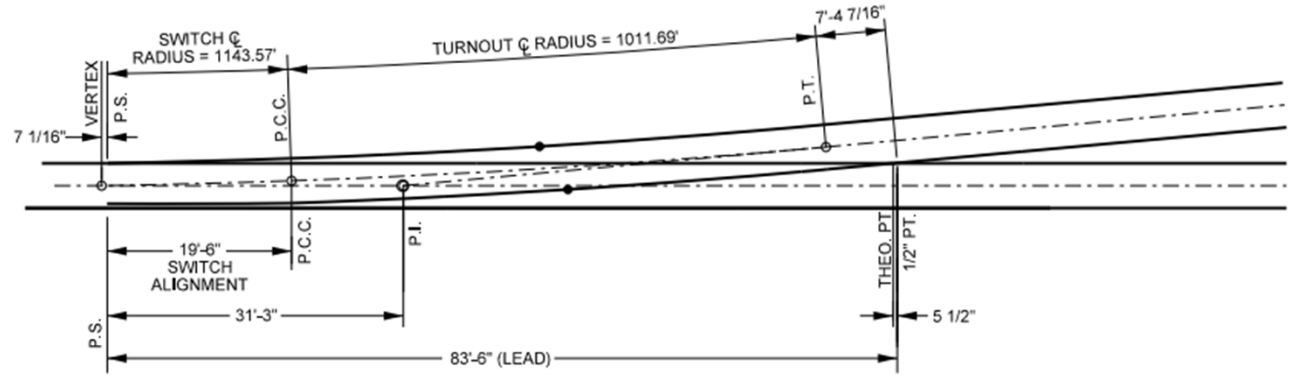
Derailment Trends

The distance between frogs in a crossover is shorter than truck center distance on long cars

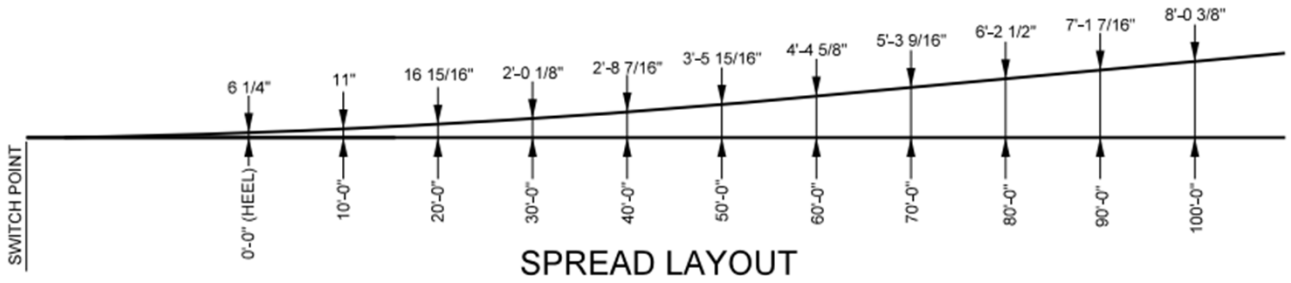


Derailment Trends

After reviewing derailment data and investigating many track caused derailments most share the same narrative pertaining to rate of change in Alignment.



GENERAL LAYOUT



SPREAD LAYOUT

SWITCH DATA	
SWITCH LENGTH	19'-6"
HEEL SPREAD	6 1/4"
HEEL ANGLE	1°-59'-16"
SWITCH ANGLE	1°-00'-40"
THROW AT ROD #1	4 3/4"
RADIUS (CENTER LINE)	1143.57'
T =	9.69'
CENTRAL ANGLE - CLOSURE CURVE	0°58'16"
DEGREE OF CURVE	5°00'06"
TURNOUT POINT: THICKNESS AT POINT	1/8"
TURNOUT POINT: RADIUS (CLOSURE CURVE)	1145.92'
TURNOUT POINT: VERTEX DISTANCE	7 1/16"

FROG DATA	
ANGLE	5°-12'-18"
LENGTH	VARIES

TURNOUT DATA	
RADIUS OF CENTER LINE	1011.69'
T =	28.35'
CENTRAL ANGLE - CLOSURE CURVE	3°13'02"
DEGREE OF CURVE	5°40'44"

UNION PACIFIC RAILROAD
COMMON STANDARDS
BNSF RAILWAY

NO. 11 TURNOUT
136/141 LB.

UNION PACIFIC
ADOPTED: SEP. 21, 2020
REVISED:
FILE NO.: 5011

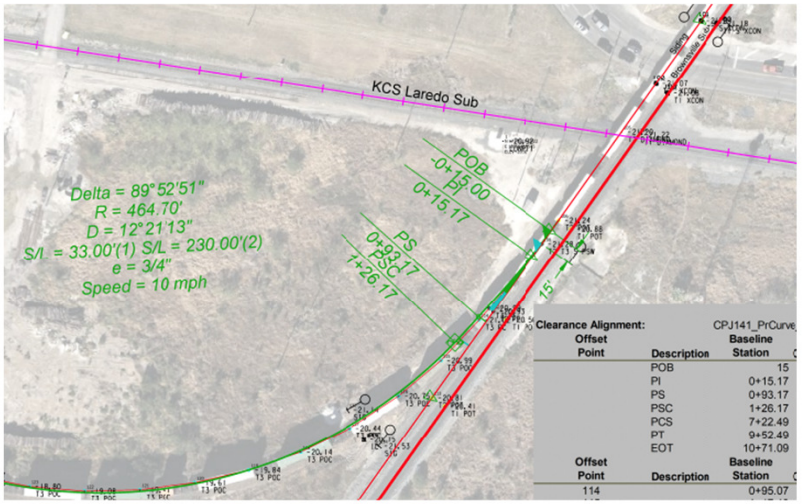
STD DWG
5011
PAGE 7 OF 8

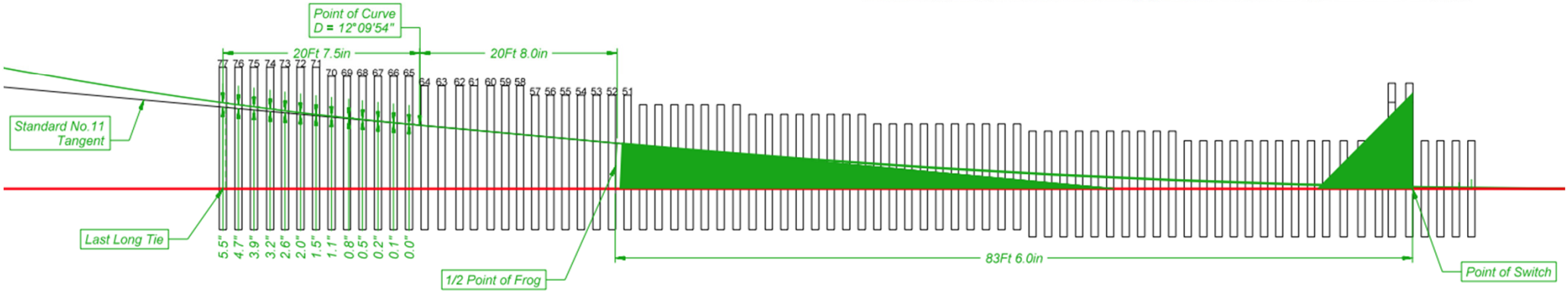
STD DWG
5011
PAGE 7 OF 8

Derailment Trends

A spiral or ***uniform rate of change in Alignment*** must be maintained anywhere there is track curvature, including Turnouts & Comeback curves.

Design software models can help us set the proper Geometry. Communication & understanding is critical.

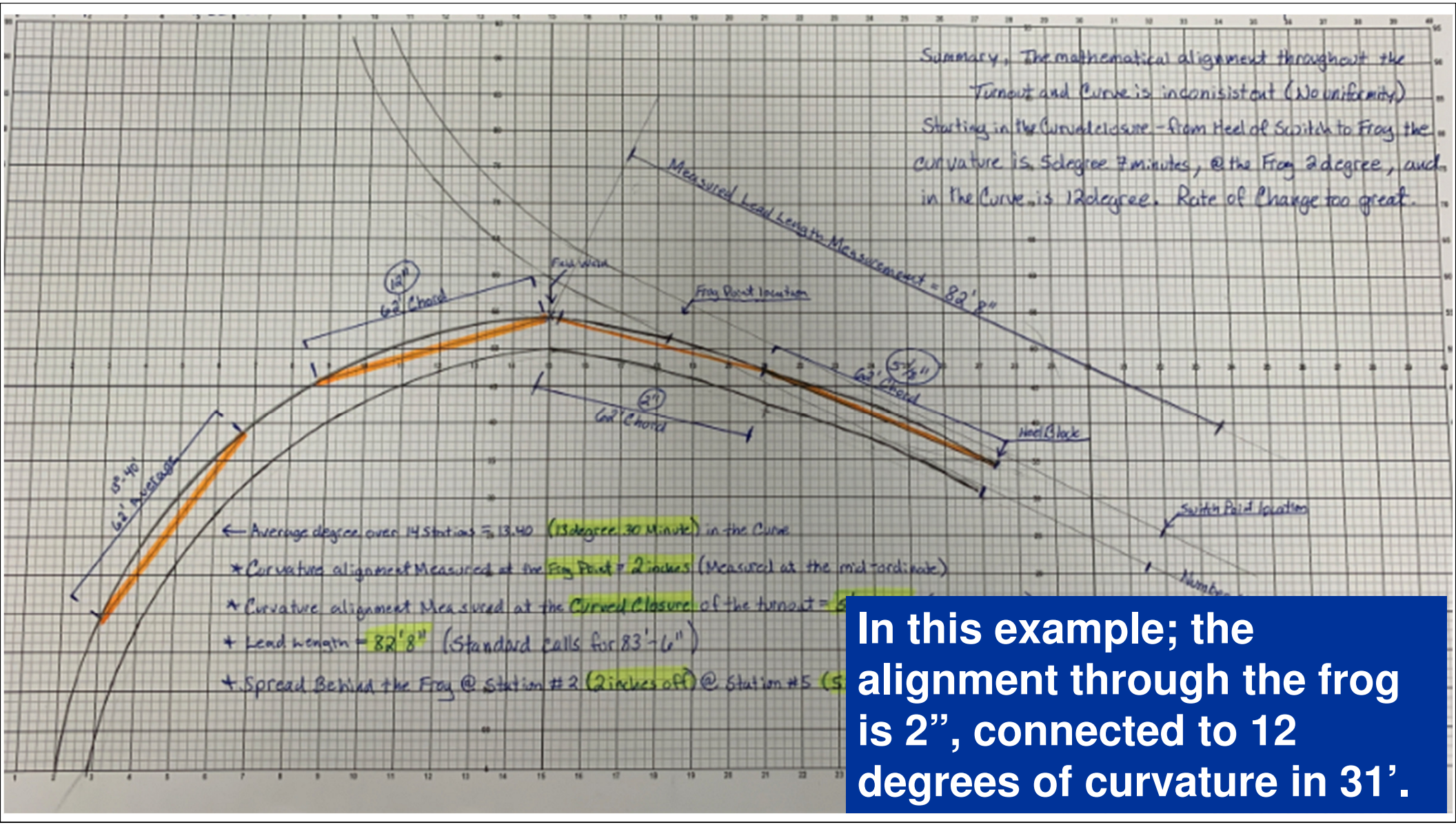




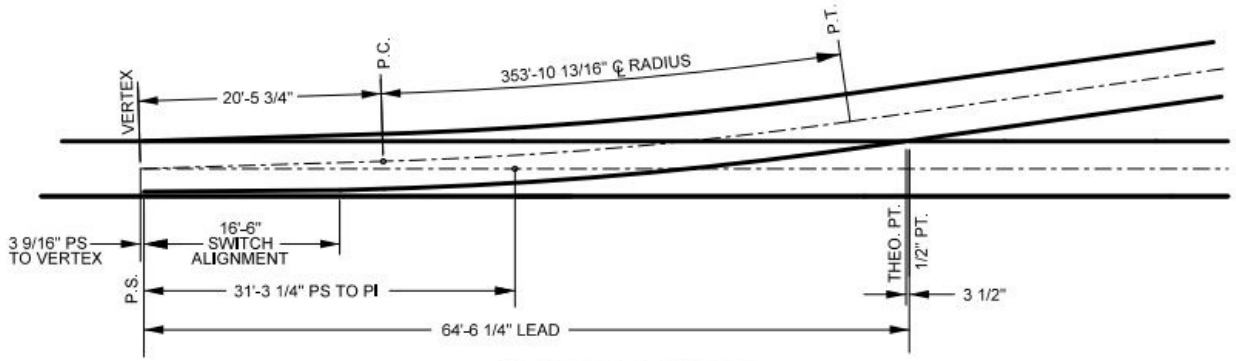
Derailment Trends / Solution

After taking the alignment measurements we originally had 12” of alignment within 31 feet, now down to under 5”.

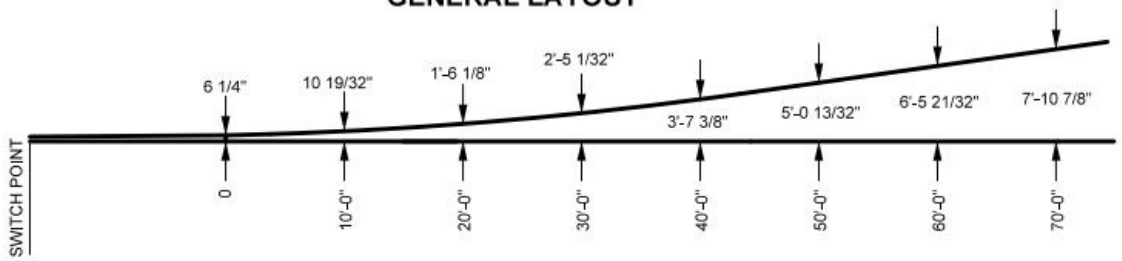
Spike line (Alignment) – Had to implement a spiral (Engineered rate of change) from turnout to curve to lower derailment potential.



In this example; the alignment through the frog is 2”, connected to 12 degrees of curvature in 31’.



GENERAL LAYOUT



SPREAD LAYOUT

SWITCH DATA	
SWITCH LENGTH	16'-6"
HEEL SPREAD	6 1/4"
HEEL ANGLE	1°-46'-22"
SWITCH ANGLE	1°-46'-22"
THROW AT ROD #1	4 3/4"
TURNOUT POINT: THICKNESS AT POINT	0"
TURNOUT POINT: RADIUS (CLOSURE CURVE)	616.3542'
TURNOUT POINT: VERTEX DISTANCE	7 1/16"

FROG DATA	
ANGLE	8°-10'-16"
LENGTH	VARIES

TURNOUT DATA	
RADIUS OF CENTER LINE	353.9'
T =	19'-10 11/16"
CENTRAL ANGLE - CLOSURE CURVE	6°26'05"
DEGREE OF CURVE	16°14'39"

UNION PACIFIC RAILROAD ENGINEERING STANDARDS

NO. 7 TURNOUT 136 LB. RAIL

ADOPTED: SEP. 21, 2020
REVISED: FEB. 4, 2022
FILE NO.: 5007

STD DWG 5007A PAGE 3 OF 4

Derailment Trends / Solution

Frog was originally 151’ 11-3/4” and should have been 131’4”, Over 20 feet off from standard.

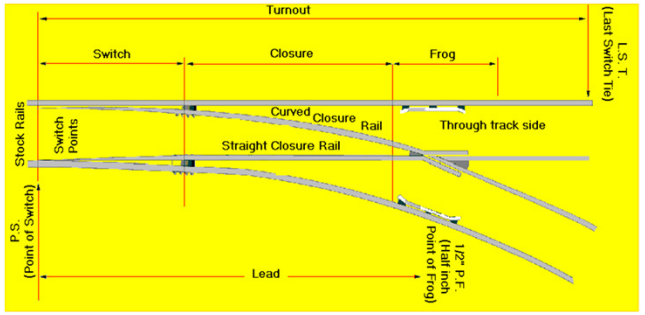
Derailment Trends / Solution

A turnout is designed by its mathematical geometric angle. Frog design is the same.

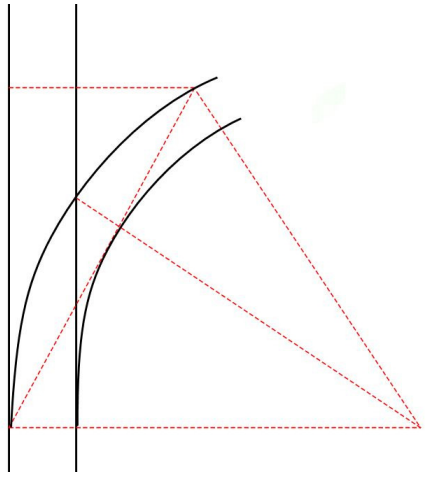
Turnout alignment through the switch, closure, and frog section is critical. There must be a uniform degree of curvature (angle) throughout the entire turnout consistent through the last long tie.

This degree of curvature is defined by line ordinates and the frog's location is established by the lead length measurement.

Note: Improper frog location will create either a flat alignment or too much curvature which causes additional force/wear through the frog section.



Mathematical example:



Turnout	Curve Degree	Lead Length
Current Turnouts		
No. 7 136lb #5007	16°14'39"	64' 6 1/4"
No. 8 136lb #5008	10°48'28"	69' 1/2"
No. 9 136lb #5009	9°20'31"	72' 11"
No. 11 136/141lb #5011	5°40'44"	83' 6"
No. 15 136/141LB #5015	3°05'30"	111' 2 3/4"
No. 20 136/141LB #5020	1°43'15"	156' 11/16"
No.24 136/141lb #5024	1°7'22"	177' 3"
Historical Turnouts		
#8 Standard 115lb Yard Turnout #5070	11°43'34"	69' 1/2"
Layout Plans for No. 8 1/2 Yard Turnout #5071	9°30'30"	71' 8"
No. 9 Turnout 133lb Rail #5072	9°48'23"	75' 11 11/16"
No. 9 Turnout SP Design #5073	8°41'10"	74' 3/4"
No. 10 Standard 133lb Turnout #5075	7°38'31"	80' 3 5/8"
No. 10 Turnout SP Design #5076	7°27'14"	78' 3 3/4"
No. 10 Premium Wood Turnout 133lb Rail #5077	7°38'31"	80' 3 5/8"
No. 14 Turnout SP Design #5080	4°15'21"	111' 3/8"
No. 14 Premium Wood Turnout 133lb Rail #5081	3°51'34"	115' 8 3/8"
No. 14 133lb Mainline Turnout #5082	3°51'34"	115' 8 3/8"
No. 15 Turnout #5085	3°05'30"	111 2 3/4"
No. 16 Turnout MP Design #5087	2°51'18"	131' 4"
No. 20 Turnout SP Design #5090	1°55'32"	166' 1 7/8"
No. 20 Wood Turnout 133lb Rail #5091	1°43'15"	156' 11/16"

Alignment in Turnouts & Crossovers

Closure Section - Alignment

The picture on the left represents a reoccurring gage condition caused by improper alignment.

The picture on the right is the permanent repair established with the proper alignment utilizing the string line methodology.

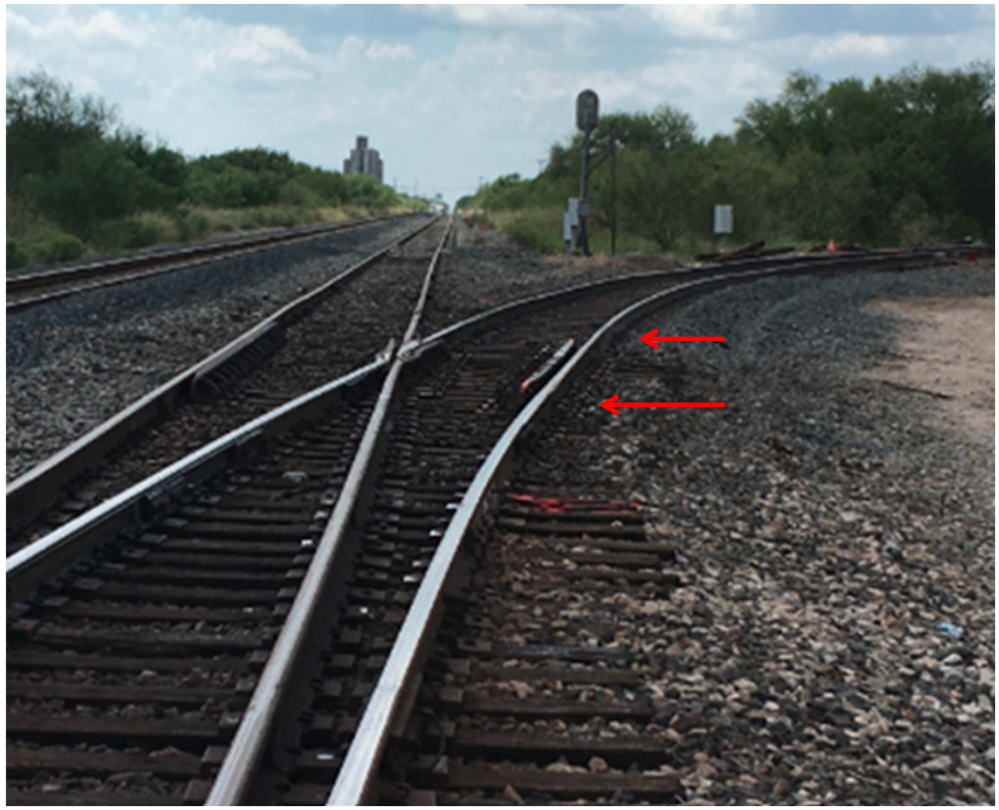
Alignment in Turnouts and Crossovers

Frog Installation

Common alignment irregularities are found through the frog section of the turnout due to the improper guard & gauge relationship.

Know the standards for gage & guard check gage.

Do not allow for spike line (alignment) on the line rail of the turnout.



Conclusion

- **What we Know**
  - Alignment Irregularities create L/V ratio conditions
  - Alignment variations are a result of engineered design and track degradation
  - Alignment variations create high coupler angles
  - High coupler angles increase the lateral force applied to the rail
- **What we need to define**
  - Coupler angle thresholds
  - Lateral force applied due to coupler angles
  - Measurements to identify and correct alignment variations