Principles of Track Geometry

Presented by:
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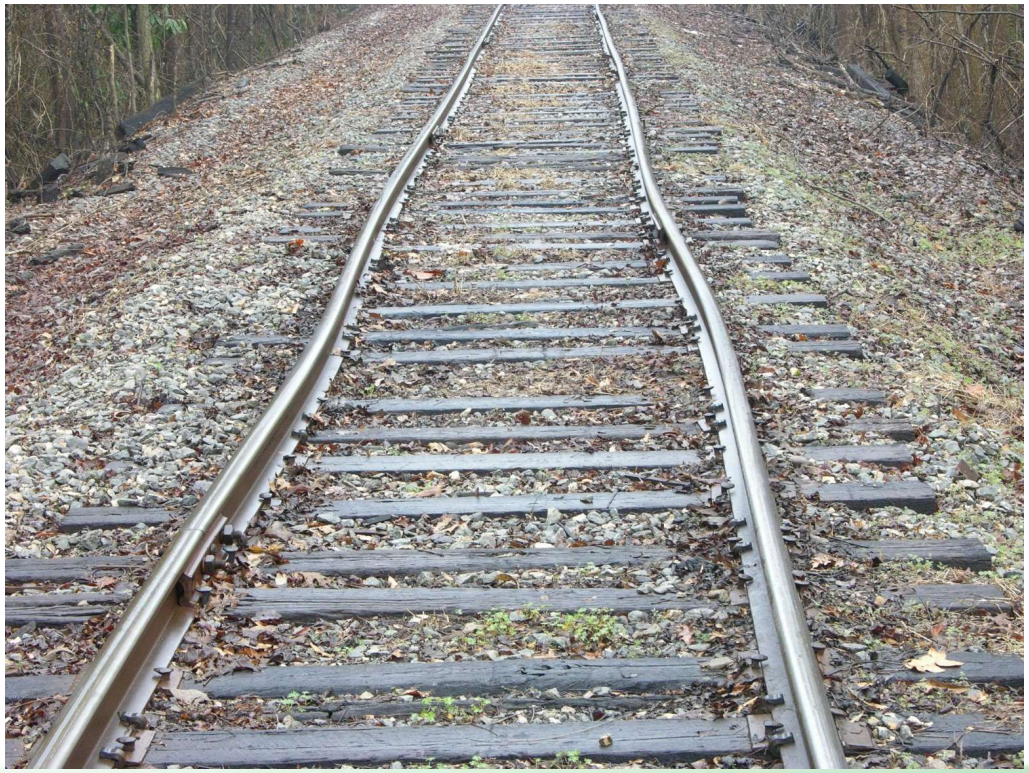
Individual Geometry Topics

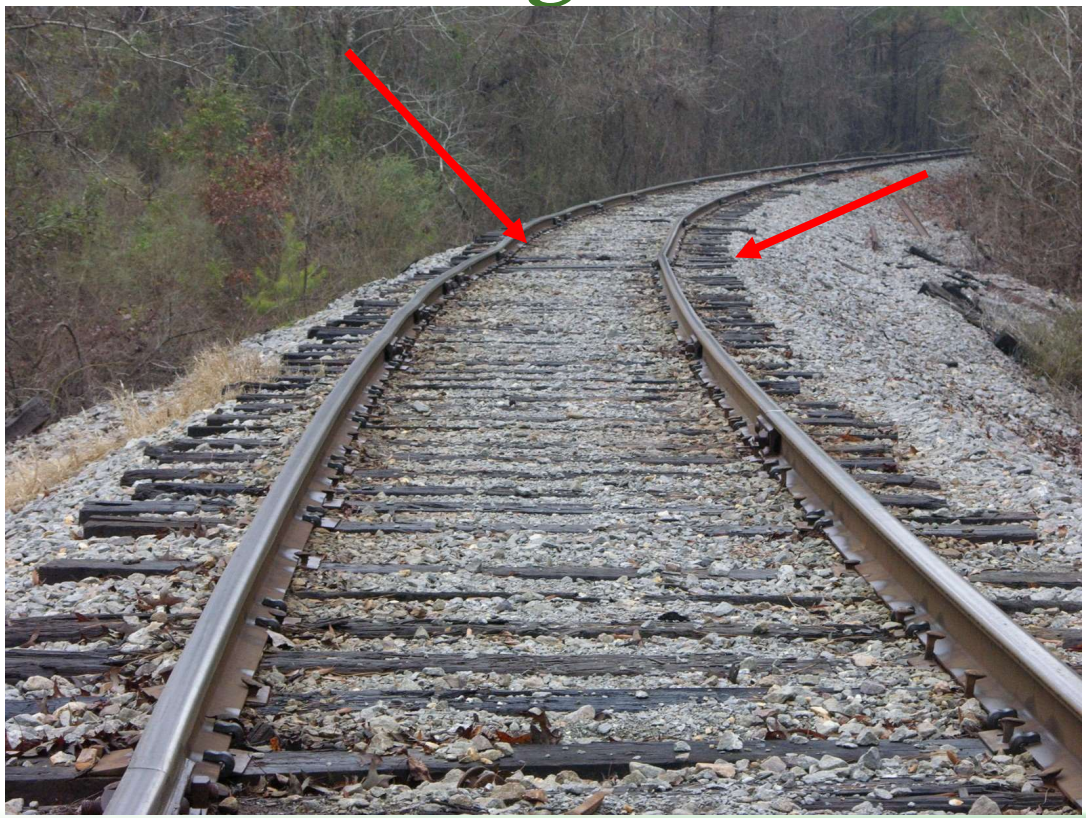
- Gage
- Curves and Curve Alignment
- Superelevation
- Crosslevel Variance and Deviation
- Vertical Profile
- Runoff from a Raise

Gage, Alignment, Profile, and Crosslevel Variations

Gage and Alignment Variations



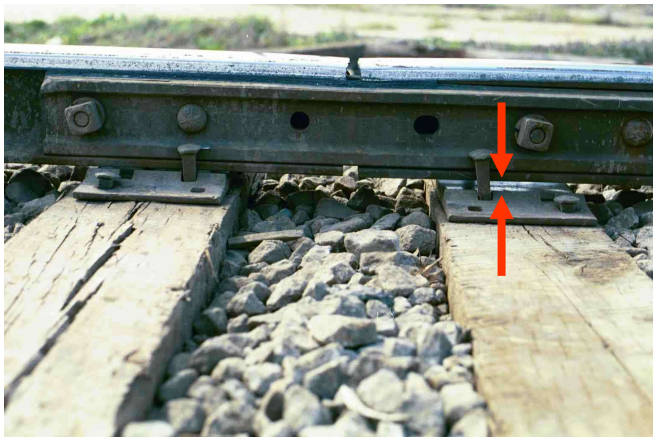
Crosslevel and Alignment Variations

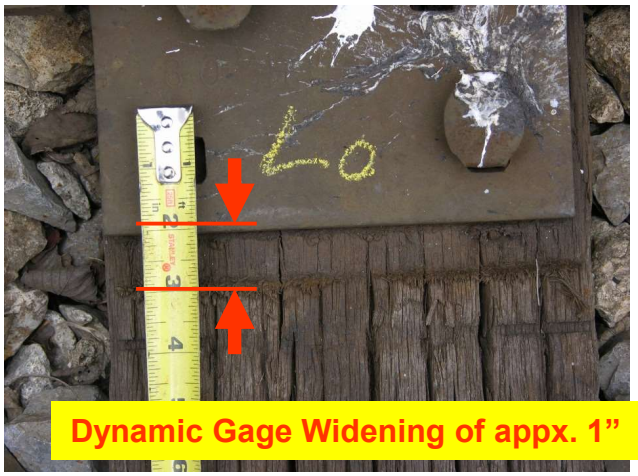


Surface and Profile Deviations

§ 213.13 Measuring track not under load.

When unloaded track is measured to determine compliance with requirements of this part, the amount of rail movement, if any, that occurs while the track is loaded must be added to the measurements of the unloaded track.






Measuring Crosslevel Under Load

For North American Freight Operations[9]

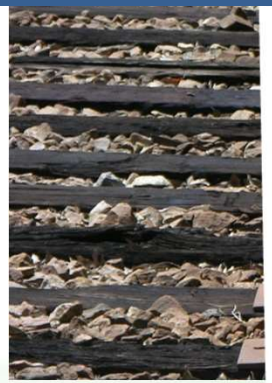
CLASSES OF TRACK

CLASS	OPERATING SPEEDS (MPH)			
	1FREIGHT		2. PASSENGER	
	FROM	TO	FROM	TO
1	1	10	1	15
2	11	25	16	30
3	26	40	31	60
4	41	60	61	80
5	61	80	81	90

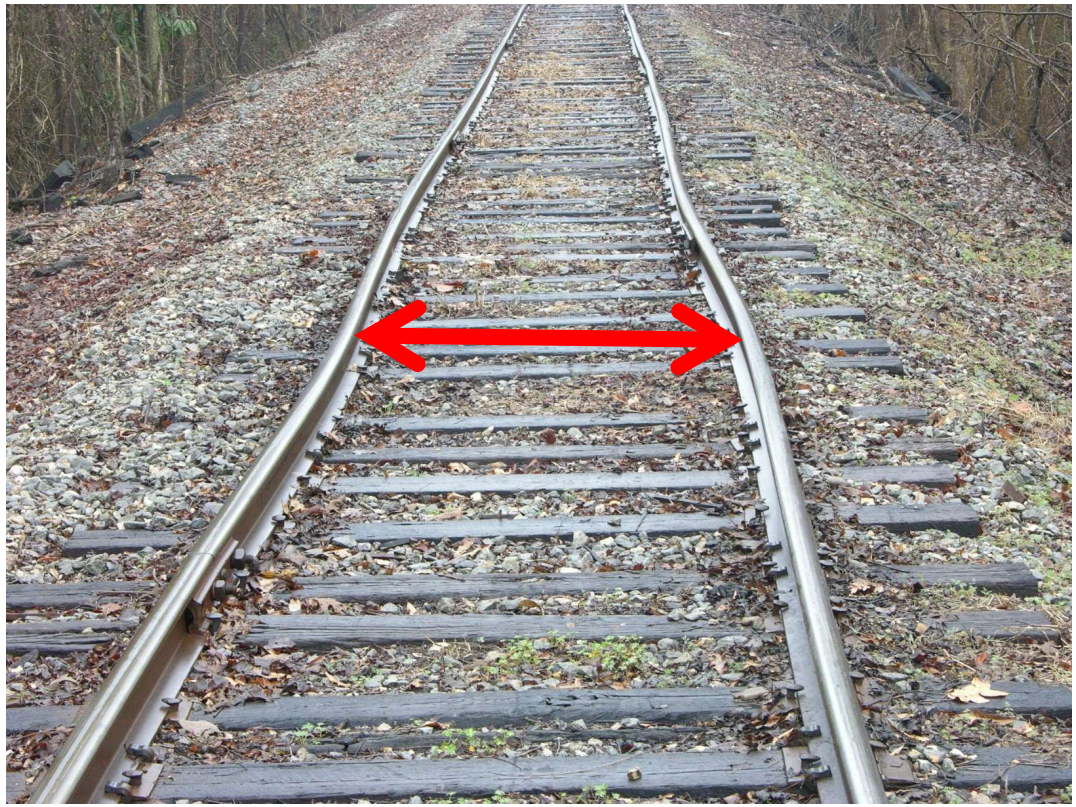
§ 213.53 Gage.

(a) Gage is measured between the heads of the rails at right-angles to the rails in a plane five-eighths of an inch below the top of the rail head.

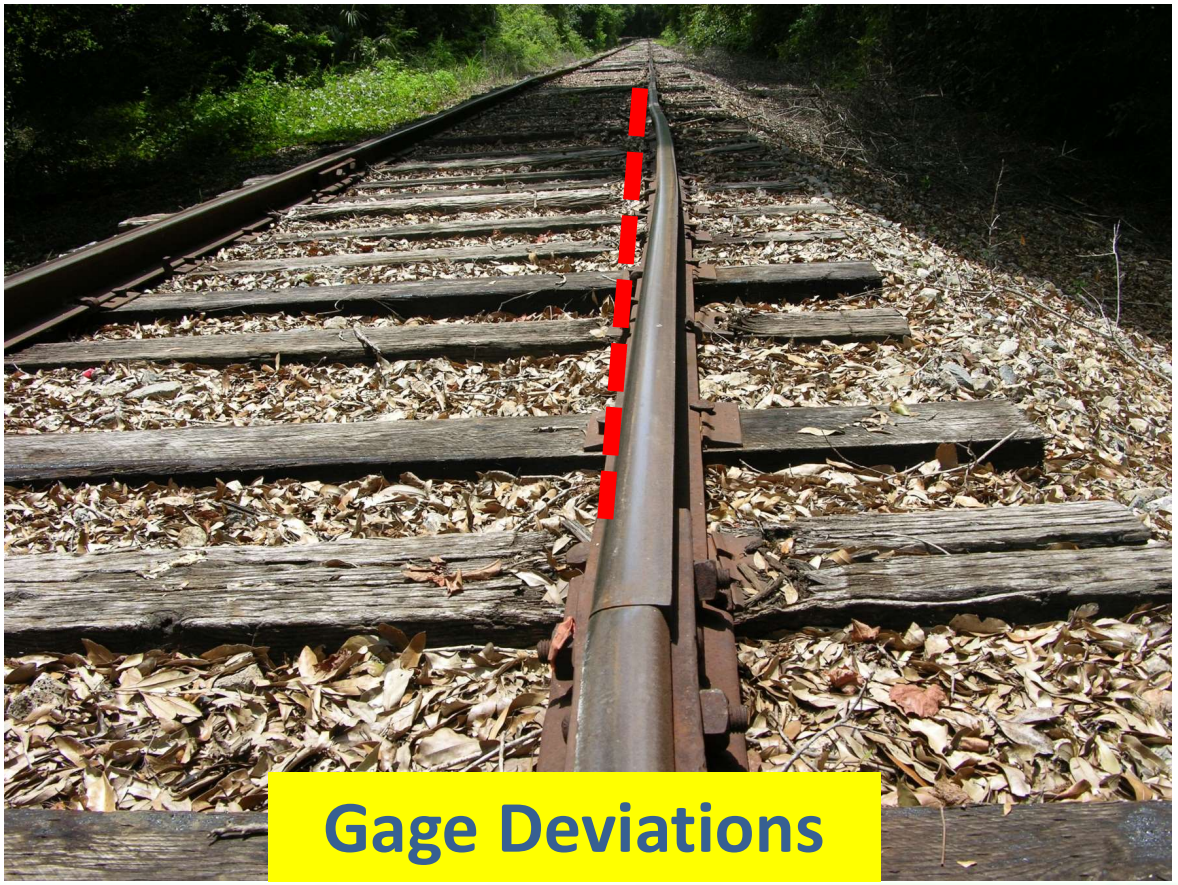
(b) Gage shall be within the limits prescribed in the following table —



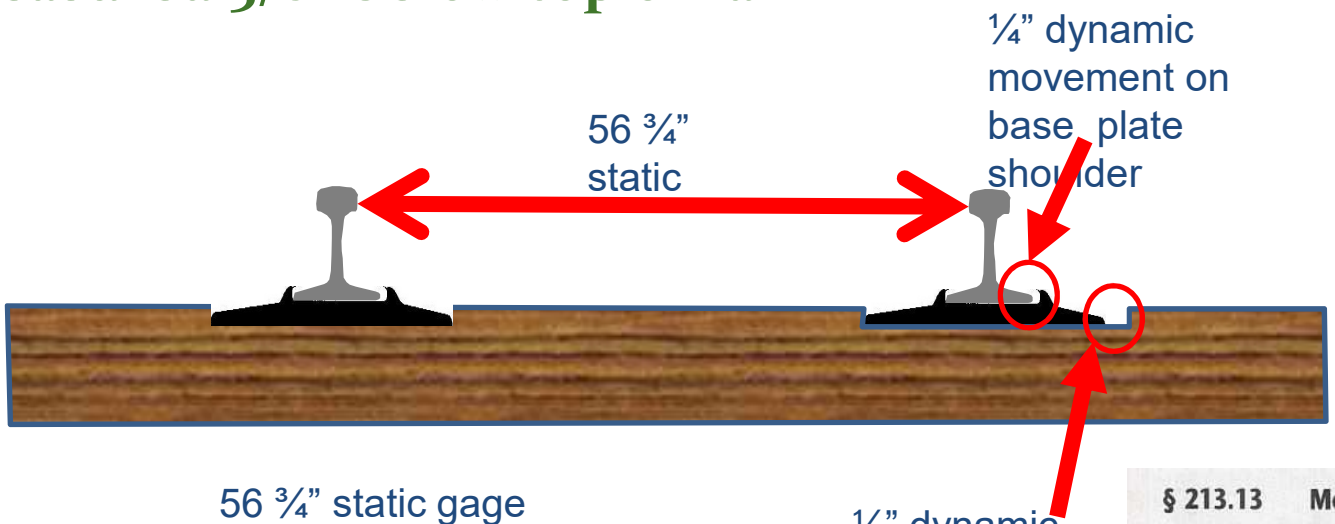
Class of track	The gage must be at least—	But not more than—
Excepted track.	N/A	4'10¼"
Class 1 track	4'8"	4'10"
Class 2 and 3 track	4'8"	4'9¾"
Class 4 and 5 track	4'8"	4'9½"



Gage Deviations


Gage Deviations

Gage – Distance between the rail heads measured 5/8" below top of rail

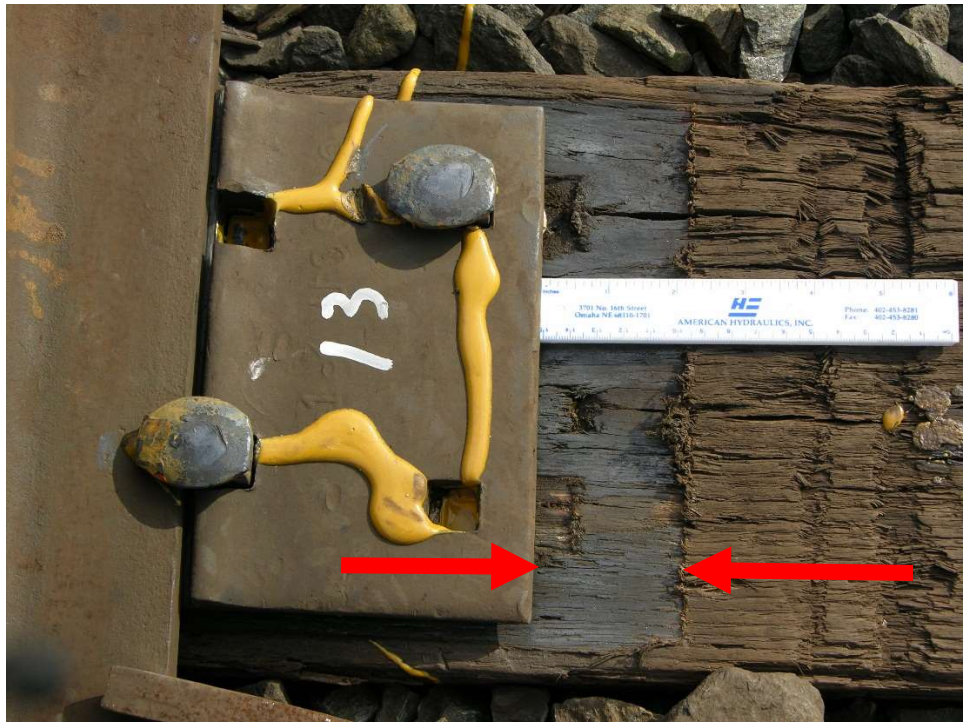


56 ¾" static gage
¼" dynamic base movement
½" dynamic plate movement

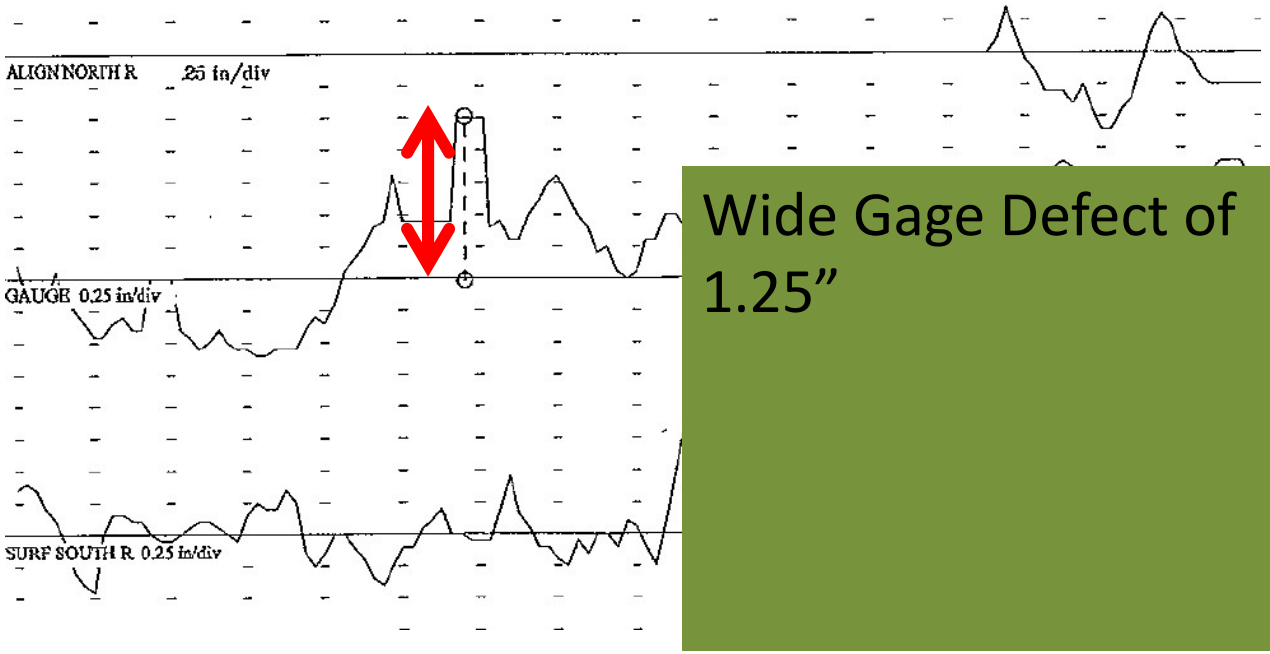
57 ½" total gage for FRA Compliance

§ 213.13 Measuring track not under load.

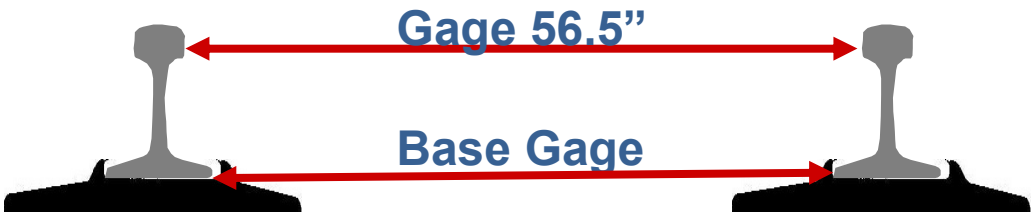
When unloaded track is measured to determine compliance with requirements of this part, the amount of rail movement, if any, that occurs while the track is loaded must be added to the measurements of the unloaded track.



Dynamic Gage Widening



Wide Gage Defect of 1.25”



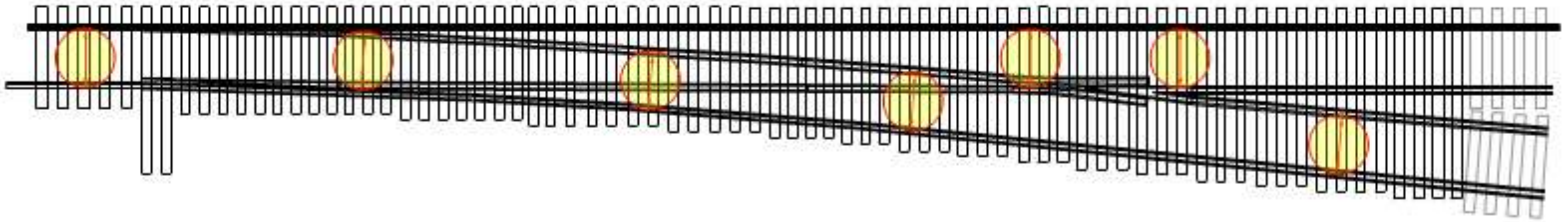
Rail Wt.	Base Gage Decimal(in.)	Base Gage Fraction(in.)
100	54.16	54 5/32
115	53.96	53 31/32
119	53.91	53 29/32
132	53.77	53 ¾
133	53.69	53 11/16
136	53.72	53 23/32
141	53.72	53 23/32

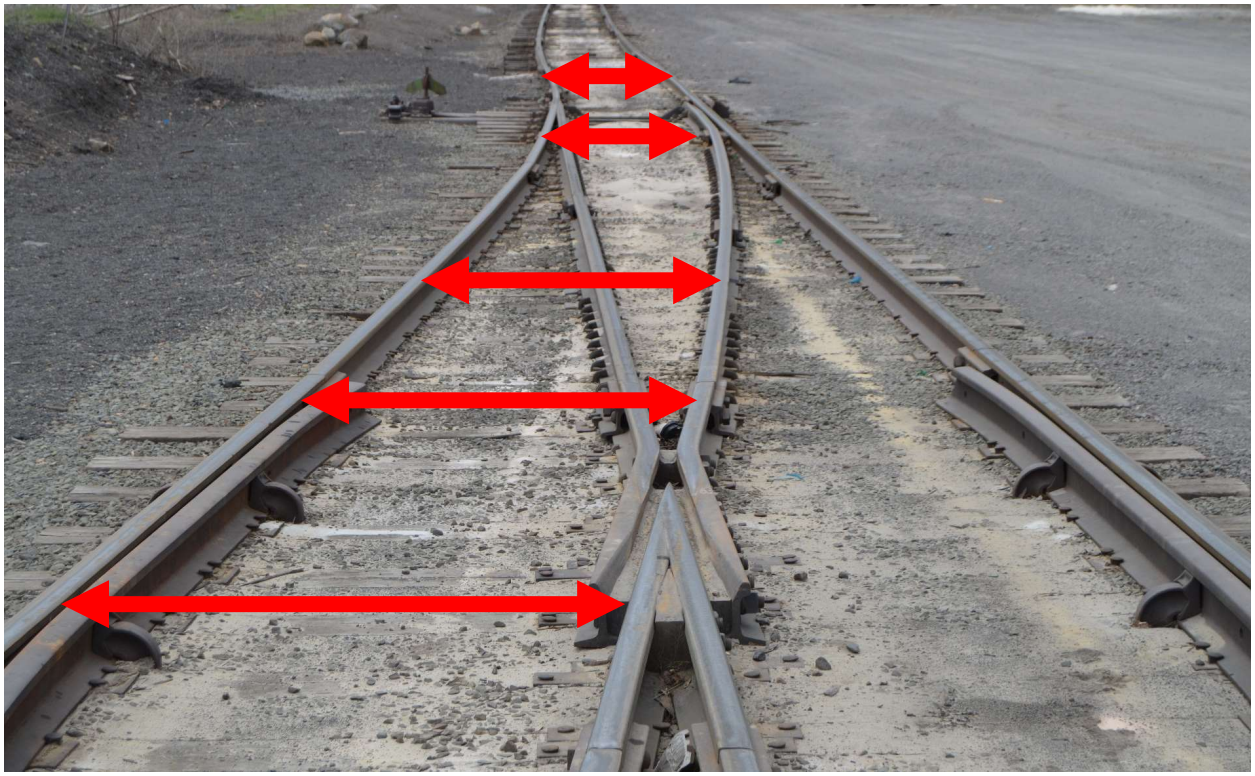
Measuring gage 5/8” below head of rail

Subpart C - Track Geometry
§213.53 Gage

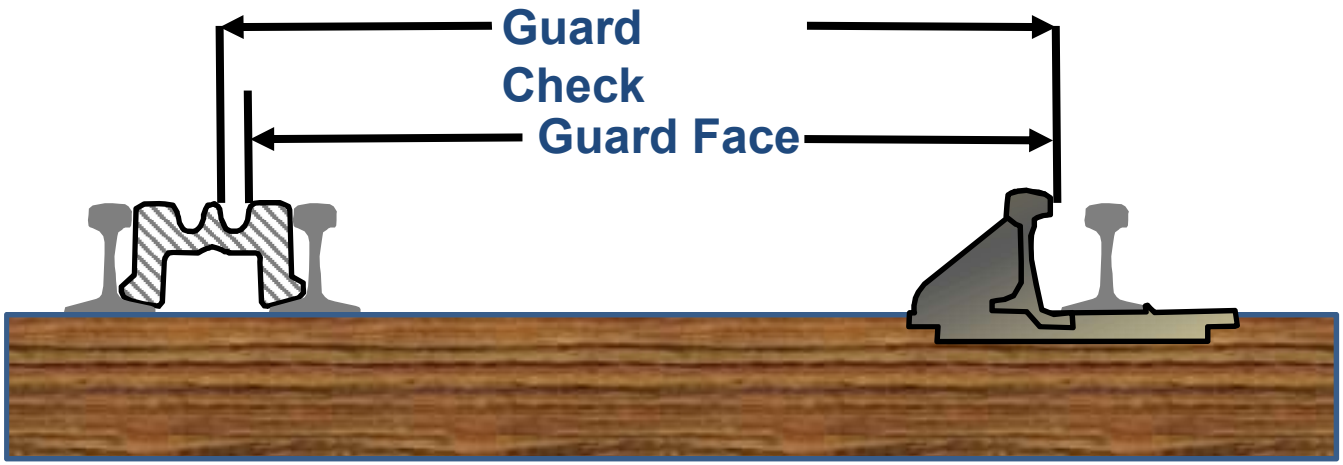
Particular attention should be given to track gage in turnouts or locations where high lateral train forces are expected or evident.

These areas include the curved closure rails, the toe and heel of frogs, the curved track behind the frog and several feet ahead of the switch points.





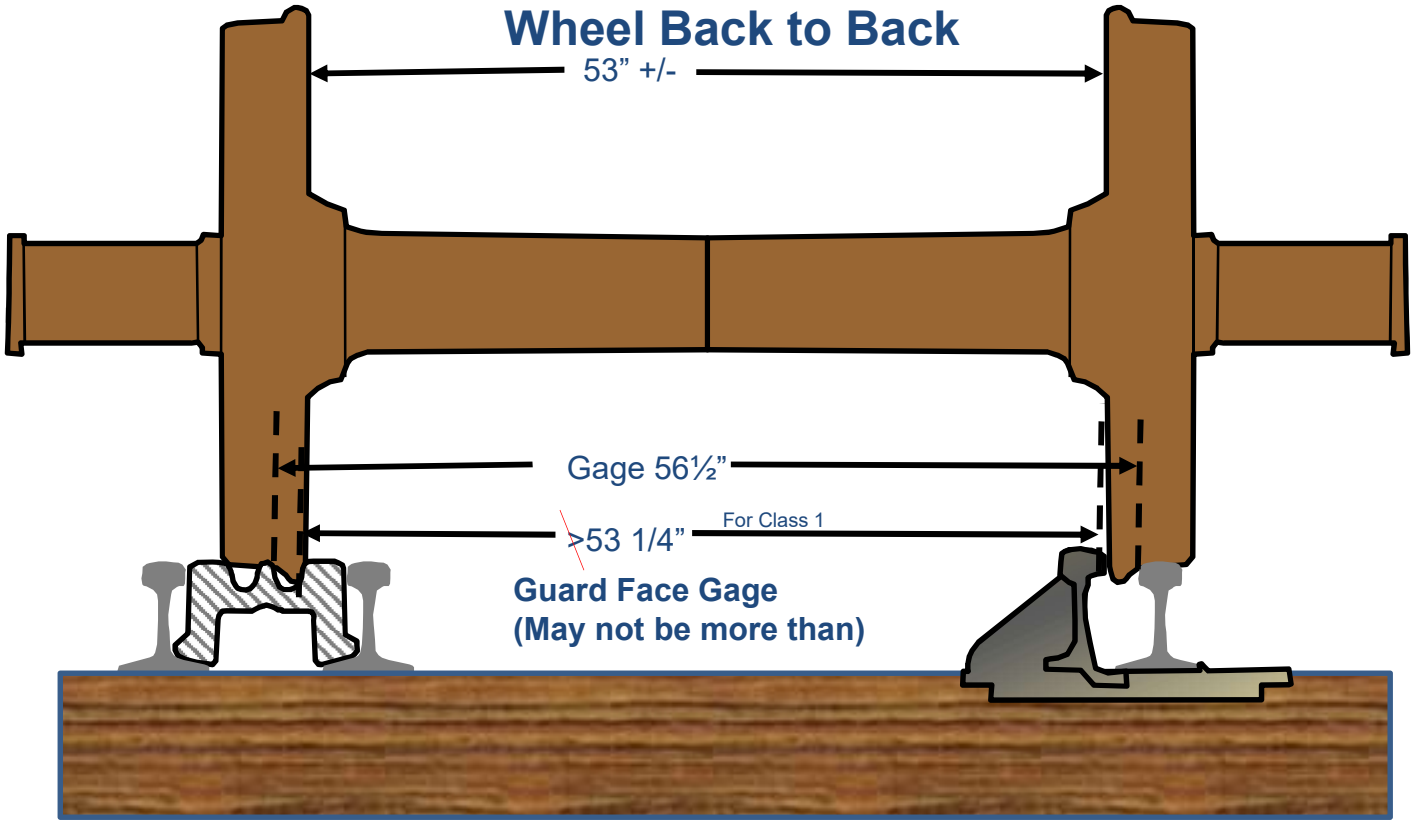
Checking Gage in a Turnout at Multiple locations

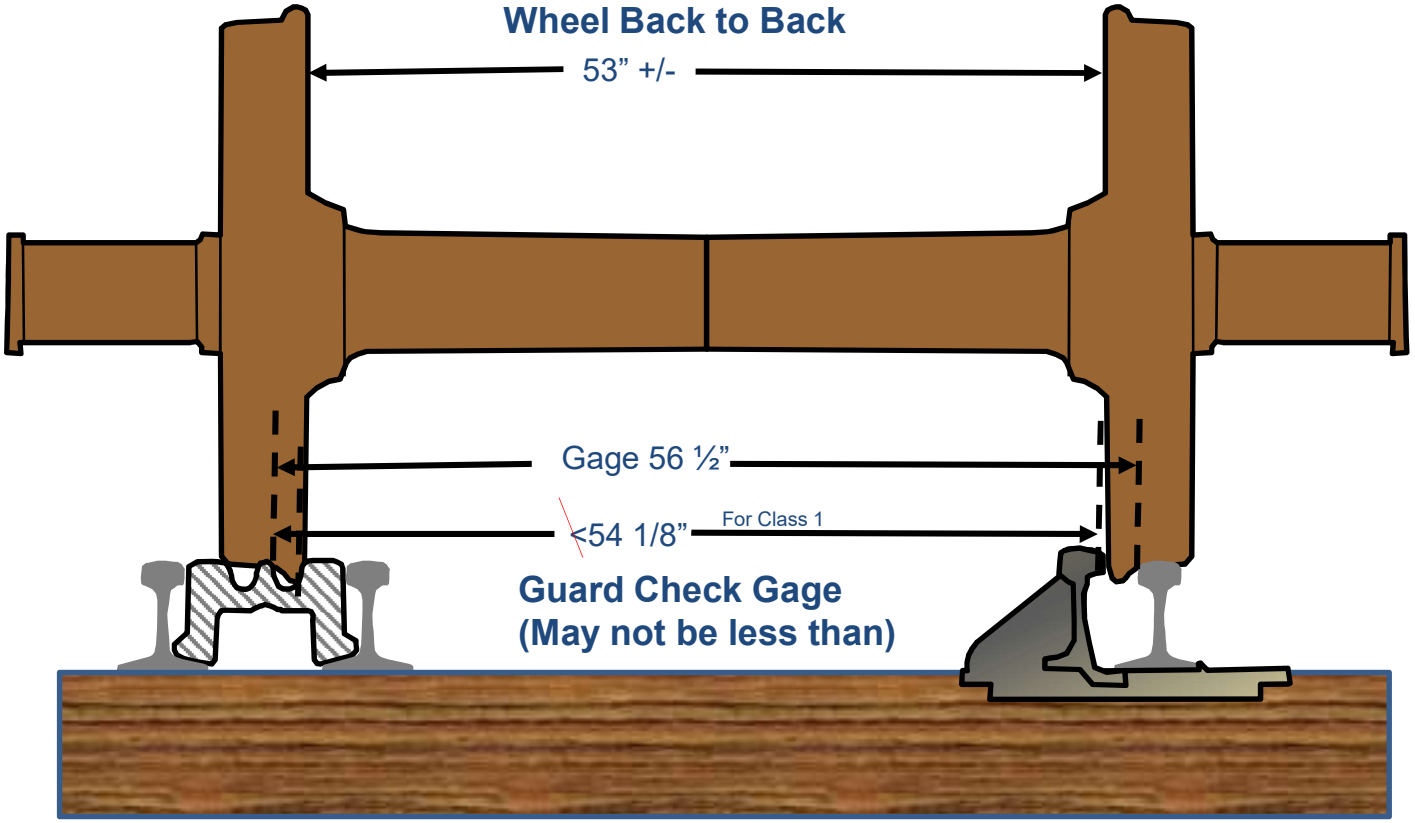

Guard
Check
Guard Face

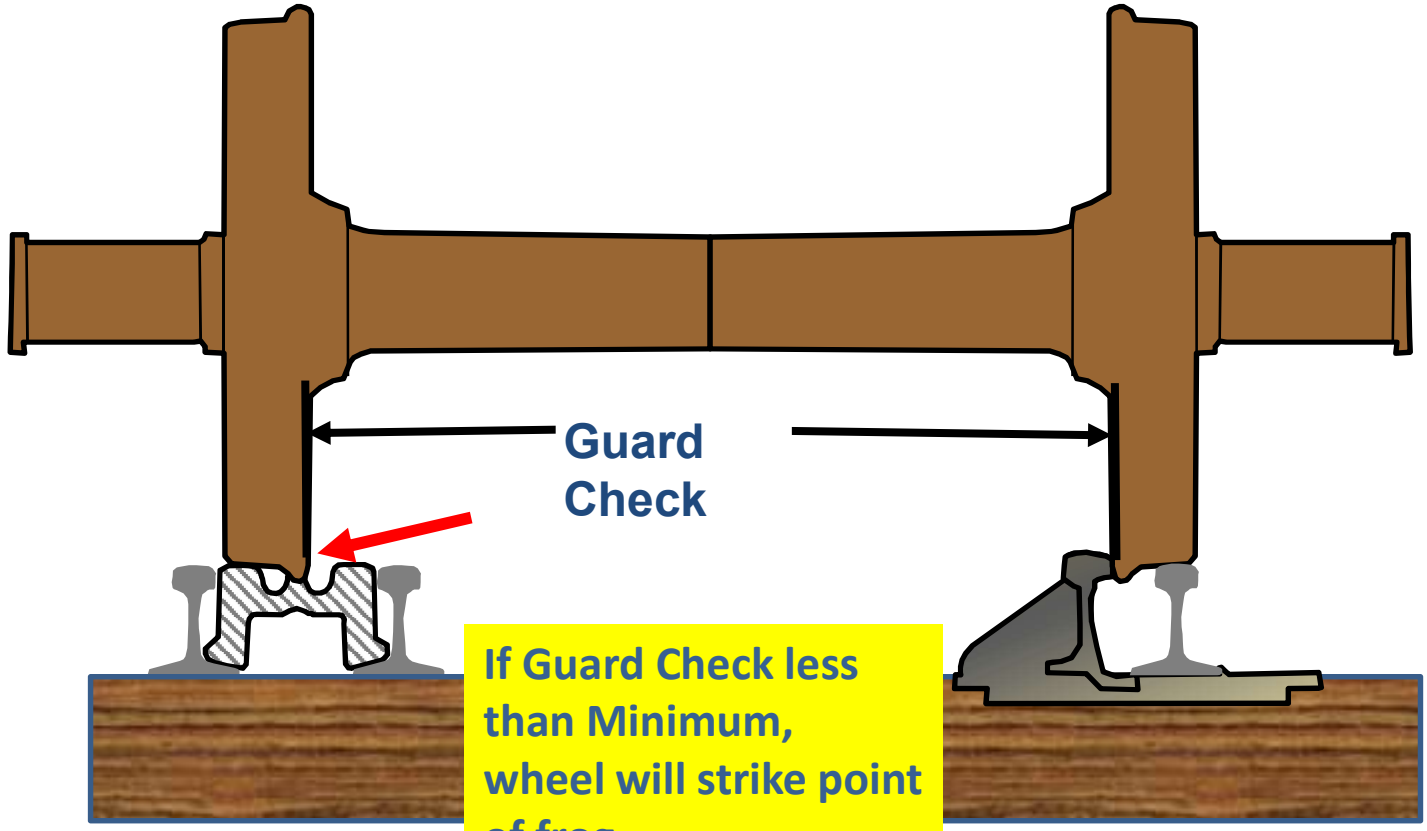
213.143 Guard Check and Face Gage

The guard check and guard face gages in frogs shall be within the limits prescribed by the following table:

Class of Track	Guard Check gage may not be less than	Guard Face gage may not be more than
Class 1	4’ 6 1/8”	4’ 5 ¼”
Class 2	4’ 6 ¼”	4’ 5 1/8”
Class 3 & 4	4’ 6 3/8”	4’ 5 1/8”
Class 5	4’ 6 ½”	4’ 5”

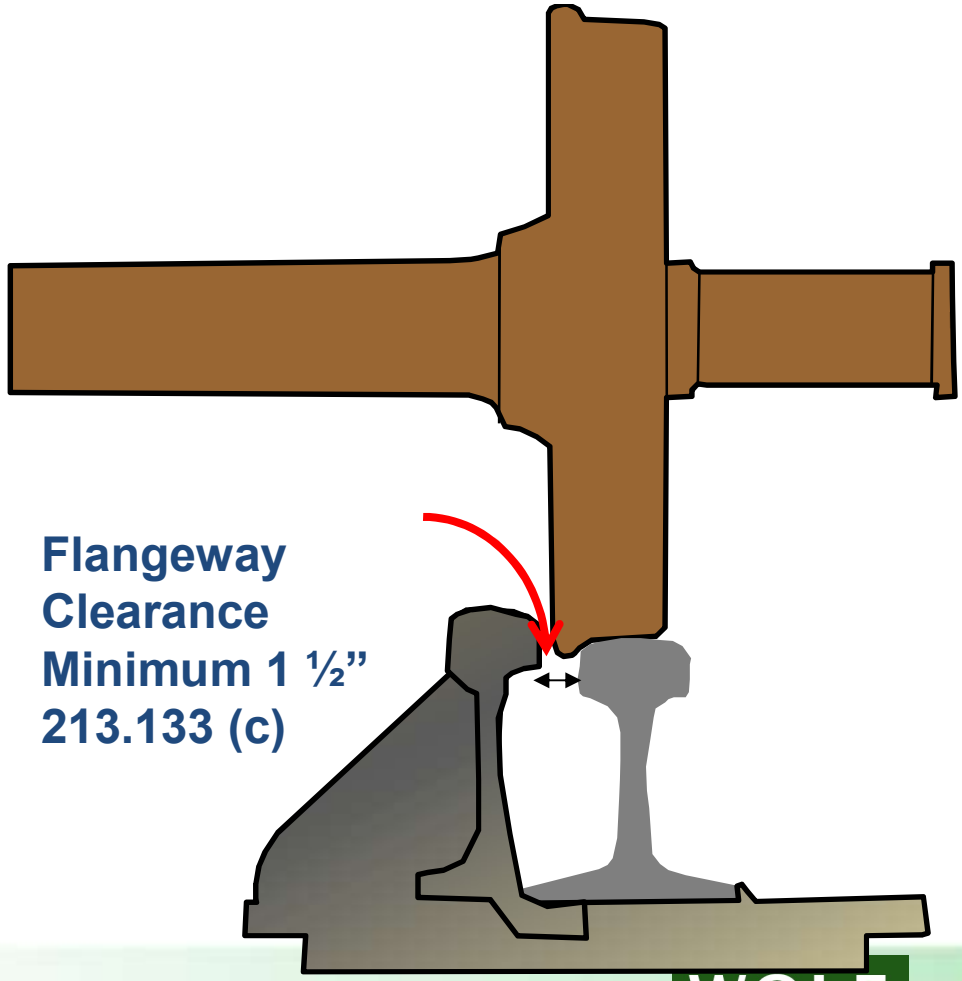

Wheel Back to Back
53” +/-
Gage 56½”
For Class 1
>53 1/4”
Guard Face Gage
(May not be more than)


Wheel Back to Back
53” +/-
Gage 56 ½”
<54 1/8”
For Class 1
Guard Check Gage
(May not be less than)



If Guard Check less than Minimum, wheel will strike point of frog

Wheel Striking point of Frog;
Guard check less than minimum


Flangeway
Clearance
Minimum 1 ½”
213.133 (c)

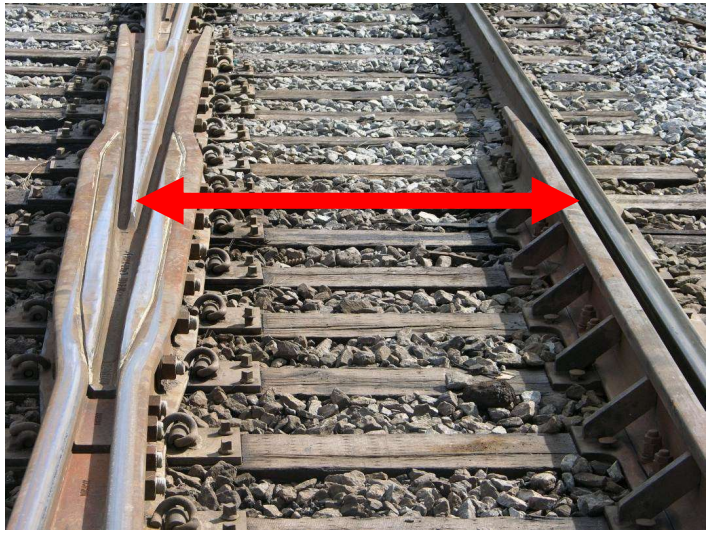
Class 5 Track

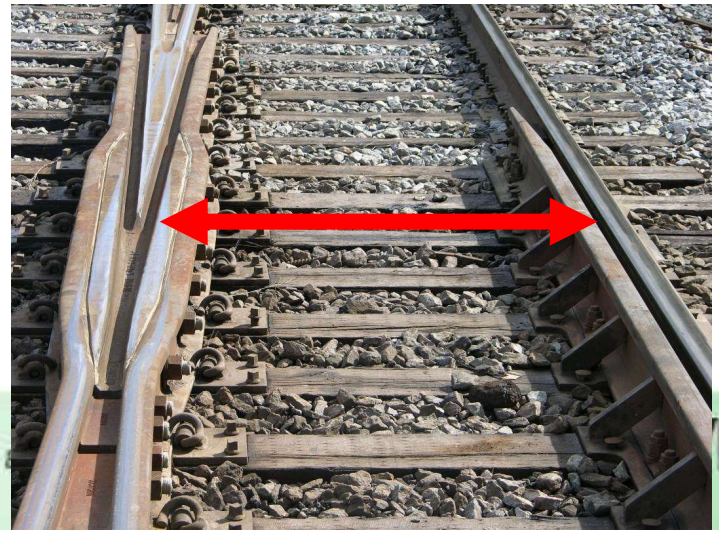
Guard Check- Gage
Line of frog to Guard Line

Minimum = 54 1/2”

Guard Face - Distance Between Wing Rail and Guard Line

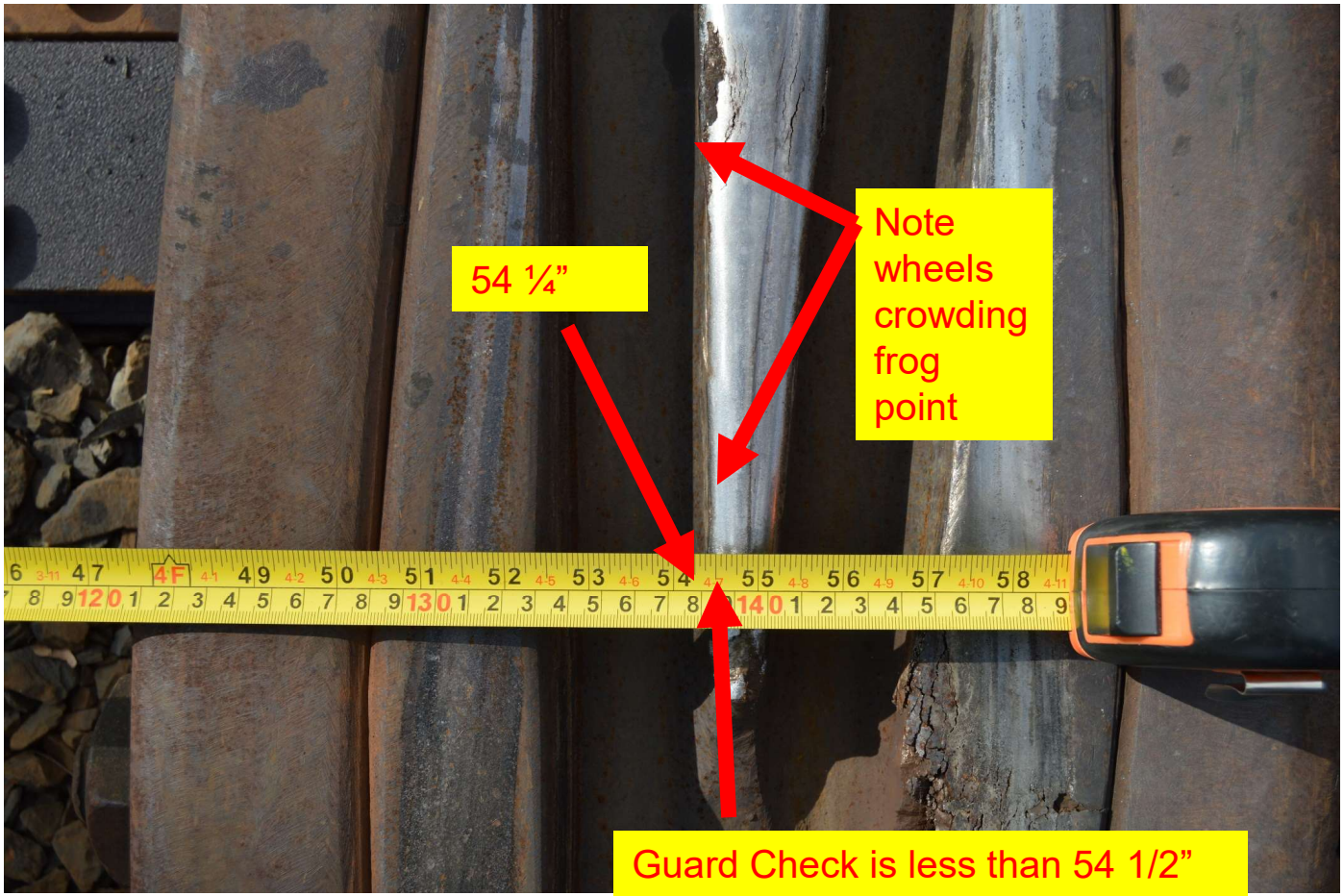
Maximum = 53 ”

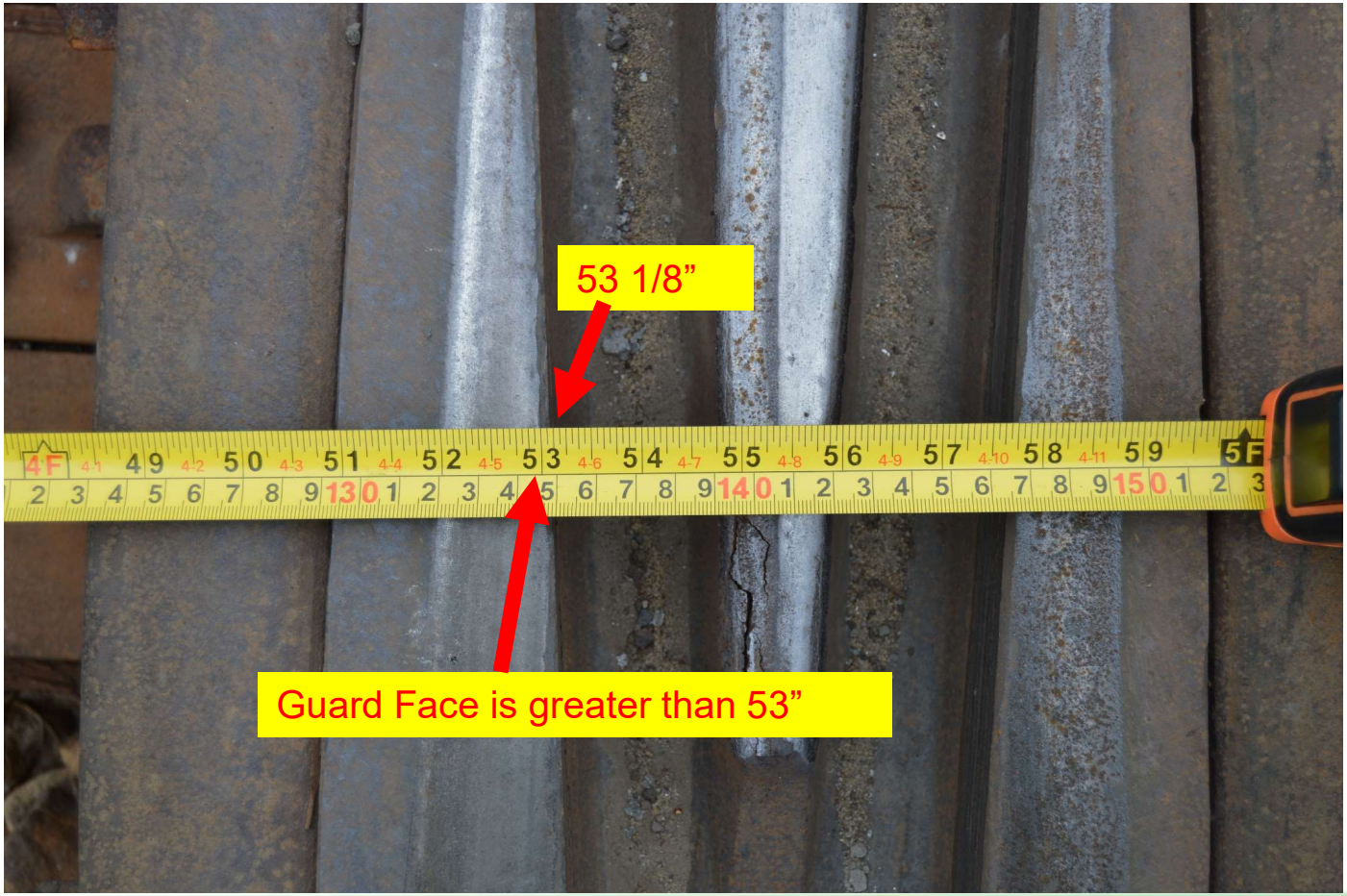


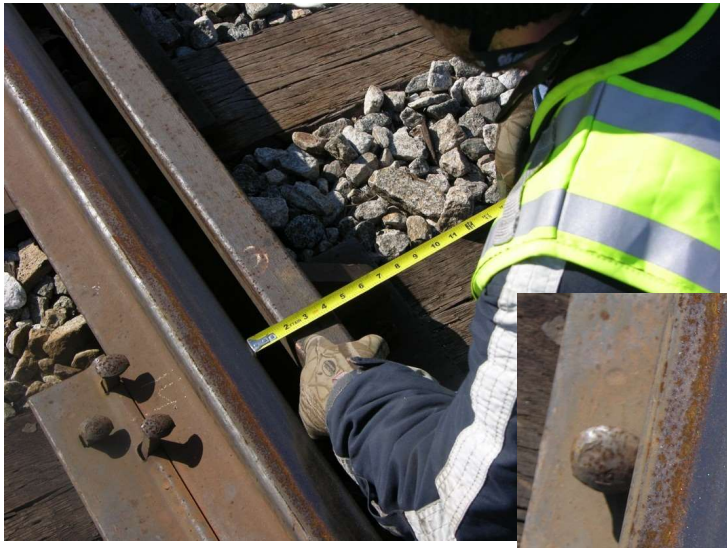


Guard Face may not be more than 53” for Class 5.

Guard Check may not be less than 54 1/2” for Class 5.


54 ¼”
Note wheels crowding frog point
Guard Check is less than 54 1/2”


53 1/8”
Guard Face is greater than 53”



Checking minimum Flange way Clearance of 1 ½”

Issues with Gage

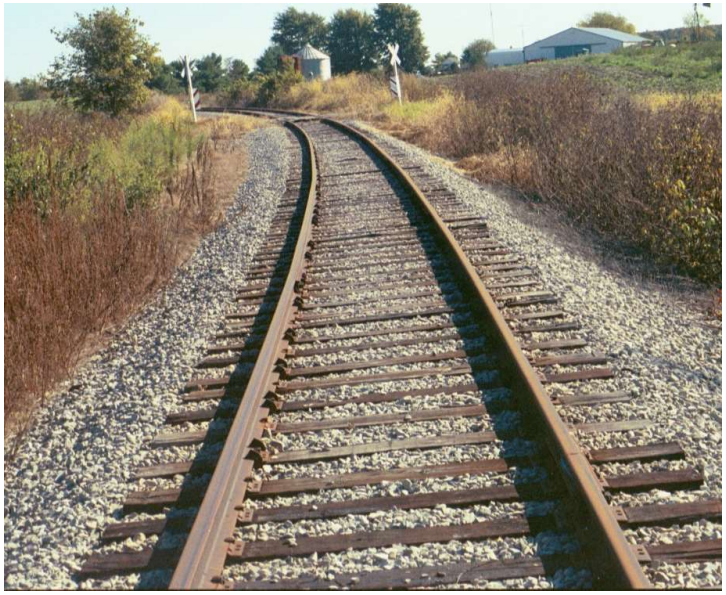
- Tight Gage
  - Can induce hunting at lower speed ranges
  - Wears wheels and rail at accelerated rate
- Wide Gage
  - Indication of weak ties and fasteners
  - Can allow greater wheelset angles of attack
  - Reduces safety margin for rail roll and wheel drop in

Curves and Curve Geometry

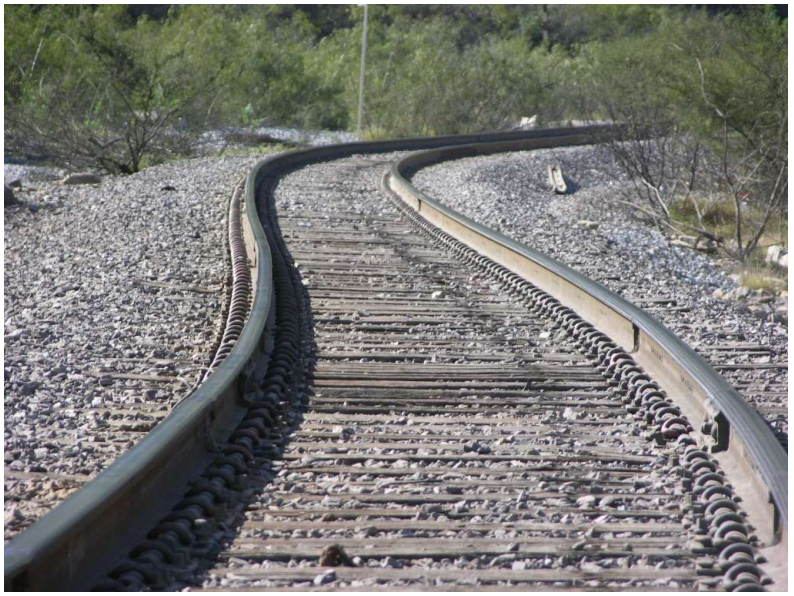
A high percentage of all derailments occur on curved track, including turnouts! It is important to understand curve geometry and how it affects car performance.

Curves and Curve Geometry

2 characteristics of curves

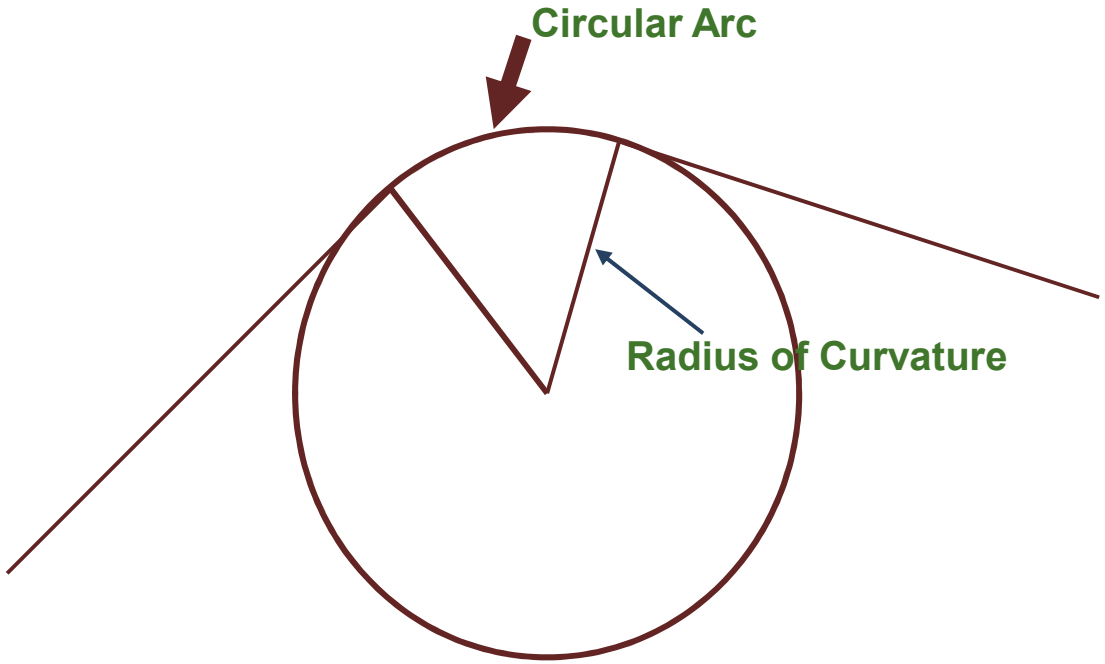


Elevation



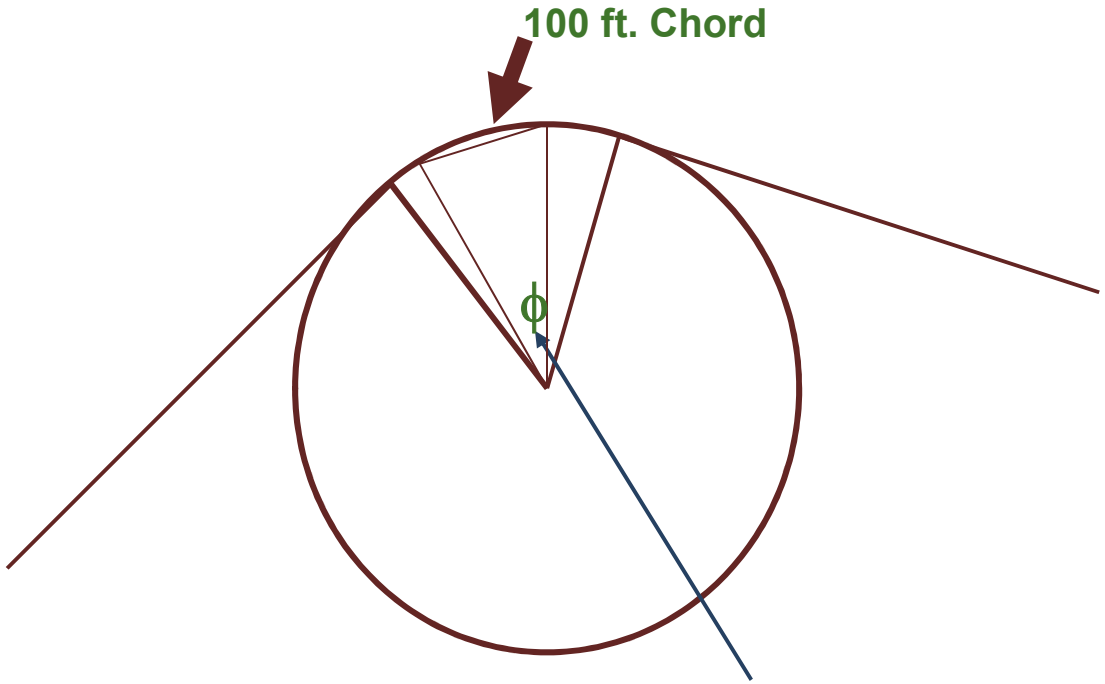
Alignment

Definition of a Curve



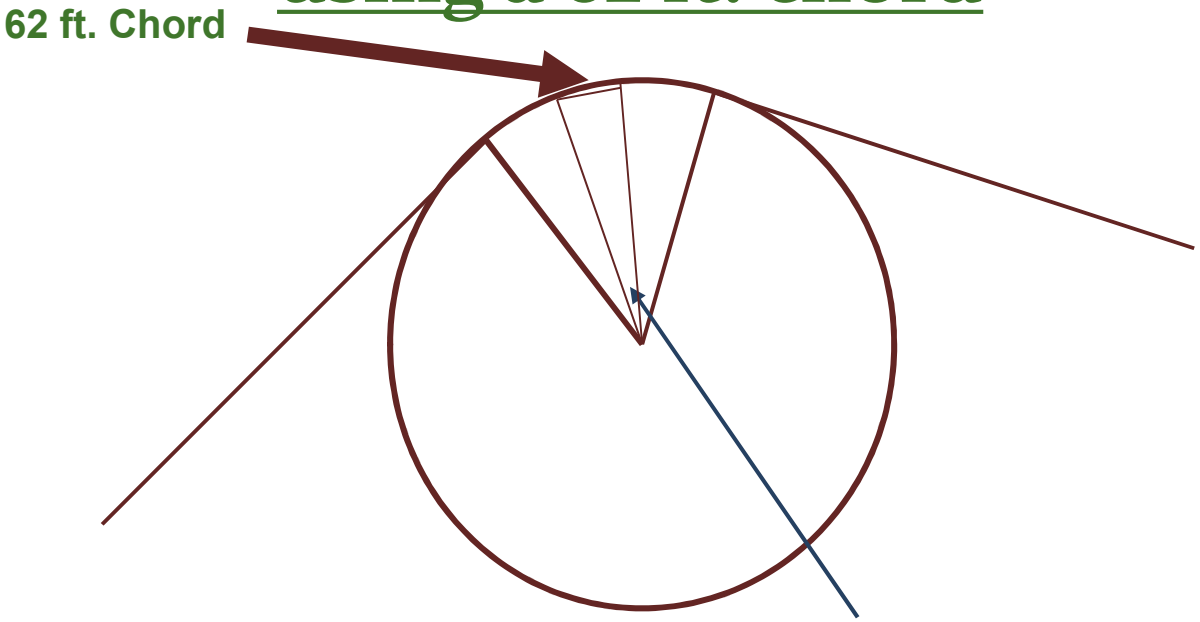
A curve is defined as a path along the edge of a circular arc defined by a circle of with a given radius

Railroad Definition of a Curve



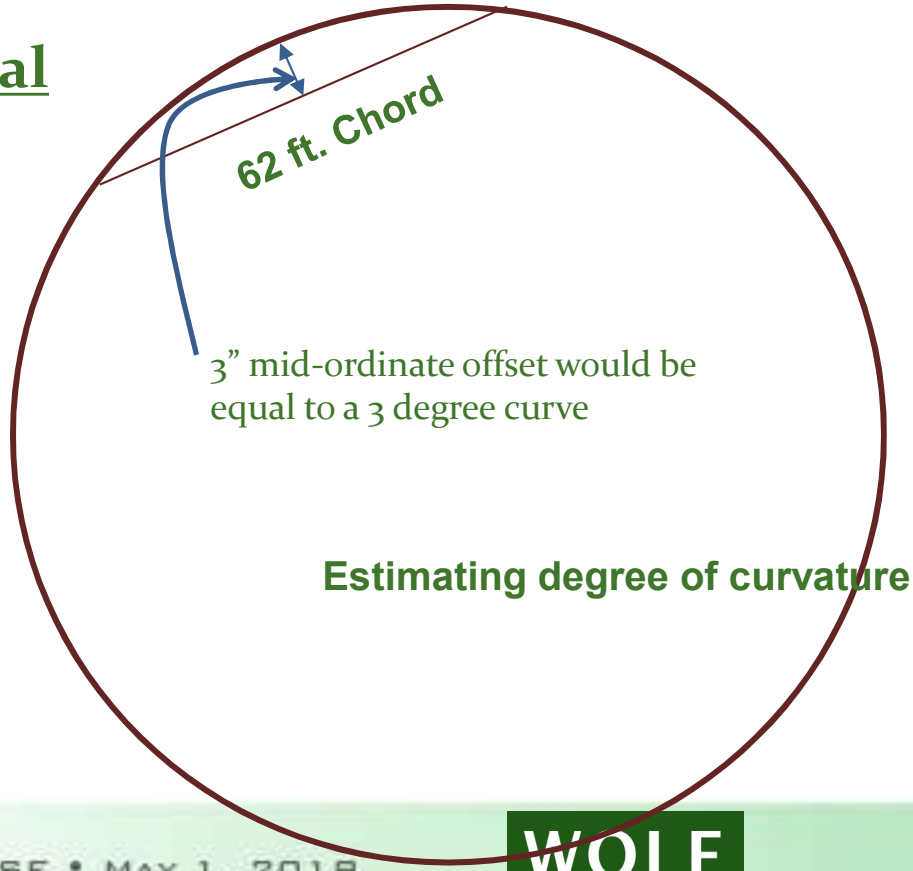
Degree of curve is the angle ϕ subtended by a 100 ft. chord

Estimating degree of curvature using a 62 ft. chord



Degree of curve can be estimated by using a 62 ft. chord and measuring the mid-ordinate offset

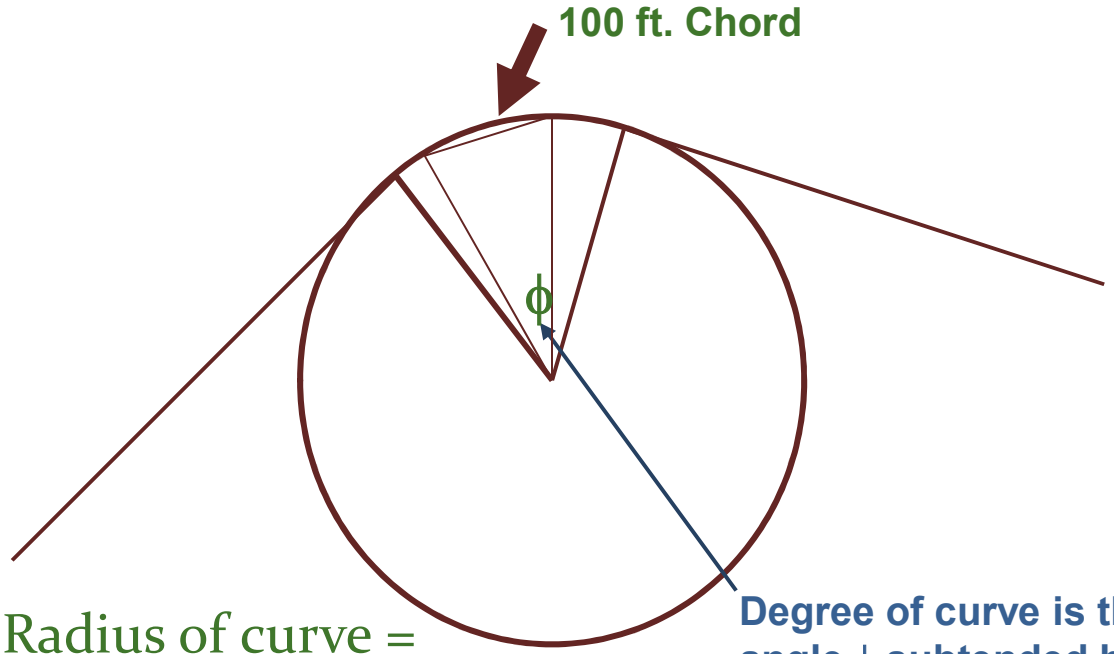
Midordinate offset in inches is approximately equal to the degree of curve



Estimating degree of curvature using a 62 ft. chord

Stringlining using 62 ft. Chord

Radius of a Curve



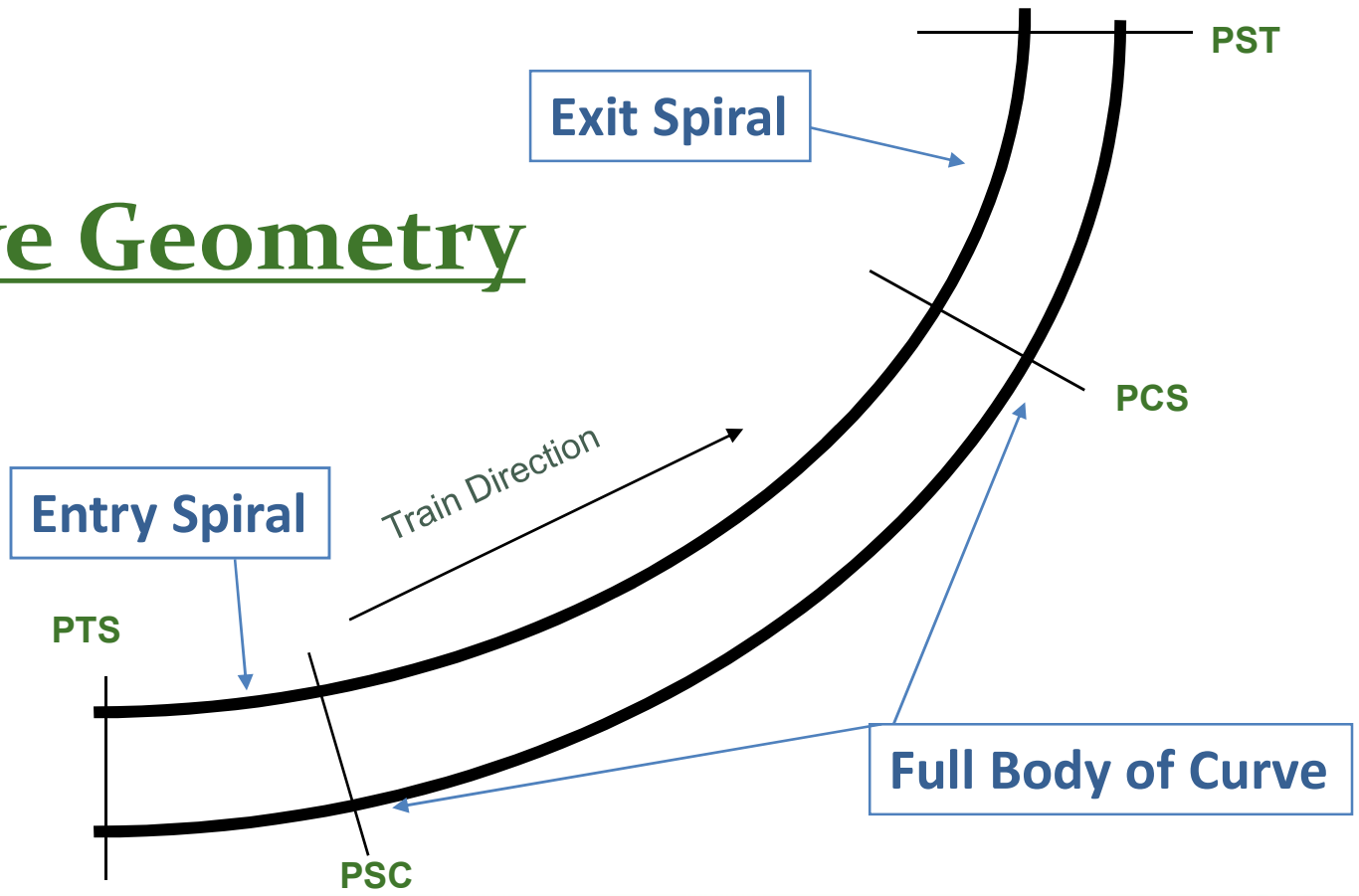
Radius of curve = 5730'/Degree of curve

Degree of curve is the angle ϕ subtended by a 100 ft. chord

Degree of Curve & Radius

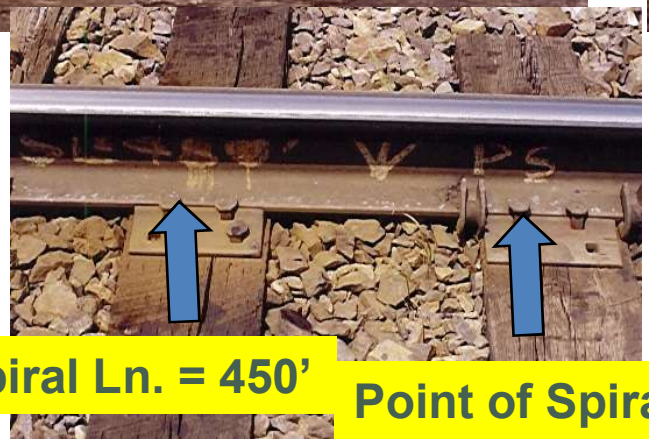
Degree of Curve	Mid-Ordinate **of a 62' Chord**	Radius of Curve
1	1"	5730'
2	2"	2865'
3	3"	1910'
5	5"	1146
10	10"	573'

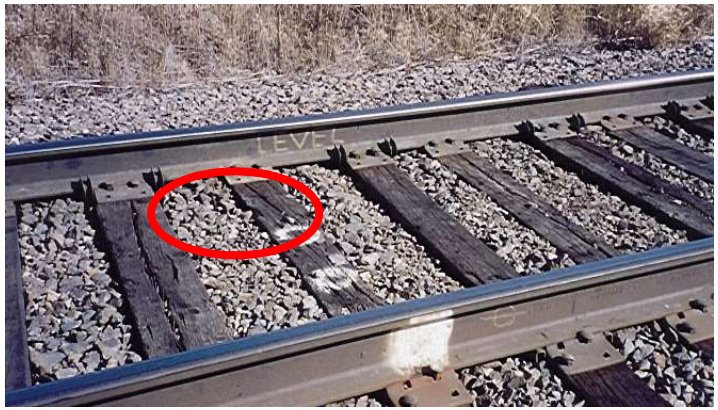
Curve Geometry




Full - PSC or PCS


Level - PST or PTS


Spiral Ln. = 450'
Point of Spiral



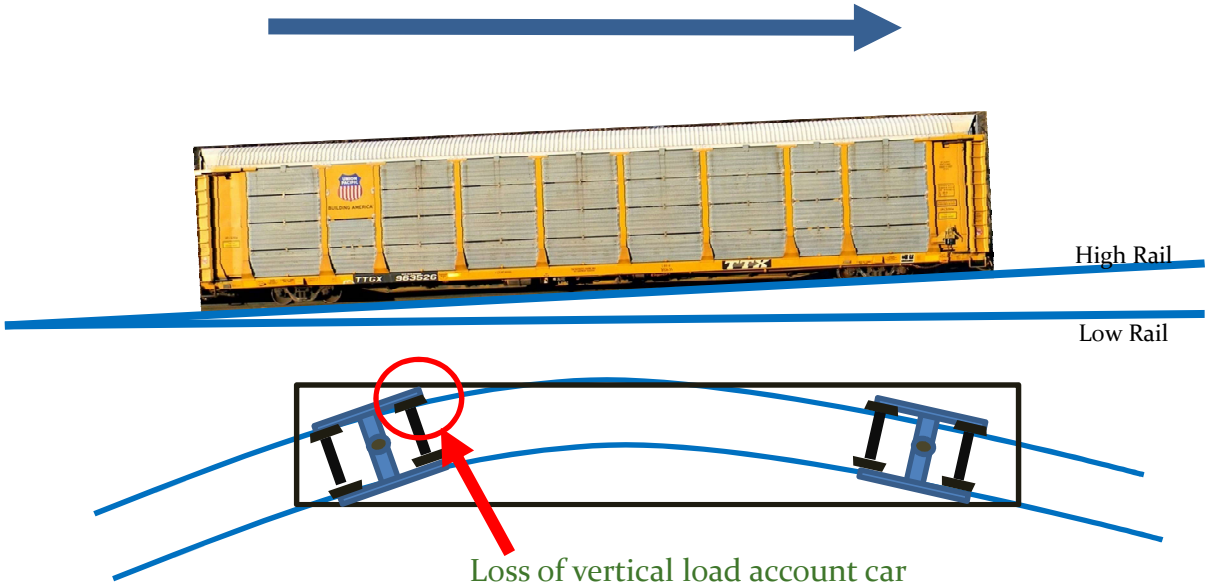
PSC
5º01’46”
3 ½” Elevation

1/2” Elevation

1” Elevation

Well Marked Track Geometry Designations

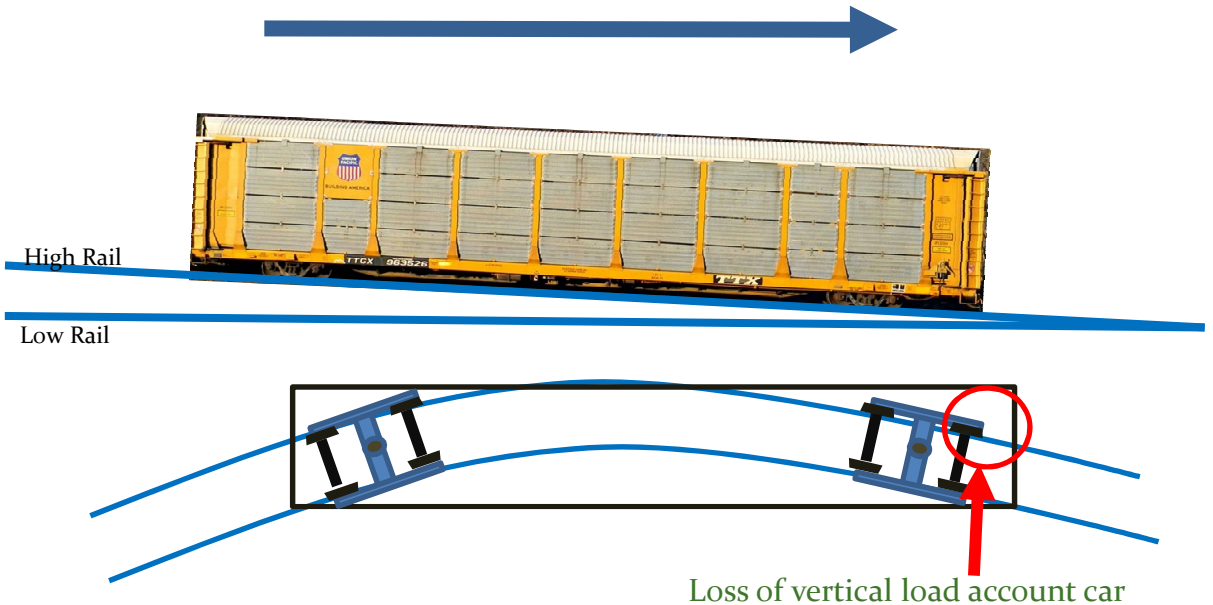
Train direction



Loss of vertical load account car twist at outer rail, trail truck, third axle. This is most frequently derailing wheel.

Most Likely Derailing Wheel in Entrance Spiral

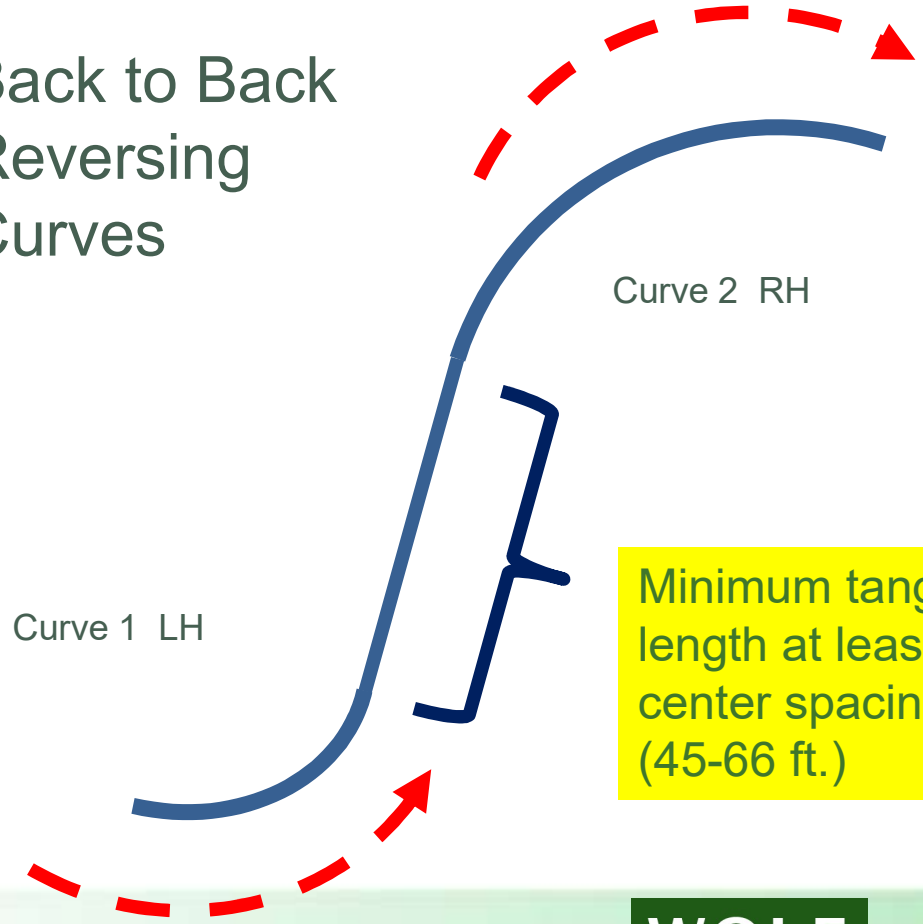
Train direction



Loss of vertical load account car twist at outer rail, lead truck, first axle. This is most frequently derailing wheel. Also, lateral forces are highest on lead truck.

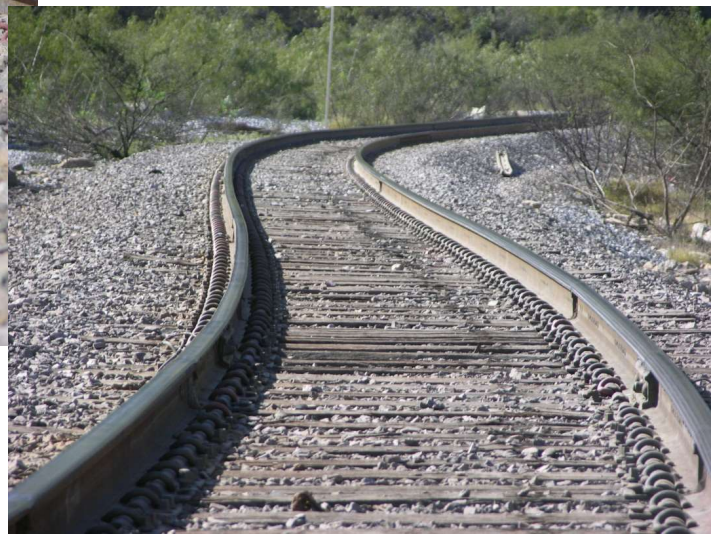
Most Likely Derailing Wheel in Exit Spiral

Back to Back Reversing Curves



Minimum tangent length at least truck center spacing; (45-66 ft.)

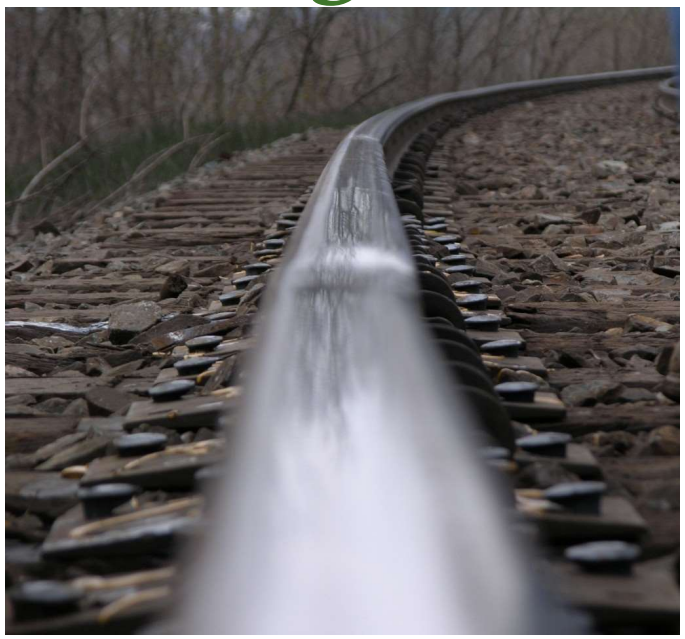
Lack of sufficient intervening tangent between back to back reverse curves

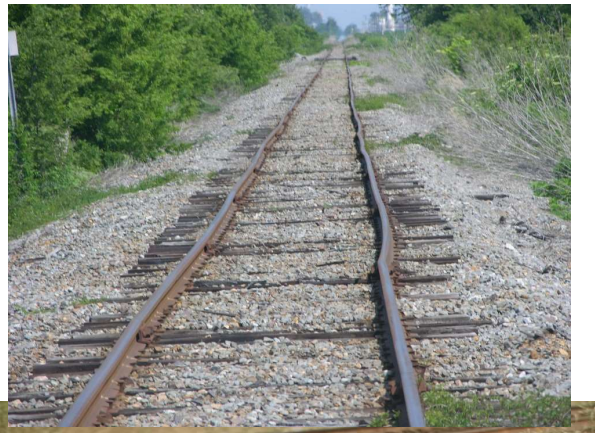


Summary of Curve Derailment Issues

- Most frequent type of derailment in body of curve is rail rollover; wheel climb due to crosslevel and alignment defects
- Most frequent type of derailment in entry spiral is wheel climb of wheel on trail truck, third axle, on high rail.
- Most frequent type of derailment in exit spiral is wheel climb of wheel on lead truck, first axle, on high rail.
- Insufficient tangent between reversing curves can cause trucks to bind, resulting in wheel climb or gage spreading.

Alignment Deviations





§ 213.55 Track alinement.

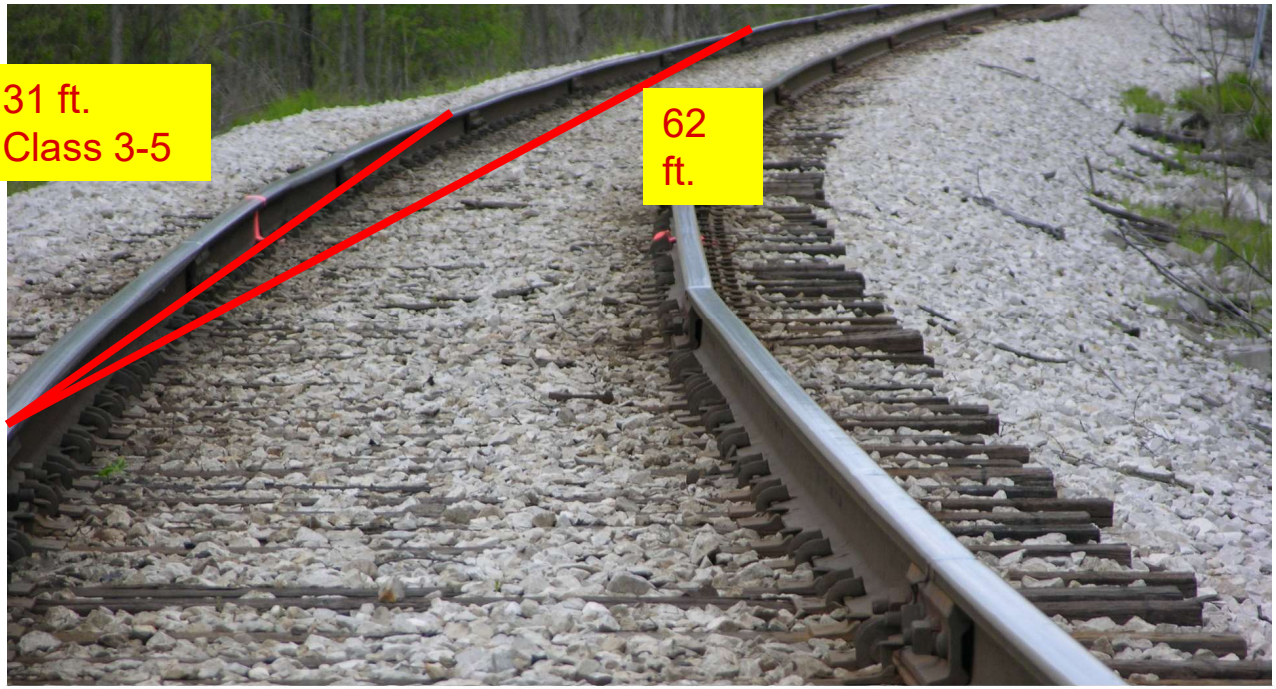
(a) Except as provided in paragraph (b) of this section, alinement may not deviate from uniformity more than the amount prescribed in the following table:

Class of Track	Tangent Track	Curved Track	
	The deviation of the mid-offset from a 62-foot line [1] may not be more than --	The deviation of the mid-ordinate from a 31-foot chord [2] may not be more than --	The deviation of the mid-ordinate from a 62-foot chord [2] may not be more than --
1	5"	N/A[3]	5"
2	3"	N/A[3]	3"
3	1¾"	1¼"	1¾"
4	1½"	1"	1½"
5	¾"	½"	⅝"

[1] The ends of the line must be at points on the gage side of the line rail, five-eights of an inch below the top of the railhead. Either rail may be used as the line rail, however, the same rail must be used for the full length of that tangential segment of track.

[2] The ends of the chord must 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



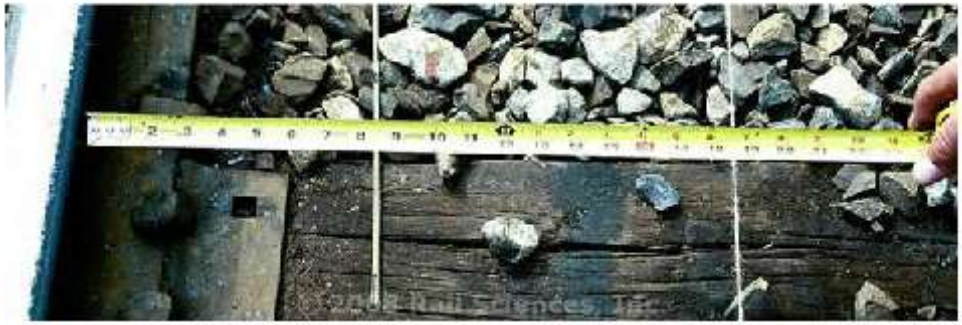
In Classes 3 through 5, both the 31-foot and 62-foot chords must be used, and corresponding measurements must be calculated to determine compliance with the required alinement thresholds. If alinement defects are found using both the 31-foot and the 62-foot chord, the inspector should report the item as one defect and note that the defect does not comply with the requirements for the second chord, e.g., "1¾ inches alinement deviation on curved track for 62-foot chord. Note: 1⅜ inches alinement deviation for 31-foot chord at this location."

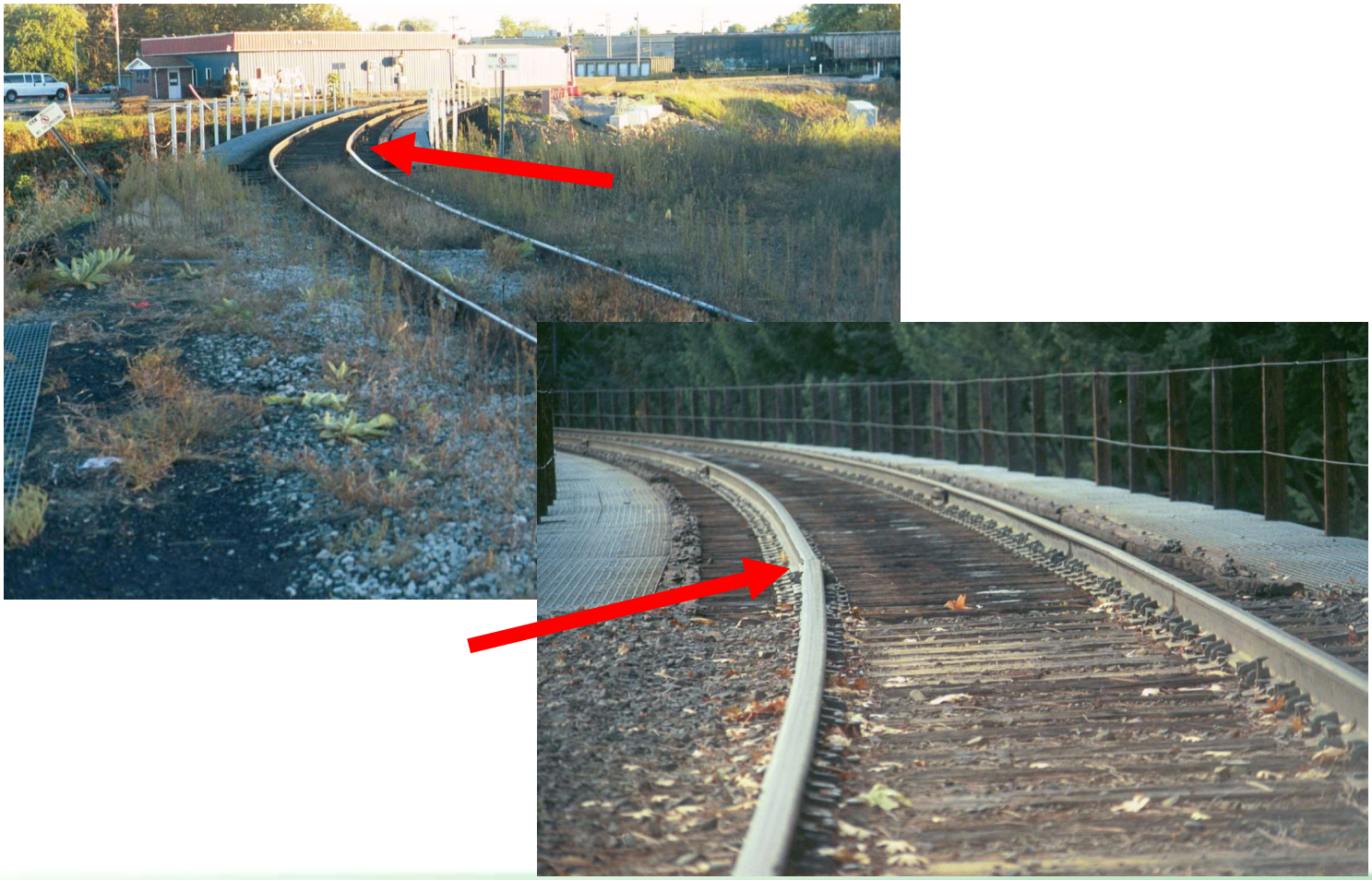
Horizontal Alignment

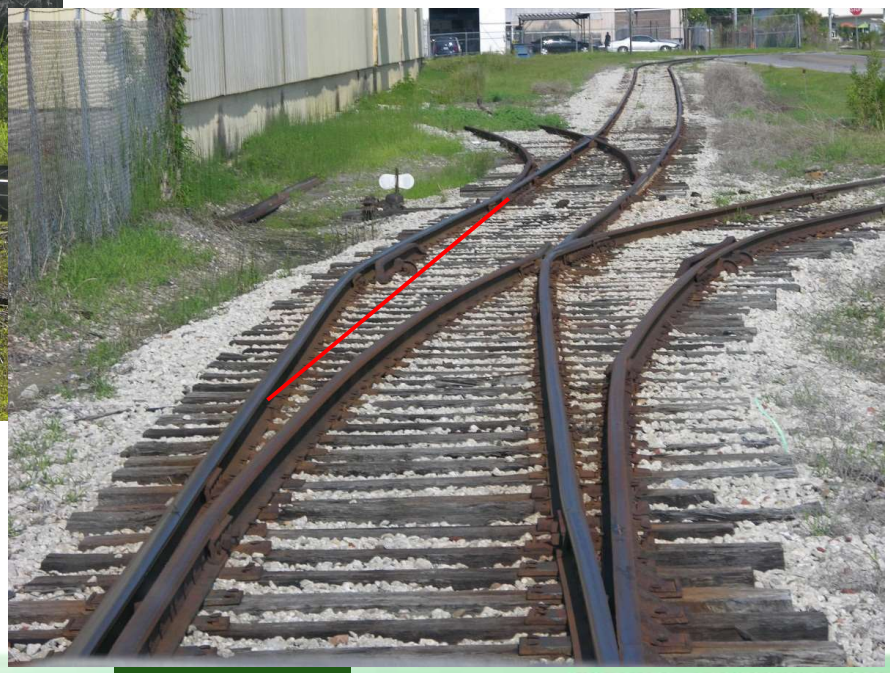
§213.55 Alinement - Stringlining

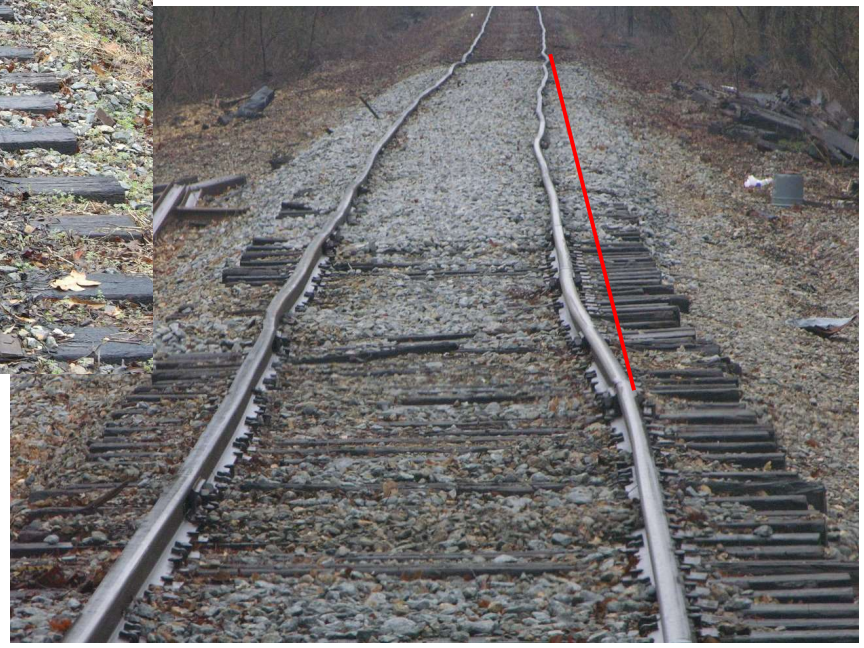
The chord (string) is stretched and held tight between two points on the rail, ⅝ inch below the top running surface of the rail.

Measure the MCO between the rail and the string with a graduated ruler, using blocks to compensate for shallow curvature and special trackwork, if necessary.

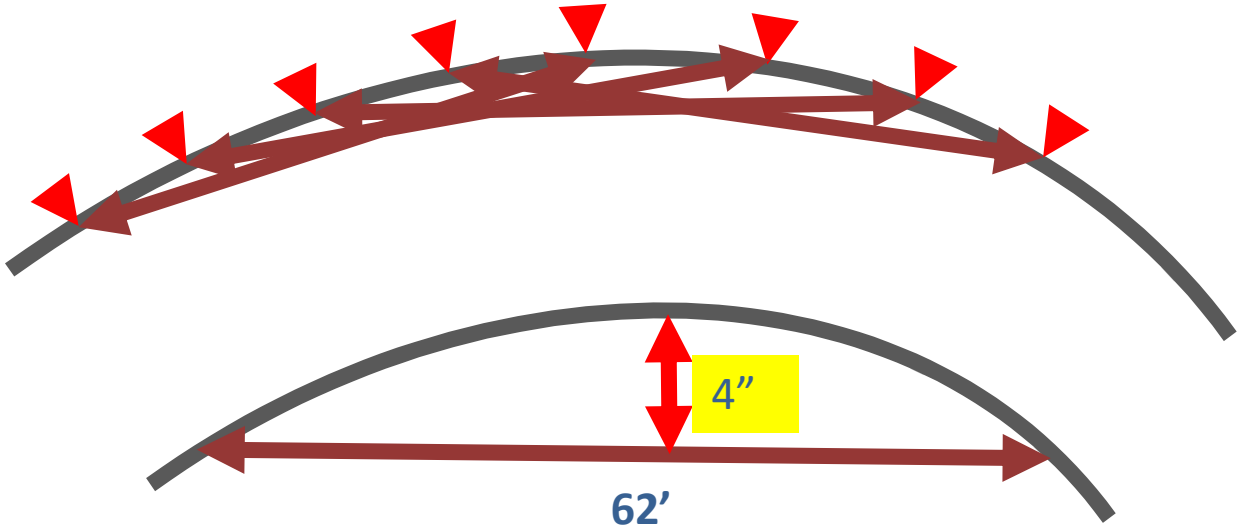






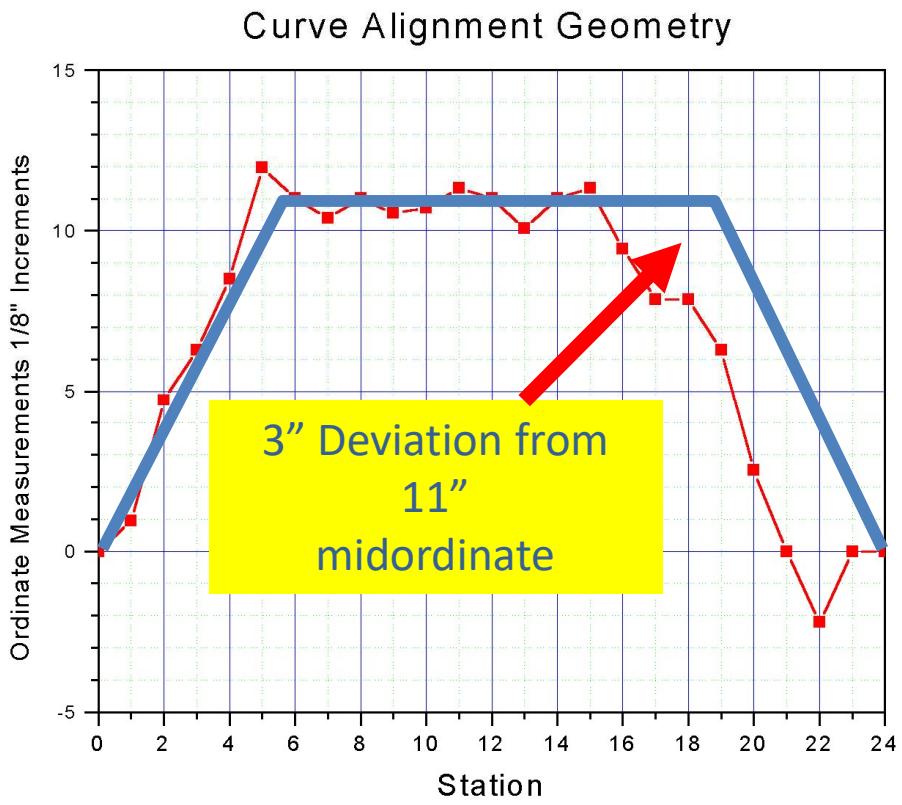


Measuring Alignment with 62’ Chord - Stringlining

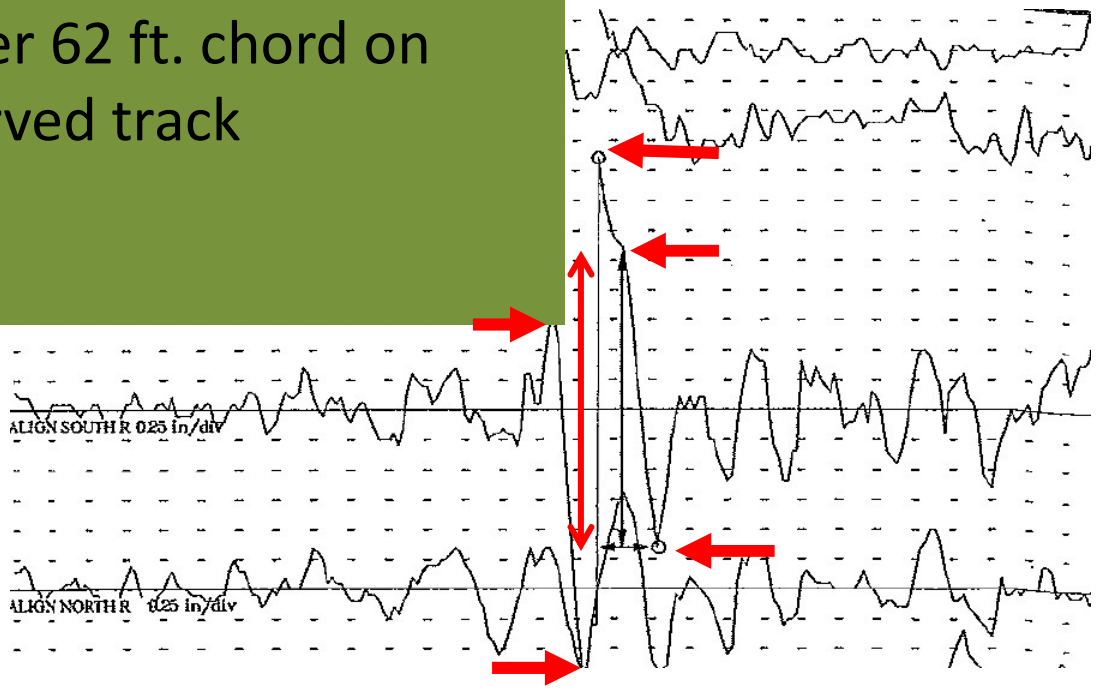


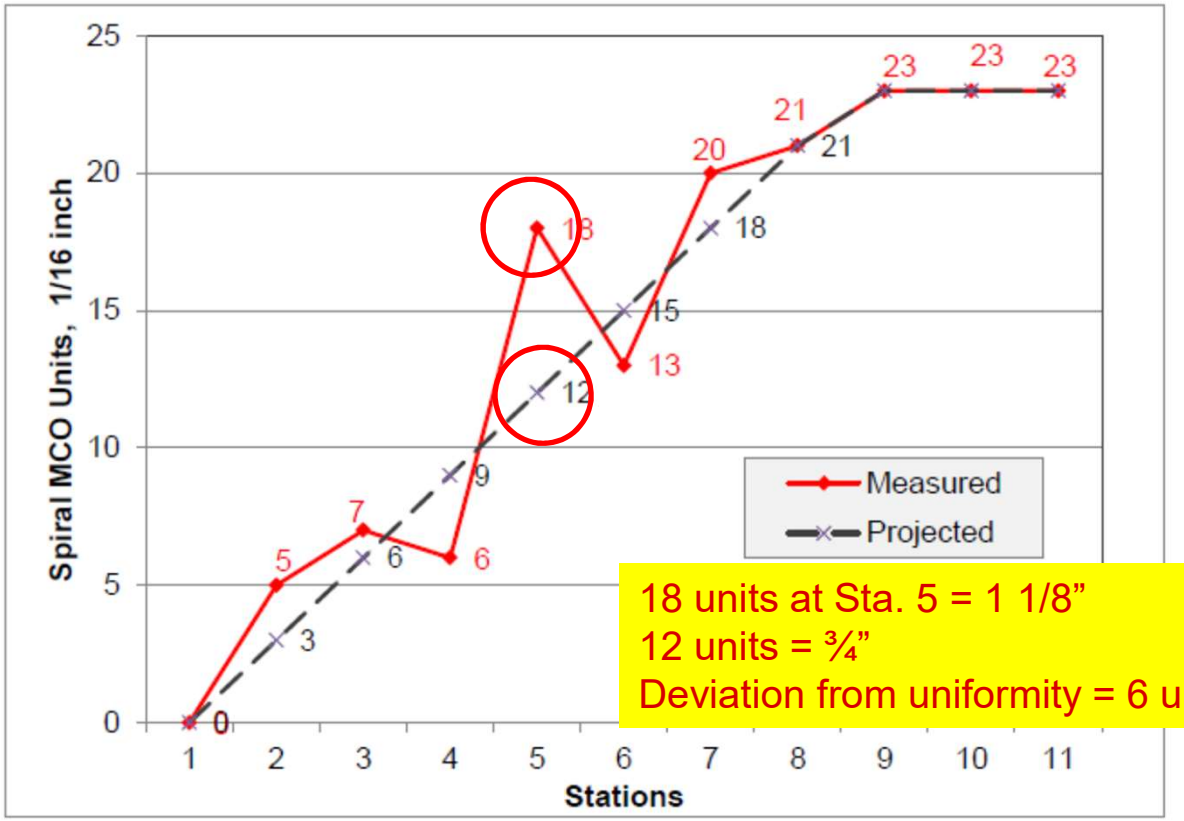
62’
Chord
Midordinate Measurement

4” = 4 Degree Curve


Curve Alignment Geometry
Ordinate Measurements 1/8" Increments
15
10
5
0
-5
0
2
4
6
8
10
12
14
16
18
20
22
24
Station
3” Deviation from 11” midordinate

Alignment Deviation over 62 ft. chord on curved track





18 units at Sta. 5 = 1 1/8”
12 units = ¾”
Deviation from uniformity = 6 units (3/8”)

Using Spring clamps to Stringline when no help available

FRA Alignment Table

§ 213.55 Alinement.

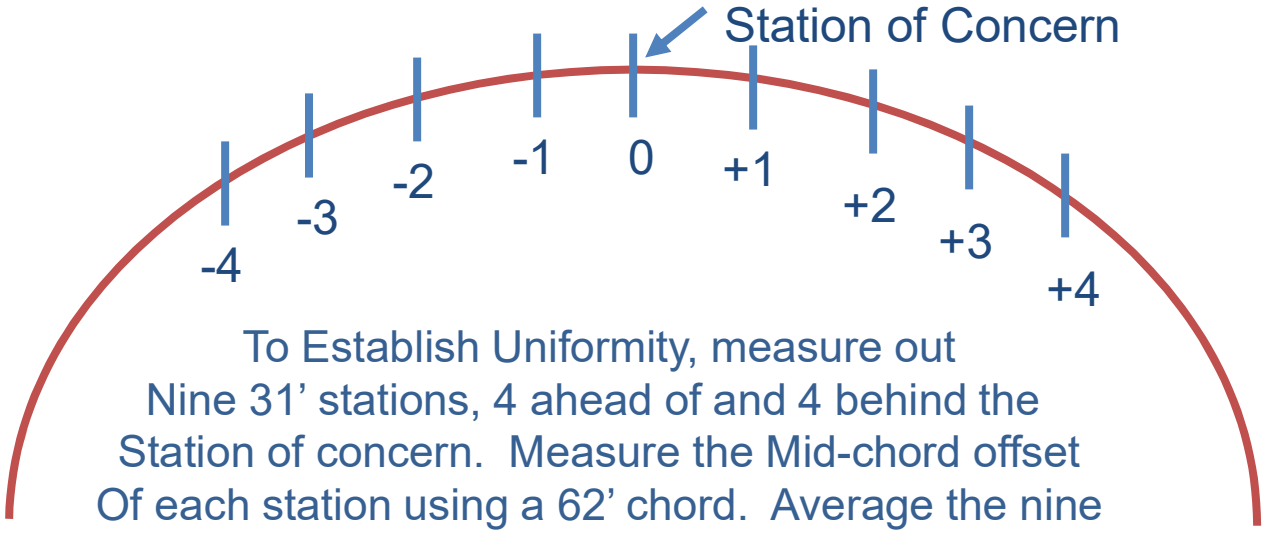
Alinement may not deviate from uniformity more than the amount prescribed in the following table:

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	1¾	1¼	1¾
Class 4 track	1½	1	1½
Class 5 track	¾	½	⅝

[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.

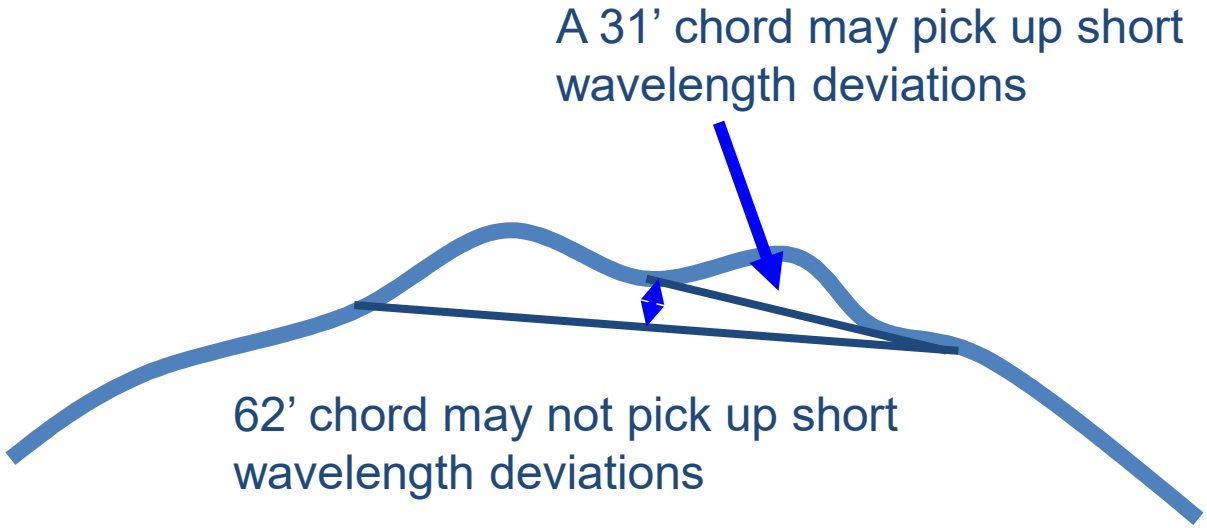
[2] The ends of the chord shall be at points on the gage side of the outer rail, five-eighths of an inch below the top of the railhead.

[3] N/A—Not Applicable.



To Establish Uniformity, measure out Nine 31' stations, 4 ahead of and 4 behind the Station of concern. Measure the Mid-chord offset Of each station using a 62' chord. Average the nine Stations and this determines Uniformity. The difference Between the MCO at the station of concern, and the Average uniformity is the "deviation from Uniformity".

Determining compliance with FRA Alignment Standard using 9 point averaging method



Why use a 31 ft. chord in certain situations?

1. Short wavelength deviations
2. Higher degree curves, easier to measure
3. Must use 31’ chord for Class 3-5
4. Easier to measure in high winds

Curve Elevation

§ 213.57 Curves; elevation and speed limitations.

(a) The maximum elevation of the outside rail of a curve may not be more than 8 inches on track Classes 1 and 2, and 7 inches on track Classes 3 through 5. The outside rail of a curve may not be lower than the inside rail by design, except when engineered to address specific track or operating conditions; the limits in § 213.63 apply in all cases.

Paragraph (a) does not imply that more than 6 inches of superelevation is recommended in a curve; rather the paragraph limits the amount of crosslevel in a curve to control the unloading of the wheels on the high rail, especially at low speeds.

§ 213.57 Curves; elevation and speed limitations.

(b) The maximum allowable posted timetable operating speed for each curve is determined by the following formula—

$$V_{max} = \sqrt{\frac{E_a + E_u}{0.0007D}}$$

V_{max} = Maximum allowable posted timetable operating speed (m.p.h.).

E_a = Actual elevation of the outside rail (inches).[1]

[1]Actual elevation, E_a, for each 155-foot track segment in the body of the curve is determined by averaging the elevation for 11 points through the segment at 15.5-foot spacing. If the curve length is less than 155 feet, the points are averaged through the full length of the body of the curve.

E_u = Qualified cant deficiency[2] (inches) of the vehicle type.

[2]If the actual elevation, E_a, and degree of curvature, D, change as a result of track degradation, then the actual cant deficiency for the maximum allowable posted timetable operating speed, V_{max}, may be greater than the qualified cant deficiency, E_u. This actual cant deficiency for each curve may not exceed the qualified cant deficiency, E_u, plus 1 inch.

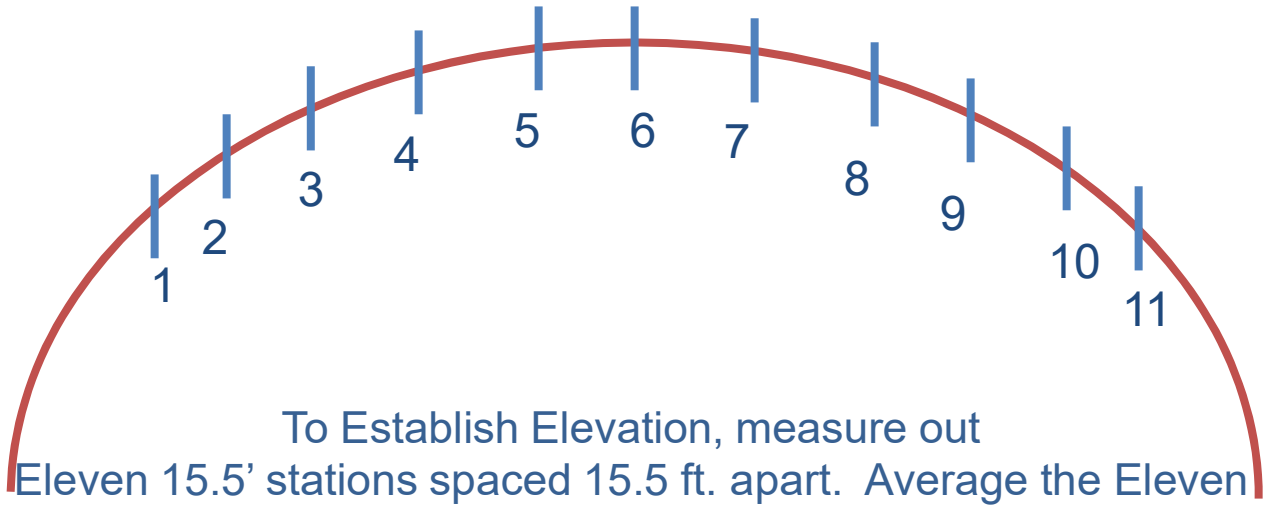
D = Degree of curvature (degrees).[3]

[3]Degree of curvature, D, is determined by averaging the degree of curvature over the same track segment as the elevation.

§ 213.57 Curves; elevation and speed limitations.

E_a = Actual elevation of the outside rail (inches).[1]

[1]Actual elevation, E_a, for each 155-foot track segment in the body of the curve is determined by averaging the elevation for 11 points through the segment at 15.5-foot spacing. If the curve length is less than 155 feet, the points are averaged through the full length of the body of the curve.



To Establish Elevation, measure out
Eleven 15.5' stations spaced 15.5 ft. apart. Average the Eleven Stations and this determines Elevation for curve.

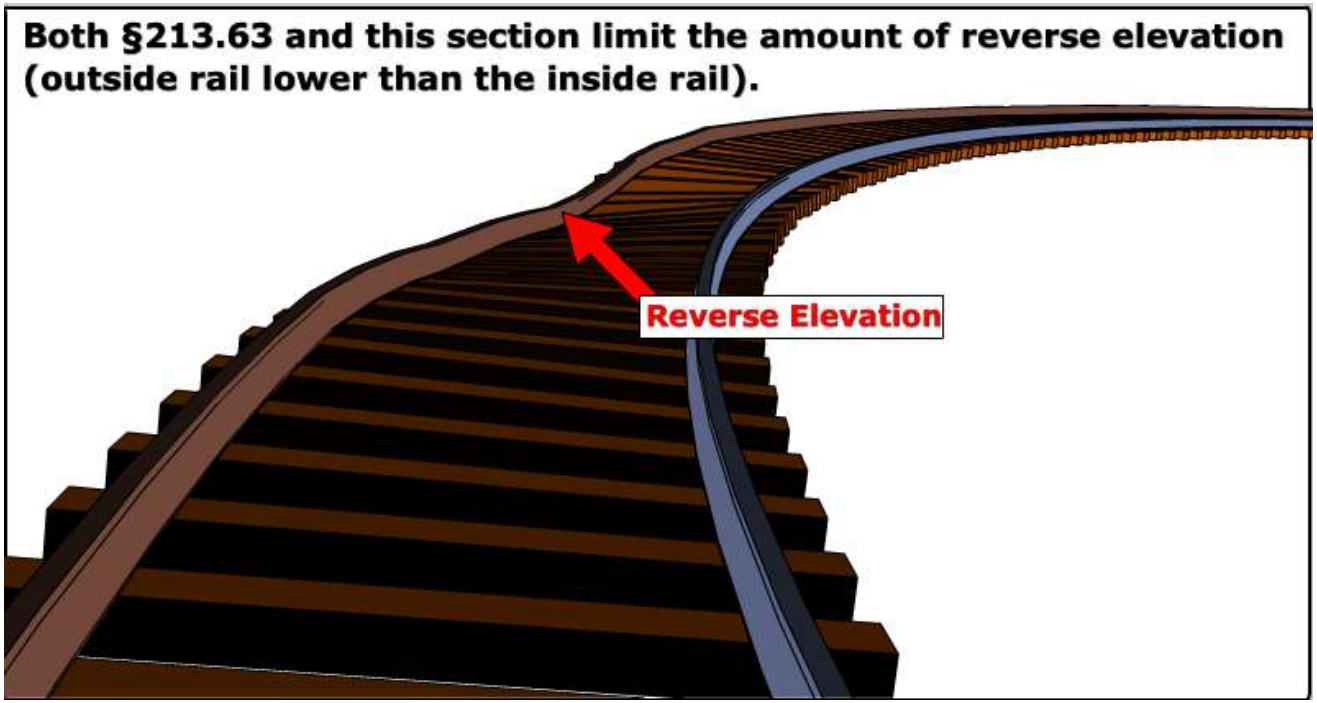
Determining compliance with FRA Elevation Standard using 11 point averaging method

§ 213.57 Curves; elevation and speed limitations.

(c) All vehicles are considered qualified for operating on track with a cant deficiency, E_u, not exceeding 3 inches. Table 1 of appendix A to this part is a table of speeds computed in accordance with the formula in paragraph (b) of this section, when E_u equals 3 inches, for various elevations and degrees of curvature.

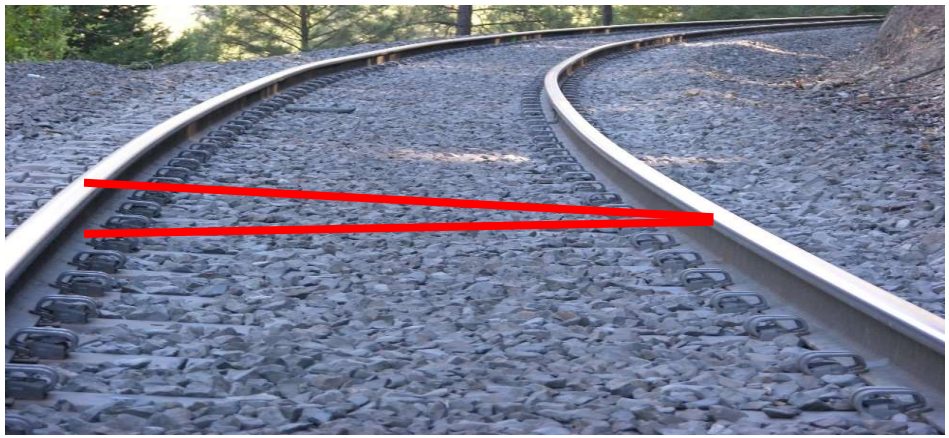
§ 213.57 Curves; elevation and speed limitations.

Reverse Elevation



Superelevation in a curve

Normally, between 0.0 to 6.0 inches of elevation is added to outer rail to counterbalance effects of centrifugal forces based on normal train speeds.



A balanced (equilibrium) condition implies the vertical forces on each rail are equal.

Figure 8 illustrates the three types of balance conditions.

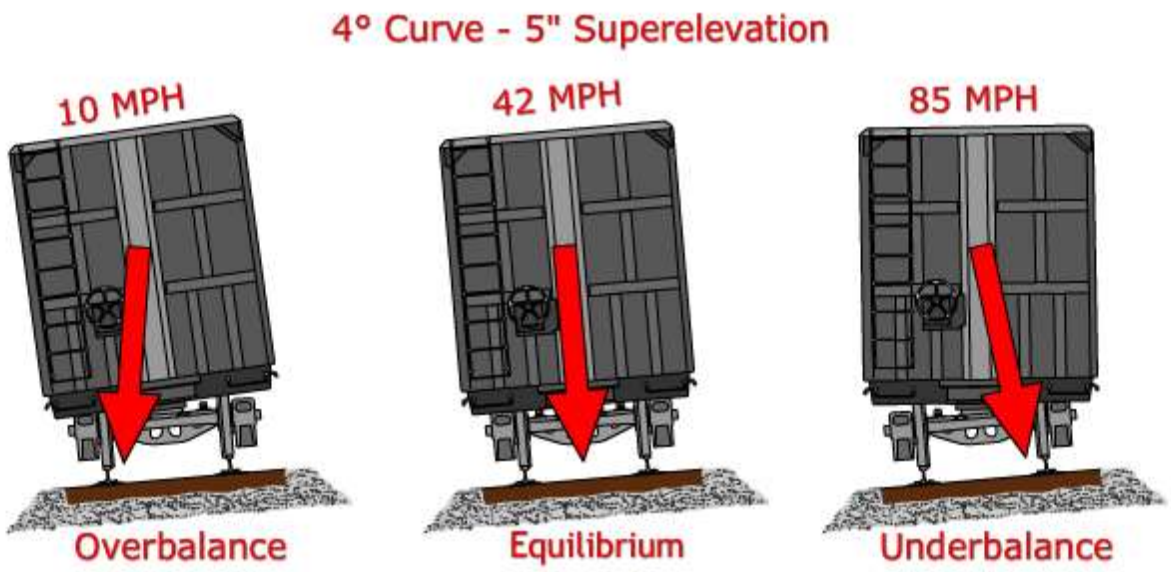
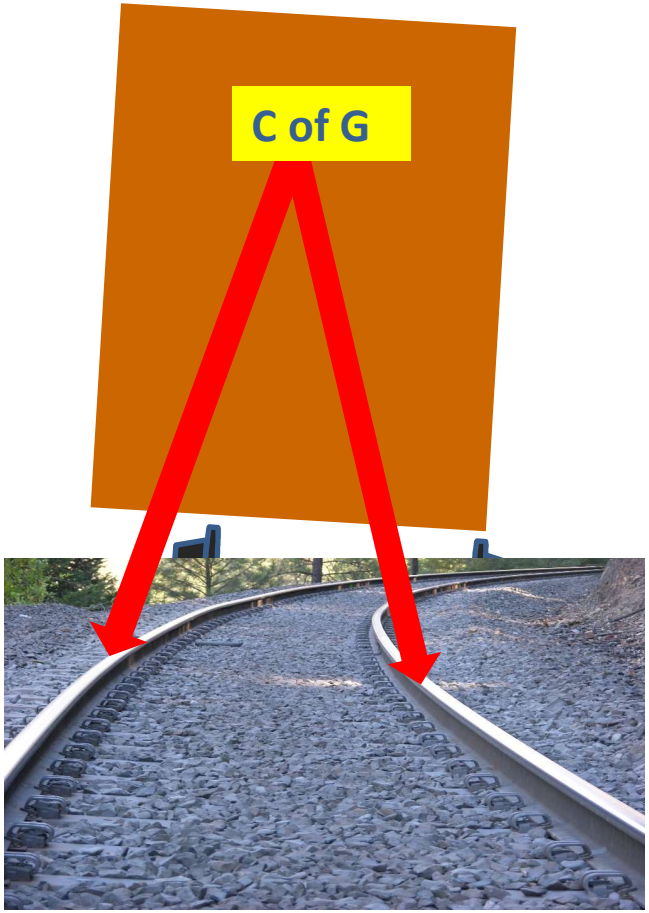


Figure 8



At equilibrium, There are equal vertical weights on both high and low rail.

Eq. Elevation = .0007 (D) (V^2)

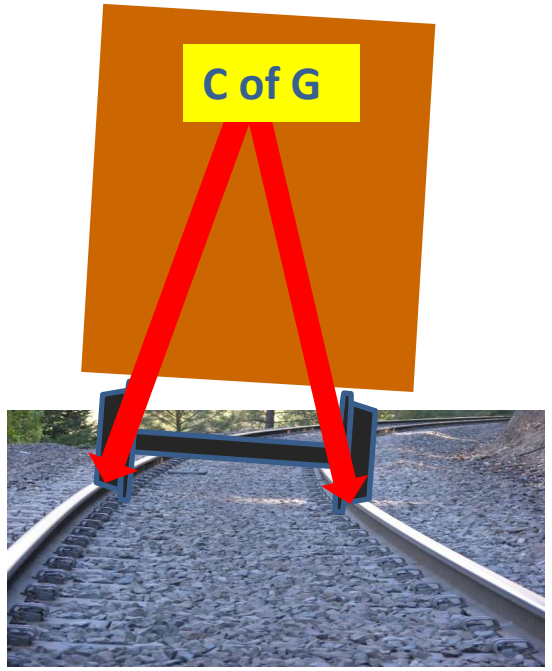
For 5 degree curve; 30 MPH

Eq. El. = .0007 (5) (30^2)

Eq. El. = .0007 (5) (900)

Eq. El. ~ 3.00”

1” Unbalance = 3.00 – 1.00 = 2.00”



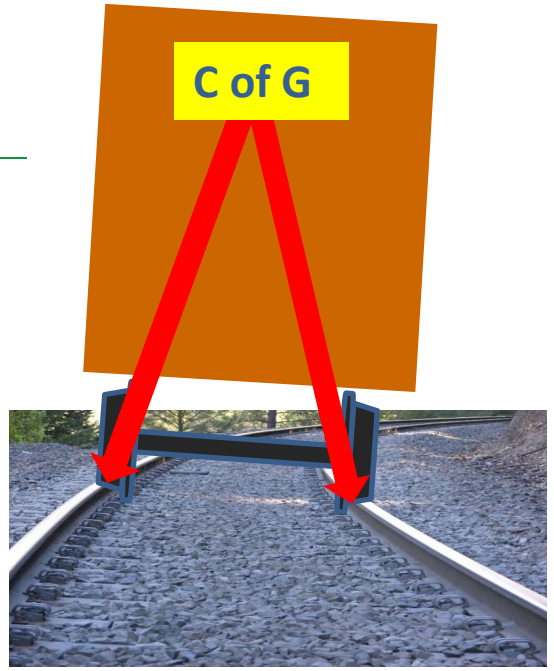
To determine Equilibrium Speed for Curve

For 5 degree curve; 3” Elevation
3” cant deficiency

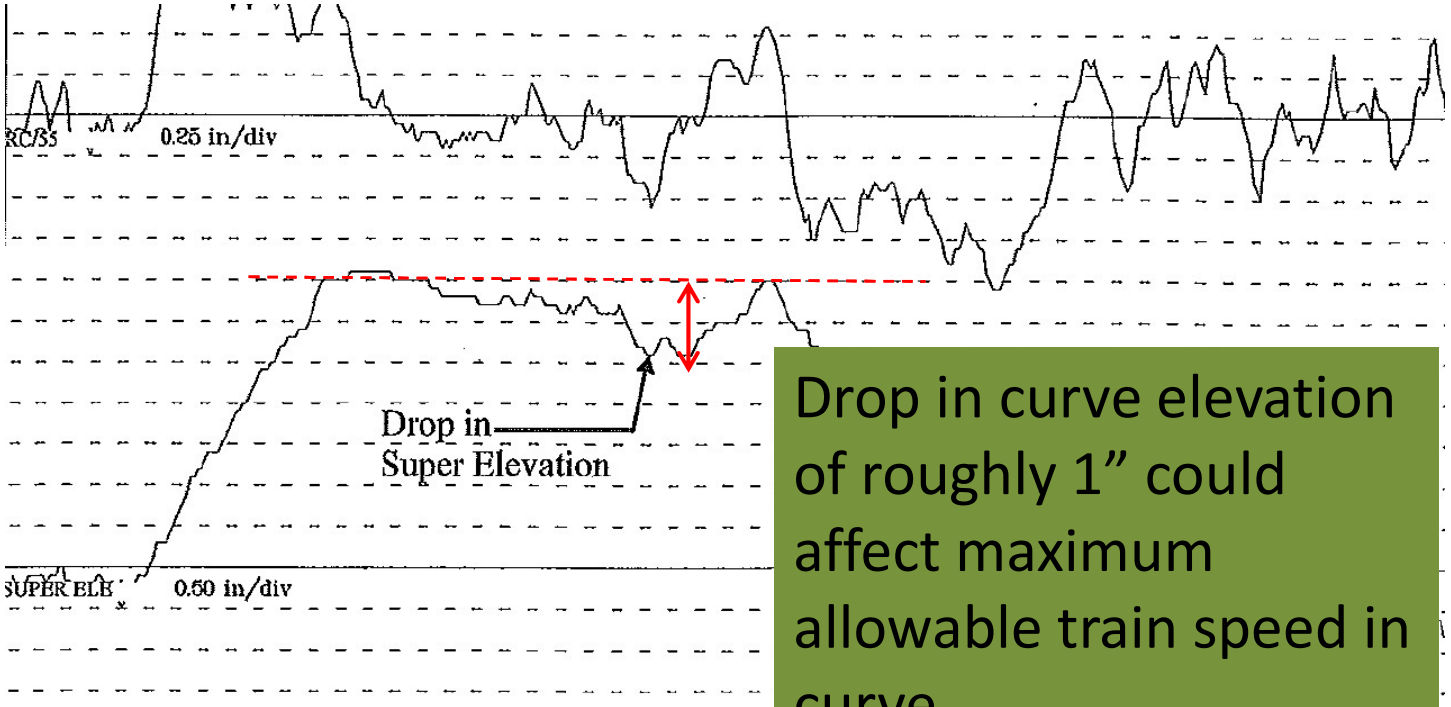
$V_{max} = \sqrt{\text{Elevation + Cant Deficiency}/.0007\ D}$

$= \sqrt{6” /.0007\ (5)}$

$= 41$ MPH



To determine FRA Maximum Speed for Curve

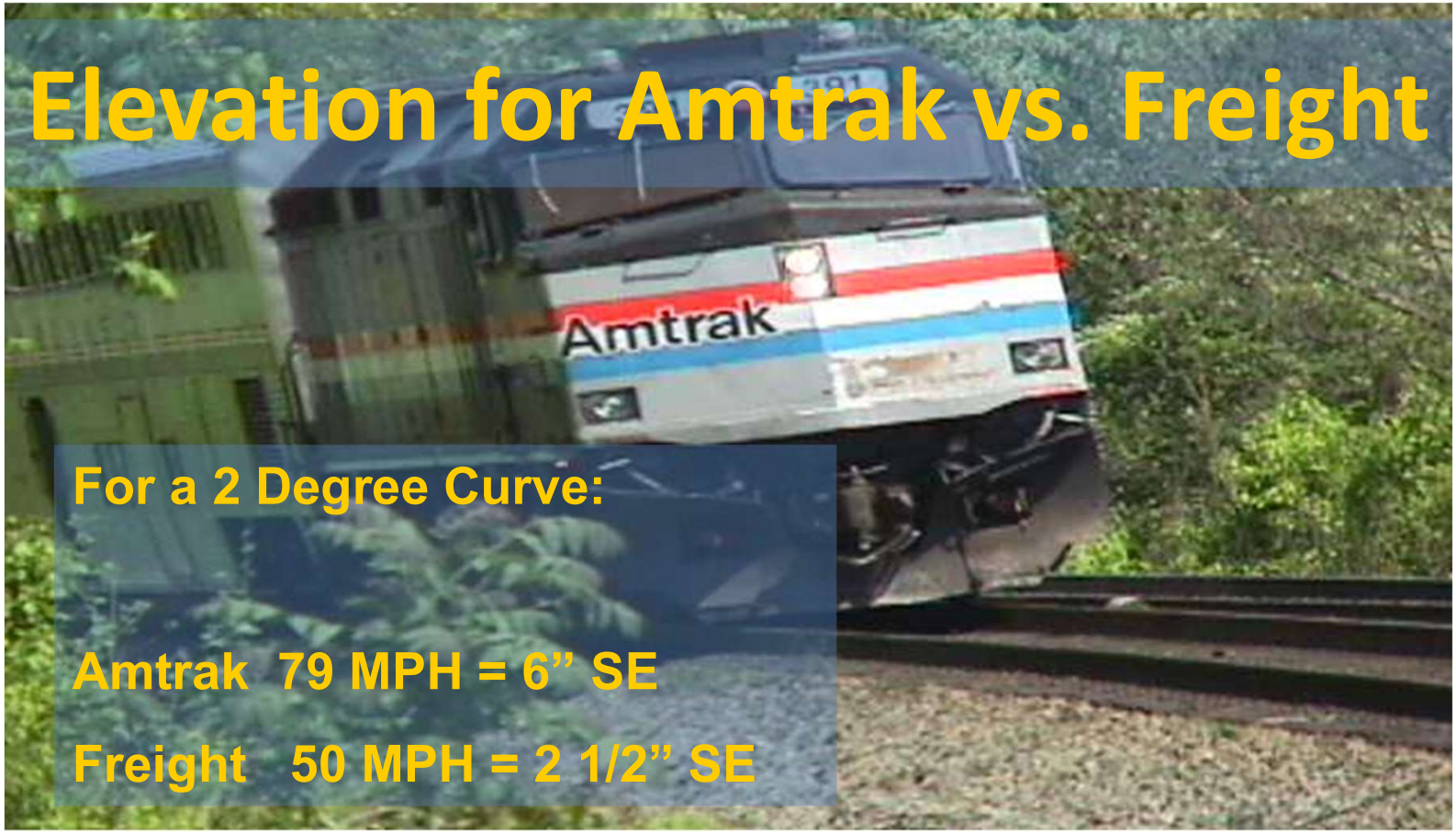


Drop in curve elevation of roughly 1” could affect maximum allowable train speed in curve.

Typical Scenarios to Watch for:

1) Elevation for once a day Amtrak/VIA/Commuter
2) Elevations on ruling grades
3) Elevations close to speed restrictions

Elevation for Amtrak vs. Freight

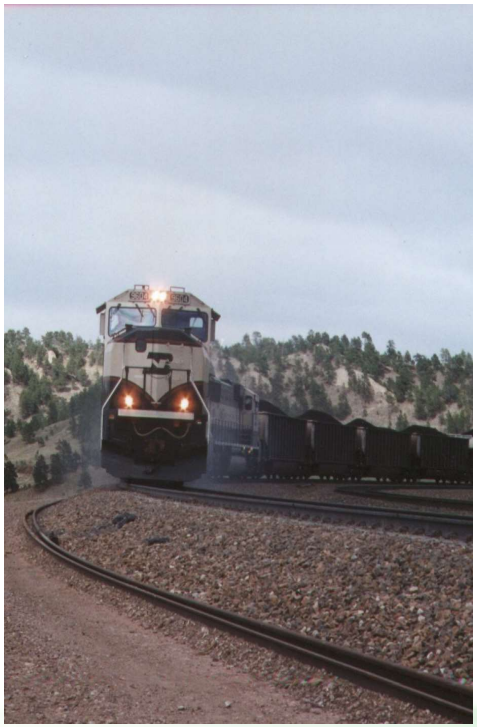


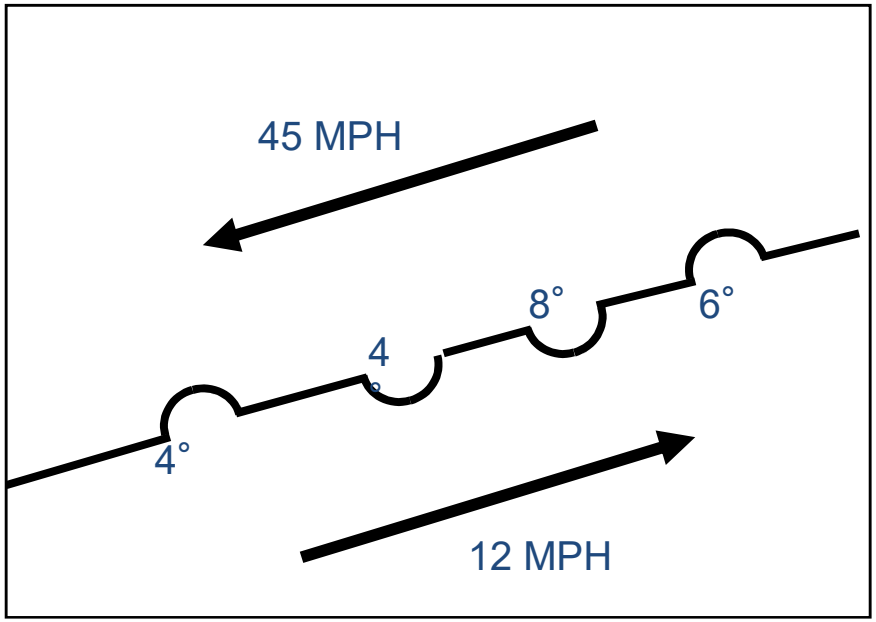
For a 2 Degree Curve:

Amtrak 79 MPH = 6” SE

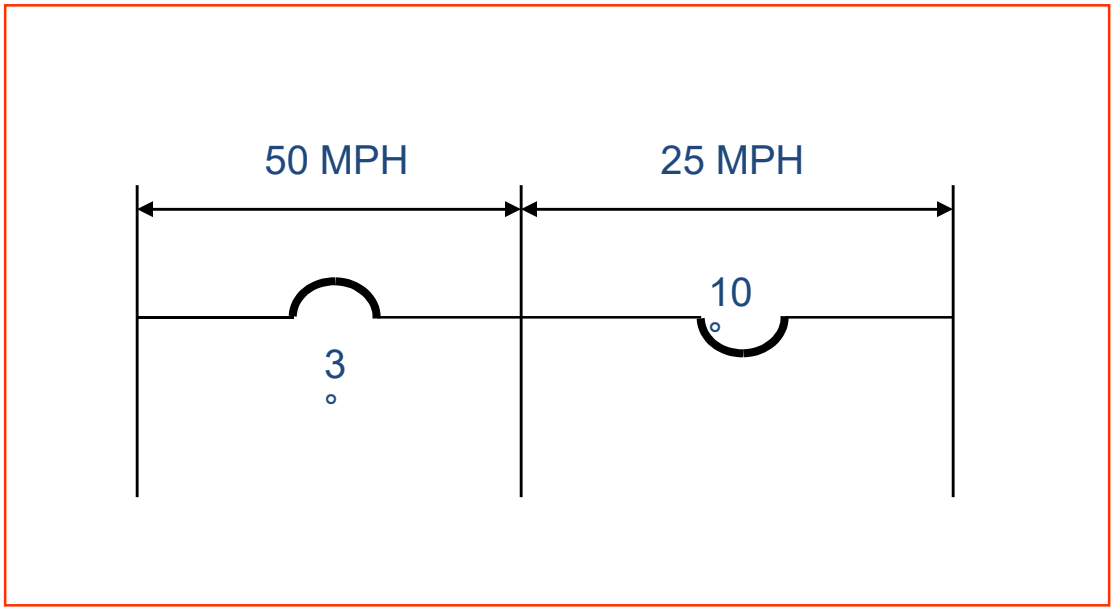
Freight 50 MPH = 2 1/2” SE

Elevation vs. Ruling Grade





Elevations Close to Speed Restrictions



Optimized Superelevation

An amount of superelevation that will minimize centrifugal force influence for a predominance of train tonnage for Normal operating speeds.

The Key Question…

What speed do you use to adjust superelevation?

Correct Superelevation for Curve & Velocity

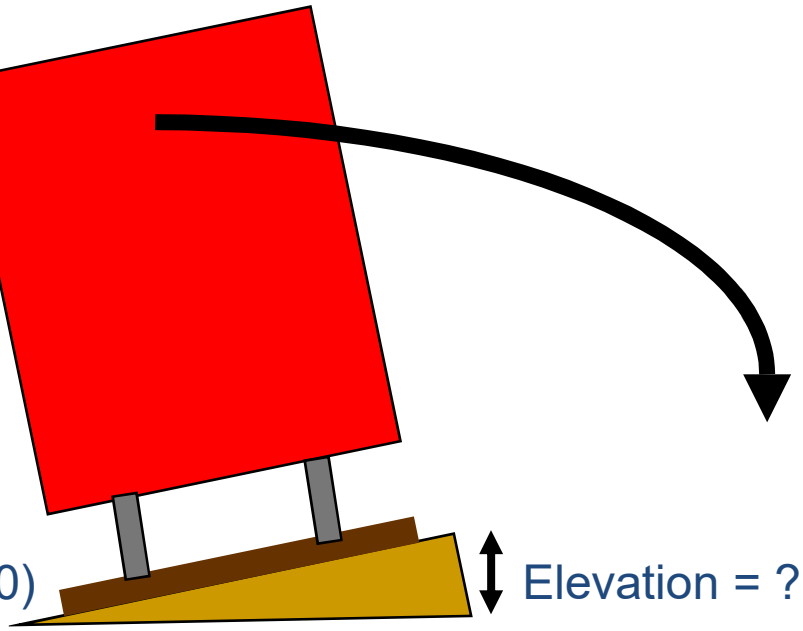
EL EQ. = .00067 DV^2

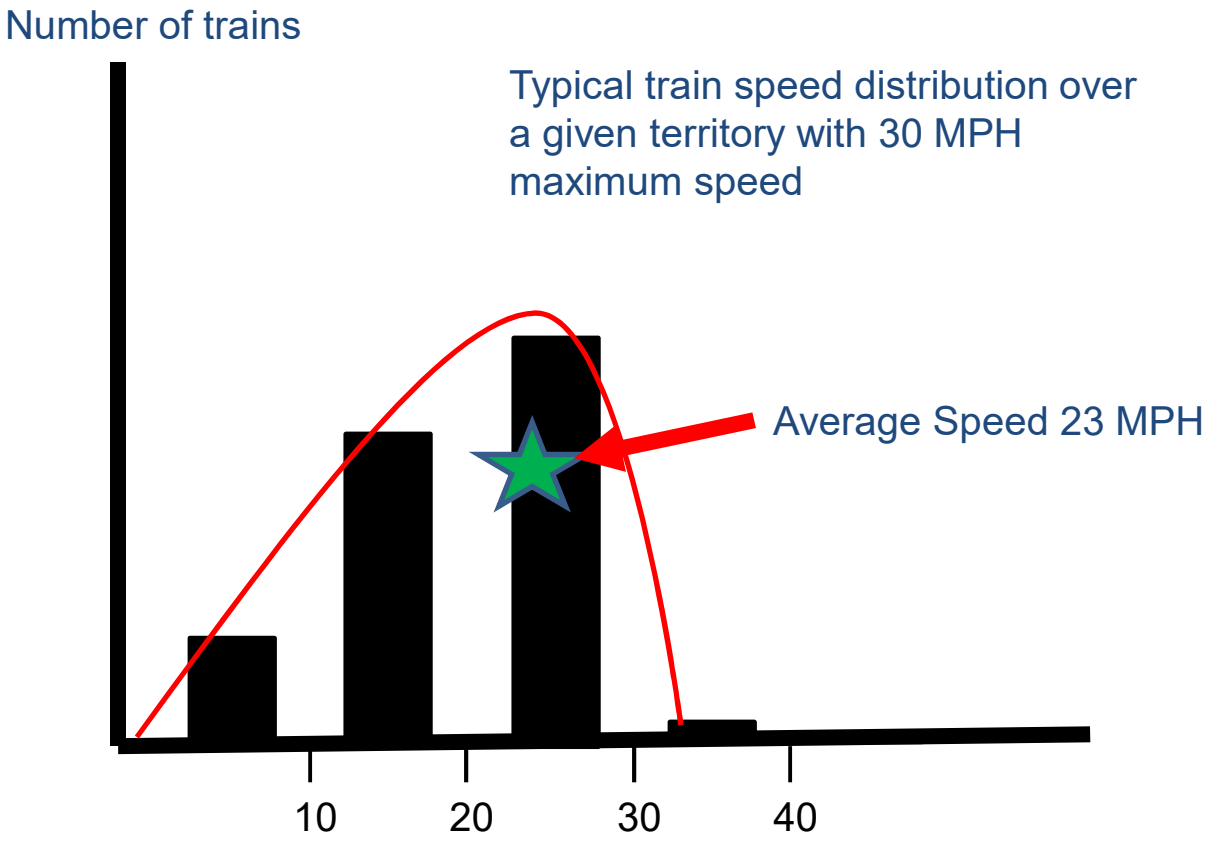
4 D. Curve

V = 30 MPH

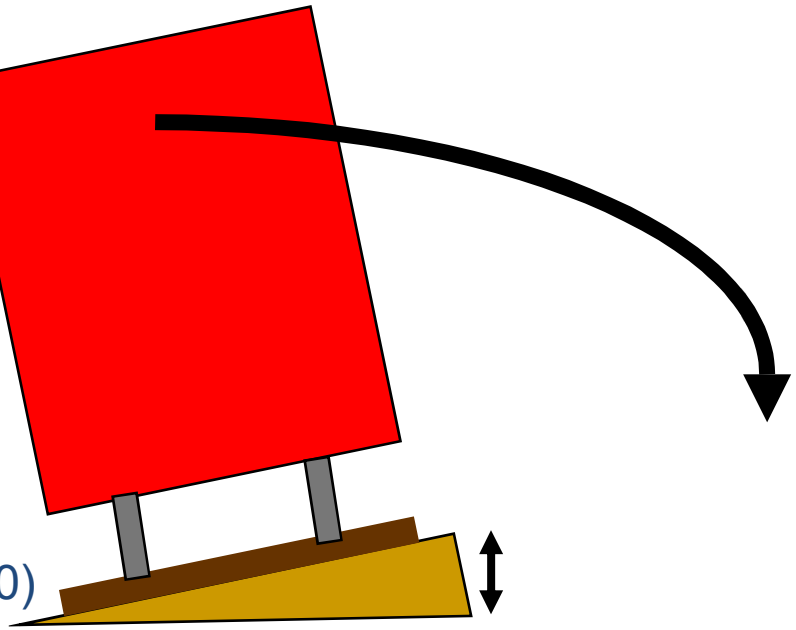
EL = .00067 (4) (30x30)

EL EQ. = 2.4 “




Number of trains
Typical train speed distribution over a given territory with 30 MPH maximum speed
Average Speed 23 MPH
10
20
30
40

Correct Superelevation for Curve & Velocity



EL EQ. = .00067 DV^2

4 D. Curve

V = 30 MPH

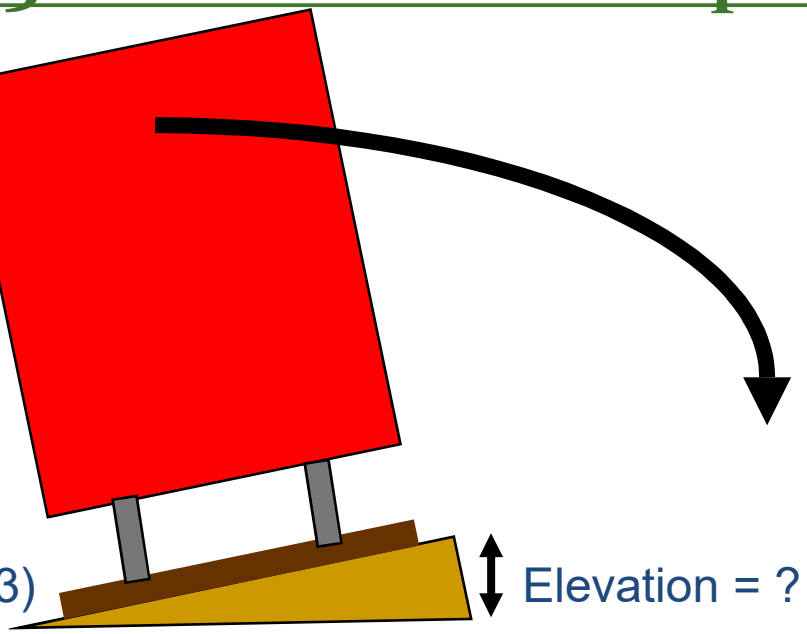
EL = .00067 (4) (30x30)

EL EQ. = 2.4 “

1 ” Unbalance

2.4” - 1.0” = 1.4”

Correct Superelevation for Average Train Speed on track with 30 MPH Timetable Speed



$EL\ EQ. = .00067\ DV^2$

4 D. Curve

V = 23 MPH

EL = .00067 (4) (23x23)

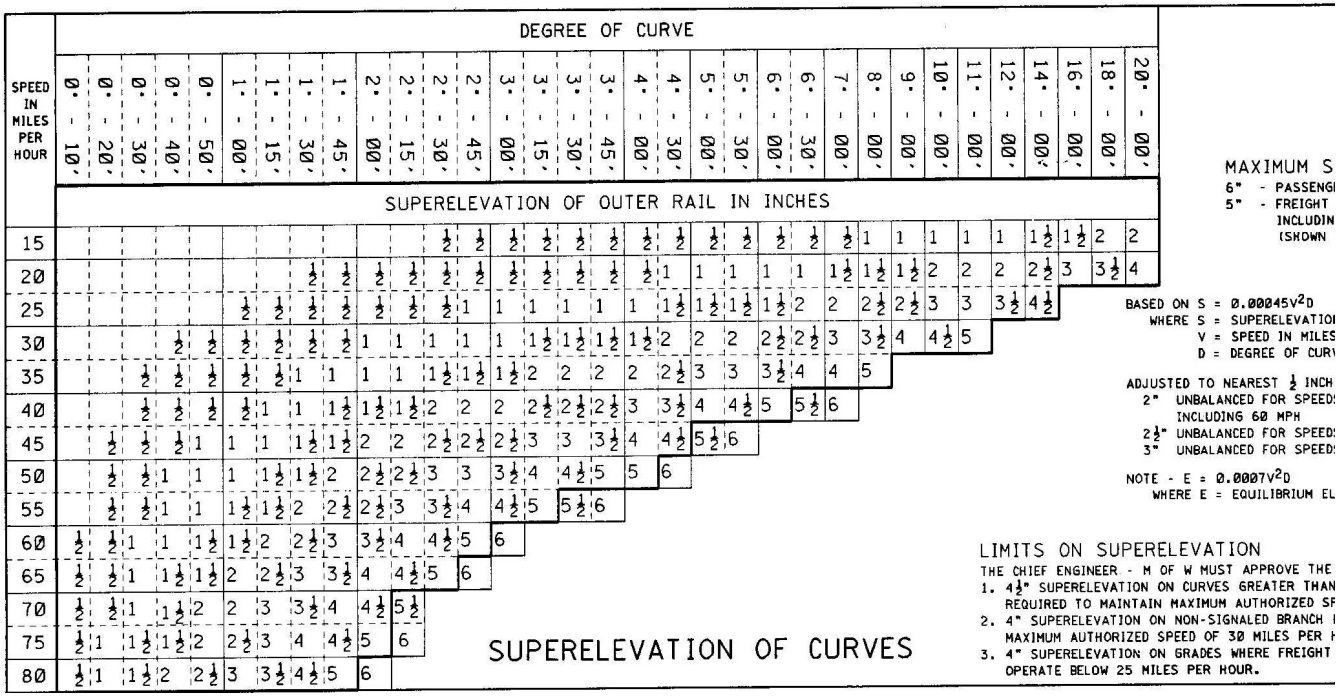
EL EQ. = 1.4 “

Elevation = ?

Railroad Practice

- Because not all trains make timetable speed, many railroads underbalance curves 1” to 2” depending on the statistical spread of train speeds.
- If you consistently run 0-5 MPH under timetable speed, then ~1” underbalance may be appropriate.
- If you consistently run 5-10 MPH under timetable speed, then ~1.5” underbalance may be appropriate.

Superelevation Chart (typical)



SUPERELEVATION OF CURVES

SPEED IN MILES PER HOUR	DEGREE OF CURVE																															
	0° - 10'	0° - 20'	0° - 30'	0° - 40'	0° - 50'	1° - 00'	1° - 15'	1° - 30'	1° - 45'	2° - 00'	2° - 15'	2° - 30'	2° - 45'	3° - 00'	3° - 15'	3° - 30'	3° - 45'	4° - 00'	4° - 30'	5° - 00'	5° - 30'	6° - 00'	6° - 30'	7° - 00'	8° - 00'	9° - 00'	10° - 00'	11° - 00'	12° - 00'	14° - 00'	16° - 00'	18° - 00'	20° - 00'
	SUPERELEVATION OF OUTER RAIL IN INCHES																															
15													½	½	½	½	½	½	½	½	½	½	½	½	1	1	1	1	1	1½	1½	2	2
20									½	½	½	½	½	½	½	½	½	½	1	1	1	1	1	1½	1½	1½	2	2	2	2½	3	3½	4
25						½	½	½	½	½	½	½	1	1	1	1	1	1	1½	1½	1½	1½	2	2	2½	2½	3	3	3½	4½			
30				½	½	½	½	½	½	1	1	1	1	1	1½	1½	1½	1½	2	2	2	2½	2½	3	3½	4	4½	5					
35			½	½	½	½	½	1	1	1	1	1½	1½	1½	2	2	2	2	2½	3	3	3½	4	4	5							
40			½	½	½	½	1	1	1½	1½	1½	2	2	2	2½	2½	2½	3	3½	4	4½	5	5½	6									
45		½	½	½	1	1	1	1½	1½	2	2	2½	2½	2½	3	3	3½	4	4½	5½	6												
50		½	½	1	1	1	1½	1½	2	2½	2½	3	3	3½	4	4½	5	5	6													
55		½	½	1	1	1½	1½	2	2½	2½	3	3½	4	4½	5	5½	6															
60	½	½	1	1	1½	1½	2	2½	3	3½	4	4½	5	6																		
65	½	½	1	1½	1½	2	2½	3	3½	4	4½	5	6																			
70	½	½	1	1½	2	2	3	3½	4	4½	5½																					
75	½	1	1½	1½	2	2½	3	4	4½	5	6																					
80	½	1	1½	2	2½	3	3½	4½	5	6																						

MAXIMUM S
6" - PASSENG
5" - FREIGHT
INCLUDIN
(SHOWN

BASED ON S = 0.00045v²D
WHERE S = SUPERELEVATIO
V = SPEED IN MILES
D = DEGREE OF CUR

ADJUSTED TO NEAREST ½ INCH
2" UNBALANCED FOR SPEED
INCLUDING 60 MPH
2½" UNBALANCED FOR SPEED
3" UNBALANCED FOR SPEED

NOTE - E = 0.0007v²D
WHERE E = EQUILIBRIUM EL

LIMITS ON SUPERELEVATION

THE CHIEF ENGINEER - M OF W MUST APPROVE THE
1. 4½" SUPERELEVATION ON CURVES GREATER THAN
REQUIRED TO MAINTAIN MAXIMUM AUTHORIZED SP
2. 4" SUPERELEVATION ON NON-SIGNALED BRANCH
MAXIMUM AUTHORIZED SPEED OF 30 MILES PER
3. 4" SUPERELEVATION ON GRADES WHERE FREIGHT
OPERATE BELOW 25 MILES PER HOUR.

Appendix A to Part 213—Maximum Allowable Curving Speeds

This appendix contains four tables identifying maximum allowing curving speeds based on 3, 4, 5, and 6 inches of unbalance (cant deficiency), respectively.

Table 1—Three Inches Unbalance

	Elevation of outer rail (inches)												
	0	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6
Degree of curvature	Maximum allowable operating speed (m.p.h.)												
0°30′	93	100	107	113	120	125	131	136	141	146	151	156	160
0°40′	80	87	93	98	104	109	113	118	122	127	131	135	139
0°50′	72	77	83	88	93	97	101	106	110	113	117	121	124
1°00′	65	71	76	80	85	89	93	96	100	104	107	110	113
1°15′	59	63	68	72	76	79	83	86	89	93	96	99	101
1°30′	53	58	62	65	69	72	76	79	82	85	87	90	93
1°45′	49	53	57	61	64	67	70	73	76	78	81	83	86
2°00′	46	50	53	57	60	63	65	68	71	73	76	78	80
2°15′	44	47	50	53	56	59	62	64	67	69	71	73	76
2°30′	41	45	48	51	53	56	59	61	63	65	68	70	72
2°45′	39	43	46	48	51	53	56	58	60	62	64	66	68
3°00′	38	41	44	46	49	51	53	56	58	60	62	64	65
3°15′	36	39	42	44	47	49	51	53	55	57	59	61	63
3°30′	35	38	40	43	45	47	49	52	53	55	57	59	61
3°45′	34	37	39	41	44	46	48	50	52	53	55	57	59
4°00′	33	35	38	40	42	44	46	48	50	52	53	55	57
4°30′	31	33	36	38	40	42	44	45	47	49	50	52	53
5°00′	29	32	34	36	38	40	41	43	45	46	48	49	51
5°30′	28	30	32	34	36	38	39	41	43	44	46	47	48
6°00′	27	29	31	33	35	36	38	39	41	42	44	45	46
6°30′	26	28	30	31	33	35	36	38	39	41	42	43	44
7°00′	25	27	29	30	32	34	35	36	38	39	40	42	43
8°00′	23	25	27	28	30	31	33	34	35	37	38	39	40
9°00′	22	24	25	27	28	30	31	32	33	35	36	37	38
10°00′	21	22	24	25	27	28	29	30	32	33	34	35	36
11°00′	20	21	23	24	25	27	28	29	30	31	32	33	34
12°00′	19	20	22	23	24	26	27	28	29	30	31	32	33

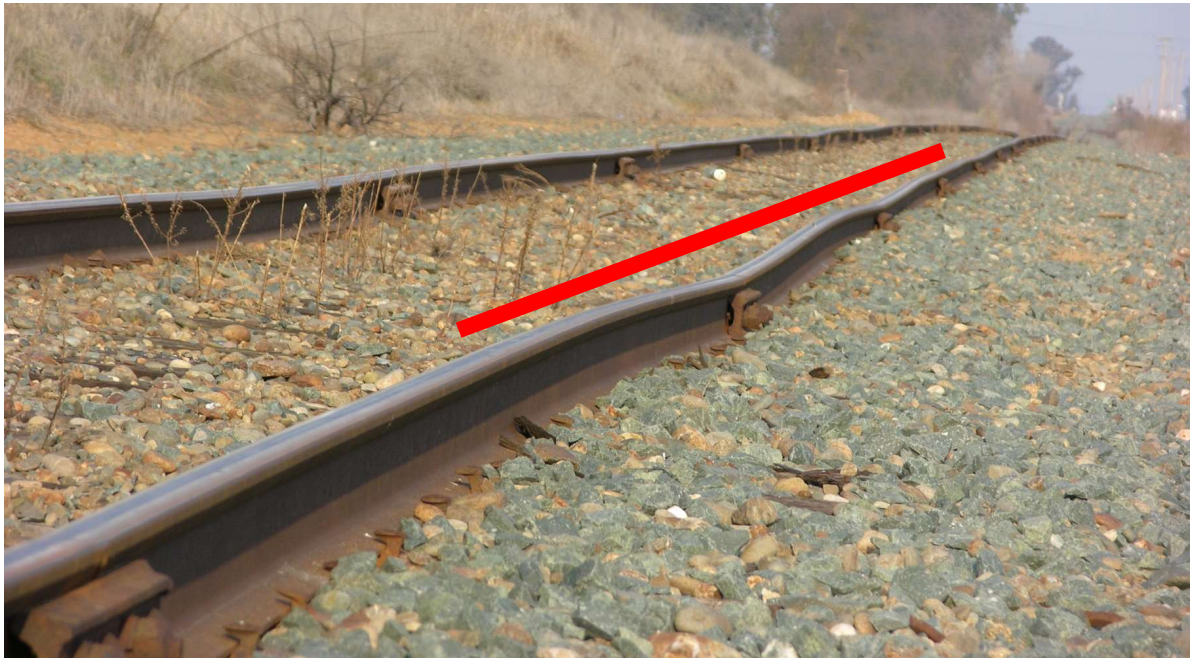
§ 213.63 Track surface.

(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero crosslevel at any point on tangent or reverse crosslevel elevation on curves may not be more than	3	2	1 3/4	1 1/4	1
The difference in crosslevel between any two points less than 62 feet apart may not be more than[* 1 2]	3	2 1/4	2	1 3/4	1 1/2
*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

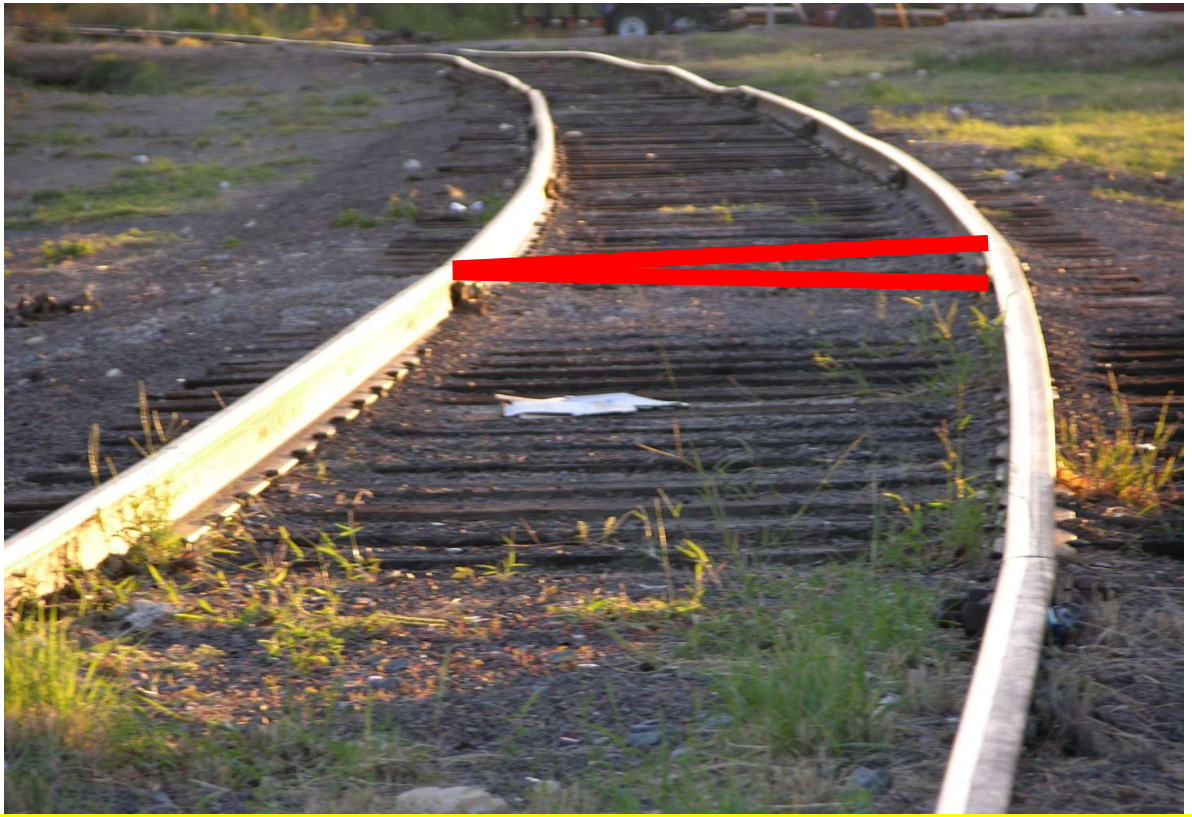
[1]Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 11/2 inches.

[2]However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 11/4 inches in all of six consecutive pairs of joints, as created by seven low joints. Track with joints staggered less than 10 feet apart shall not be considered as having staggered joints. Joints within the seven low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.



Vertical Profile

Crosslevel Variations/Deviation

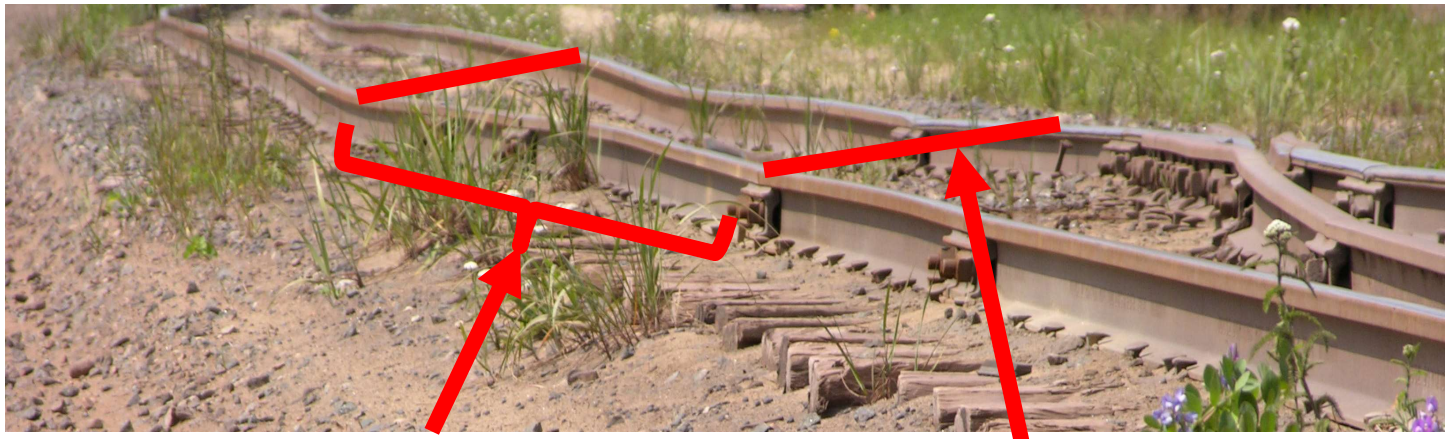


Curve Superelevation and Crosslevel

2 Key Words Used in the FRA Regulations

1. Variation or Difference
2. Deviation

They sound similar, but have different; yet, important, meanings.



This is a variance or difference in two Crosslevel measurements over 62'. Variations are relative differences between any two measurements.

This is a deviation from zero Crosslevel; or a deviation from where the Crosslevel should be. Deviations are singular measurements.

§ 213.13 Measuring track not under load.

When unloaded track is measured to determine compliance with requirements of this part, the amount of rail movement, if any, that occurs while the track is loaded must be added to the measurements of the unloaded track.

§ 213.63 Track surface.

(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

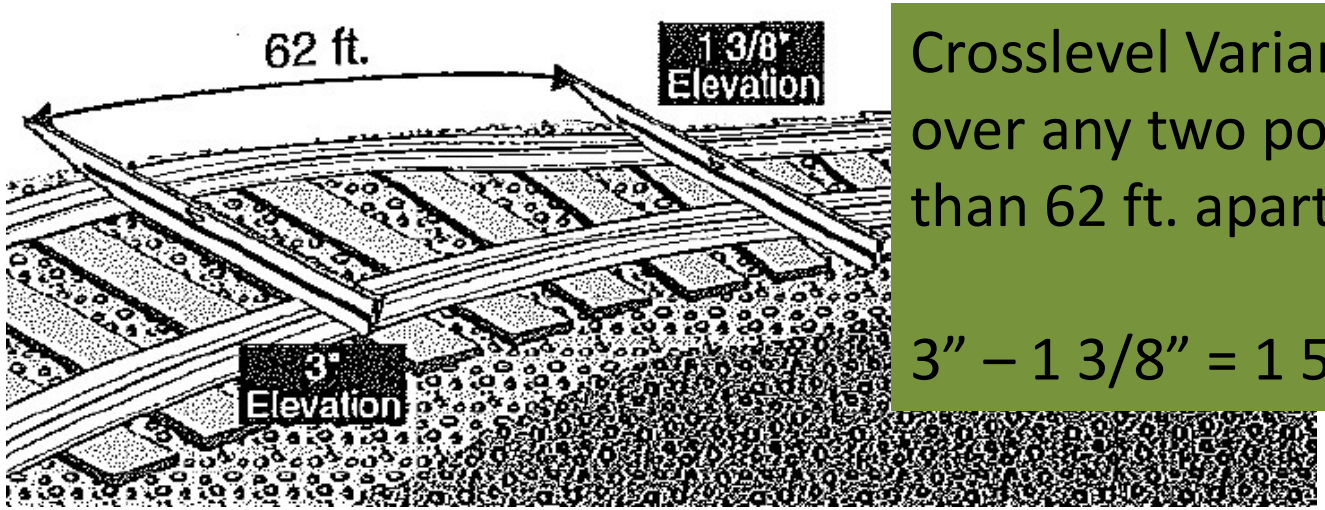
Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero crosslevel at any point on tangent or reverse crosslevel elevation on curves may not be more than	3	2	1 3/4	1 1/4	1
The difference in crosslevel between any two points less than 62 feet apart may not be more than* [1] [2]	3	2 1/4	2	1 3/4	1 1/2
*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

[1]Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 11/2 inches.

[2]However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 11/4 inches in all of six consecutive pairs of joints, as created by seven low joints. Track with joints staggered less than 10 feet apart shall not be considered as having staggered joints. Joints within the seven low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.

Crosslevel Variations

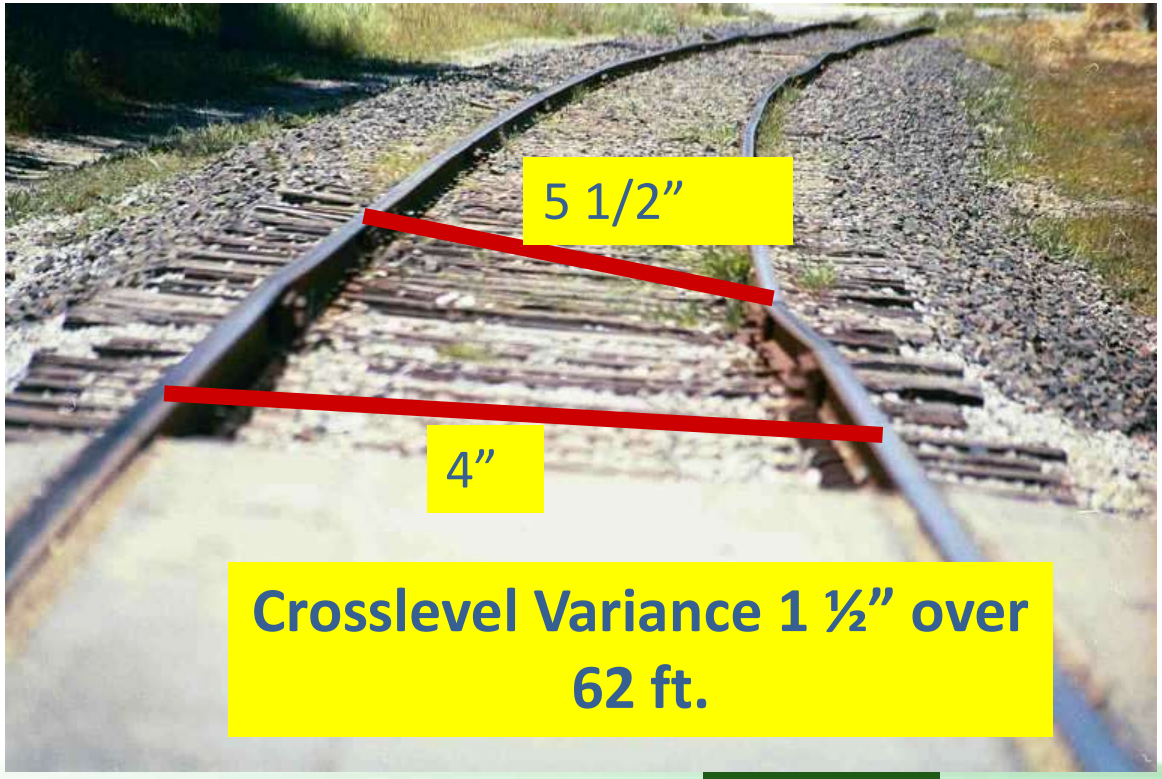
Any two Crosslevel measurements less than 62’ apart

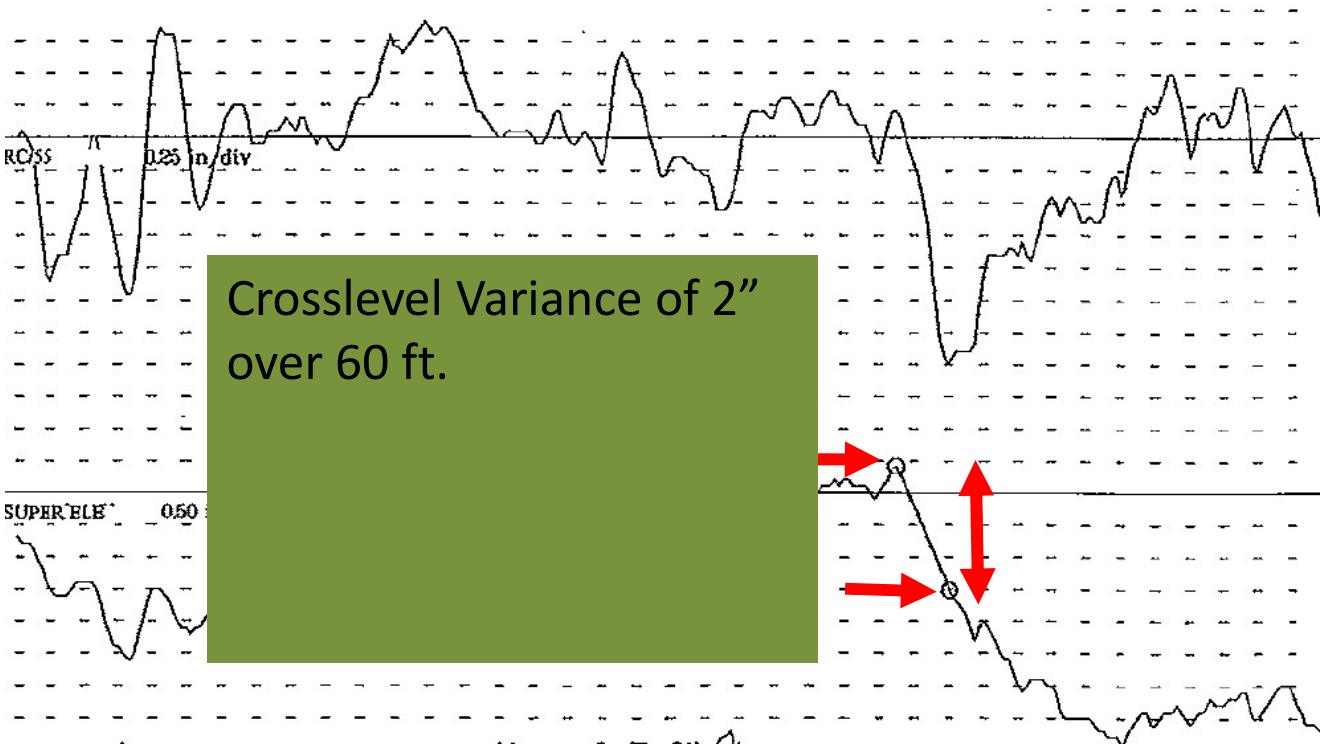


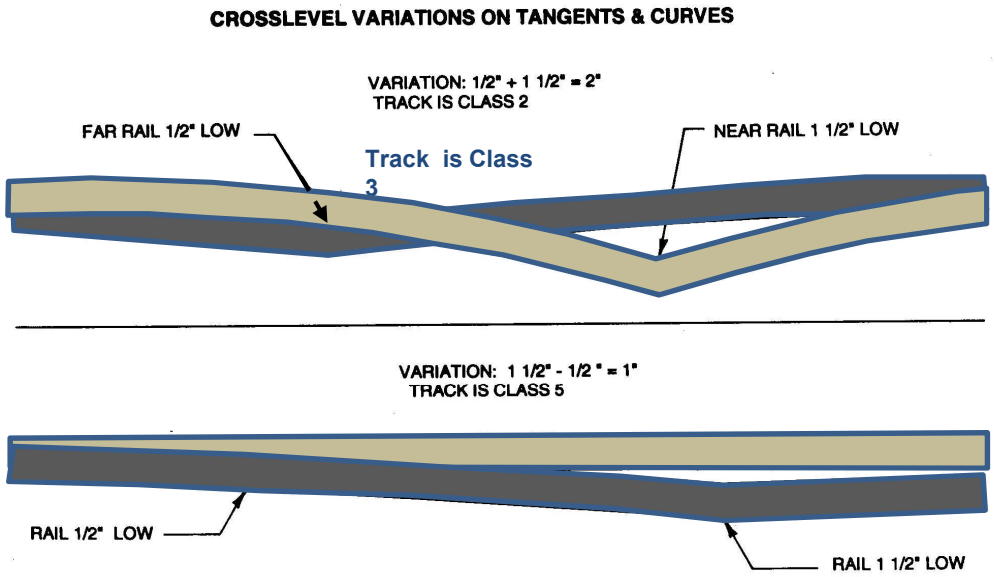
Crosslevel Variance over any two points less than 62 ft. apart.

3” – 1 3/8” = 1 5/8”

Crosslevel Variations




RCSS
0.25 in/div
SUPER ELE
0.50
Crosslevel Variance of 2” over 60 ft.



Difference in Crosslevel between any two points less than 62 ft. apart may not be more than...

1	2	3	4	5
3”	2 ¼”	2”	1 ¾”	1 ½”

Track Class Difference

§ 213.63 Track surface.

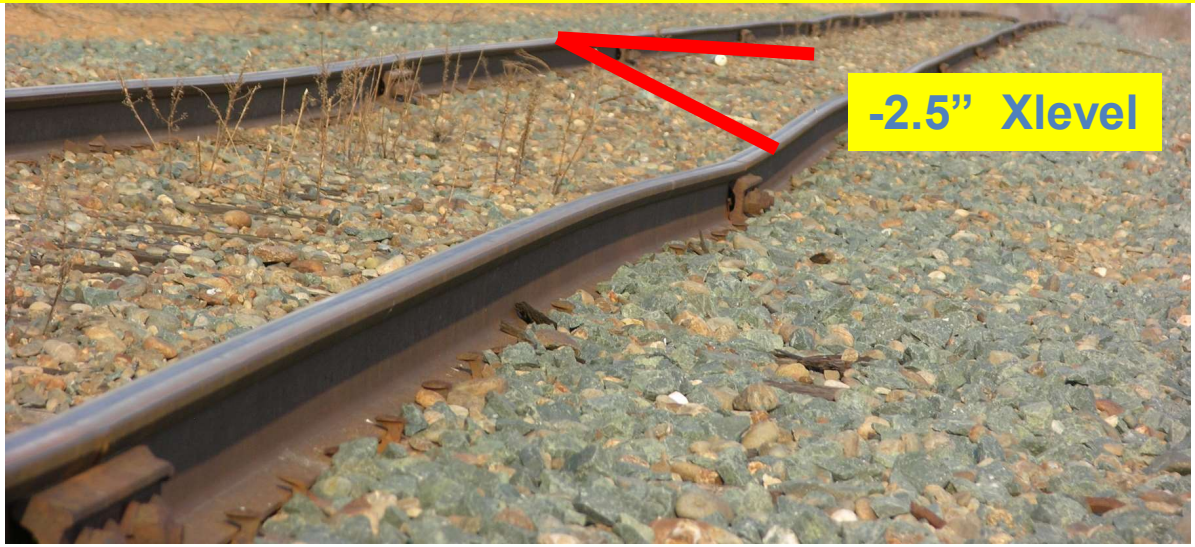
(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero crosslevel at any point on tangent or reverse crosslevel elevation on curves may not be more than	3	2	1 3/4	1 1/4	1
The difference in crosslevel between any two points less than 62 feet apart may not be more than* [1] [2]	3	2 1/4	2	1 3/4	1 1/2
*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

[1]Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 11/2 inches.

[2]However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 11/4 inches in all of six consecutive pairs of joints, as created by seven low joints. Track with joints staggered less than 10 feet apart shall not be considered as having staggered joints. Joints within the seven low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.

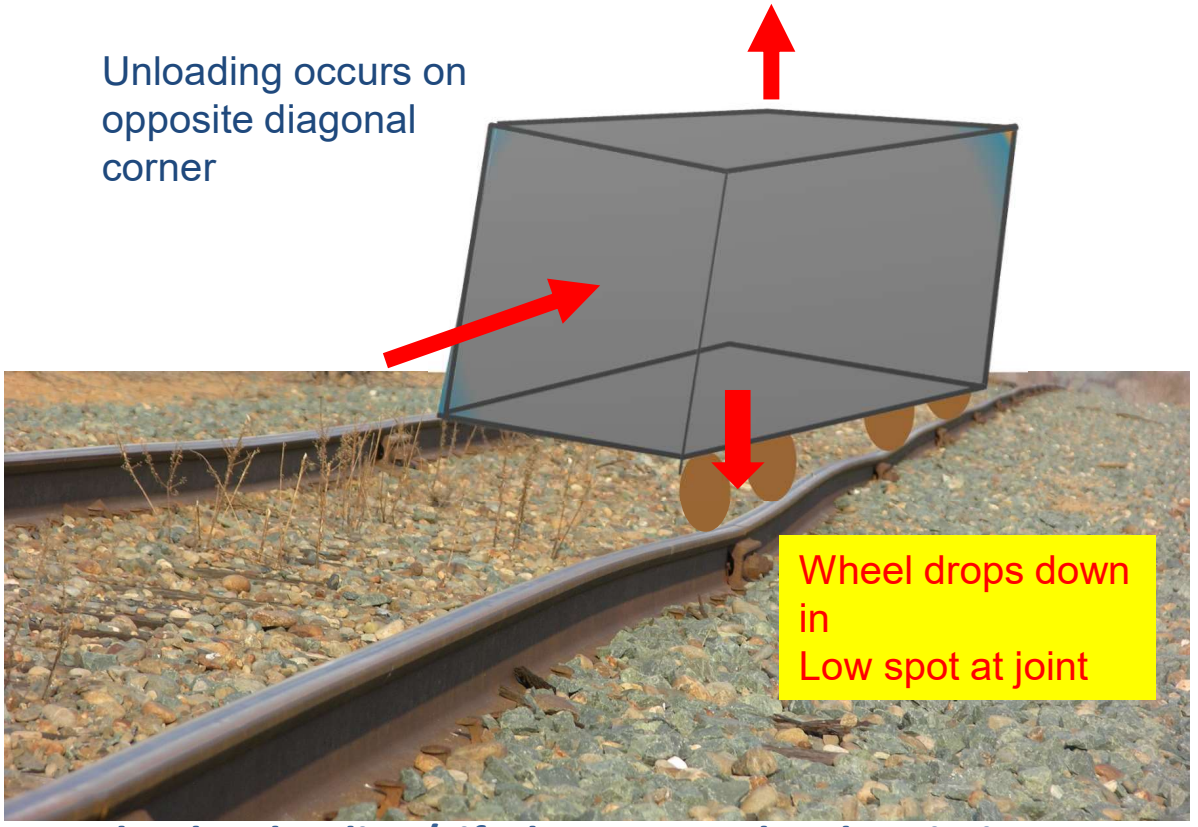
Crosslevel Deviations



Deviation from Zero Crosslevel at any point on tangent, or reverse crosslevel in curves may not be more than

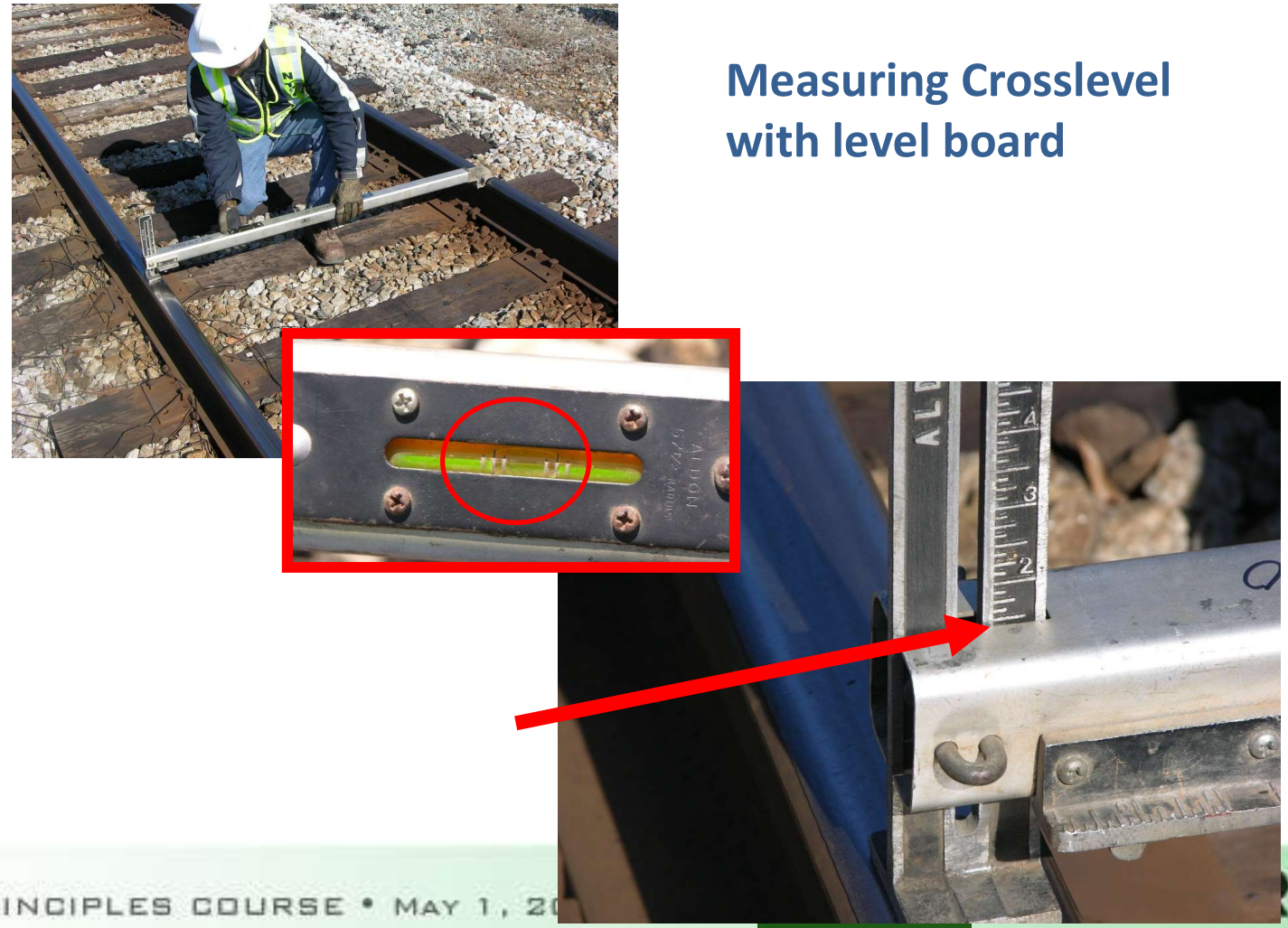
Class	1	2	3	4	5
Deviation	3”	2”	1 ¾”	1 1/4”	1 ”

Unloading occurs on opposite diagonal corner

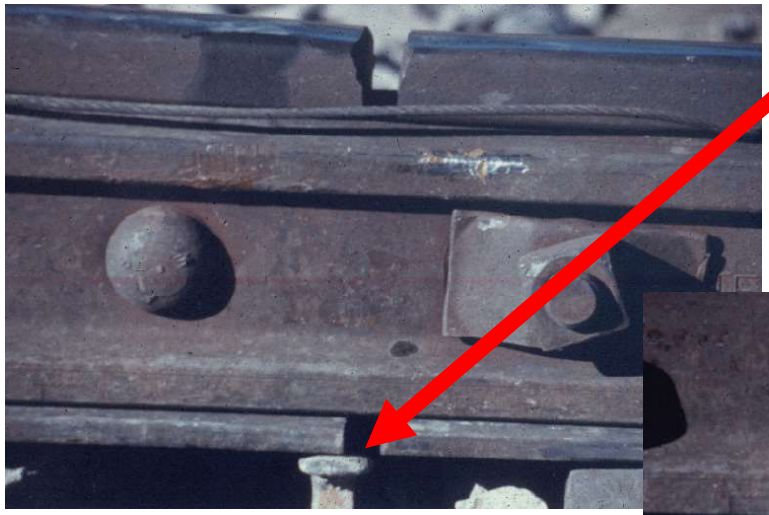


Wheel Unloading/Lift due to Crosslevel Variation Between rear and front trucks

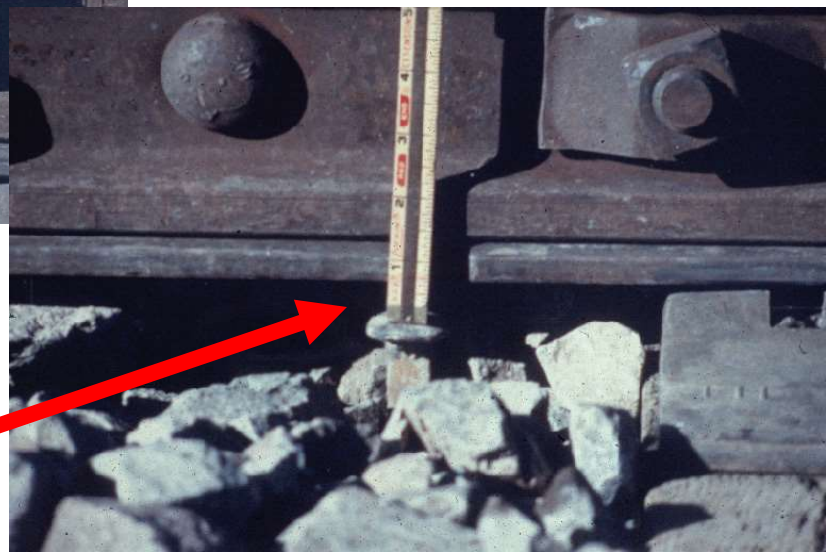
Measuring Crosslevel with level board



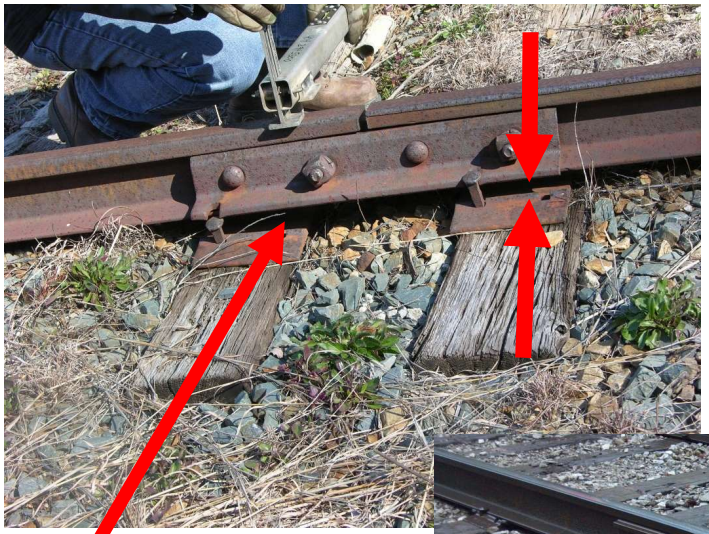

Measuring Crosslevel Under Load

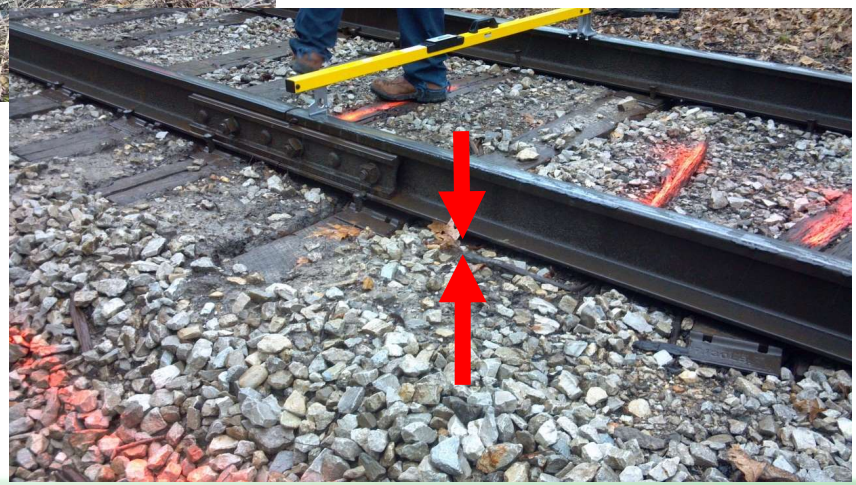


Tamp Spike up Under Base of Joint

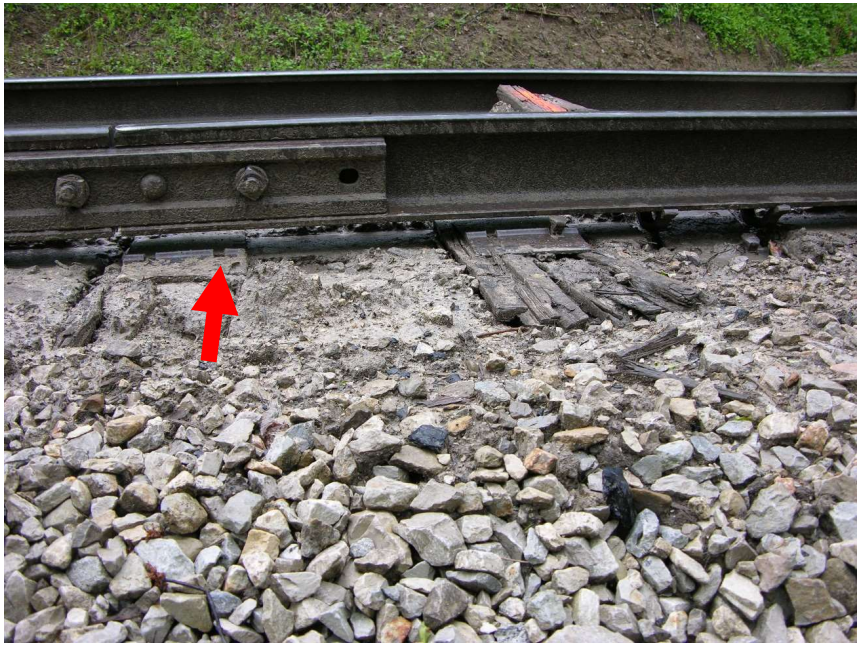


Run Train over Joint; Measure Maximum Deflection

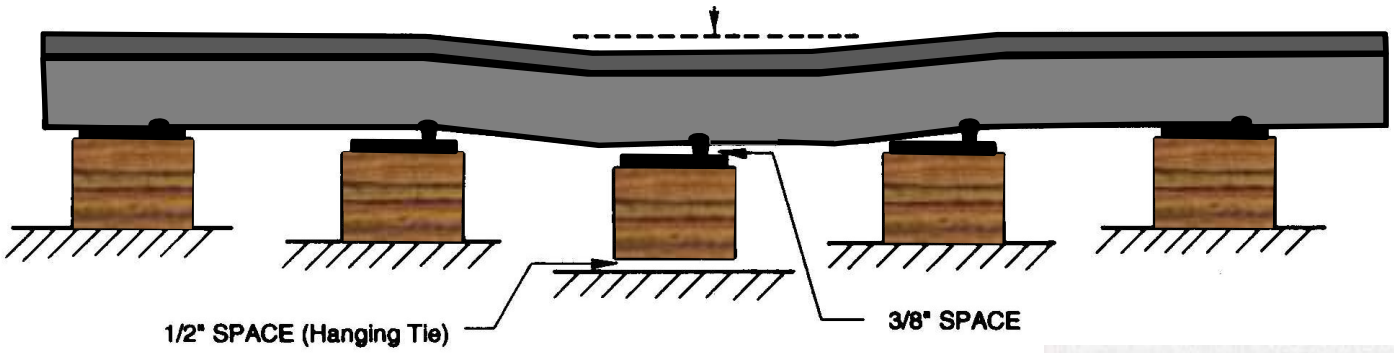




Hanging Ties



MEASURED CROSSLEVEL 1”



MEASURED CROSS LEVEL	1"
SPACE UNDER TIE PLATE	3/8"
SPACE UNDER TIE	1/2"
ACTUAL CROSSLEVEL UNDER LOAD	1 7/8"

§ 213.13 Measuring track not under load.

When unloaded track is measured to determine compliance with requirements of this part, the amount of rail movement, if any, that occurs while the track is loaded must be added to the measurements of the unloaded track.

MEASURING CROSSLEVEL NOT UNDER LOAD

§ 213.63 Track surface.

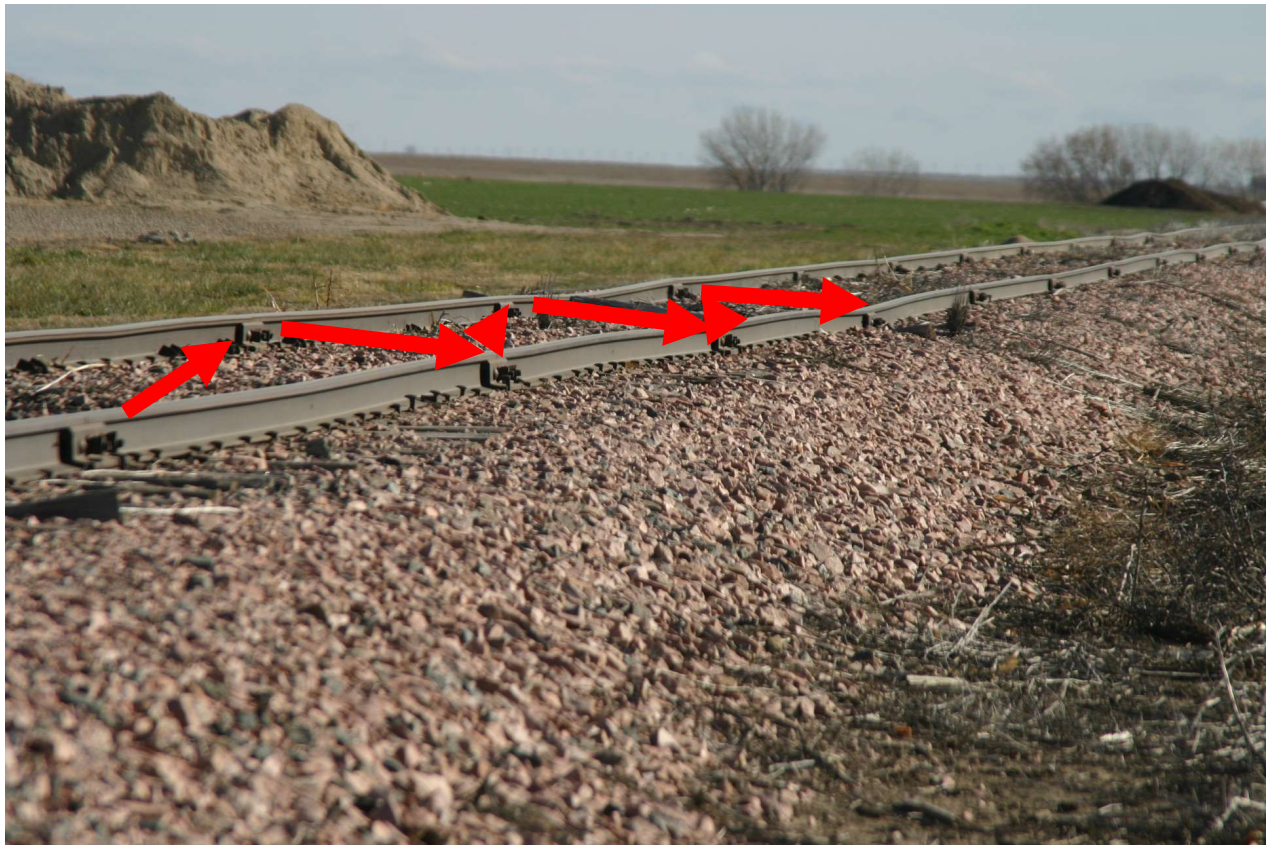
(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

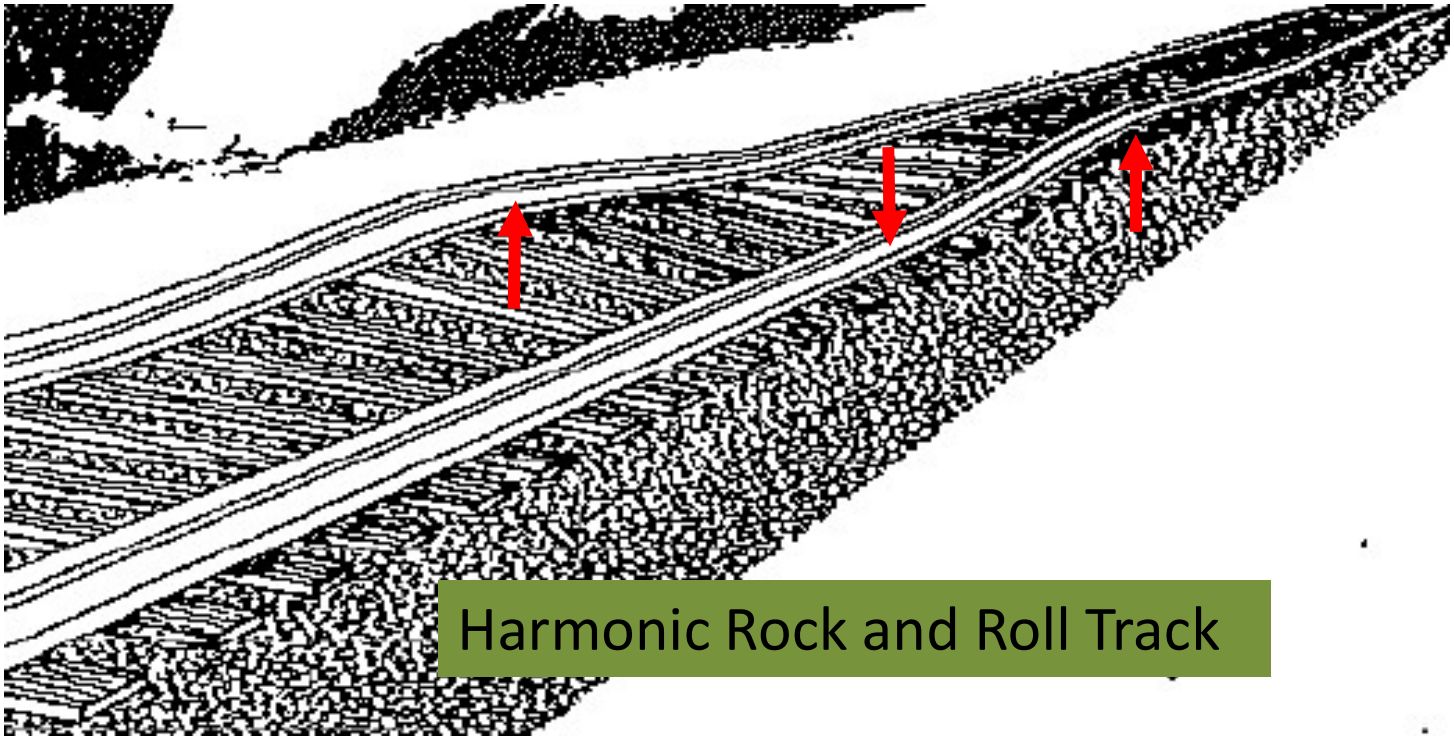
Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero crosslevel at any point on tangent or reverse crosslevel elevation on curves may not be more than	3	2	1 3/4	1 1/4	1
The difference in crosslevel between any two points less than 62 feet apart may not be more than* [1] [2]	3	2 1/4	2	1 3/4	1 1/2
*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

[1] Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 11/2 inches.

[2] However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 11/4 inches in all of six consecutive pairs of joints, as created by seven low joints. Track with joints staggered less than 10 feet apart shall not be considered as having staggered joints. Joints within the seven low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.

Staggered Jointed Rail (Joints staggered greater than 10' apart)

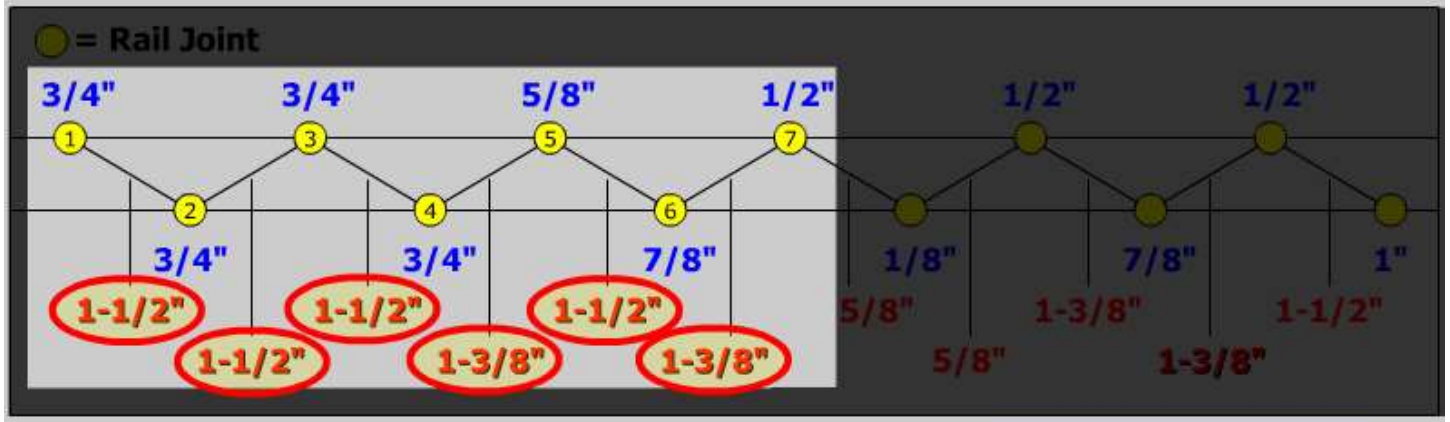




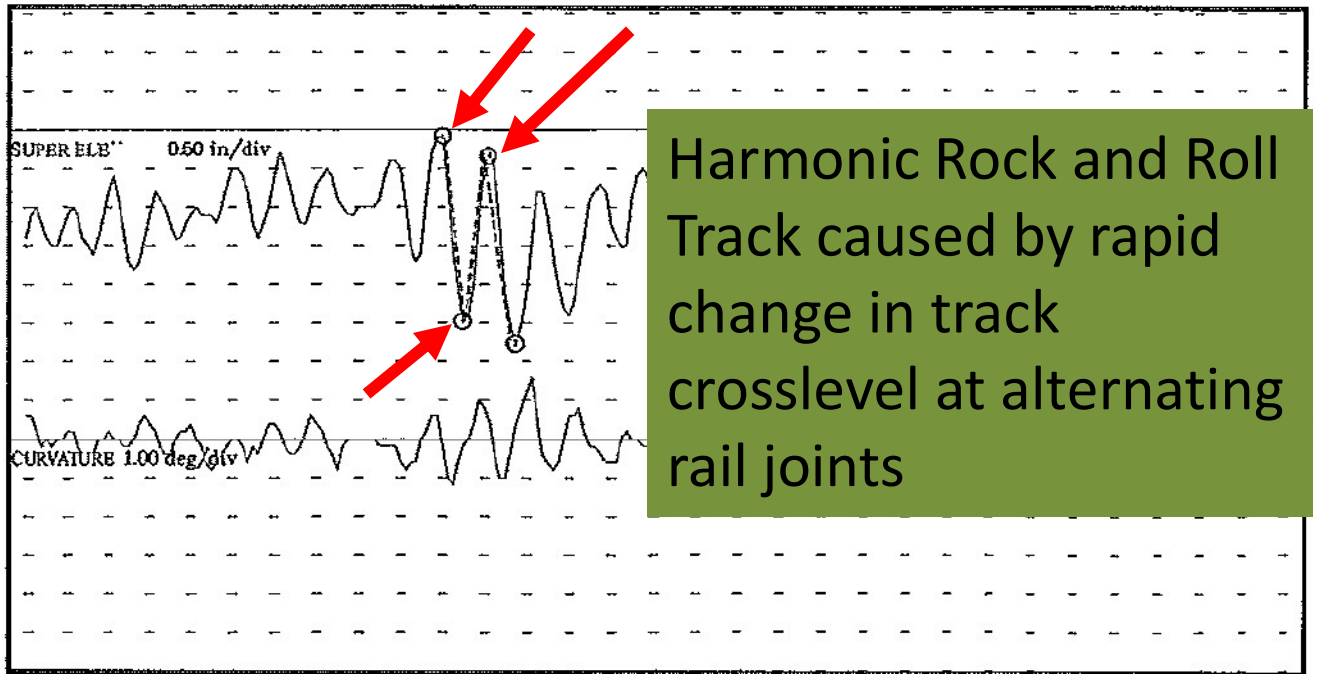
Harmonic Rock and Roll Track

FRA - Harmonic Rock-Off II

In this case, Deficient Track Crosslevel, could be considered a potential Primary Derailment Cause.



[2] However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 1-1/4 inches in all of six consecutive pairs of joints, as created by 7 low joints. Track with joints staggered less than 10 feet shall not be considered as having staggered joints. Joints within the 7 low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.
(Footnote 2 is applicable September 21, 1999.)



Harmonic Rock and Roll Track caused by rapid change in track crosslevel at alternating rail joints

§ 213.63 Track surface.

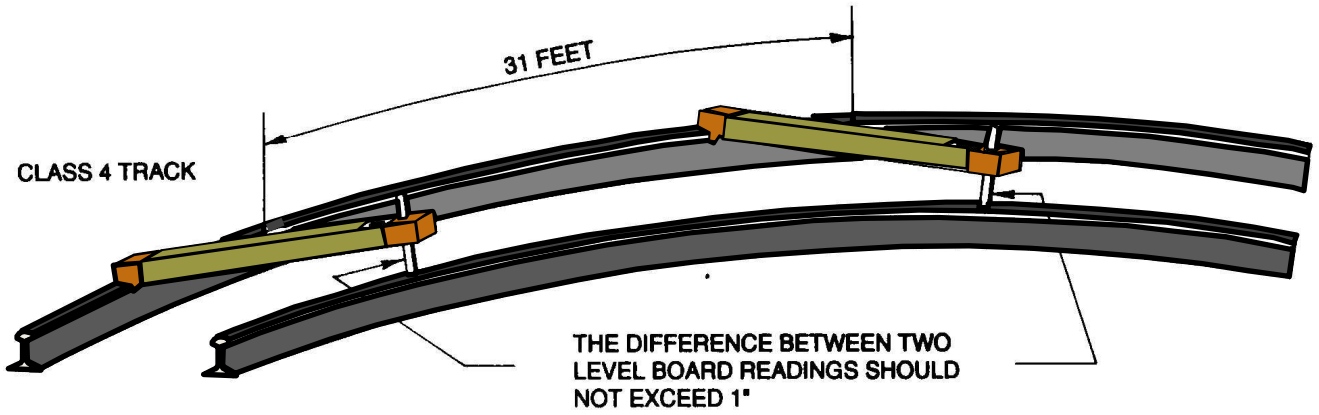
(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero crosslevel at any point on tangent or reverse crosslevel elevation on curves may not be more than	3	2	1 3/4	1 1/4	1
The difference in crosslevel between any two points less than 62 feet apart may not be more than* [1] [2]	3	2 1/4	2	1 3/4	1 1/2
*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

[1]Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 11/2 inches.

[2]However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 11/4 inches in all of six consecutive pairs of joints, as created by seven low joints. Track with joints staggered less than 10 feet apart shall not be considered as having staggered joints. Joints within the seven low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.

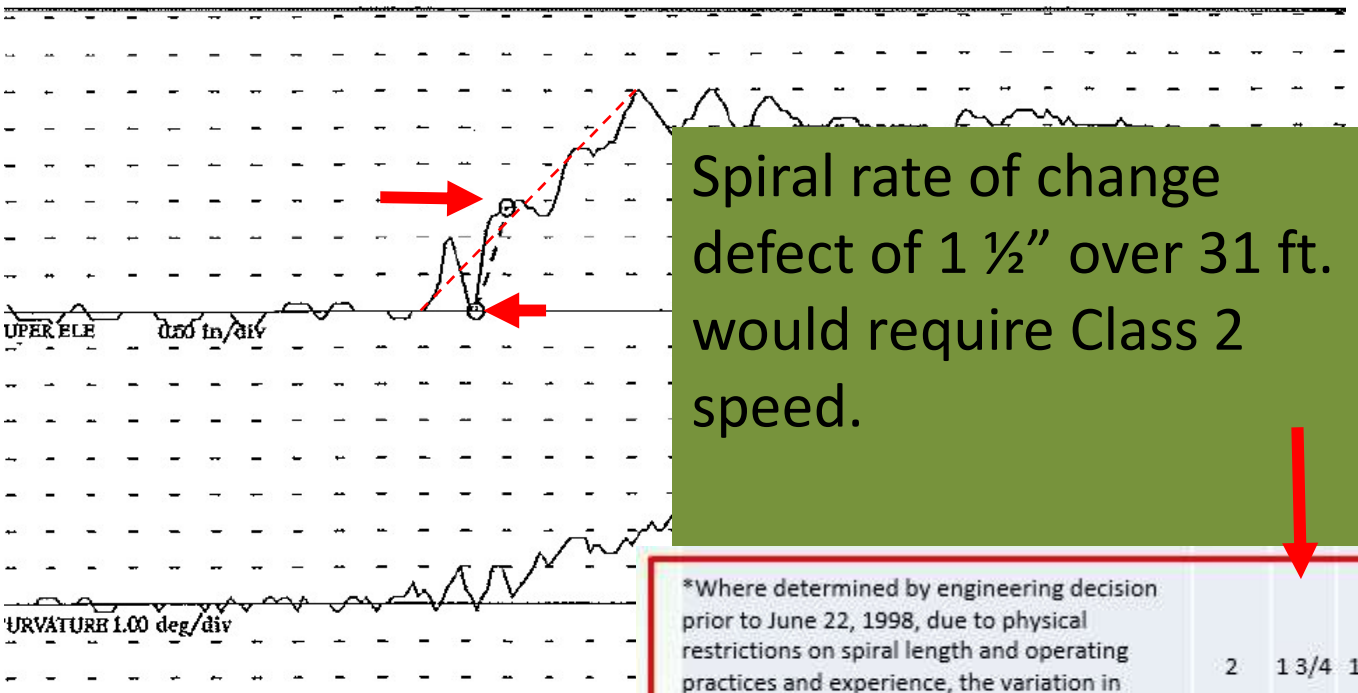
VARIATION IN CROSSLEVEL ON SPIRALS



	CLASS OF TRACK				
	1	2	3	4	5
VARIATION IN CROSSLEVEL ON SPIRALS IN ANY 31' MAY NOT BE ANY MORE THAN	2"	1 3/4"	1 1/4"	1"	3/4"

Class 5 Spiral - PTS to PSC

Station (31 ft.)	Design Elevation	Level Board Reading	Elevation Variation
1	0	0	None Exceed 3/4”
2	½”	3/8”	3/8”
3	1”	¾”	3/8”
4	1 ½”	1”	1/4”
5	2”	1 1/8”	1/8”
6	2 ½”	1 7/8”	3/4”



Spiral rate of change defect of 1 ½" over 31 ft. would require Class 2 speed.

*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

§ 213.63 Track surface.

(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

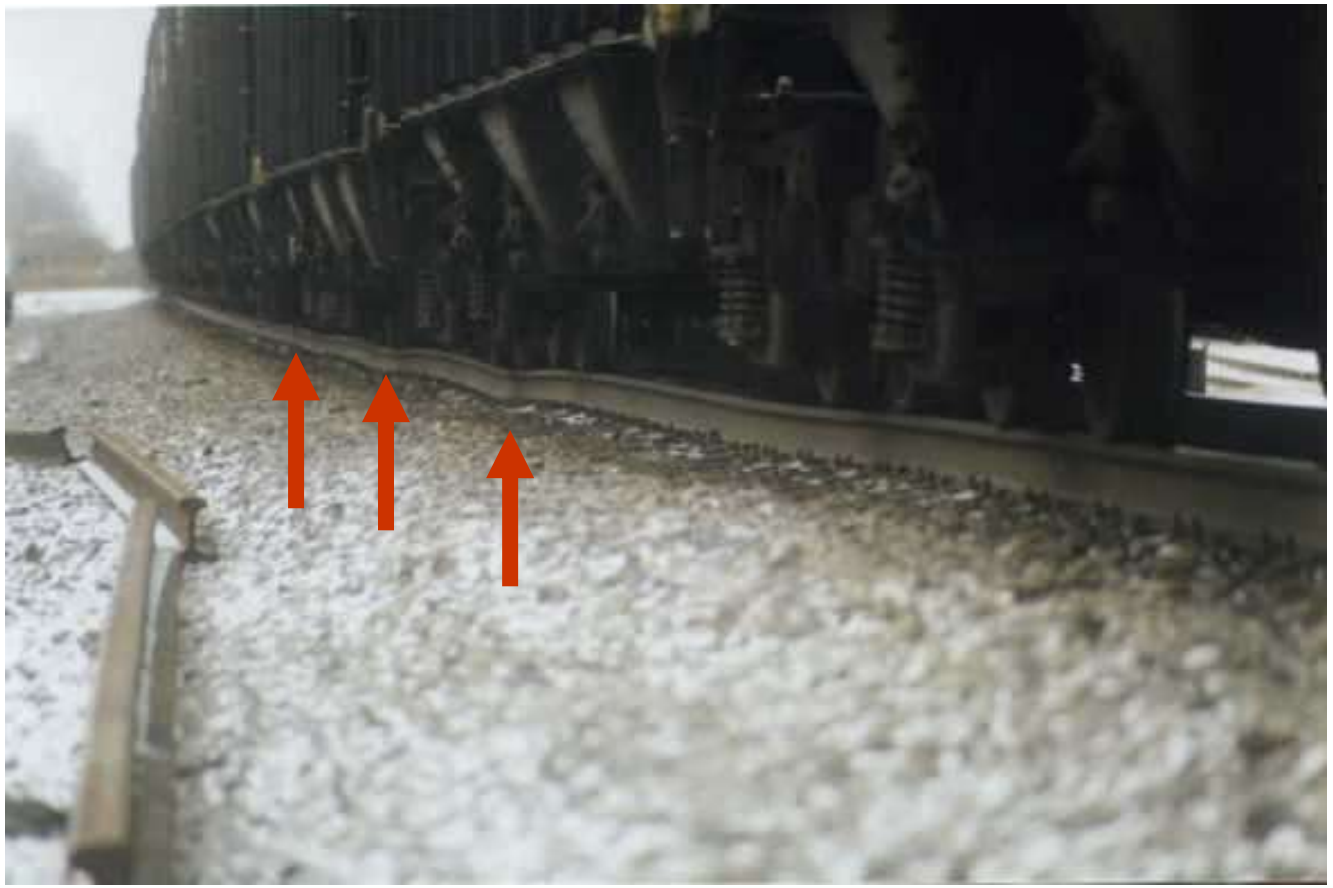
Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero crosslevel at any point on tangent or reverse crosslevel elevation on curves may not be more than	3	2	1 3/4	1 1/4	1
The difference in crosslevel between any two points less than 62 feet apart may not be more than* [1] [2]	3	2 1/4	2	1 3/4	1 1/2
*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

[1]Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 11/2 inches.

[2]However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 11/4 inches in all of six consecutive pairs of joints, as created by seven low joints. Track with joints staggered less than 10 feet apart shall not be considered as having staggered joints. Joints within the seven low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.

Vertical Profile Deviations

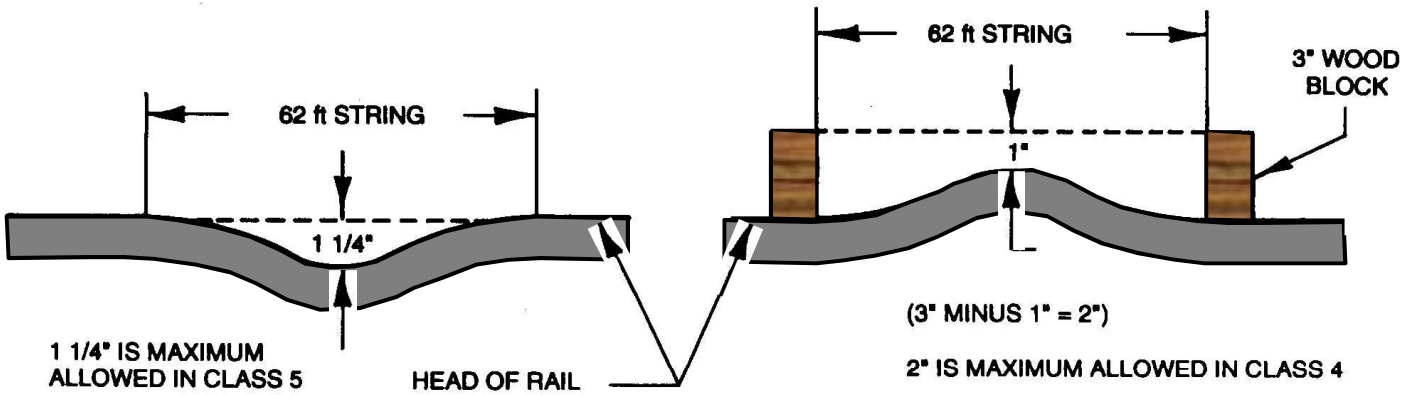
Vertical Bounce Derailments are most often due to combinations of vertical track profile variations acting in concert with vehicles possessing poor vertical damping characteristics



Vertical profile deviation caused by poor subgrade

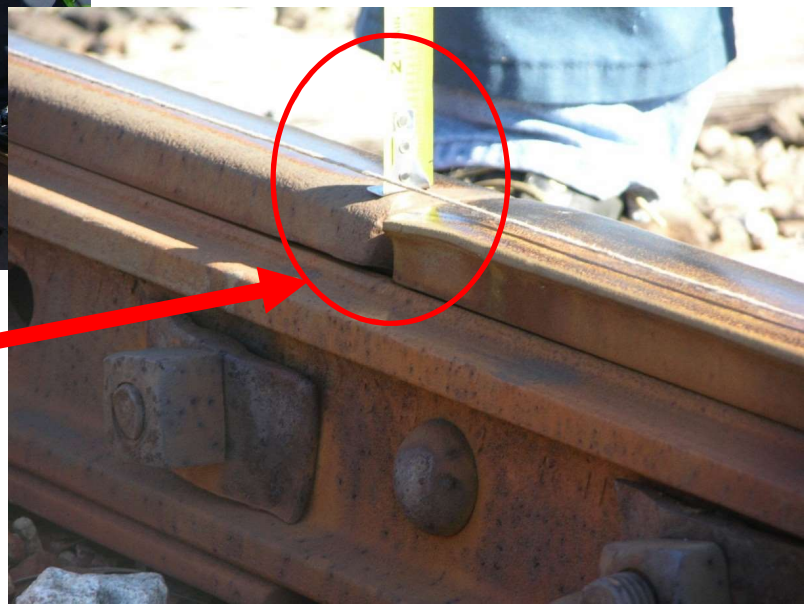
Stretch 62 ft. chord/string; measure vertical offset at center of chord

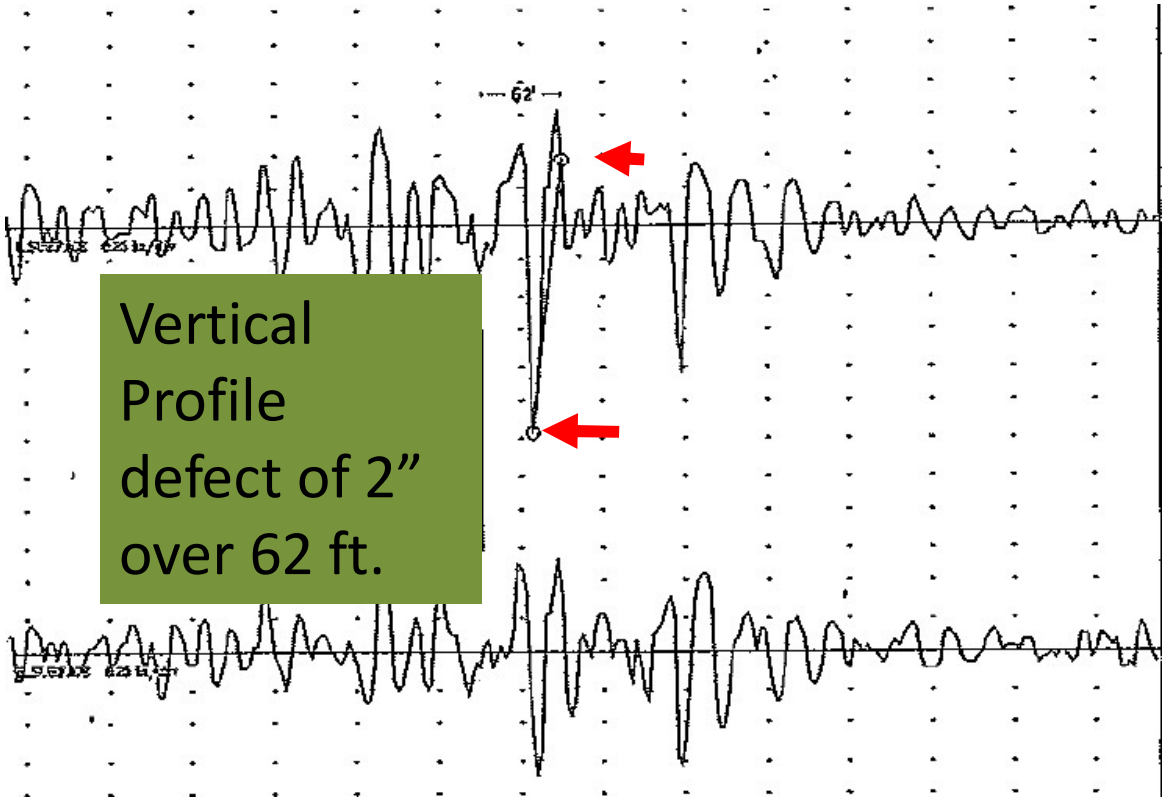
DEVIATION FROM UNIFORM PROFILE



	CLASS OF TRACK				
	1	2	3	4	5
THE DEVIATION FROM UNIFORM PROFILE ON EITHER RAIL AT THE MID-ORDINATE OF A 62' CHORD MAY NOT BE MORE THAN	3"	2 3/4"	2 1/4"	2"	1 1/4"

Checking Vertical Profile with 62’ Chord




62'
Vertical Profile defect of 2" over 62 ft.

§ 213.63 Track surface.

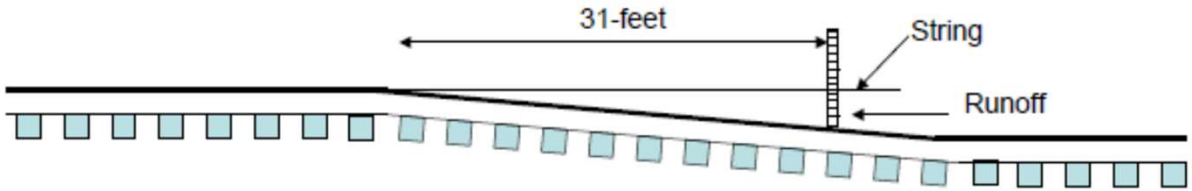
(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero crosslevel at any point on tangent or reverse crosslevel elevation on curves may not be more than	3	2	1 3/4	1 1/4	1
The difference in crosslevel between any two points less than 62 feet apart may not be more than* [1] [2]	3	2 1/4	2	1 3/4	1 1/2
*Where determined by engineering decision prior to June 22, 1998, due to physical restrictions on spiral length and operating practices and experience, the variation in crosslevel on spirals per 31 feet may not be more than	2	1 3/4	1 1/4	1	3/4

[1]Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 11/2 inches.

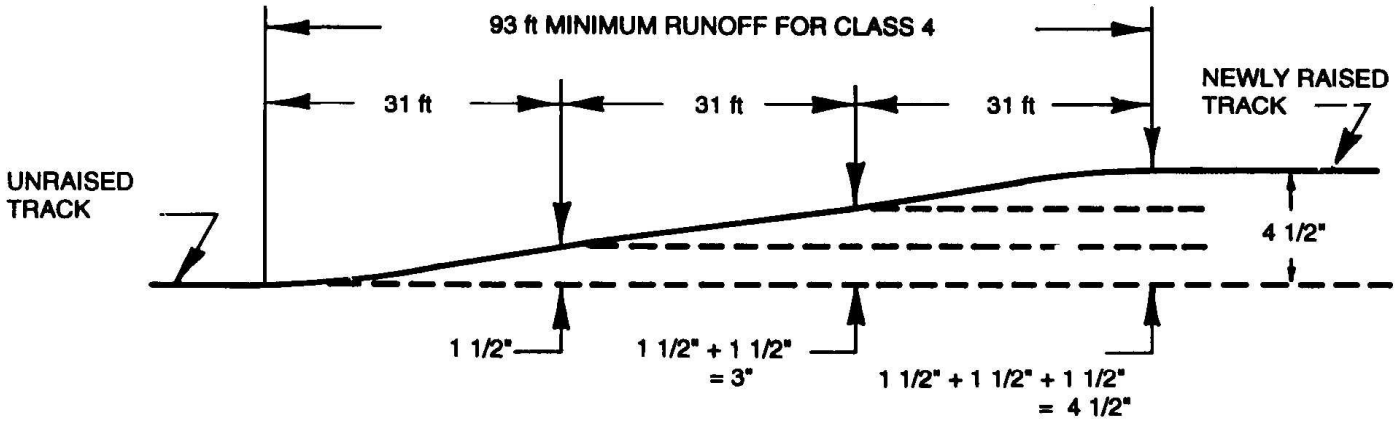
[2]However, to control harmonics on Class 2 through 5 jointed track with staggered joints, the crosslevel differences shall not exceed 11/4 inches in all of six consecutive pairs of joints, as created by seven low joints. Track with joints staggered less than 10 feet apart shall not be considered as having staggered joints. Joints within the seven low joints outside of the regular joint spacing shall not be considered as joints for purposes of this footnote.

Frost Heaves causing a raise in the track due to track degradation



Rate of Runoff over 31 feet

YOU NEED A 4 1/2" RUNOFF FROM A RAISE



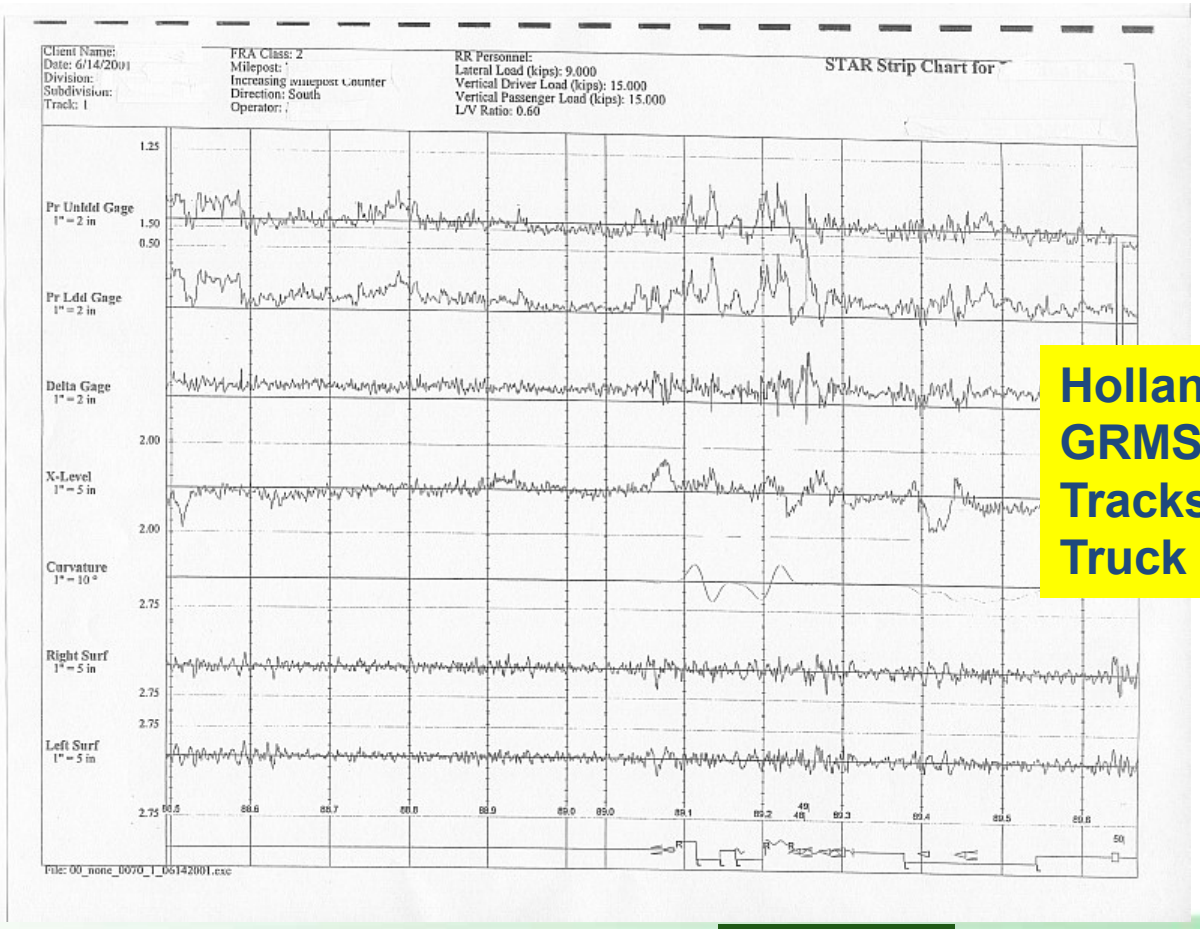
	CLASS OF TRACK				
	1	2	3	4	5
THE RUNOFF IN ANY 31' OF TRACK AT THE END OF A RAISE MAY BE NO MORE THAN	3 1/2"	3"	2"	1 1/2"	1"

Multiple Defects in Succession

§ 213.1 Scope of part.

(a) This part prescribes minimum safety requirements for railroad track that is part of the general railroad system of transportation. The requirements prescribed in this part apply to specific track conditions existing in isolation. Therefore, a combination of track conditions, none of which individually amounts to a deviation from the requirements in this part, may require remedial action to provide for safe operations over that track. This part does not restrict a railroad from adopting and enforcing additional or more stringent requirements not inconsistent with this part.

Track Geometry Recording Cars TGC



Holland GRMS Trackstar Truck


The End