

Principles of Track Geometry

Presented by:

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Individual Geometry

Topics

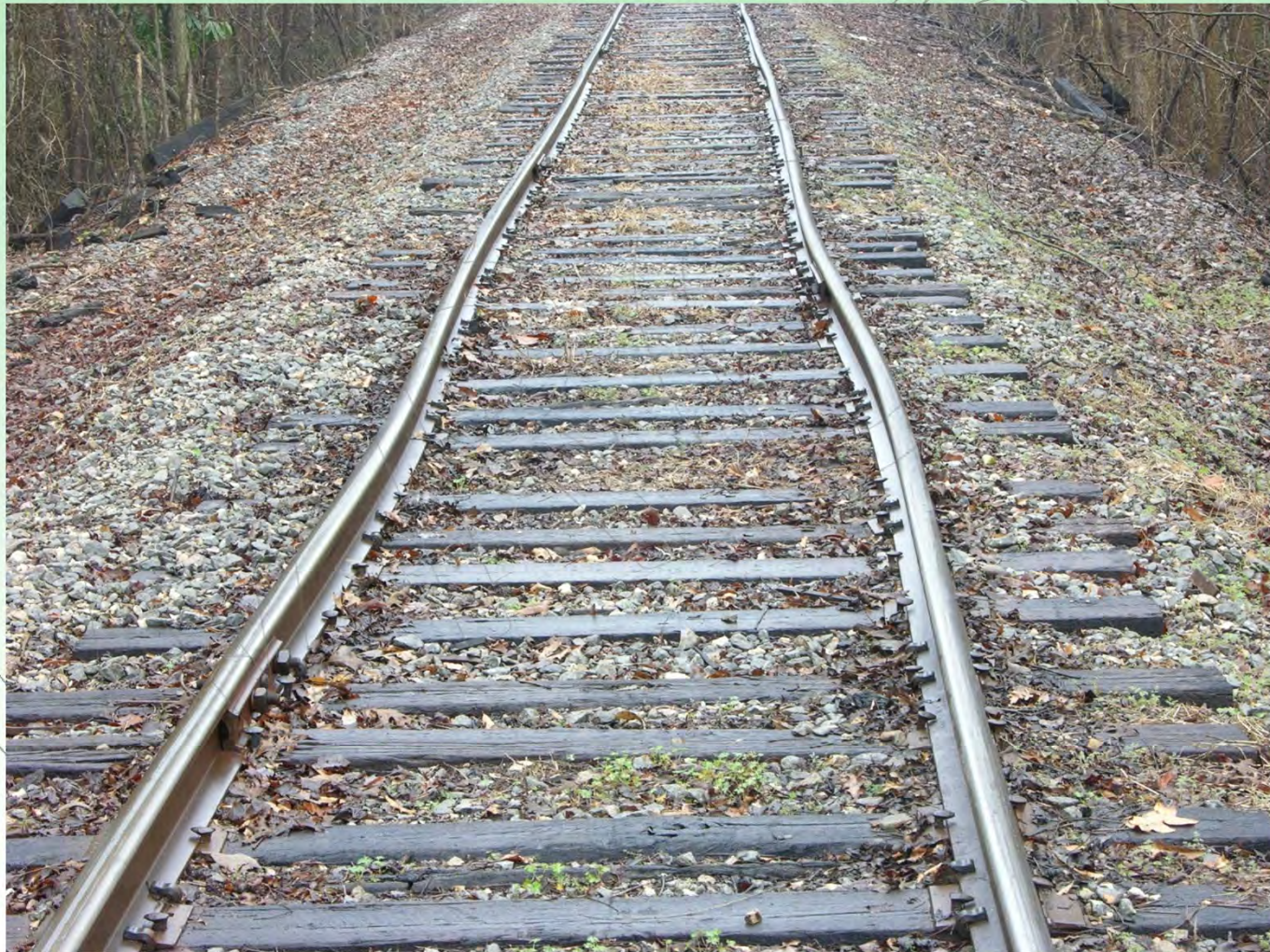
- Gage
- Curves and Curve Alignment
- Superelevation
- Crosslevel Variance and Deviation
- Vertical Profile
- Runoff from a raise



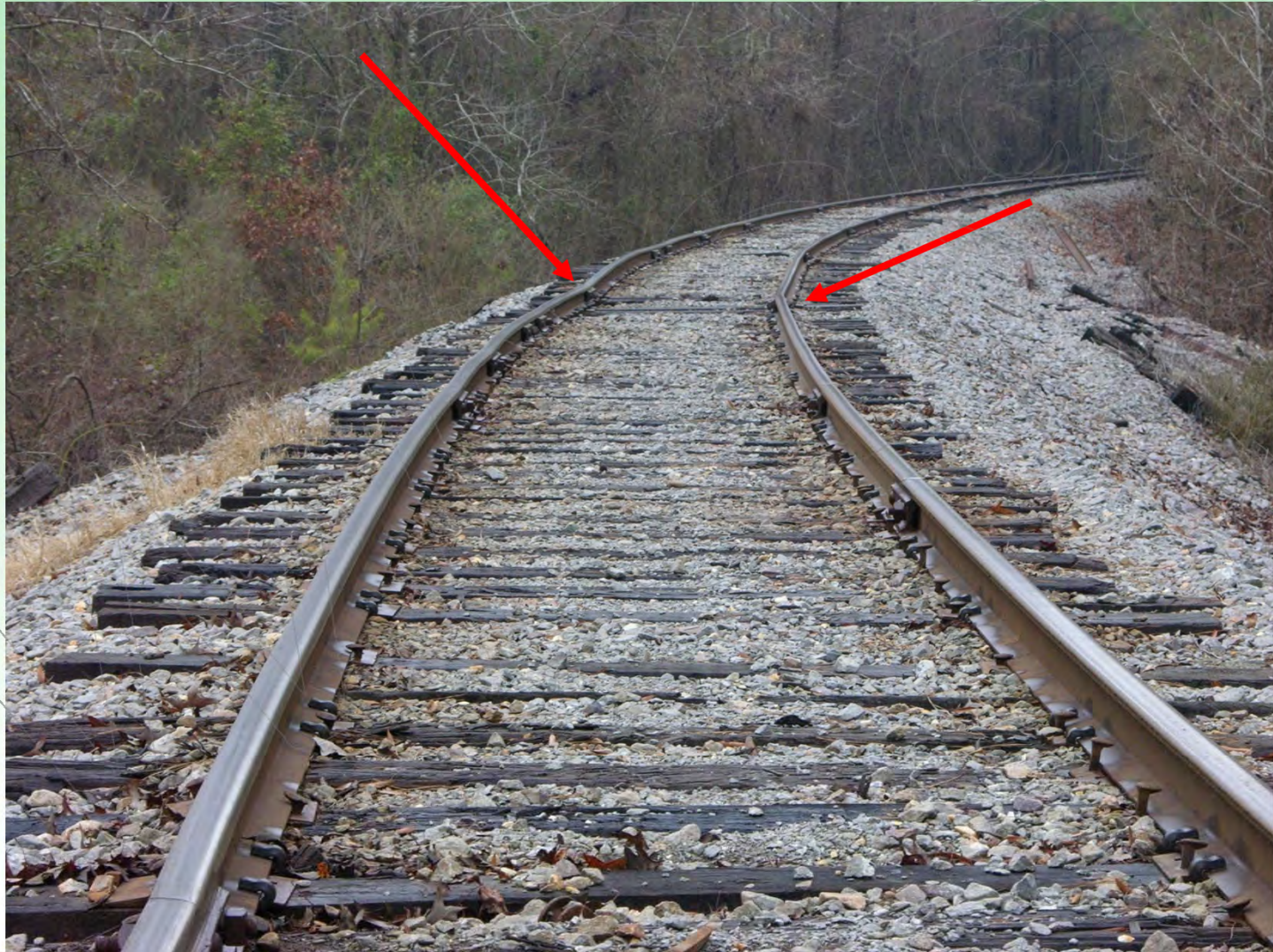
Gage, Alignment, Profile, and Crosslevel Variations



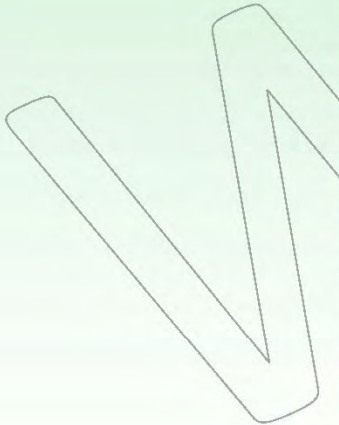
Gage and Alignment Variations



Crosslevel and Alignment Variations

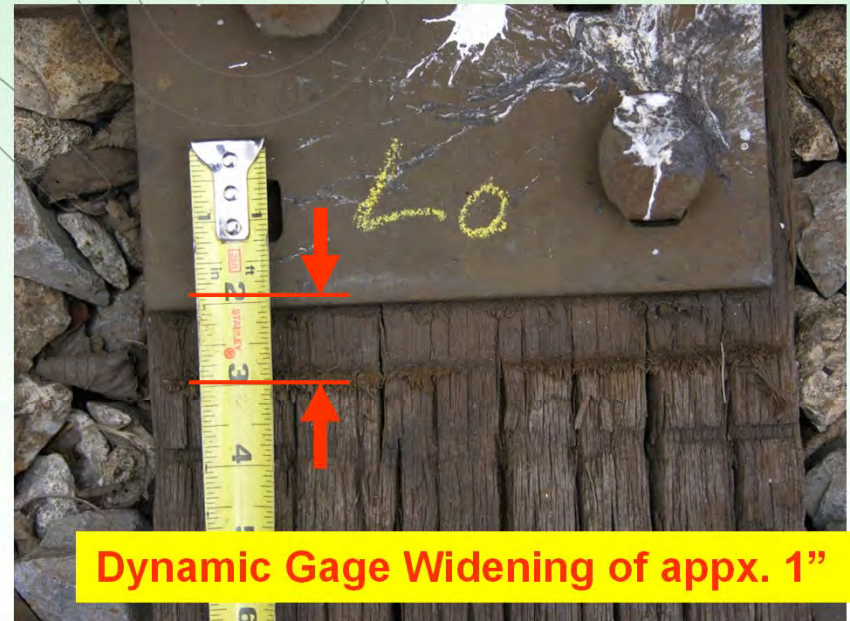
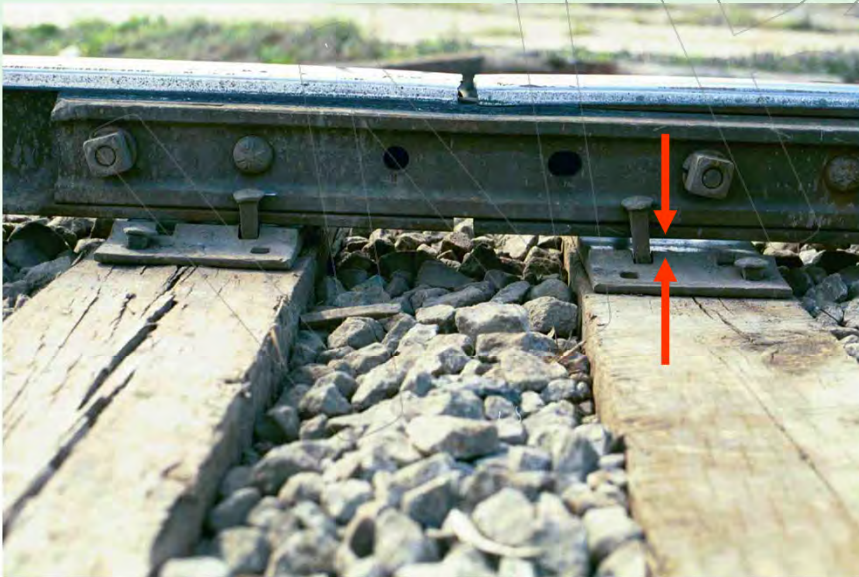


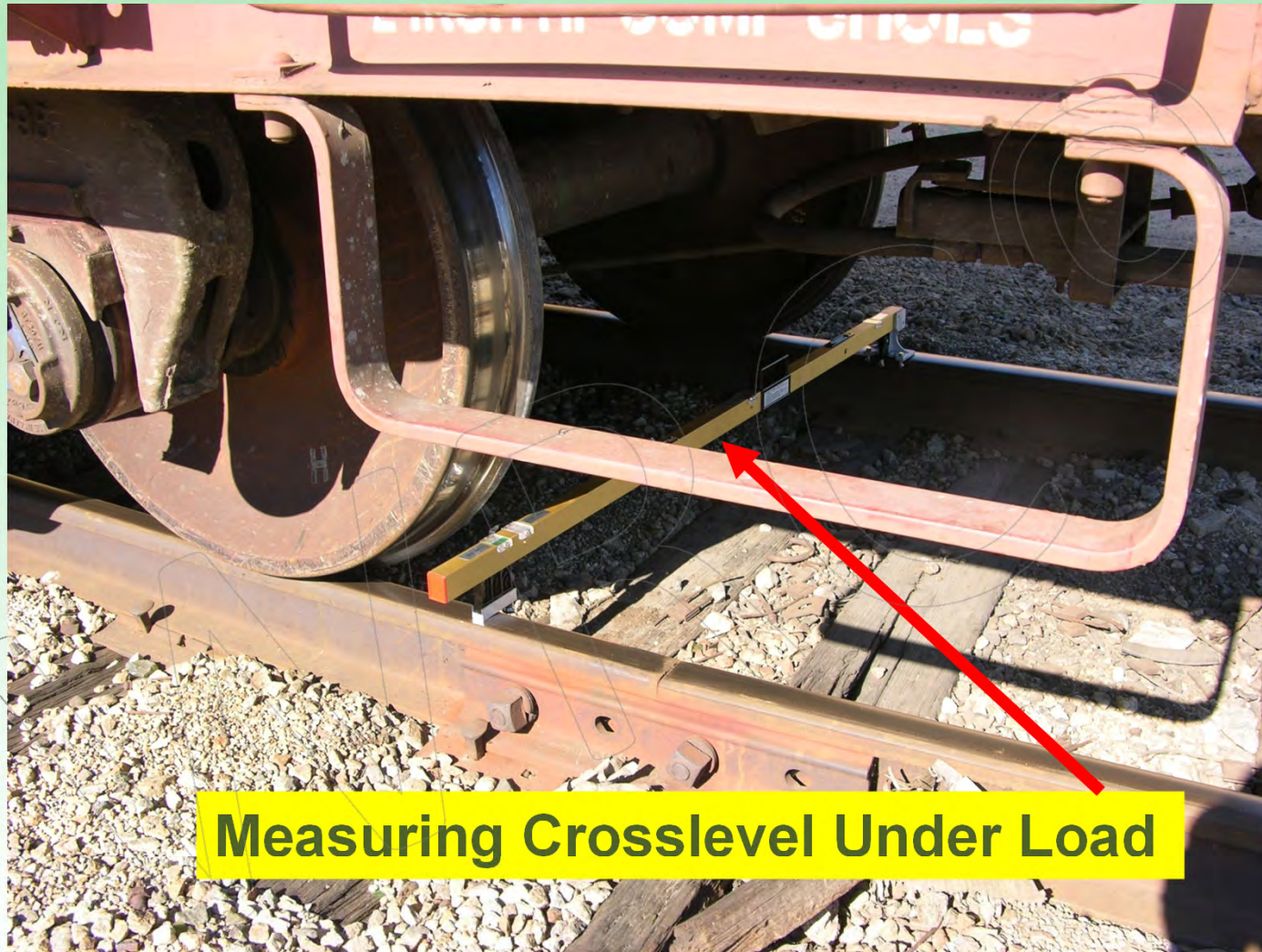
Surface and Profile Deviations



§ 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.





For North American Freight Operations

CLASSES OF TRACK

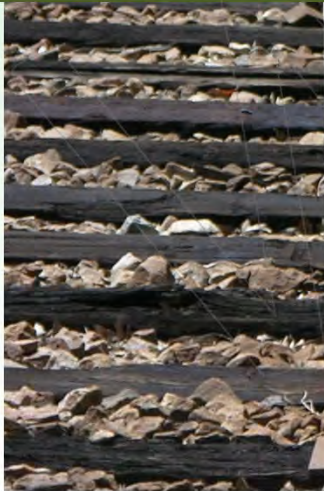
CLASS	OPERATING SPEEDS (MPH)			
	1. FREIGHT		2. PASSENGER	
	FROM	TO	FROM	TO
1	1	10	1	15
2	11	25	16	30
3	26	40	31	60
4	41	60	61	80
5	61	80	81	90



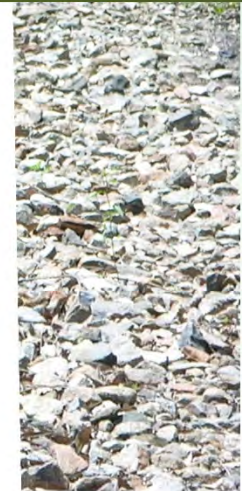


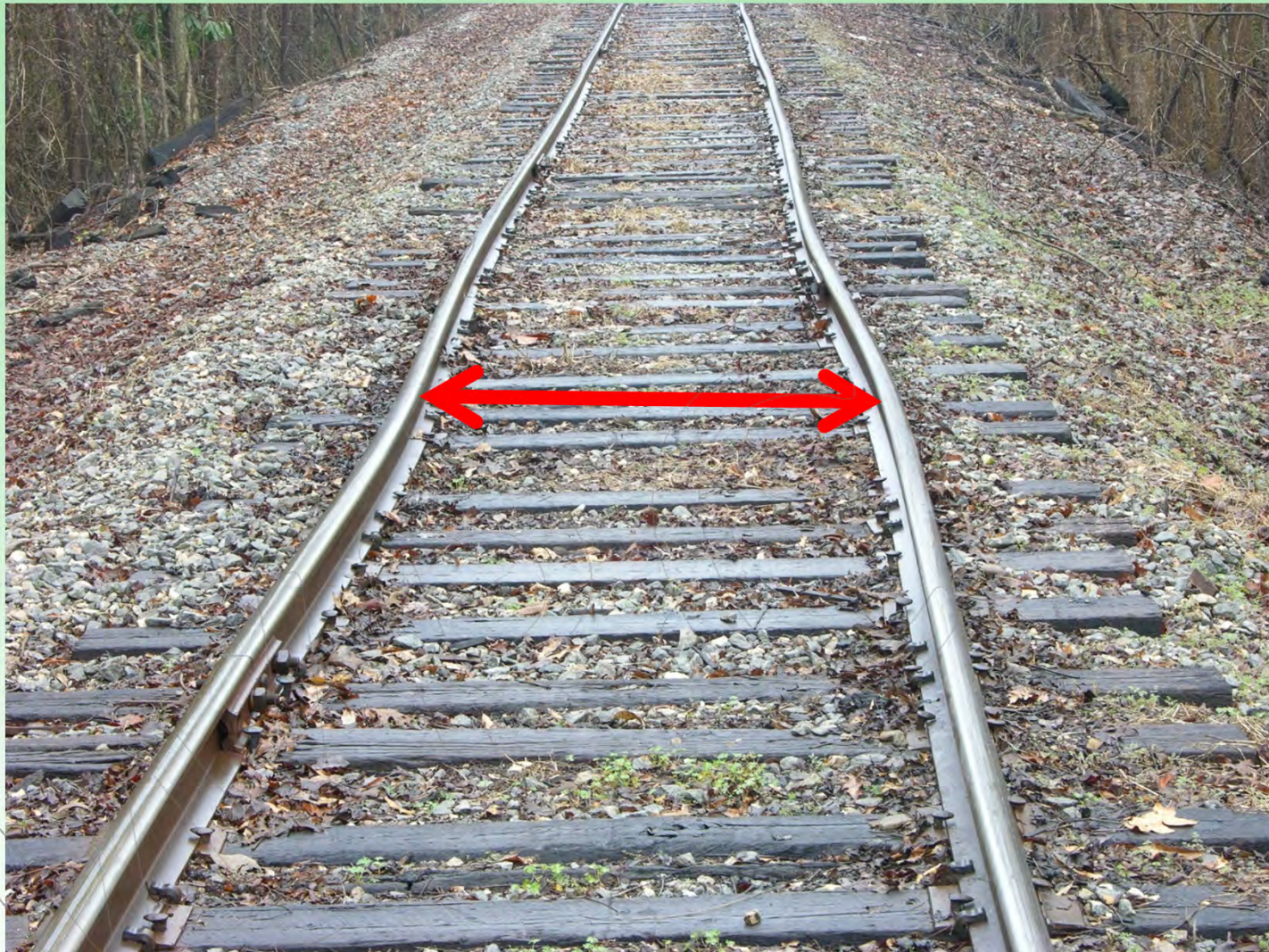
§ 213.53 Gage.

- (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—



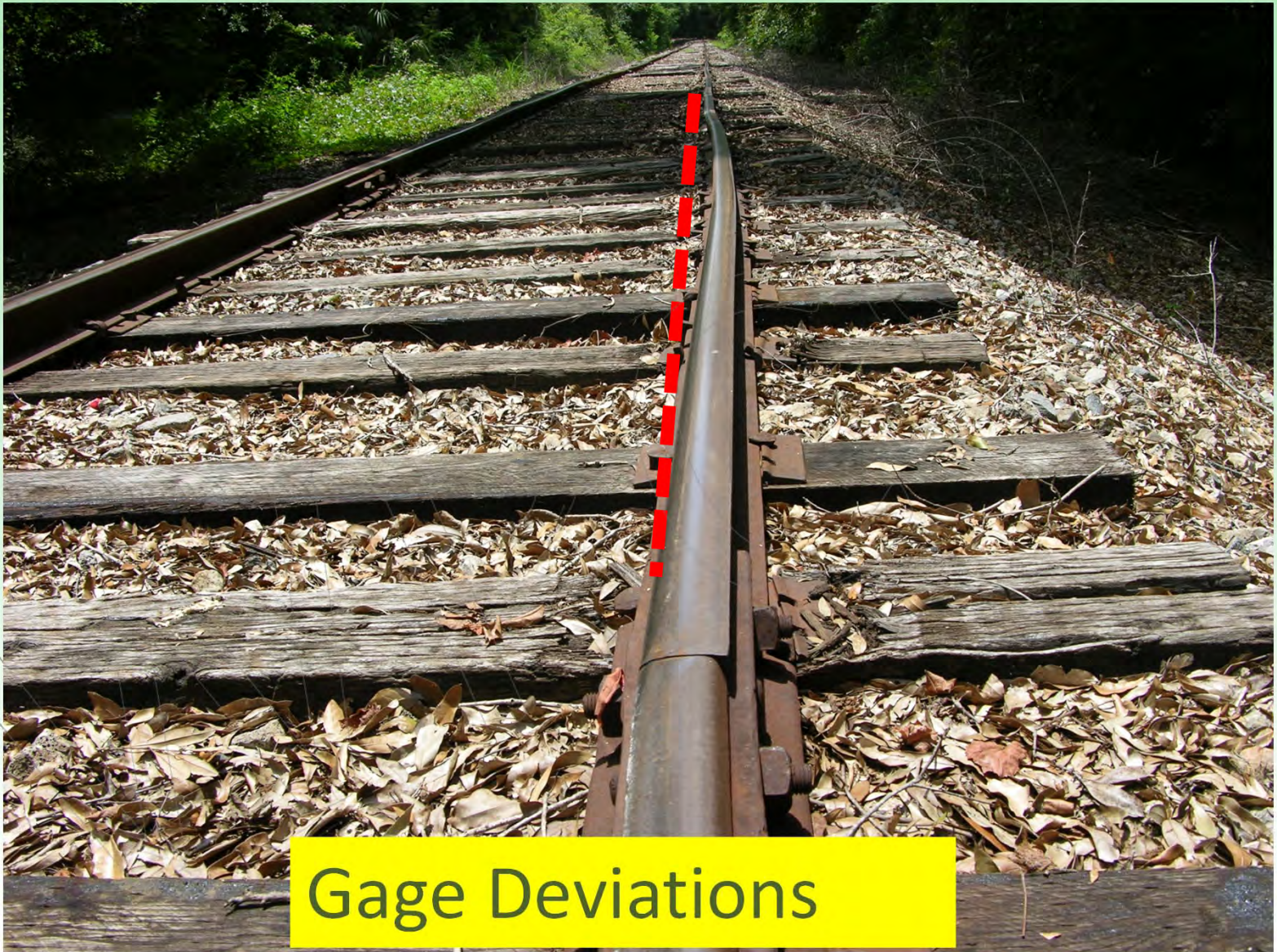
Class of track	The gage must be at least—	But not more than—
Excepted track.	N/A	4'10 ¹ / ₄ "
Class 1 track	4'8"	4'10"
Class 2 and 3 track	4'8"	4'9 ³ / ₄ "
Class 4 and 5 track	4'8"	4'9 ¹ / ₂ "





Gage Deviations

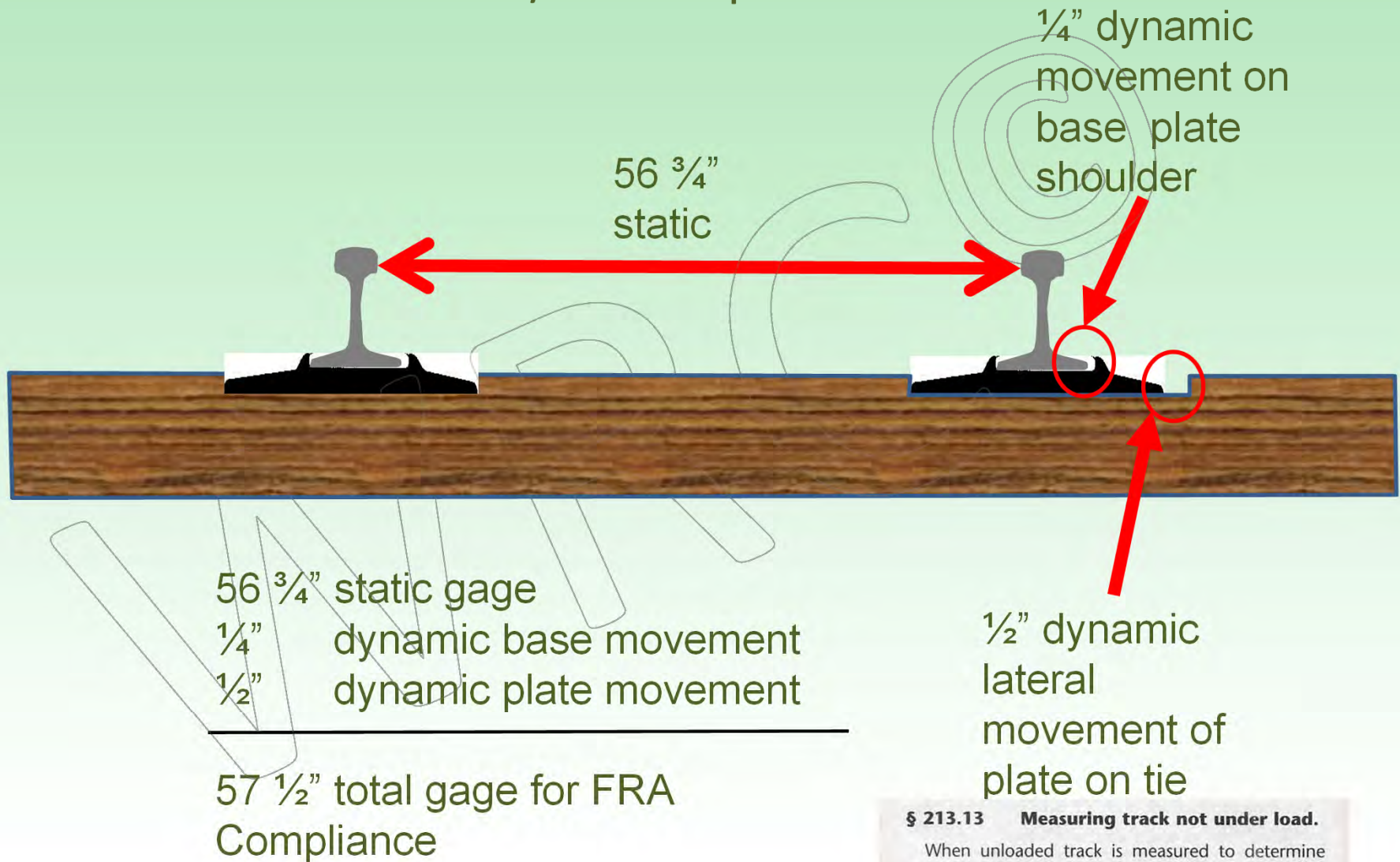




Gage Deviations



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



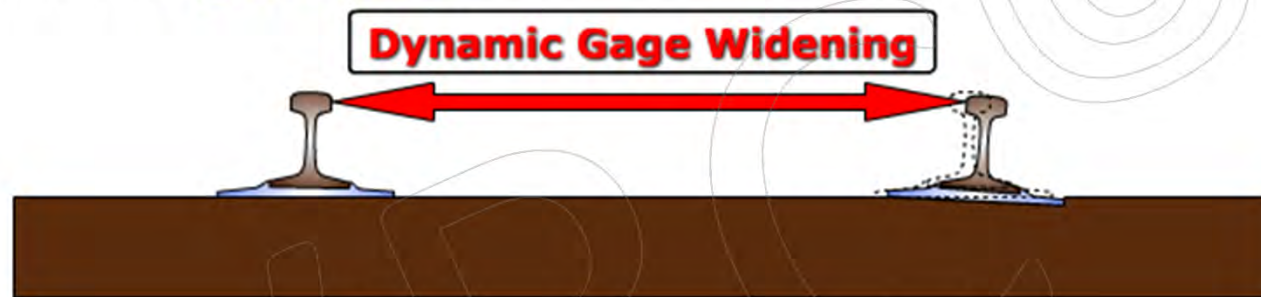
§ 213.13 Measuring track not under load.

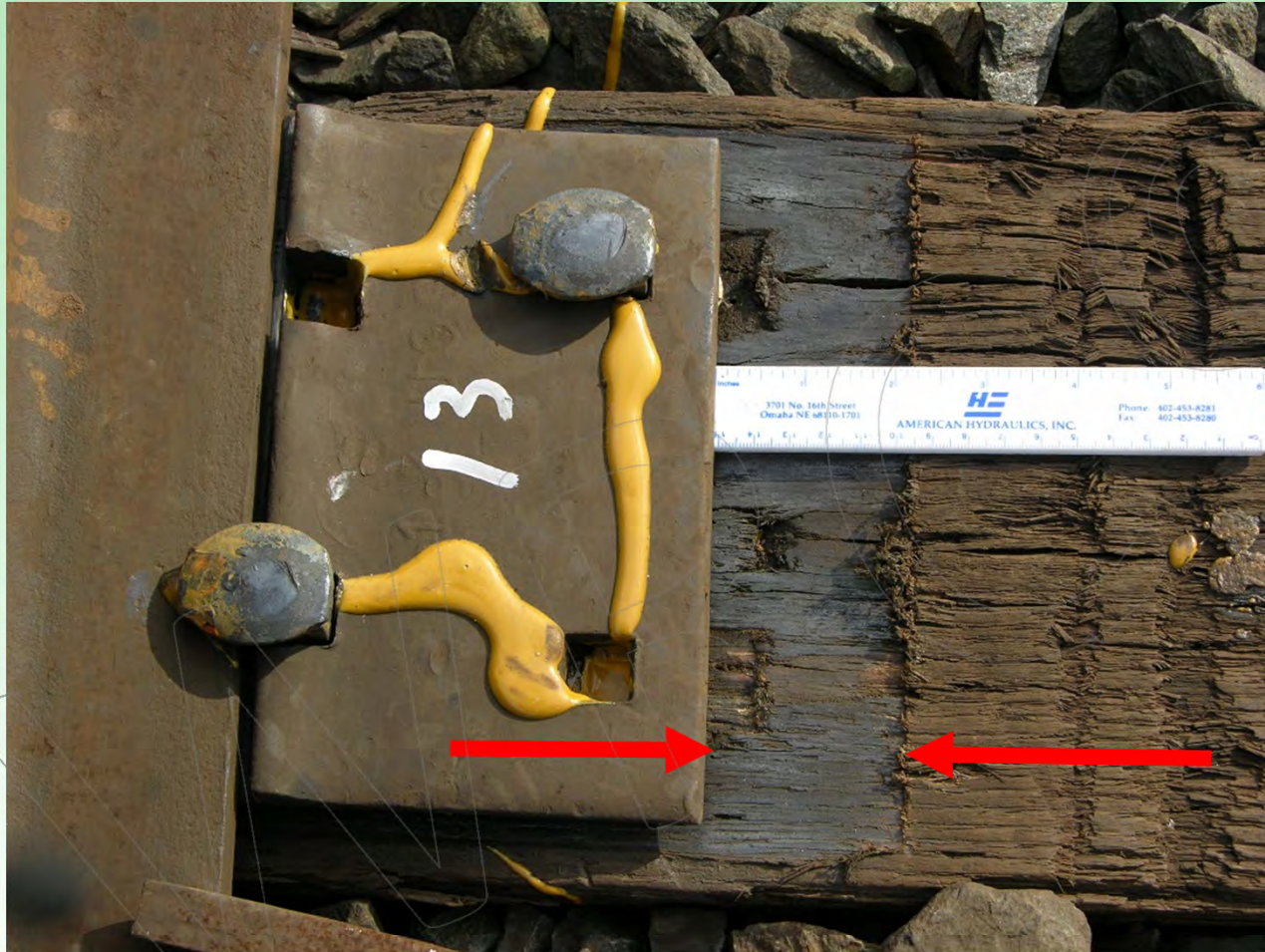
When unloaded track is measured to determine compliance with requirements of this part, the amount of rail movement, if any, that occurs while the track is loaded must be added to the measurements of the unloaded track.



Subpart C - Track Geometry §213.53 Gage

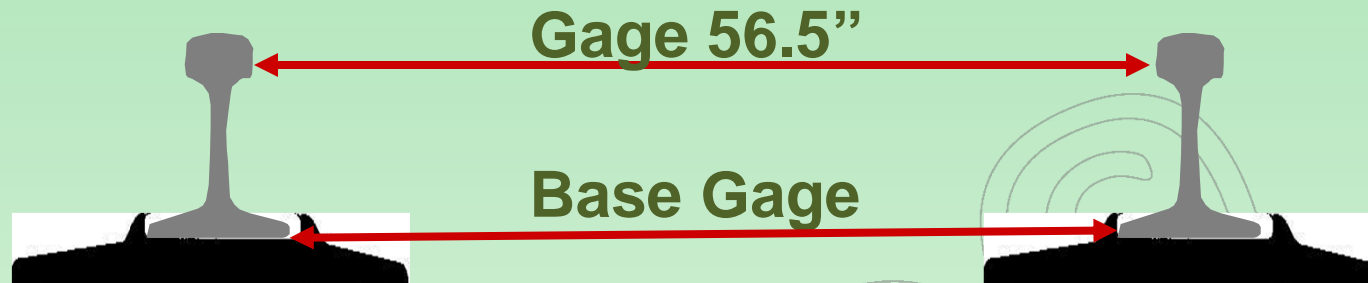
Remember to look for evidence of lateral rail movement as required in §213.13.





Dynamic Gage Widening



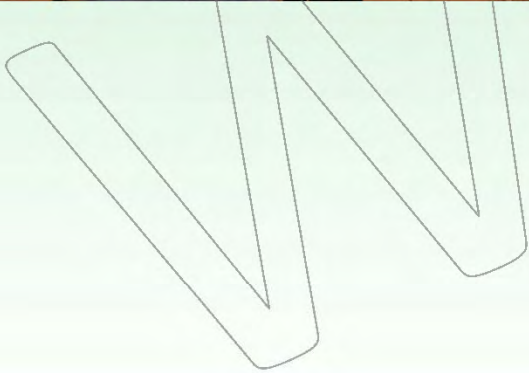


Rail Wt.	Base Gage Decimal(in.)	Base Gage Fraction(in.)
100	54.16	54 5/32
115	53.96	53 31/32
119	53.91	53 29/32
132	53.77	53 3/4
133	53.69	53 11/16
136	53.72	53 23/32
141	53.72	53 23/32





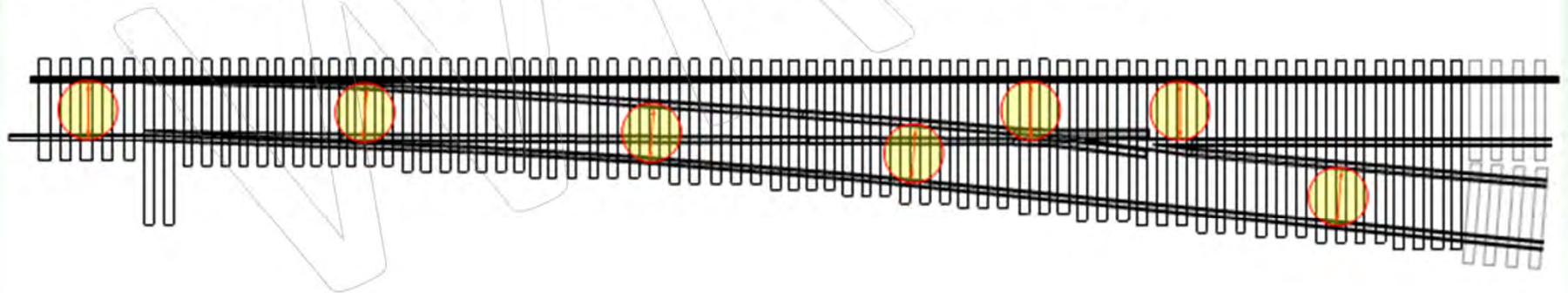
Measuring gage 5/8" below head
Of rail

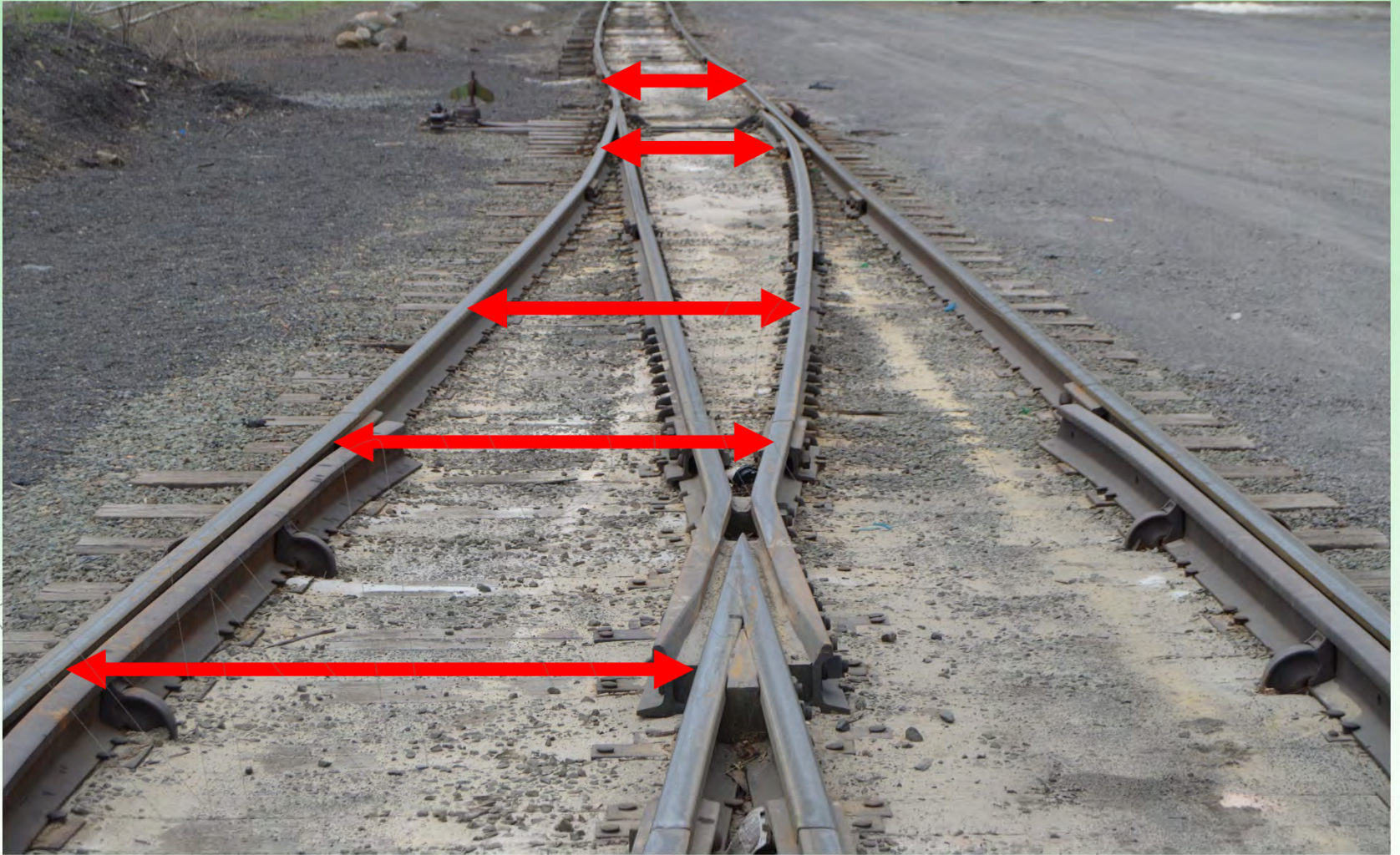


Subpart C - Track Geometry §213.53 Gage

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

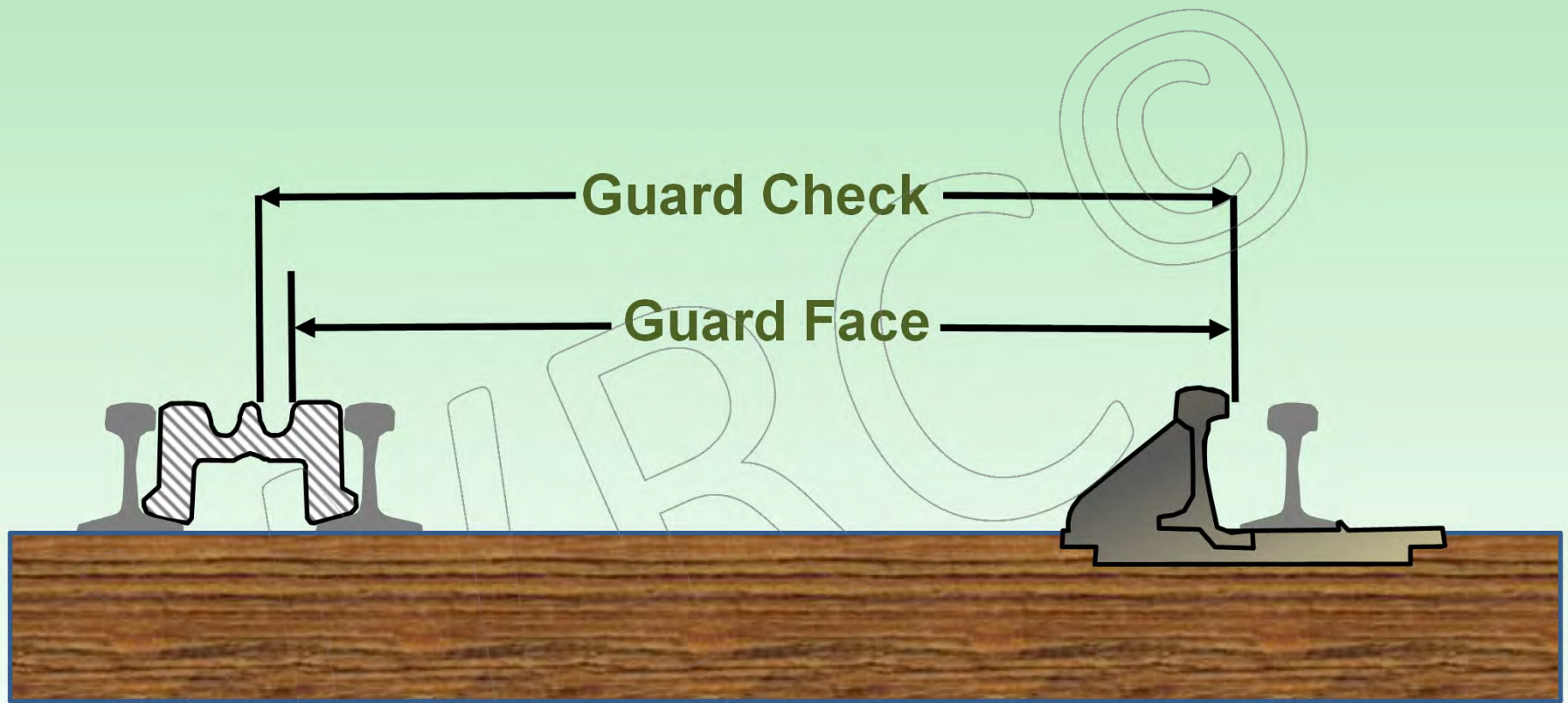
These areas include the curved closure rails, the toe and heel of frogs, the curved track behind the frog and several feet ahead of the switch points.





Checking Gage in a Turnout at Multiple locations



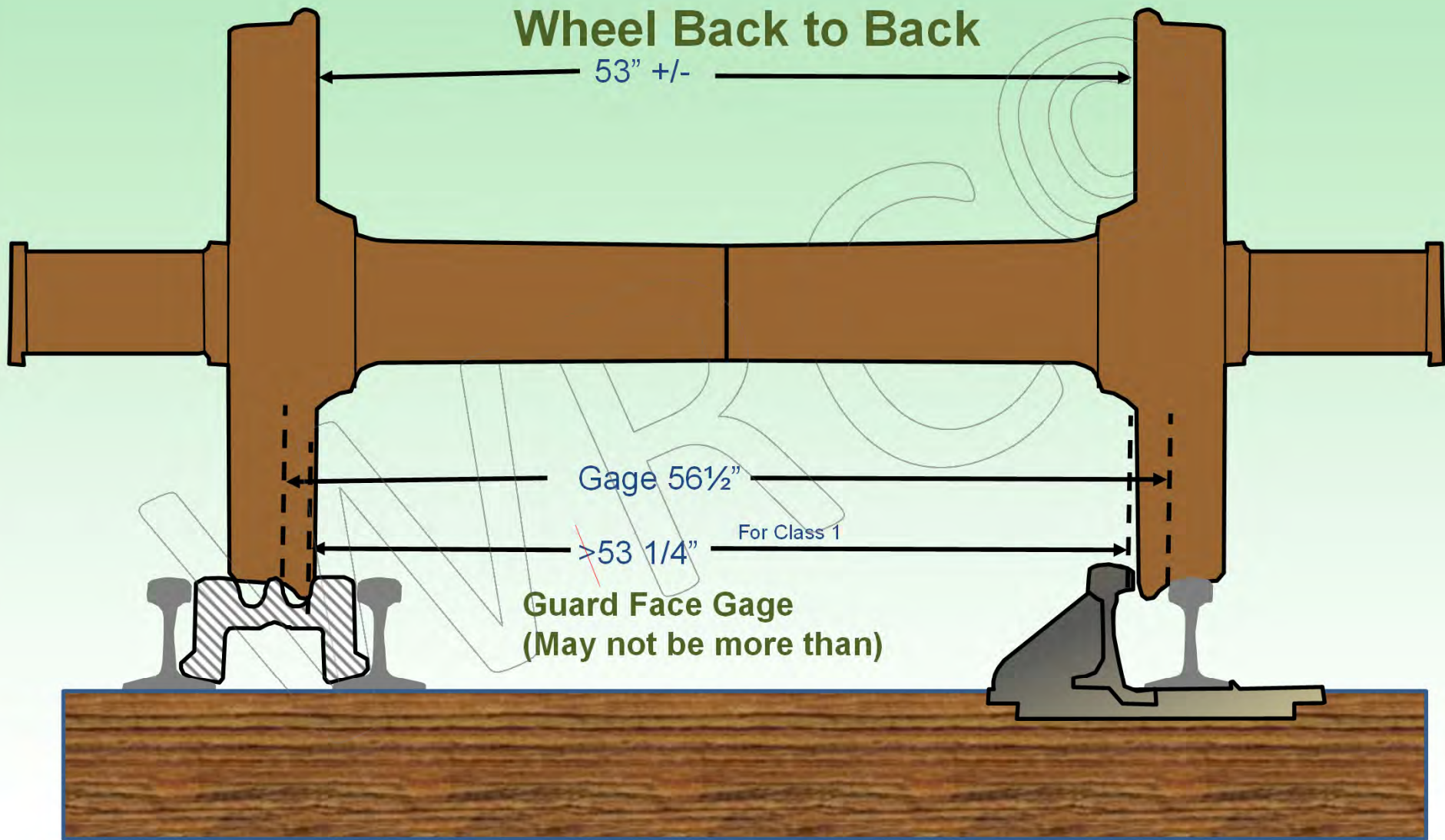


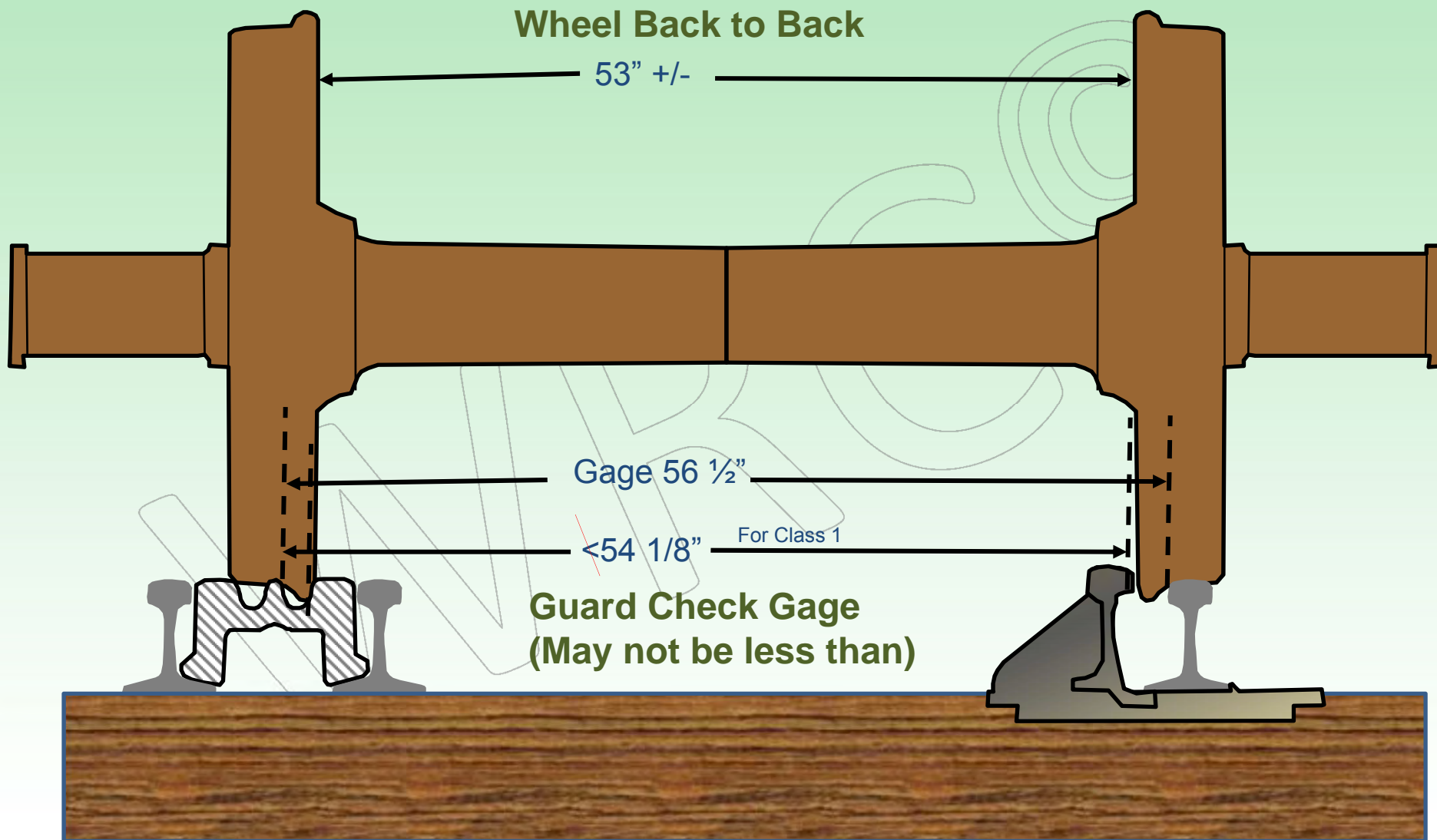
213.143 Guard Check and Face Gage

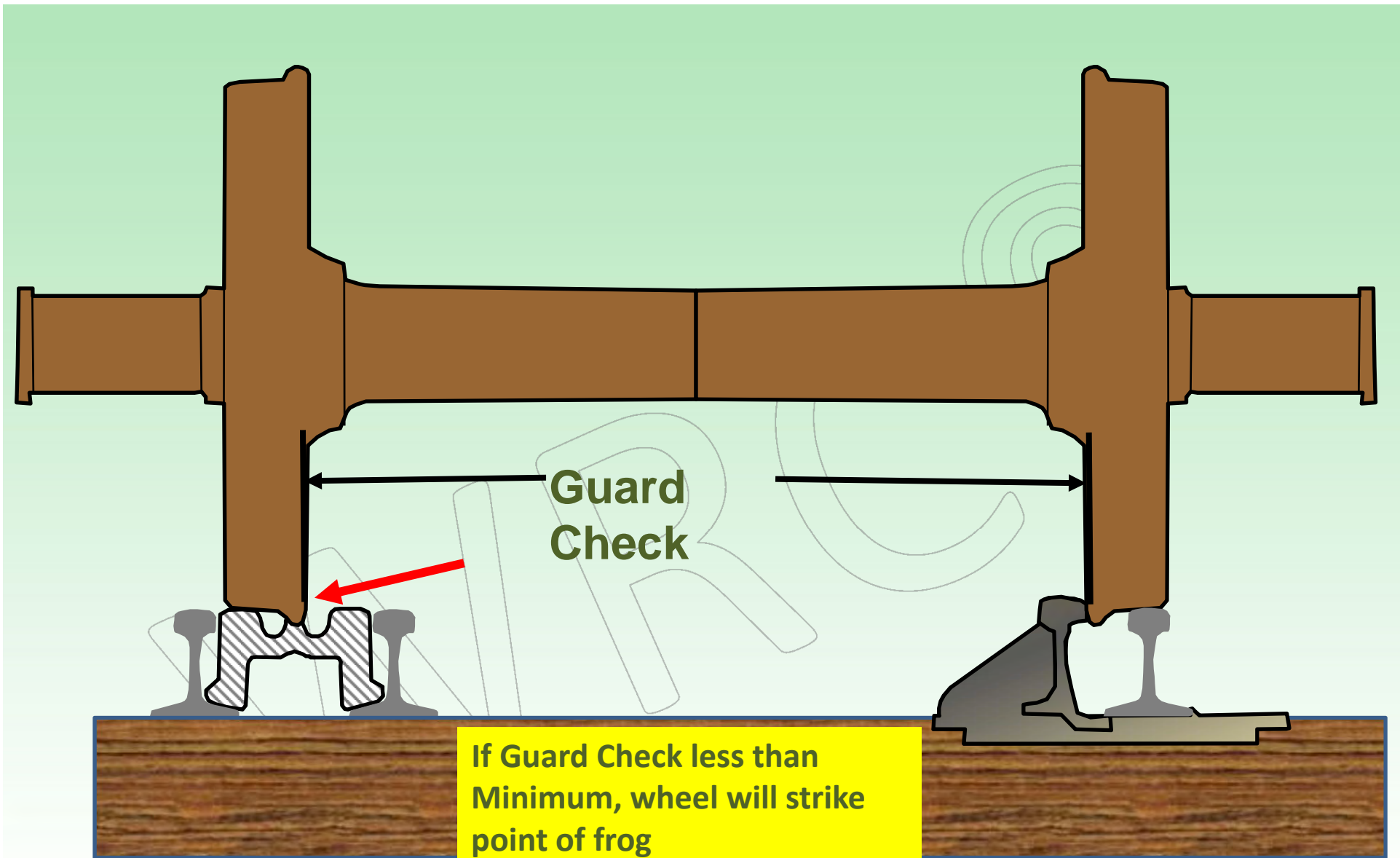
The guard check and guard face gages in frogs shall be within the limits prescribed by the following table

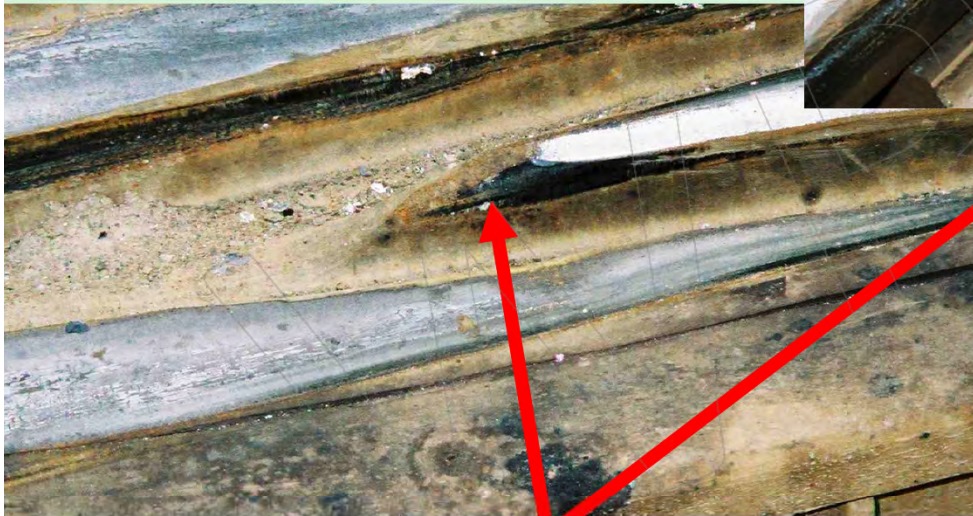
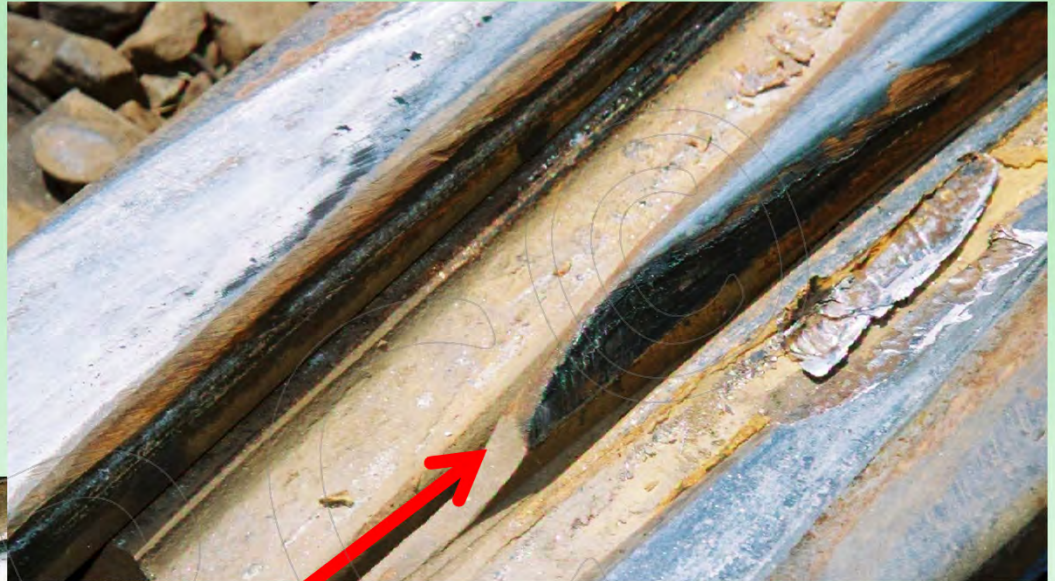
Class of Track	Guard Check gage may not be less than	Guard Face gage may not be more than
Class 1	4' 6 1/8"	4' 5 1/4"
Class 2	4' 6 1/4"	4' 5 1/8"
Class 3 & 4	4' 6 3/8"	4' 5 1/8"
Class 5	4' 6 1/2"	4' 5"





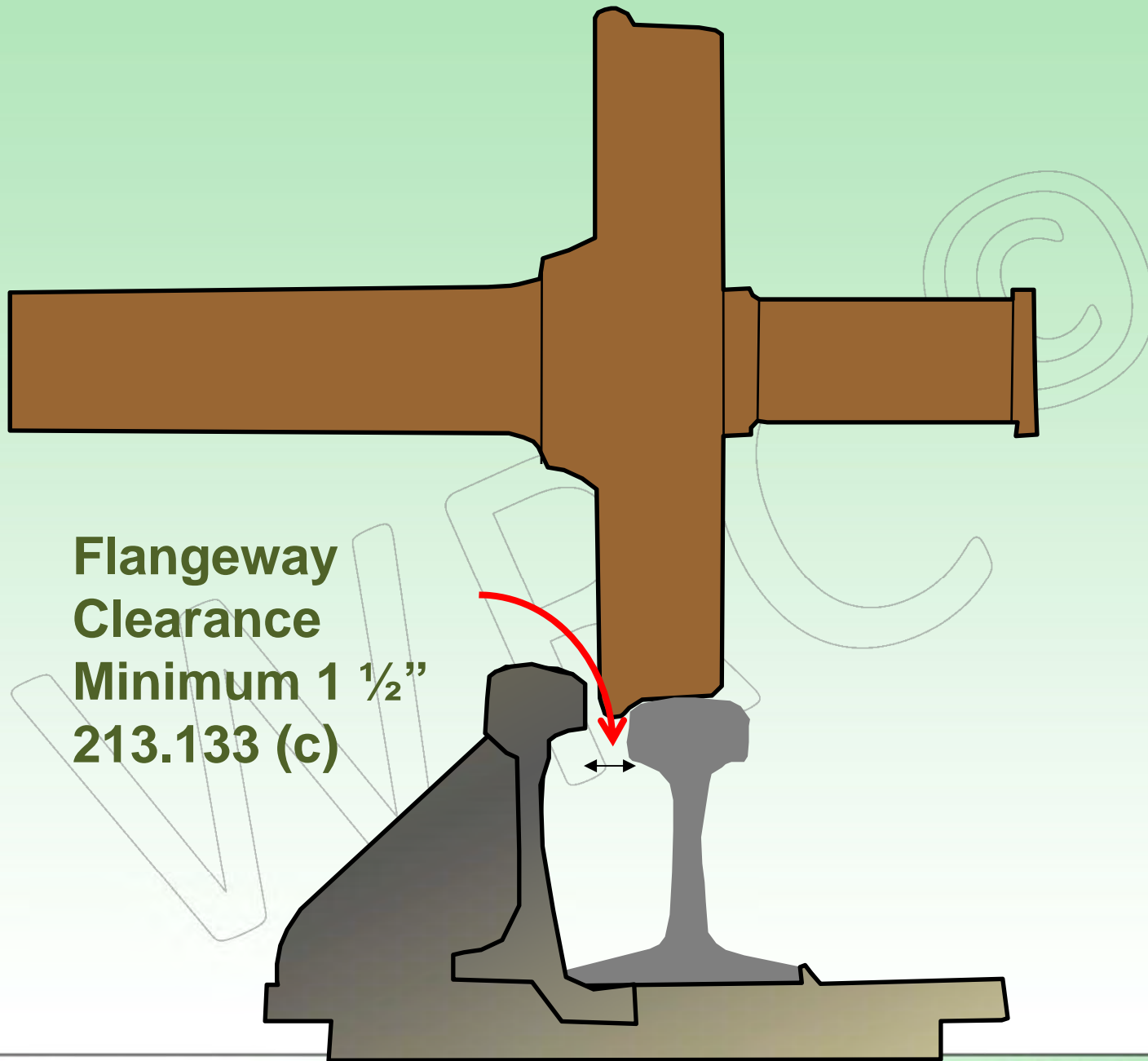






**Wheel Striking point of Frog;
Guard check less than minimum**





**Flangeway
Clearance
Minimum 1 1/2"
213.133 (c)**



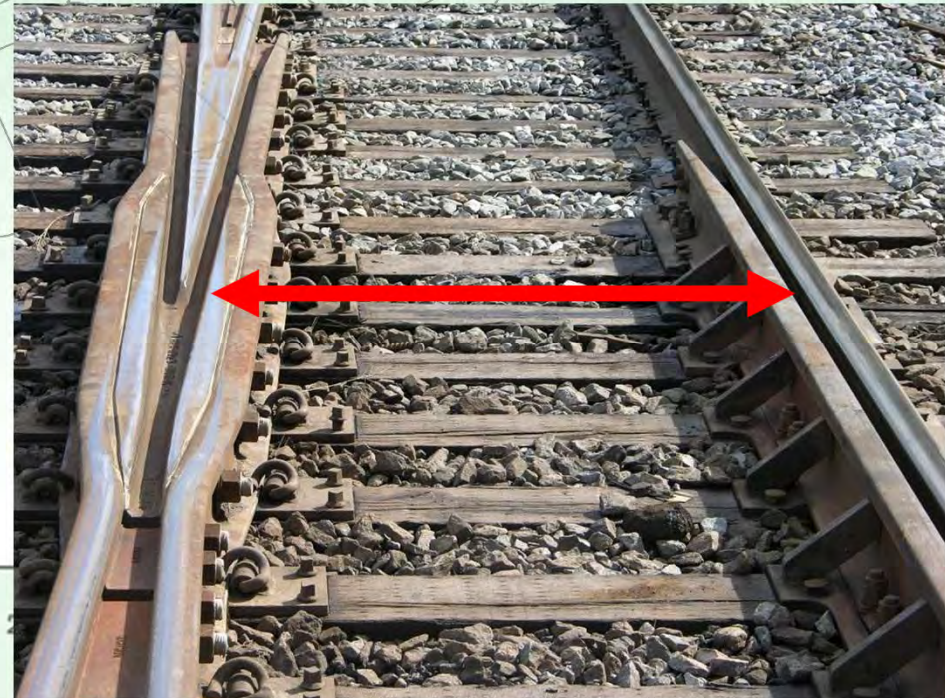
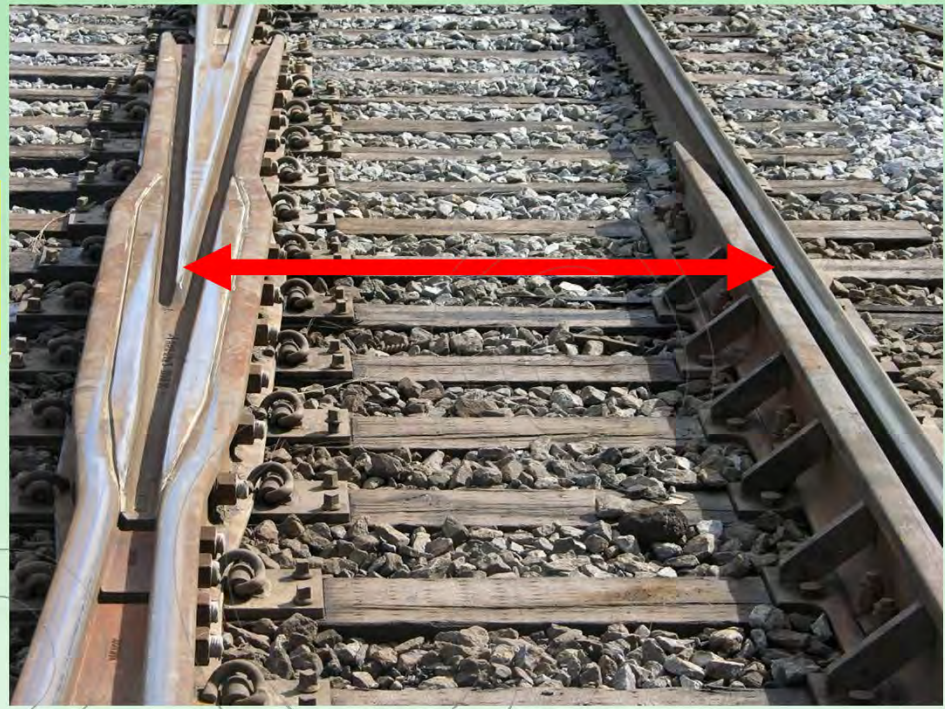
Class 5 Track

**Guard Check- Gage
Line of frog to Guard Line**

Minimum = 54 1/2"

**Guard Face -
Distance
Between Wing
Rail and Guard
Line**

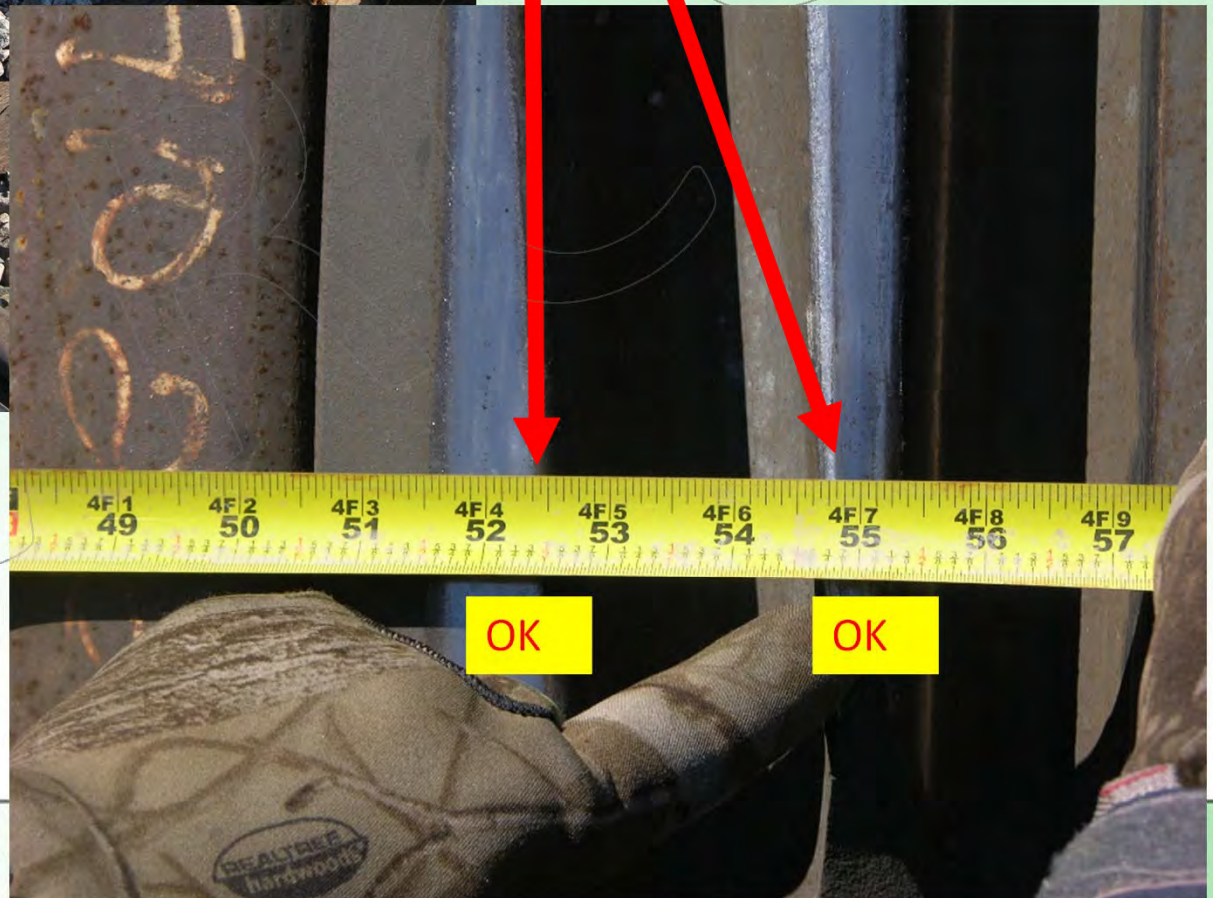
Maximum = 53 "

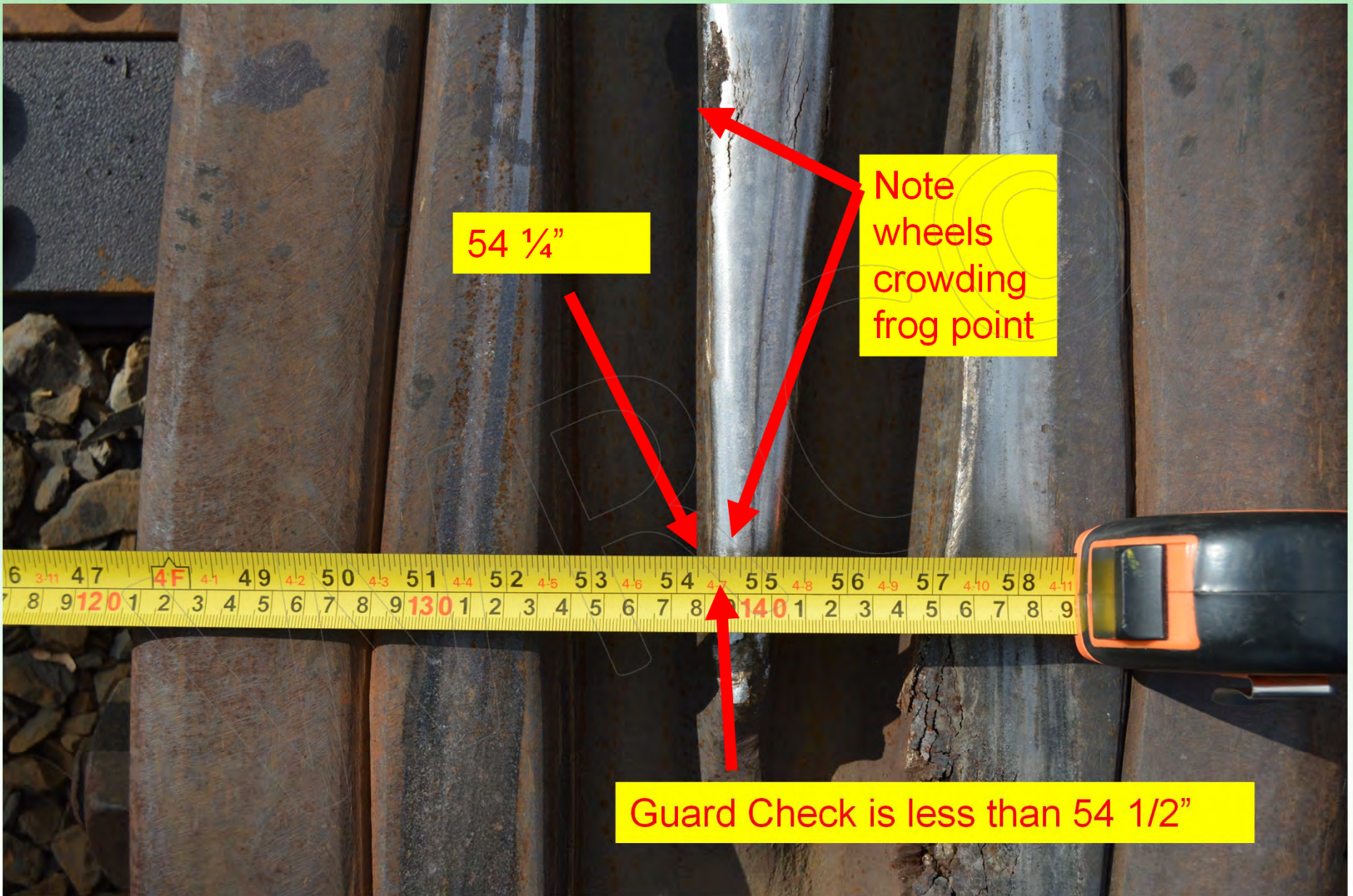


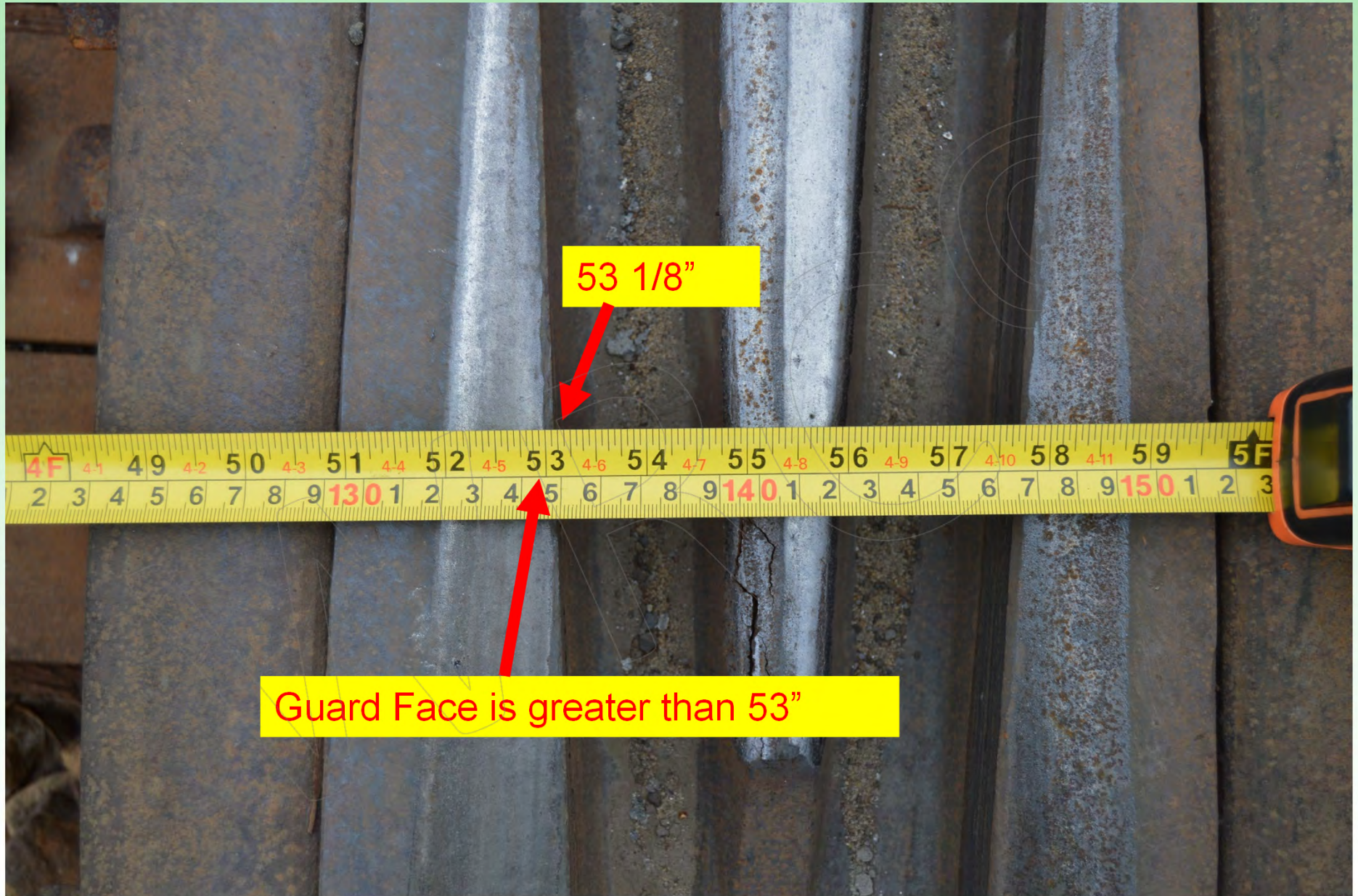


Guard Face may not be more than 53" for Class 5.

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









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



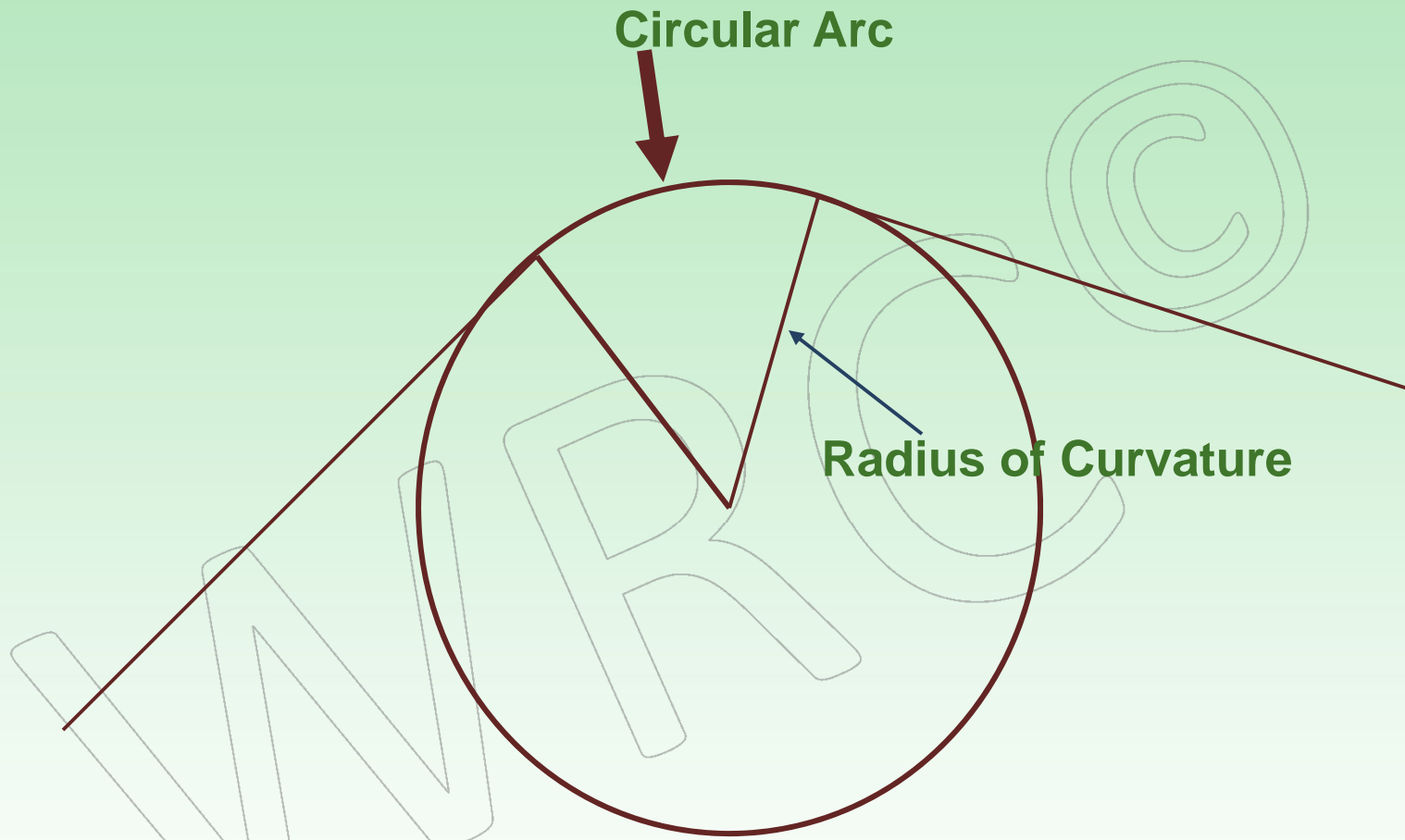
Elevation



Alignment



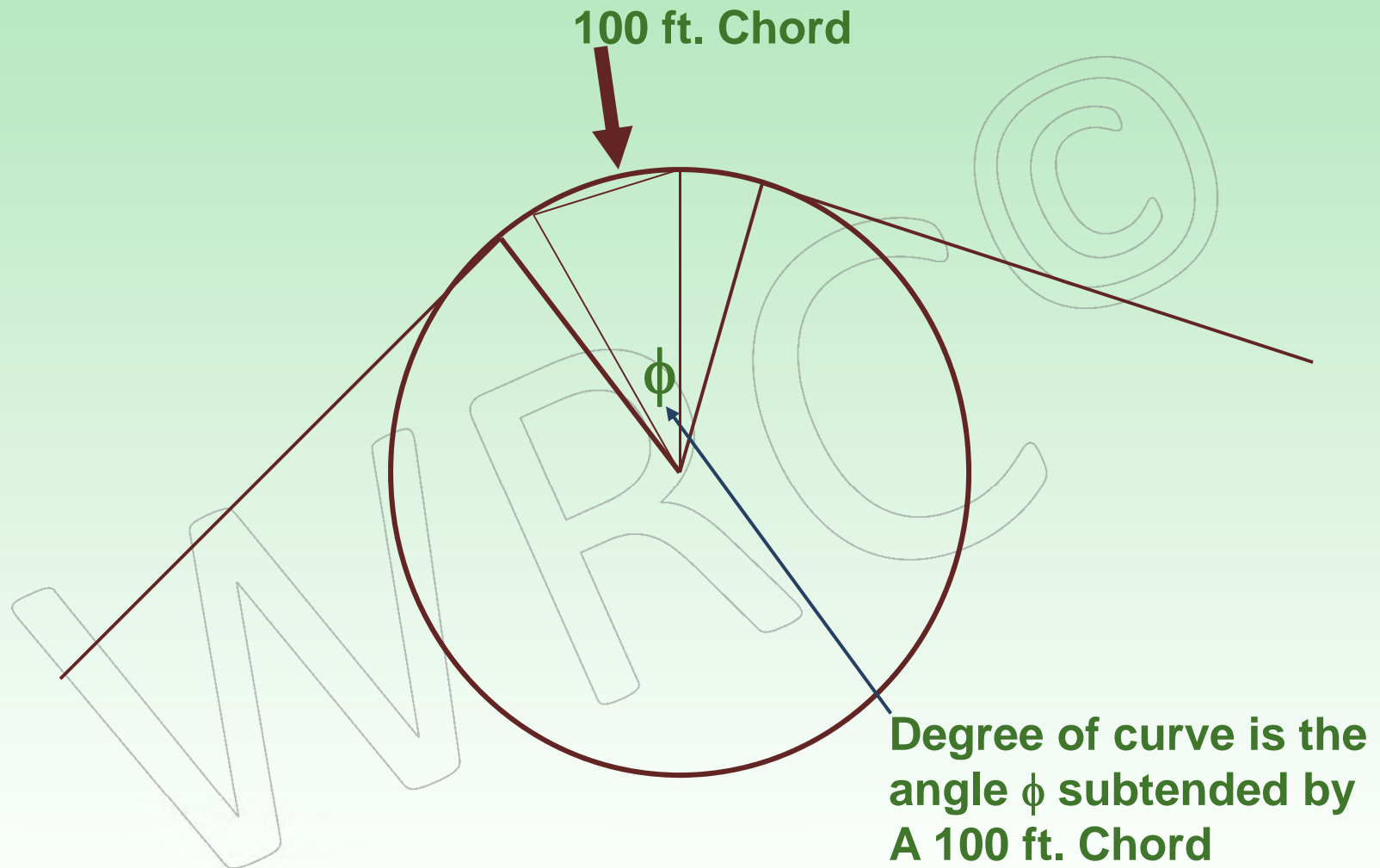
Definition of a Curve



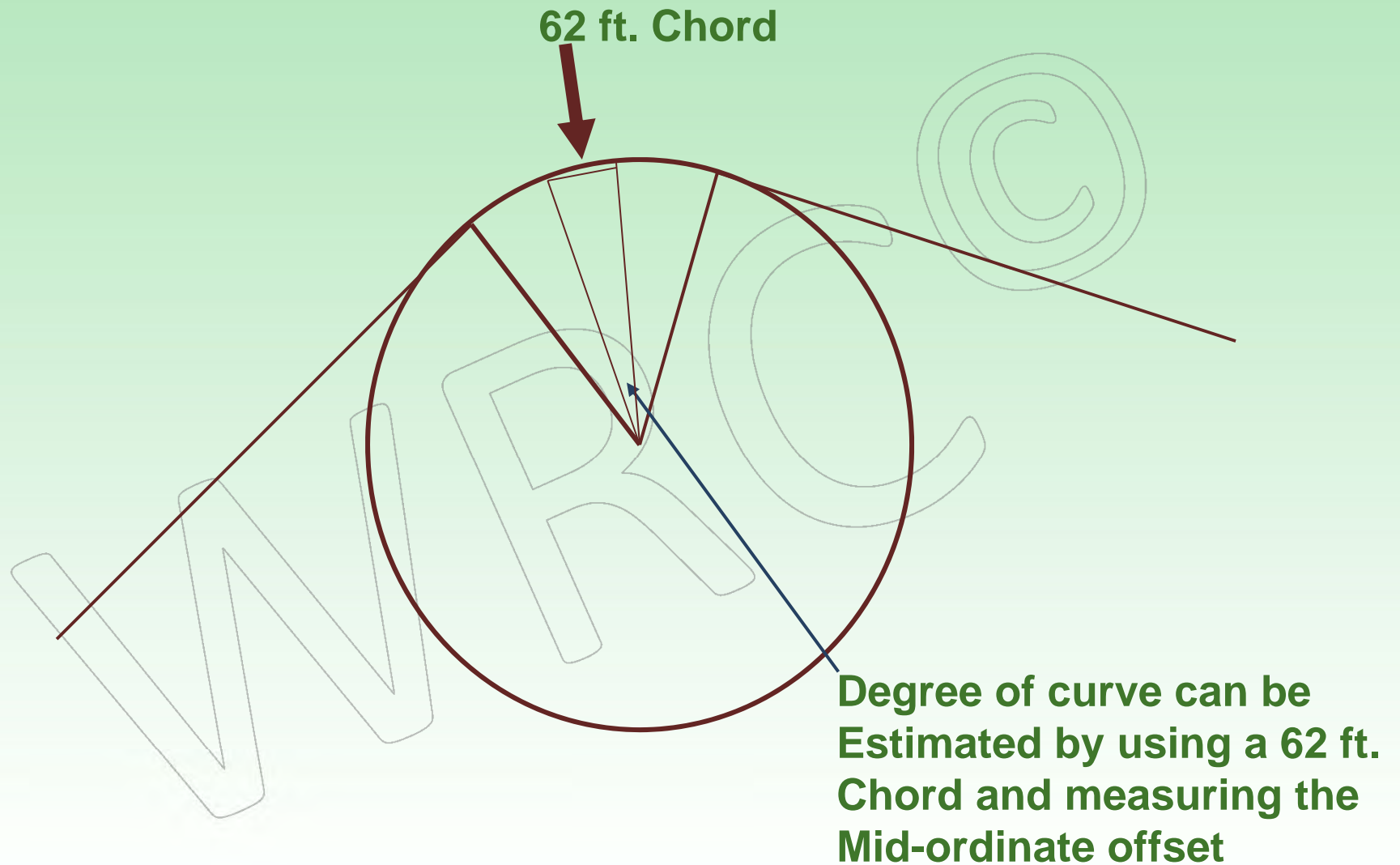
A curve is defined as a path along the edge of a circular arc defined by a circle of with a given radius



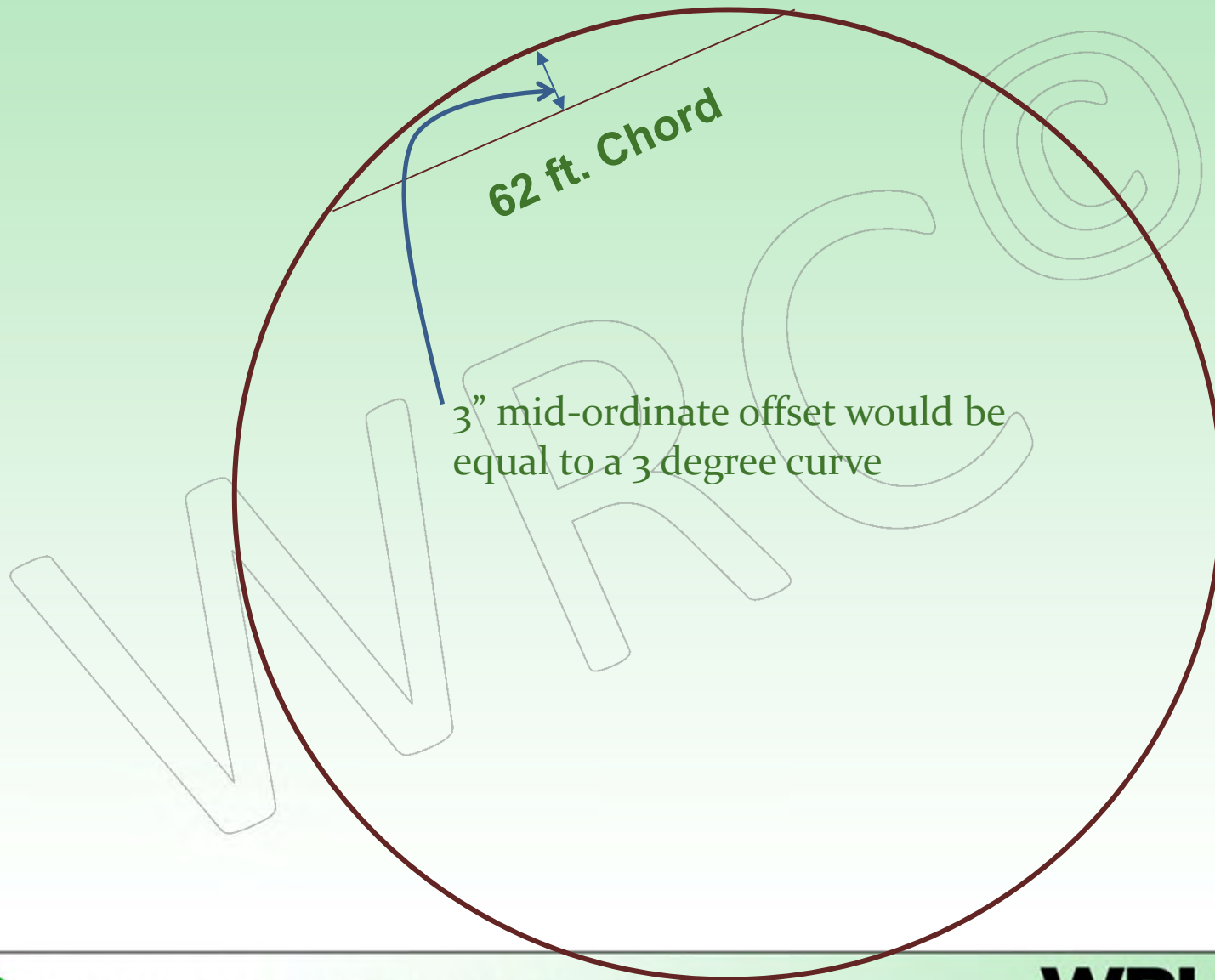
Railroad Definition of a Curve



Estimating degree of curvature using a 62 ft. chord



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

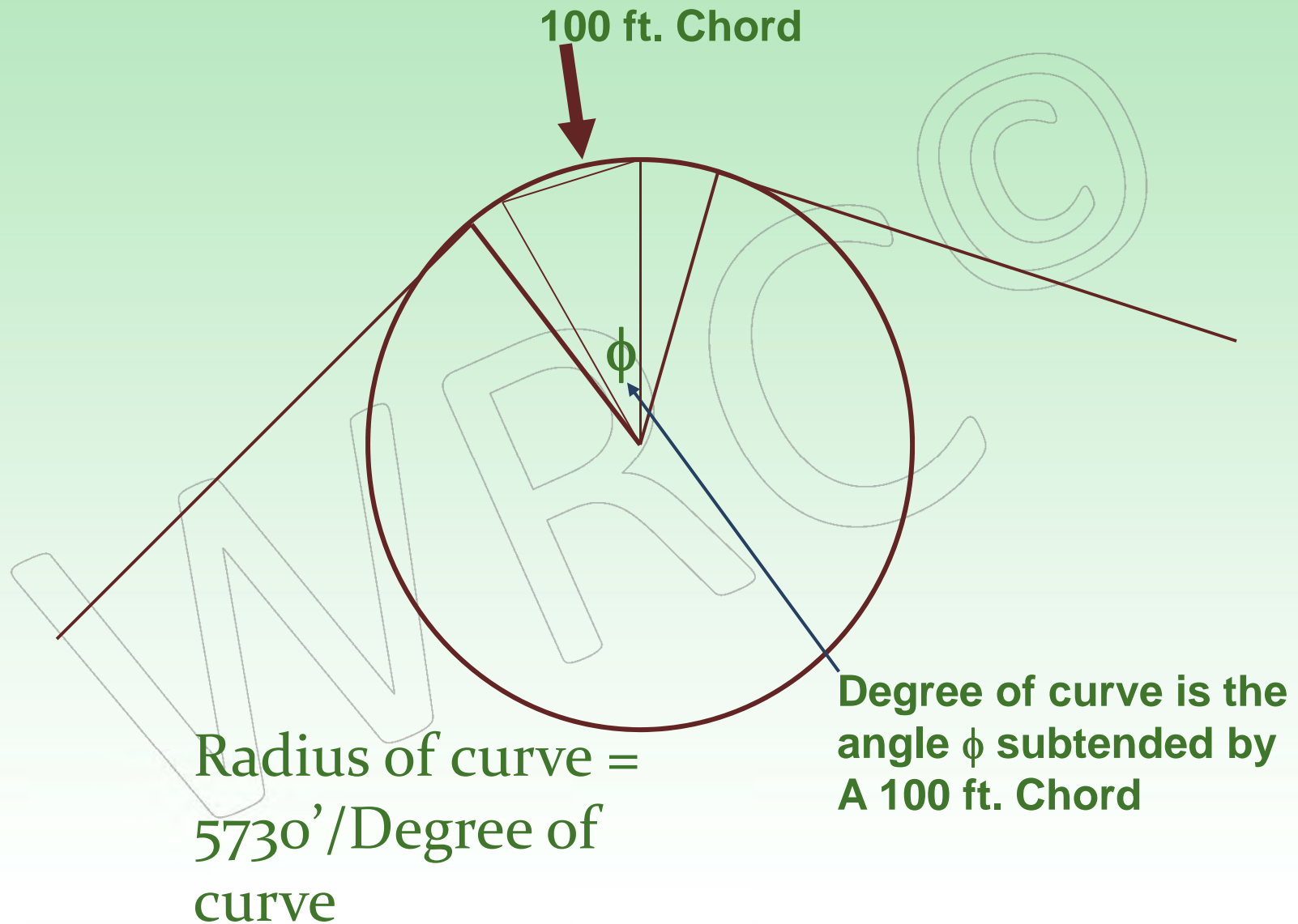




Stringlining using 62 ft. Chord



Radius of a Curve

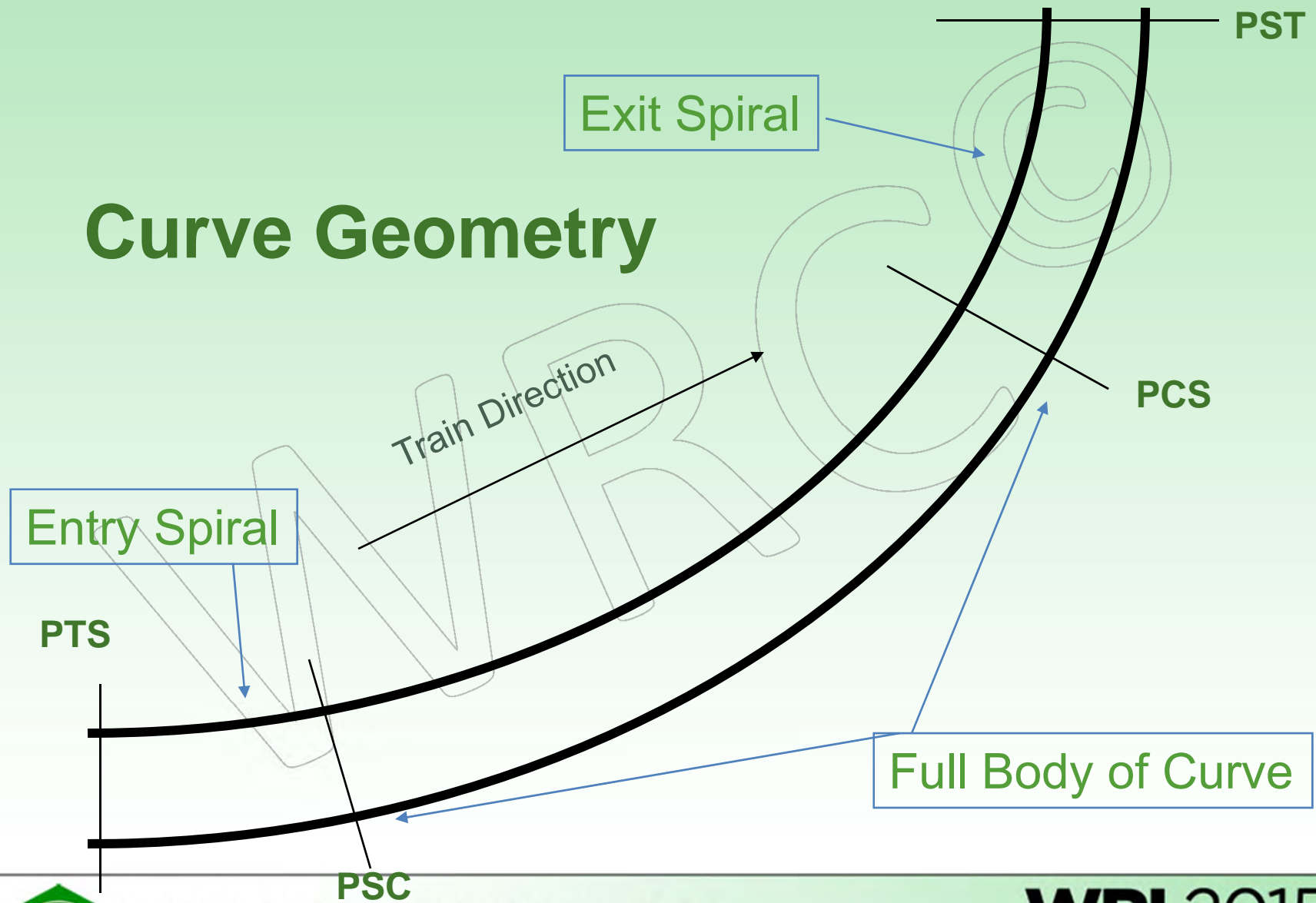


Degree of Curve & Radius

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

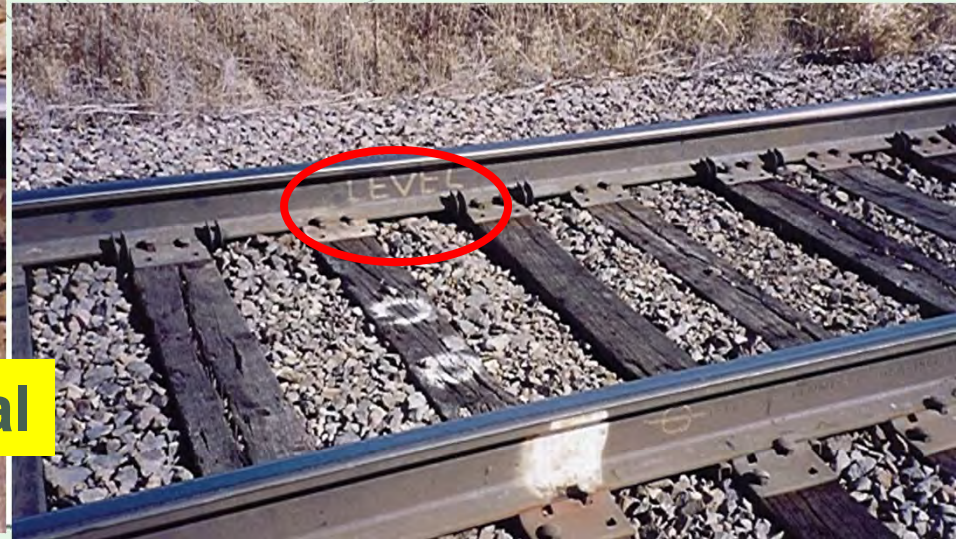


Level - PST or PTS



Spiral Ln. = 450'

Point of Spiral





PSC
5°01'46"
3 1/2" Elevation

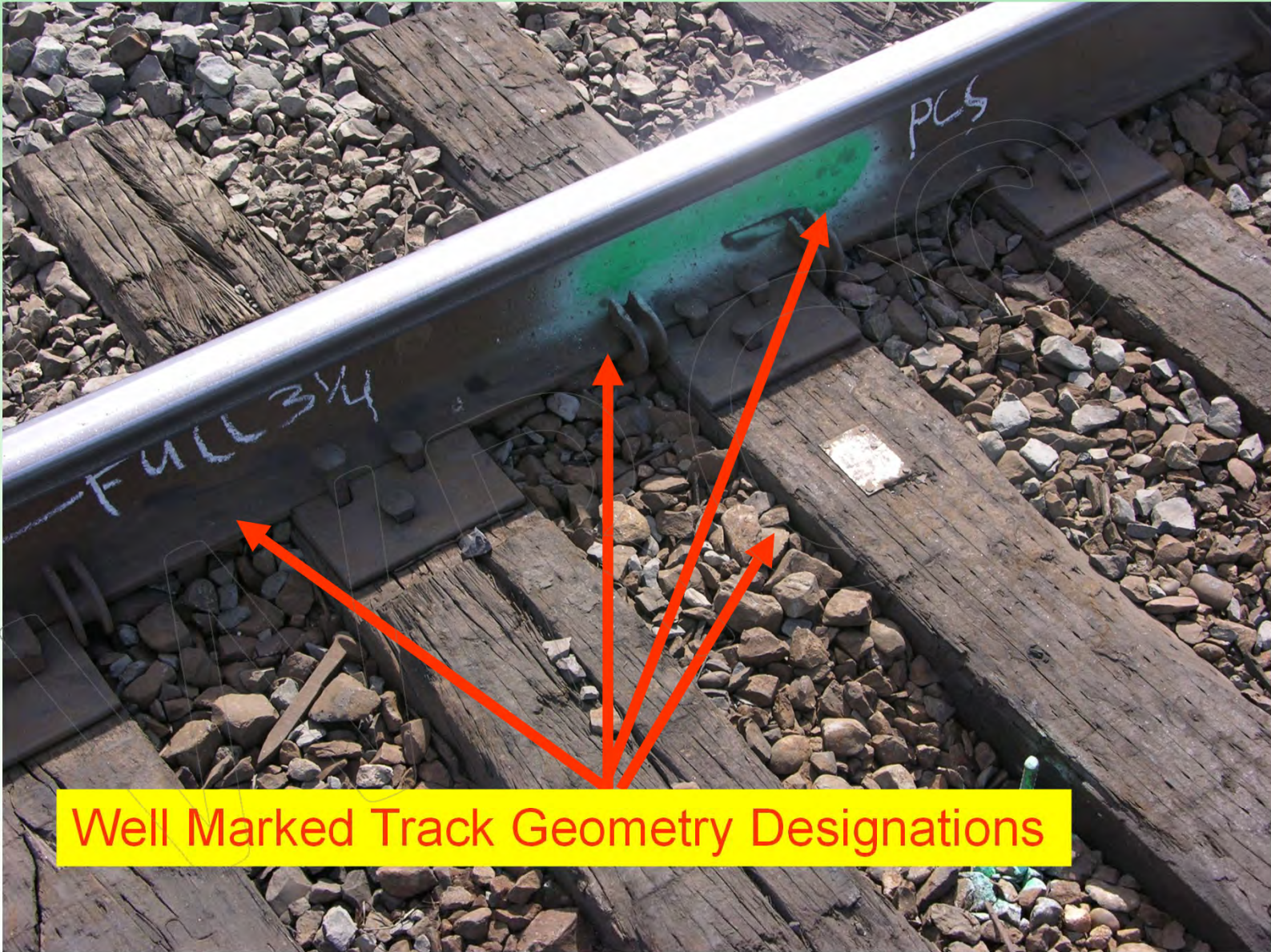


1/2" Elevation



1" Elevation





Well Marked Track Geometry Designations

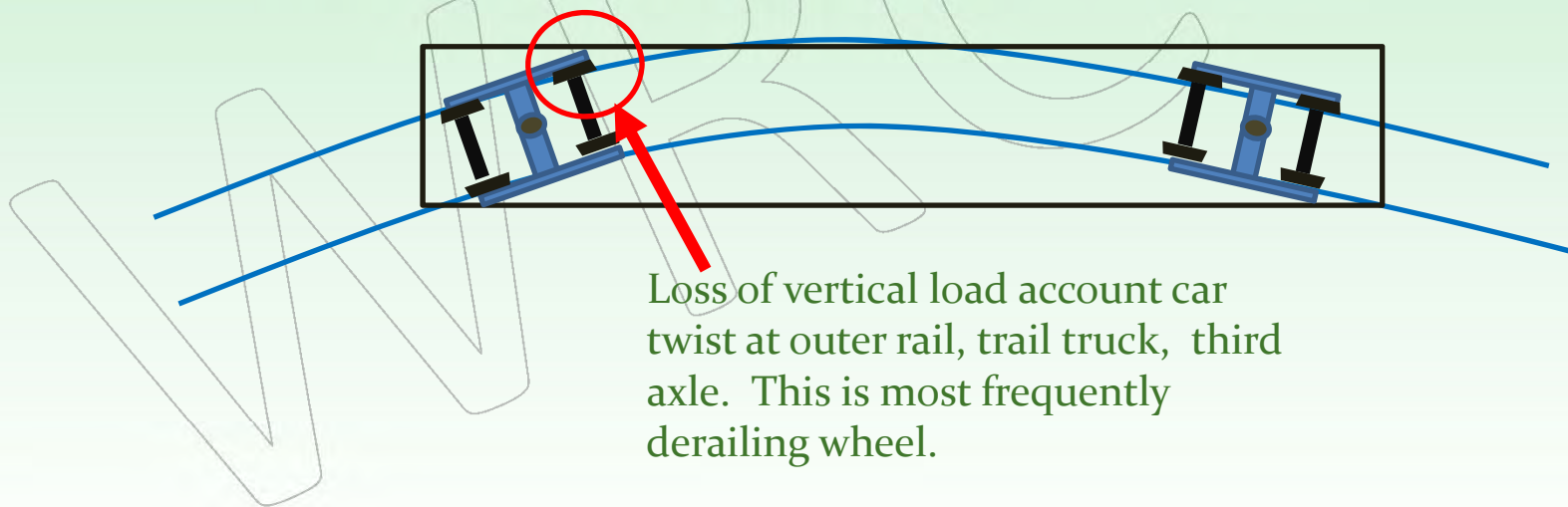


Train direction



High Rail

Low Rail



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

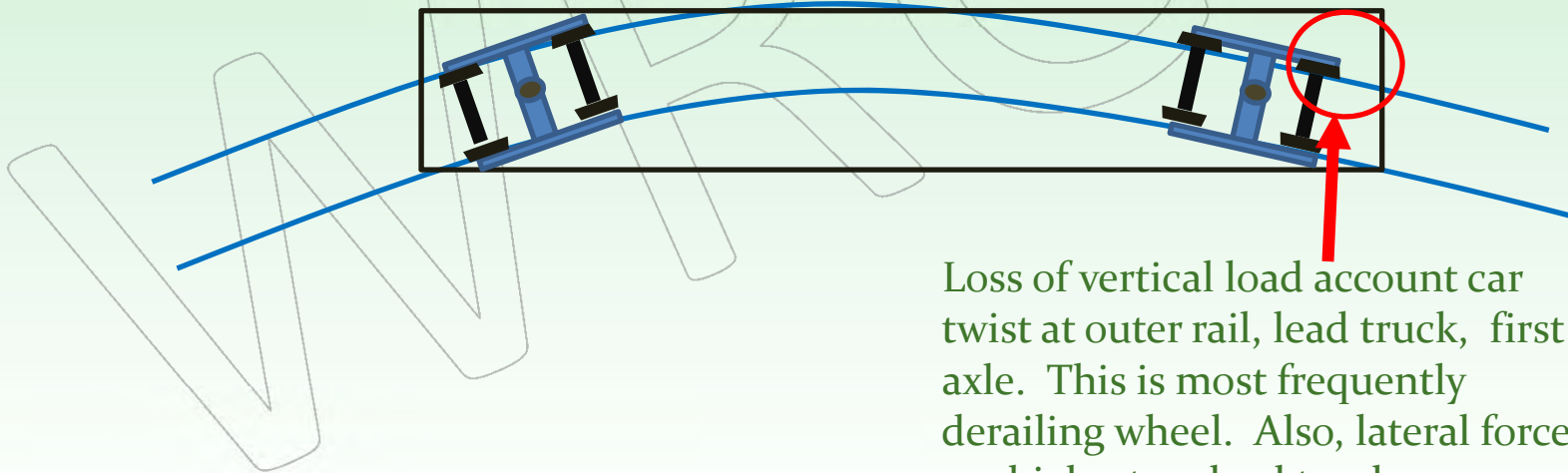


Train direction



High Rail

Low Rail

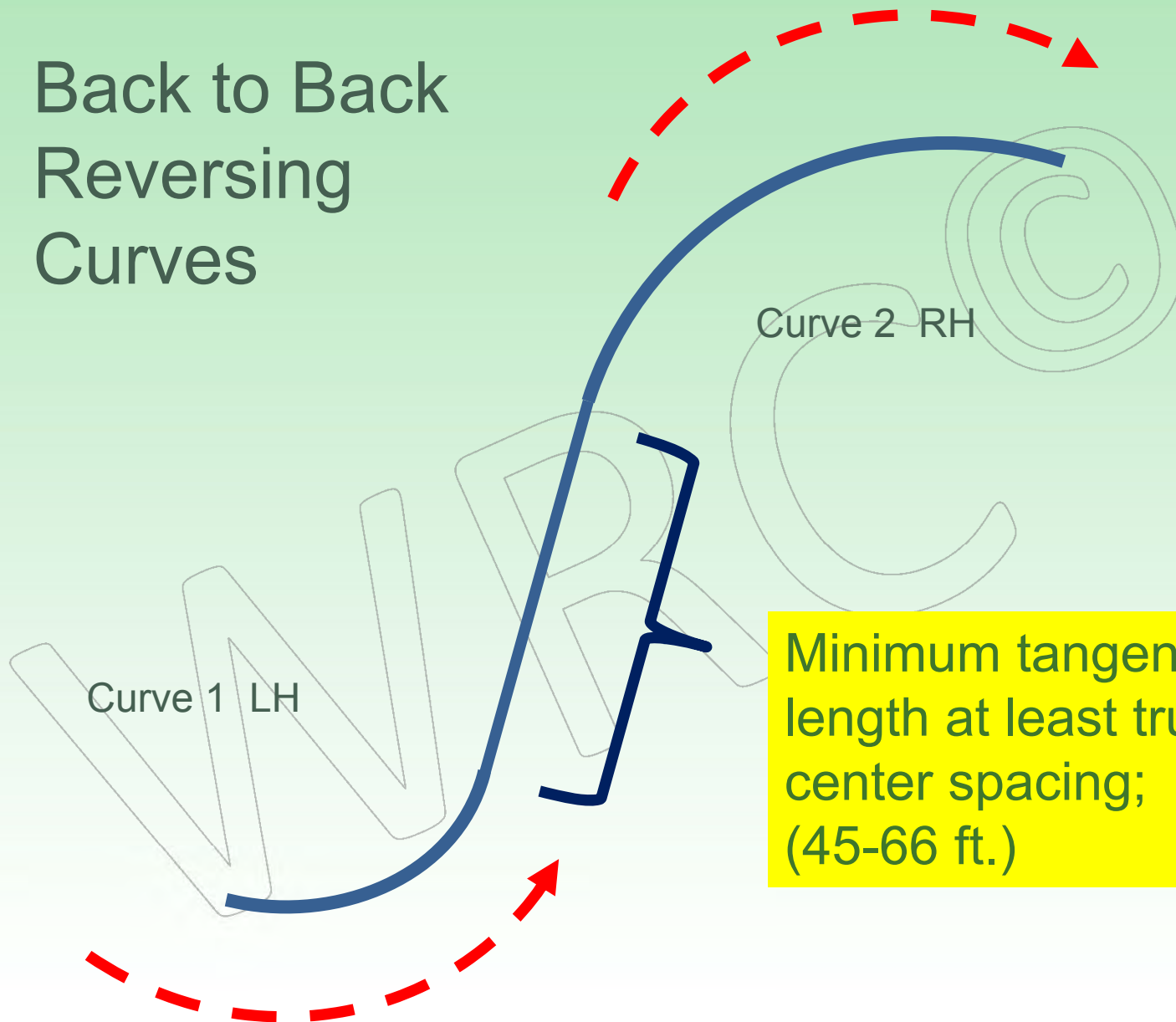


Loss of vertical load account car twist at outer rail, lead truck, first axle. This is most frequently derauling wheel. Also, lateral forces are highest on lead truck.

Most Likely Derauling Wheel in Exit Spiral



Back to Back Reversing Curves



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.



§ 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-eighths 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





31 ft.
Class 3-5

62 ft.

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 alignment thresholds. If alignment 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., “ $1\frac{3}{4}$ inches alignment deviation on curved track for 62-foot chord. Note: $1\frac{3}{8}$ inches alignment deviation for 31-foot chord at this location.”





Horizontal Alignment



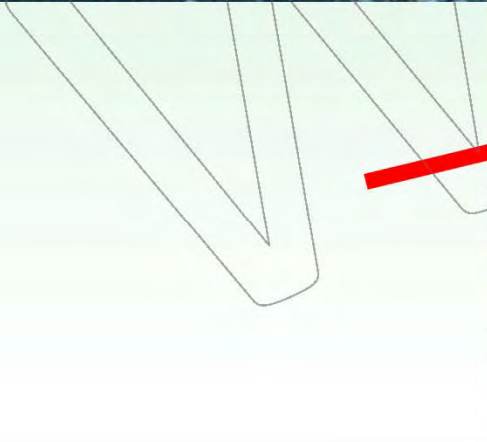
§213.55 Alinement - Stringlining

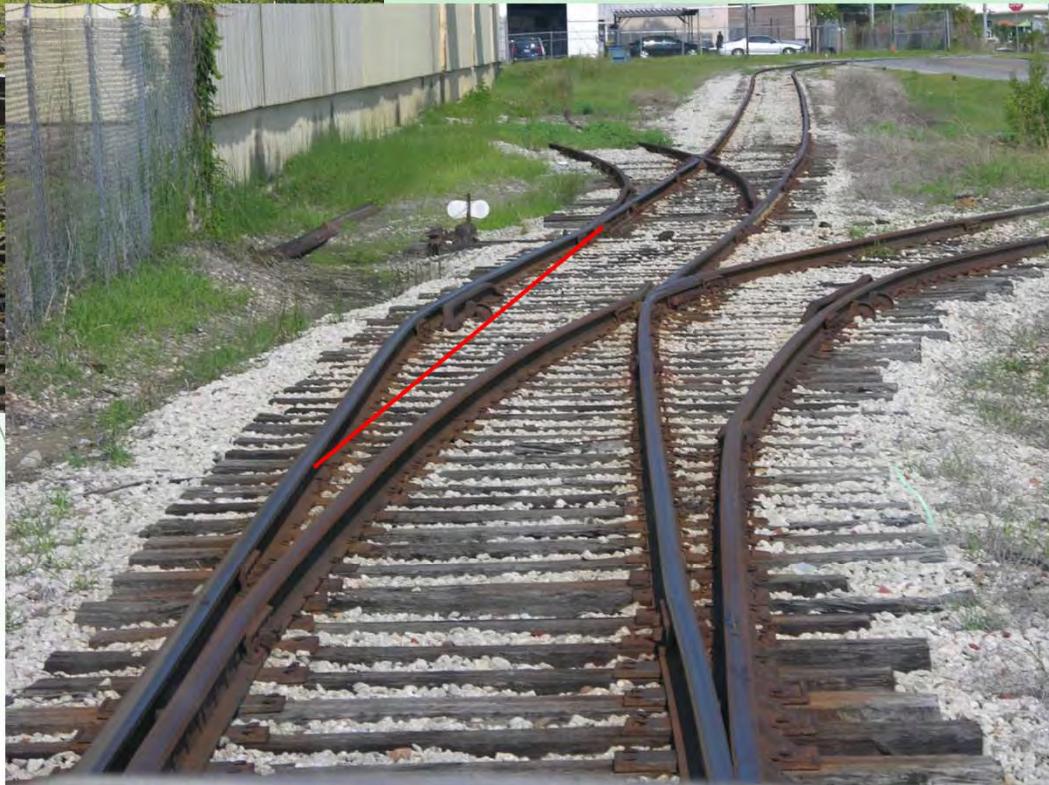
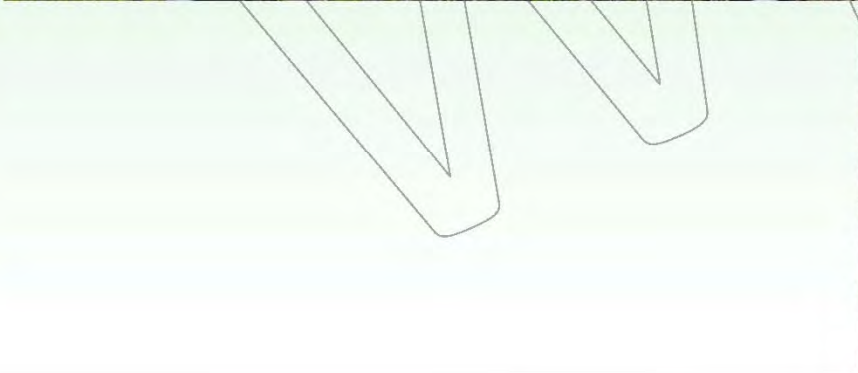
The chord (string) is stretched and held tight between two points on the rail, $\frac{5}{8}$ inch below the top running surface of the rail. Measure the MCO between the rail and the string with a graduated ruler, using blocks to compensate for shallow curvature and special trackwork, if necessary.

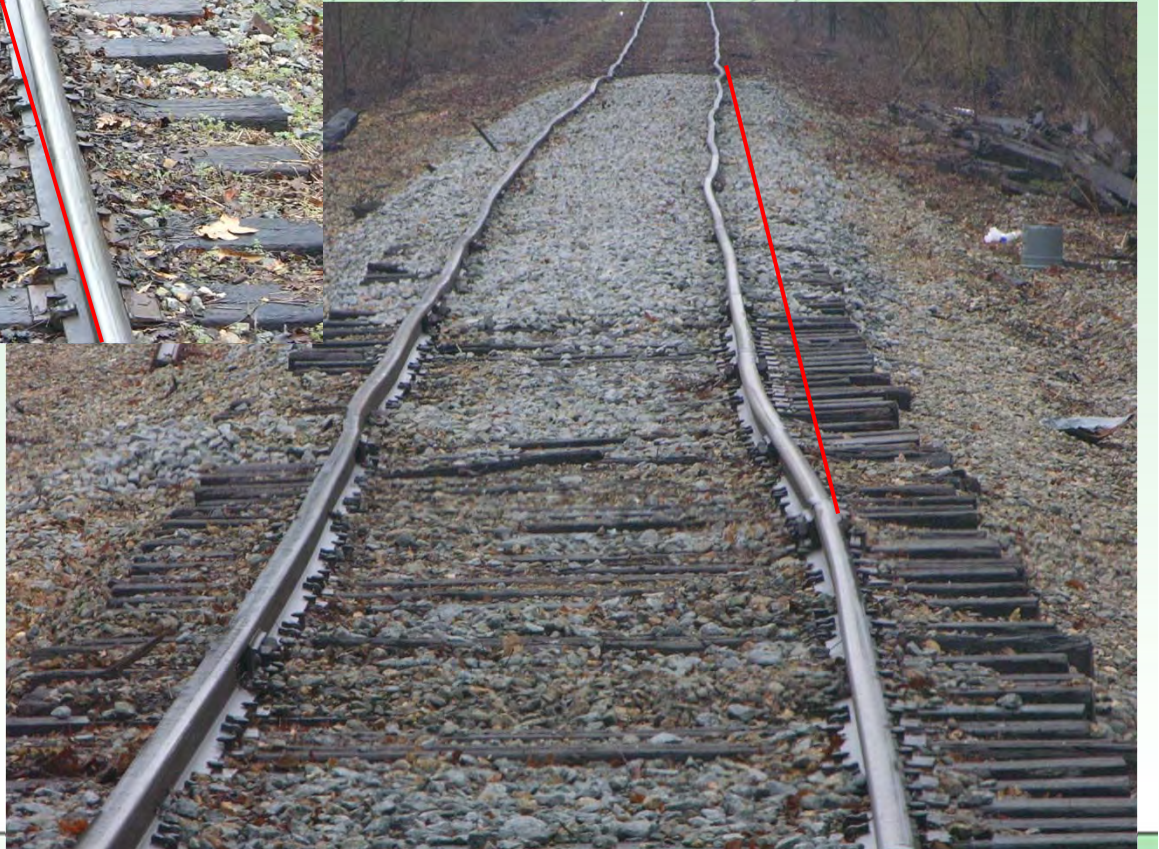
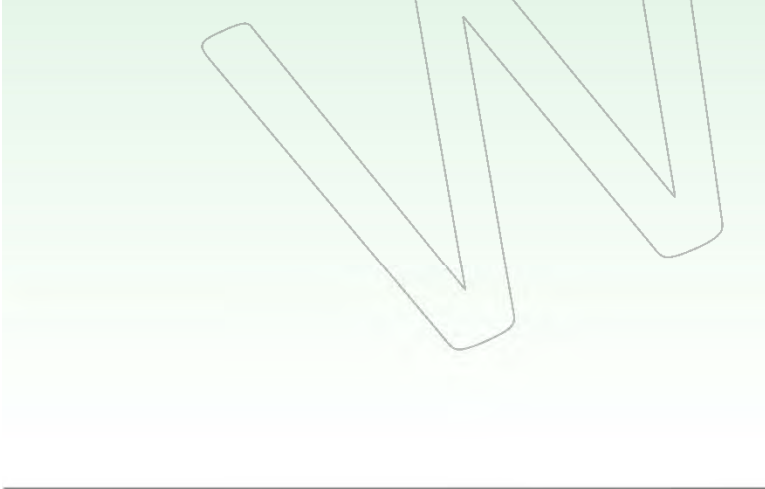


Alignment Deviations

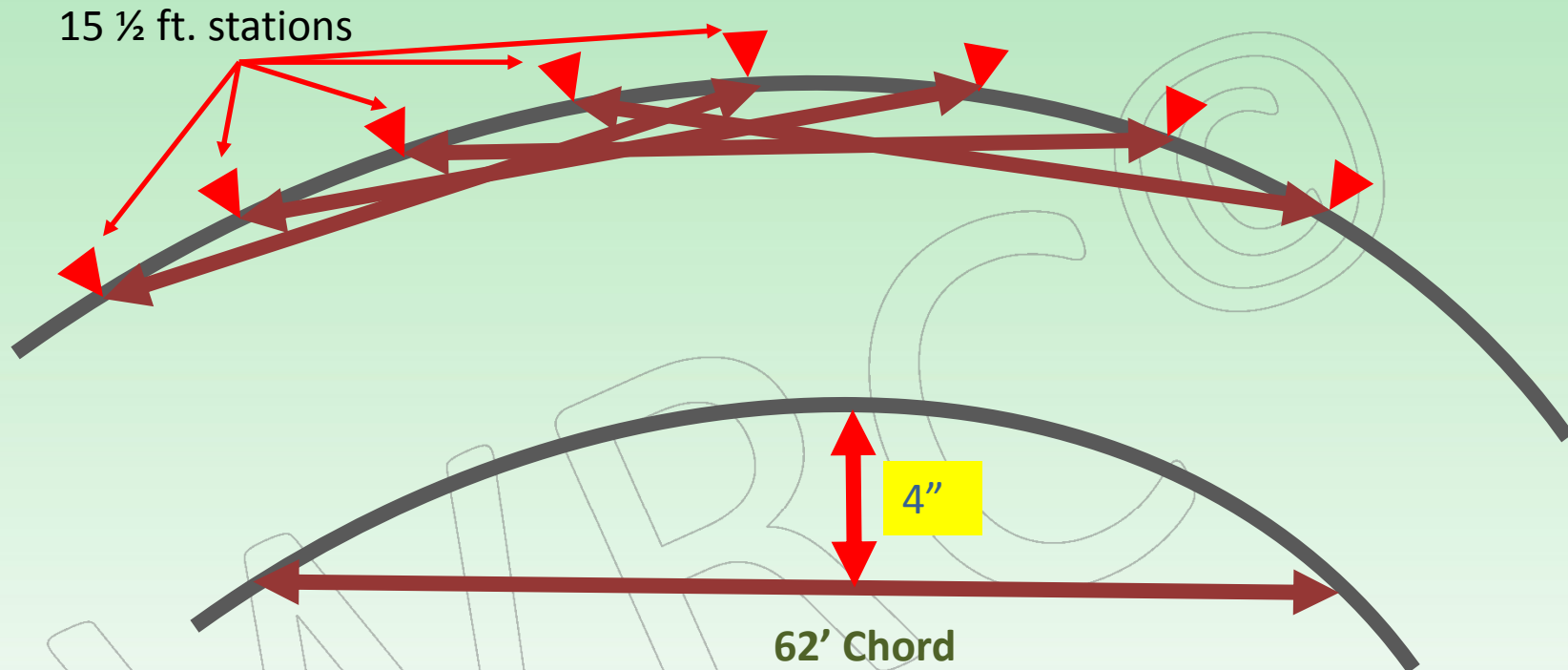








Measuring Alignment with 62' Chord - Stringlining

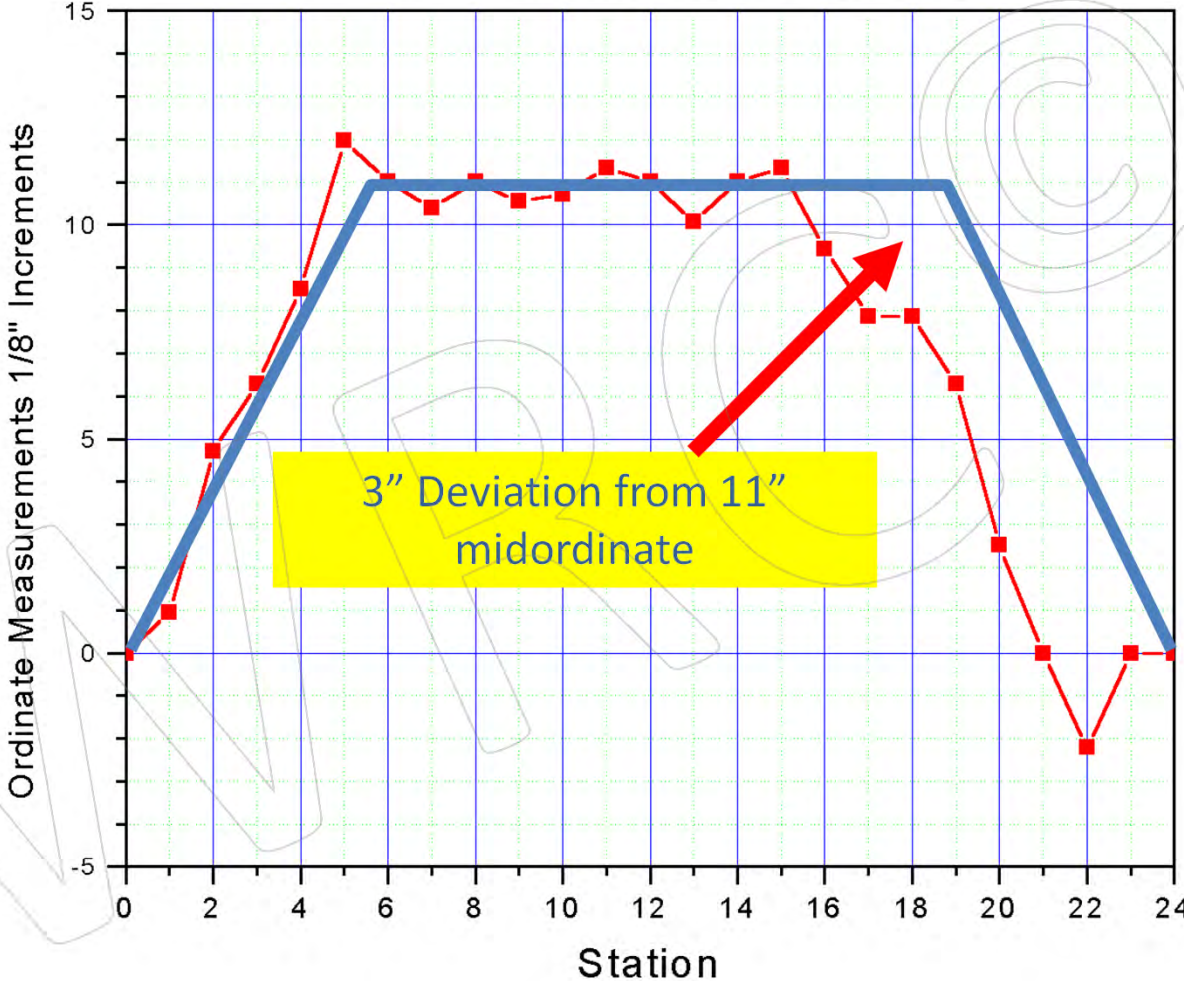


Midordinate Measurement

4" = 4 Degree Curve

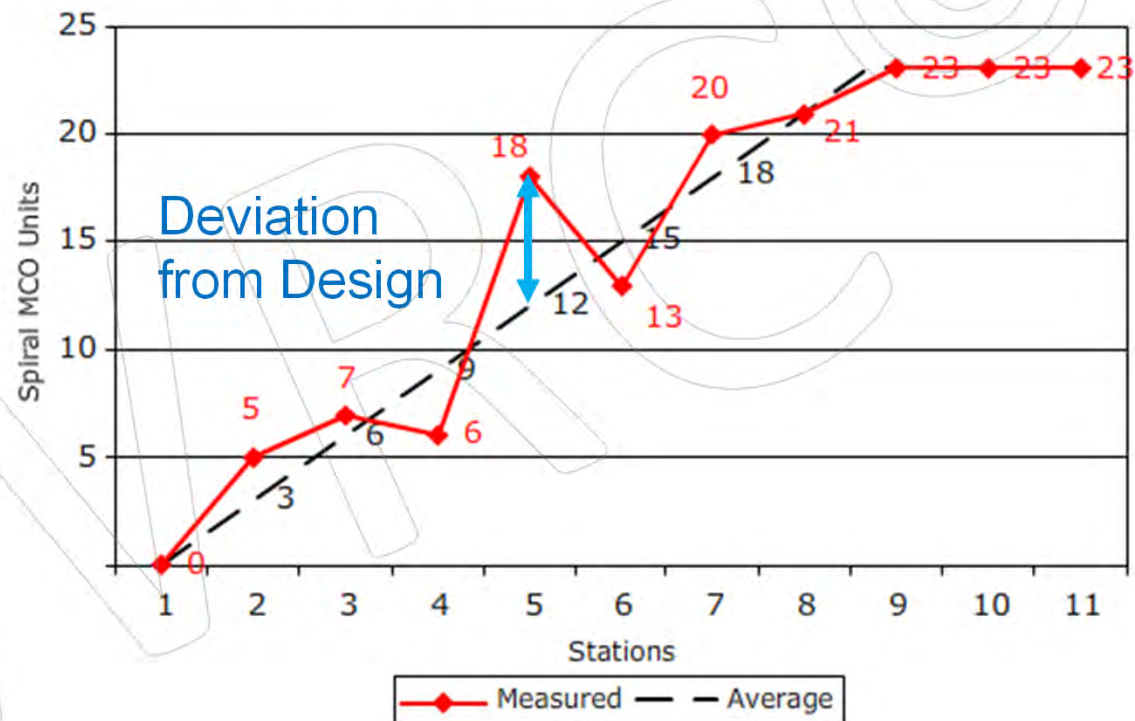


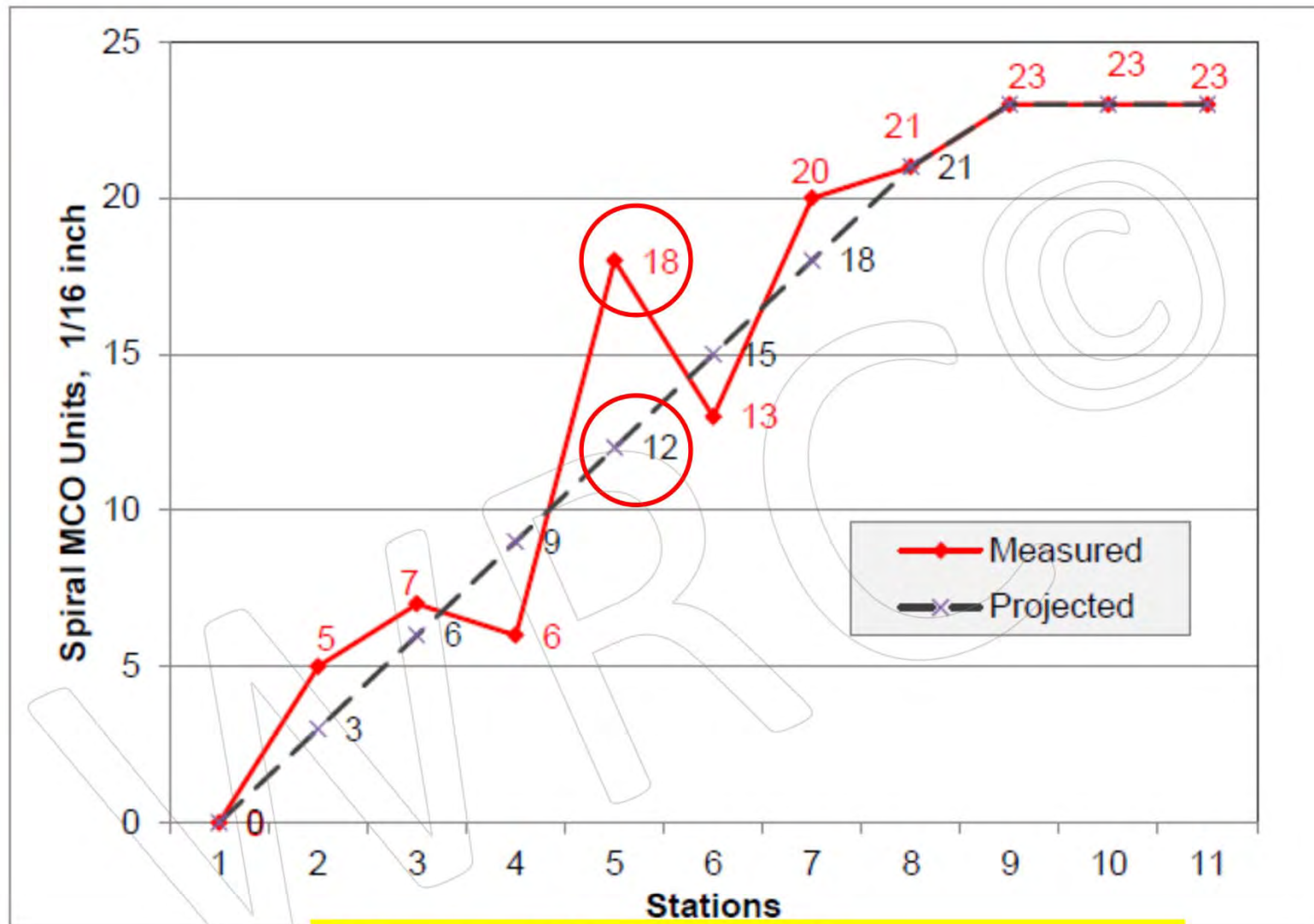
Curve Alignment Geometry



Checking Alignment Deviations in Spirals

Place the measured values in a graph and plot the spiral.

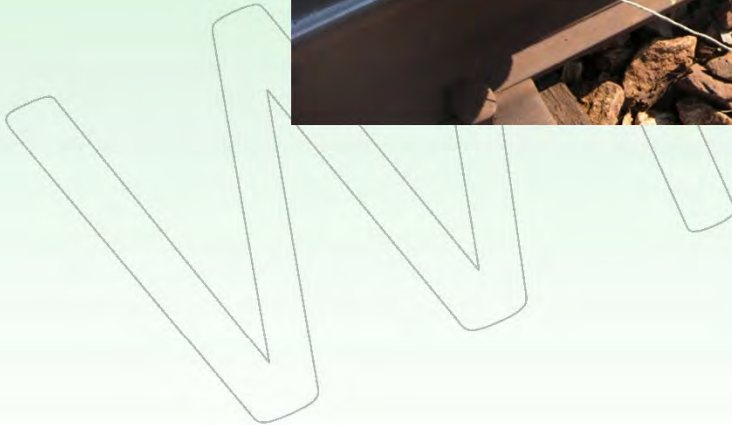
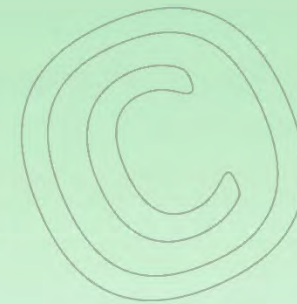




18 units at Sta. 5 = 1 1/8"
 12 units = 3/4"
 Deviation from uniformity = 6 units (3/8")



Stringlining in the field using 62' Chord





**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:

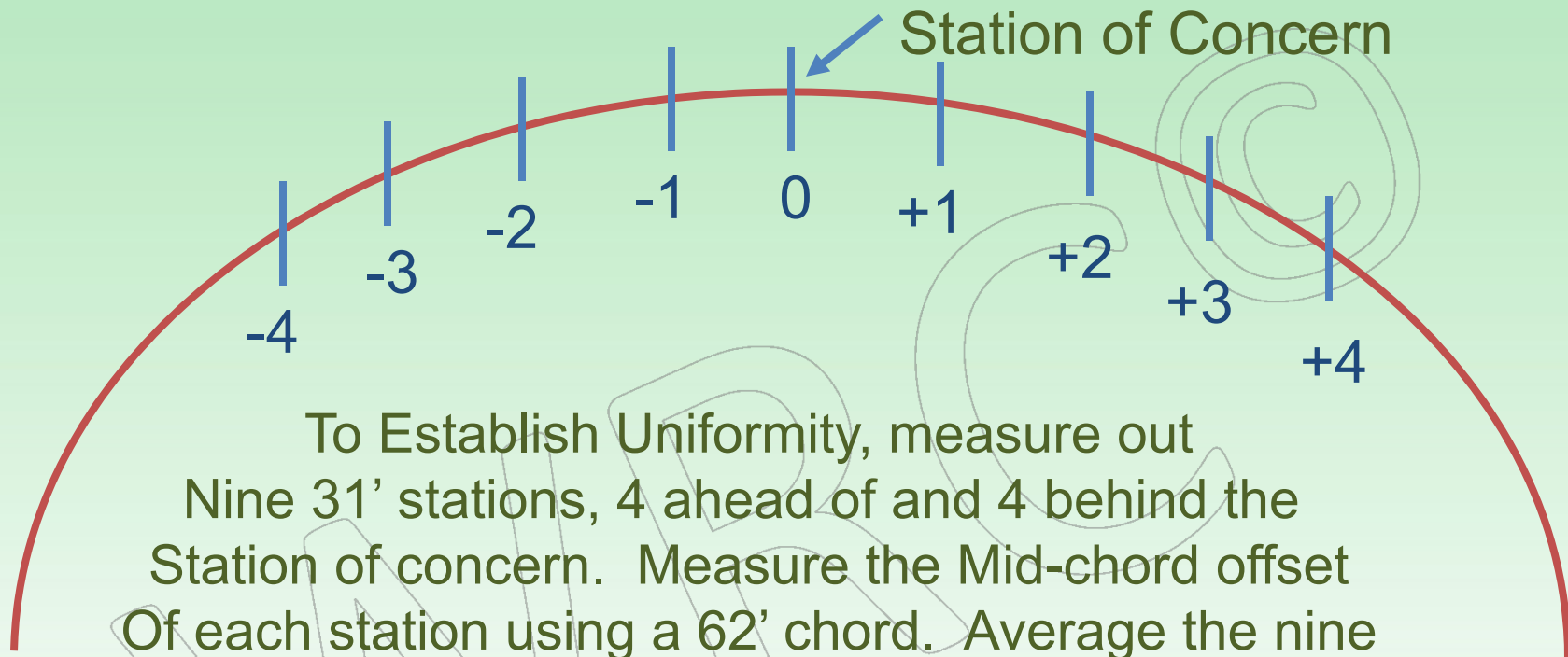
Class of track	Tangent track	Curved track	
	The deviation of the mid-offset from a 62-foot line ¹ may not be more than— (inches)	The deviation of the mid-ordinate from a 31-foot chord ² may not be more than— (inches)	The deviation of the mid-ordinate from a 62-foot chord ² may not be more than— (inches)
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**

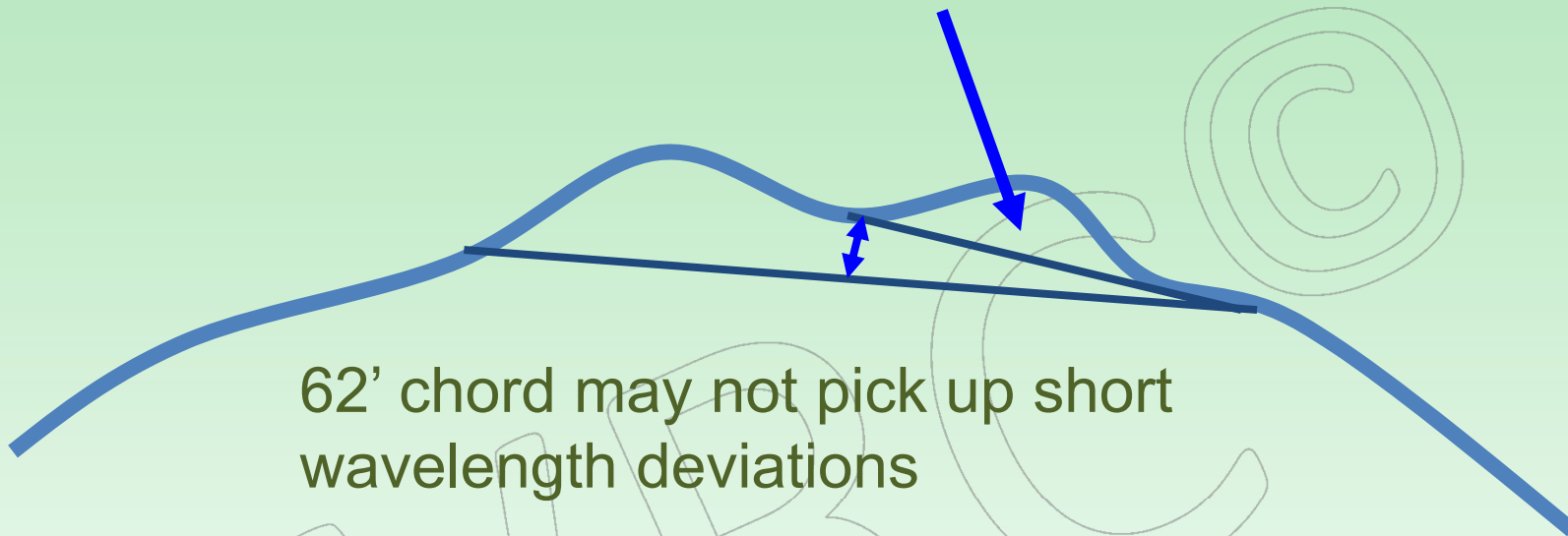


As a reference, the following table summarizes the acceptable proper chords, station spacing, and number of stations to determine alignment compliance.

Alignment Stations					
Geometry	Class	Chord (feet)	Total No. Stations	Station Spacing (feet)	Curve Length (feet)
Curve	1-2	62	9 or	31	248
		62	17	15½	248
	3-5	31	17	15½	248
		62	9 or	31	248
		62	17	15½	248
Tangent	1 - 5	62	1	n/a	n/a



A 31' chord may pick up short wavelength deviations



62' chord may not pick up short wavelength deviations

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



§ 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

¹Actual 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 deficiency² (inches) of the vehicle type.

²If 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

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

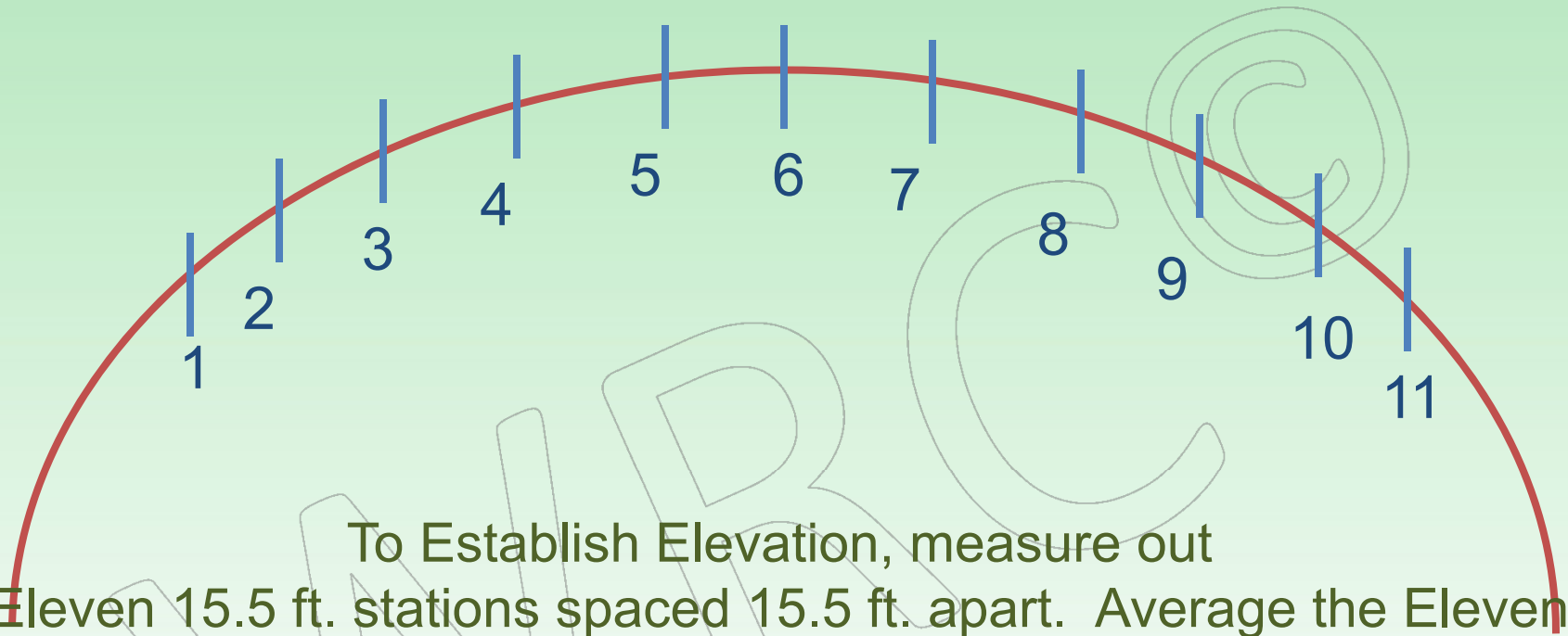


§ 213.57 Curves; elevation and speed limitations.

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

¹Actual 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 ft. 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.





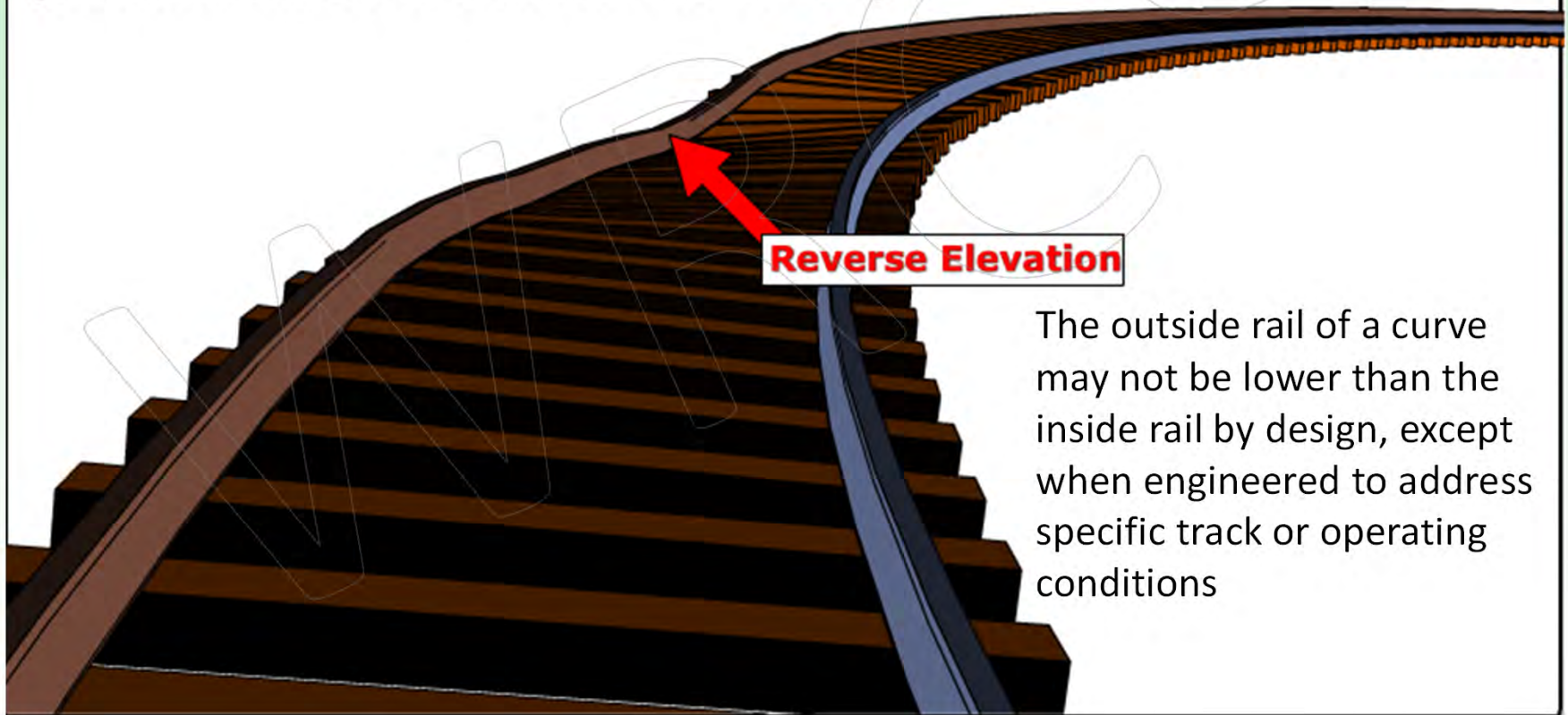
Curve elevation



§ 213.57 Curves; elevation and speed limitations.

Reverse Elevation

Both §213.63 and this section limit the amount of reverse elevation (outside rail lower than the inside rail).



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



§ 213.59 Elevation of curved track; runoff.

(a) If a curve is elevated, the full elevation shall be provided throughout the curve, unless physical conditions do not permit. If elevation runoff occurs in a curve, the actual minimum elevation shall be used in computing the maximum allowable posted timetable operating speed for that curve under § 213.57(b).

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

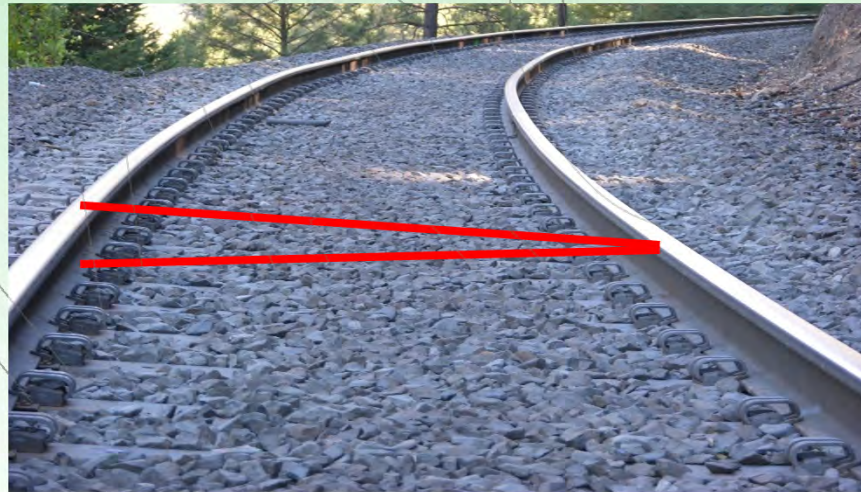
§ 213.59 Elevation of curved track; runoff.

(b) Elevation runoff shall be at a uniform rate, within the limits of track surface deviation prescribed in § 213.63, and it shall extend at least the full length of the spirals. If physical conditions do not permit a spiral long enough to accommodate the minimum length of runoff, part of the runoff may be on tangent track.



Superelevation in a curve

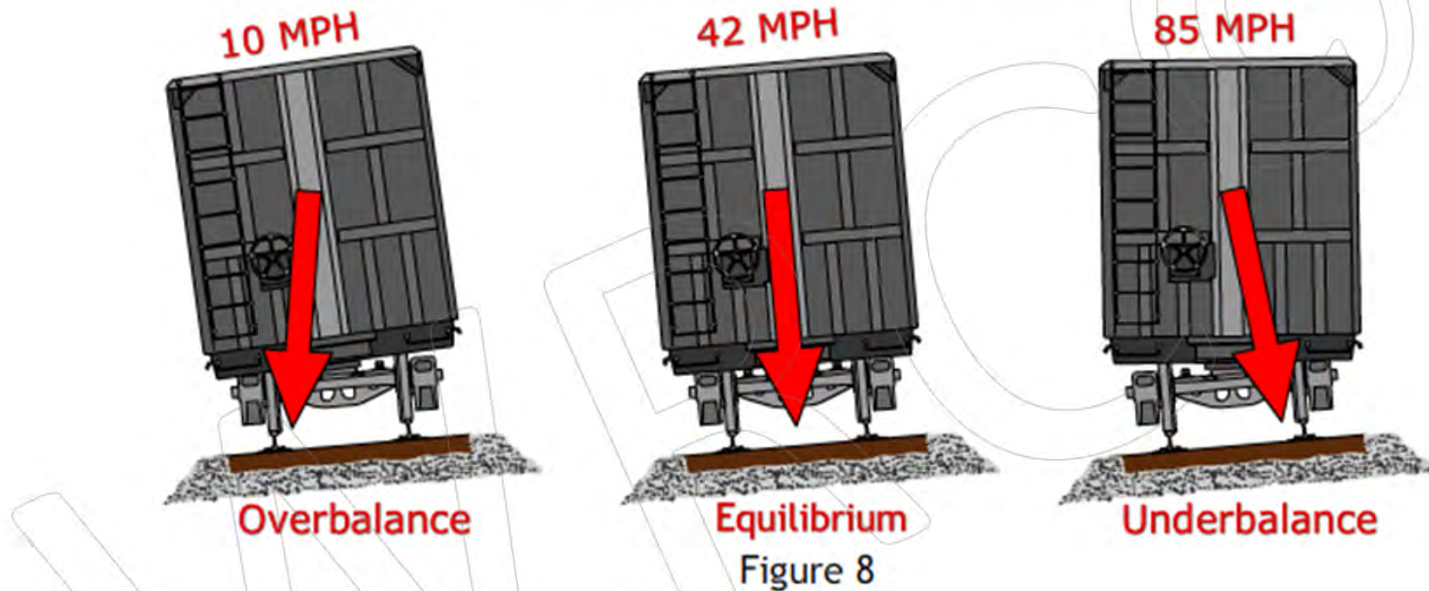
Normally, between 0.0 to 6.0 inches of elevation is added to outer rail to counterbalance effects of centrifugal forces based on normal train speeds.

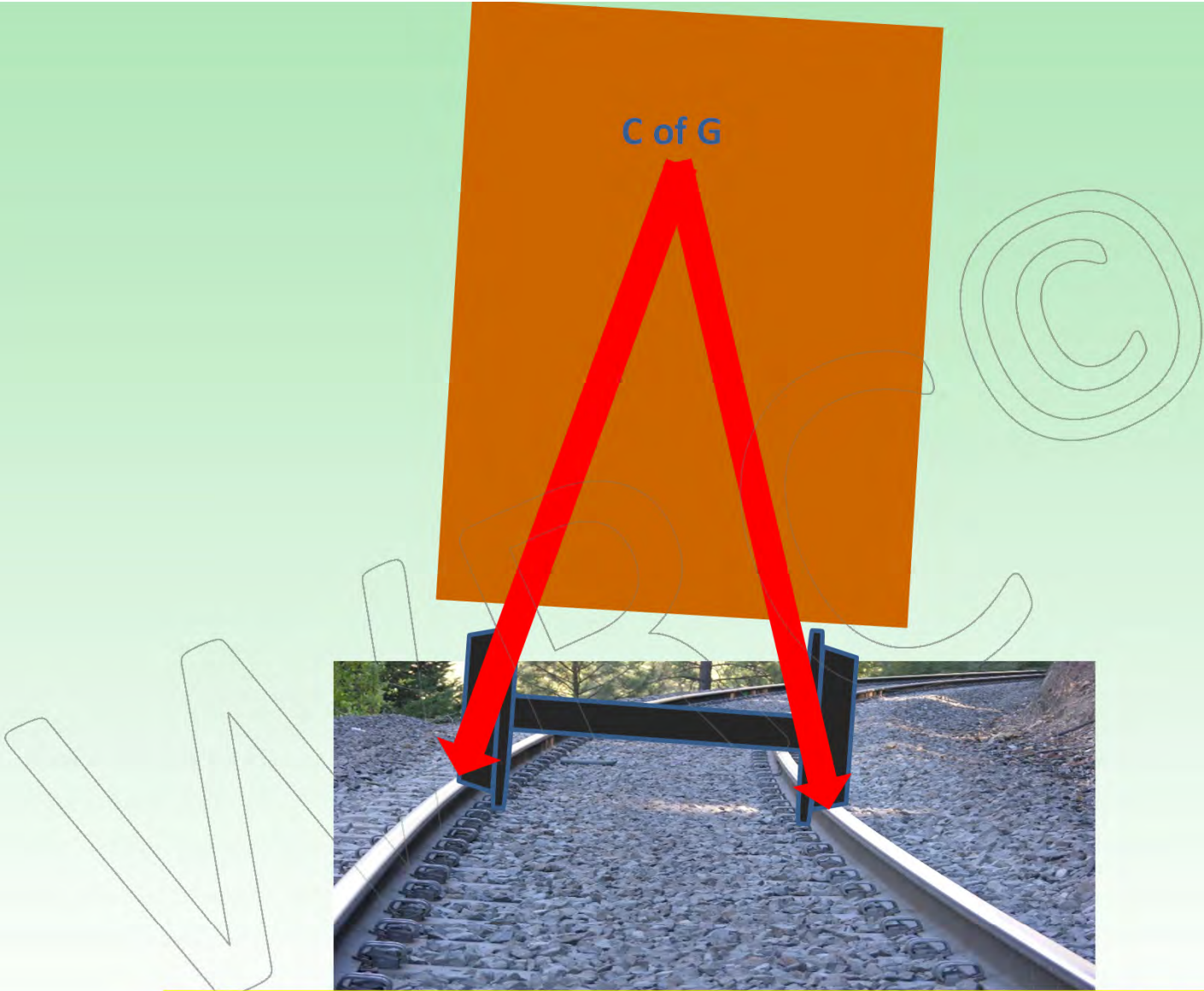


A balanced (equilibrium) condition implies the vertical forces on each rail are equal.

Figure 8 illustrates the three types of balance conditions.

4° Curve - 5" Superelevation





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



$$\text{Eq. Elevation} = .0007 (D) (V^2)$$

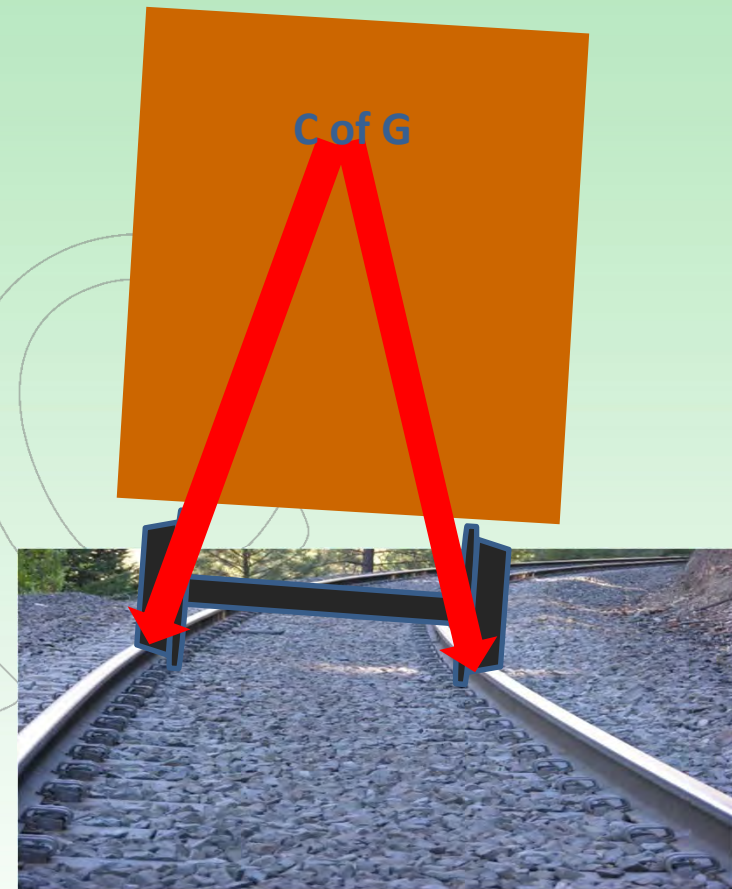
For 5 degree curve; 30 MPH

$$\text{Eq. El.} = .0007 (5) (30^2)$$

$$\text{Eq. El.} = .0007 (5) (900)$$

$$\text{Eq. El.} \sim 3.00''$$

$$1'' \text{ Unbalance} = 3.00 - 1.00 = 2.00''$$

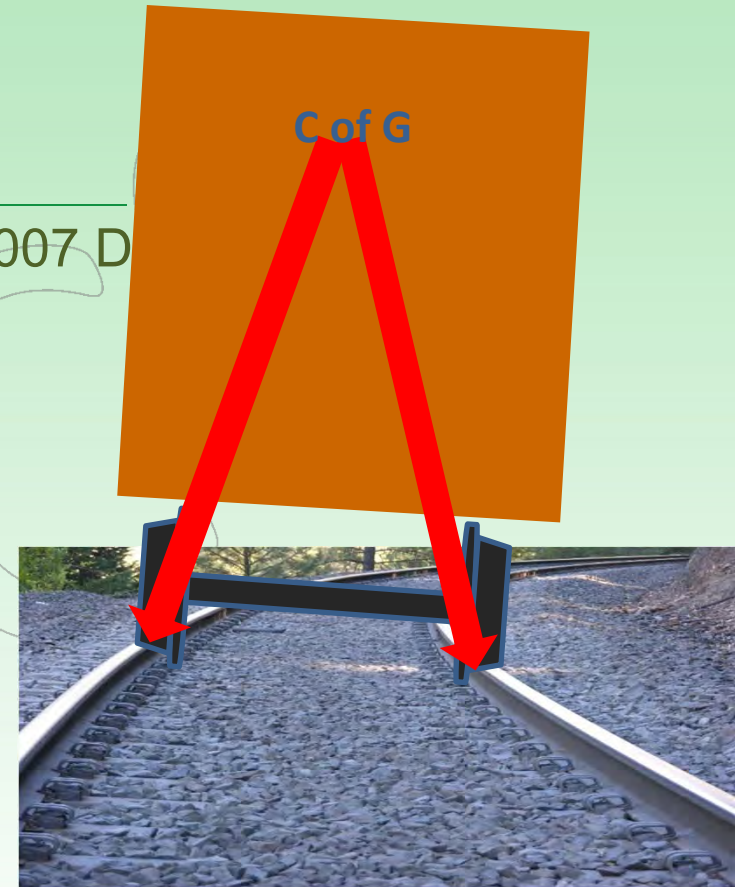


To determine Equilibrium Speed for Curve



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

$$\begin{aligned} V_{\max} &= \sqrt{\text{Elevation} + \text{Cant Deficiency} / .0007 D} \\ &= \sqrt{6" / .0007 (5)} \\ &= 41 \text{ MPH} \end{aligned}$$



To determine Maximum Speed for Curve



Curve Superelevation Issues

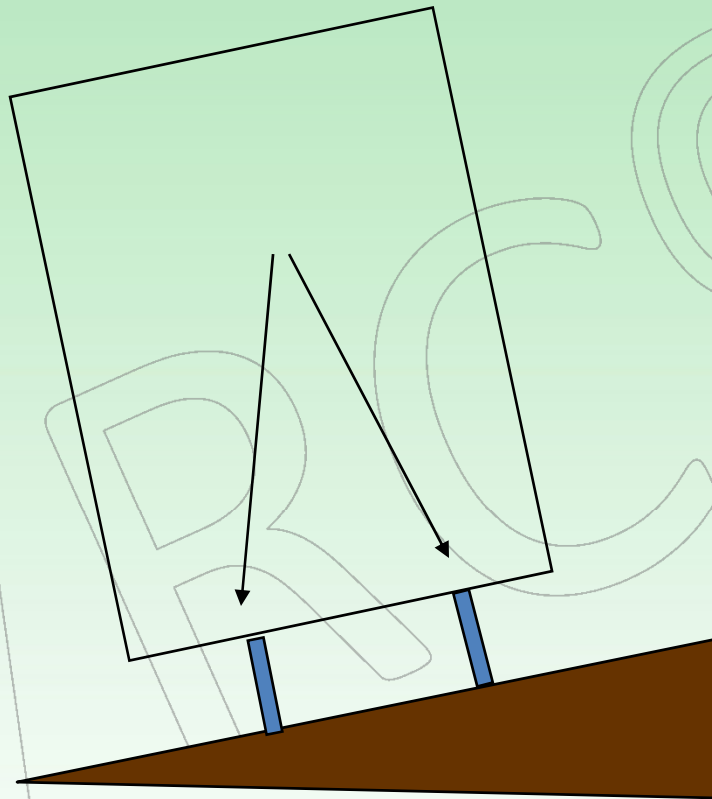


Superelevation - The Old Way

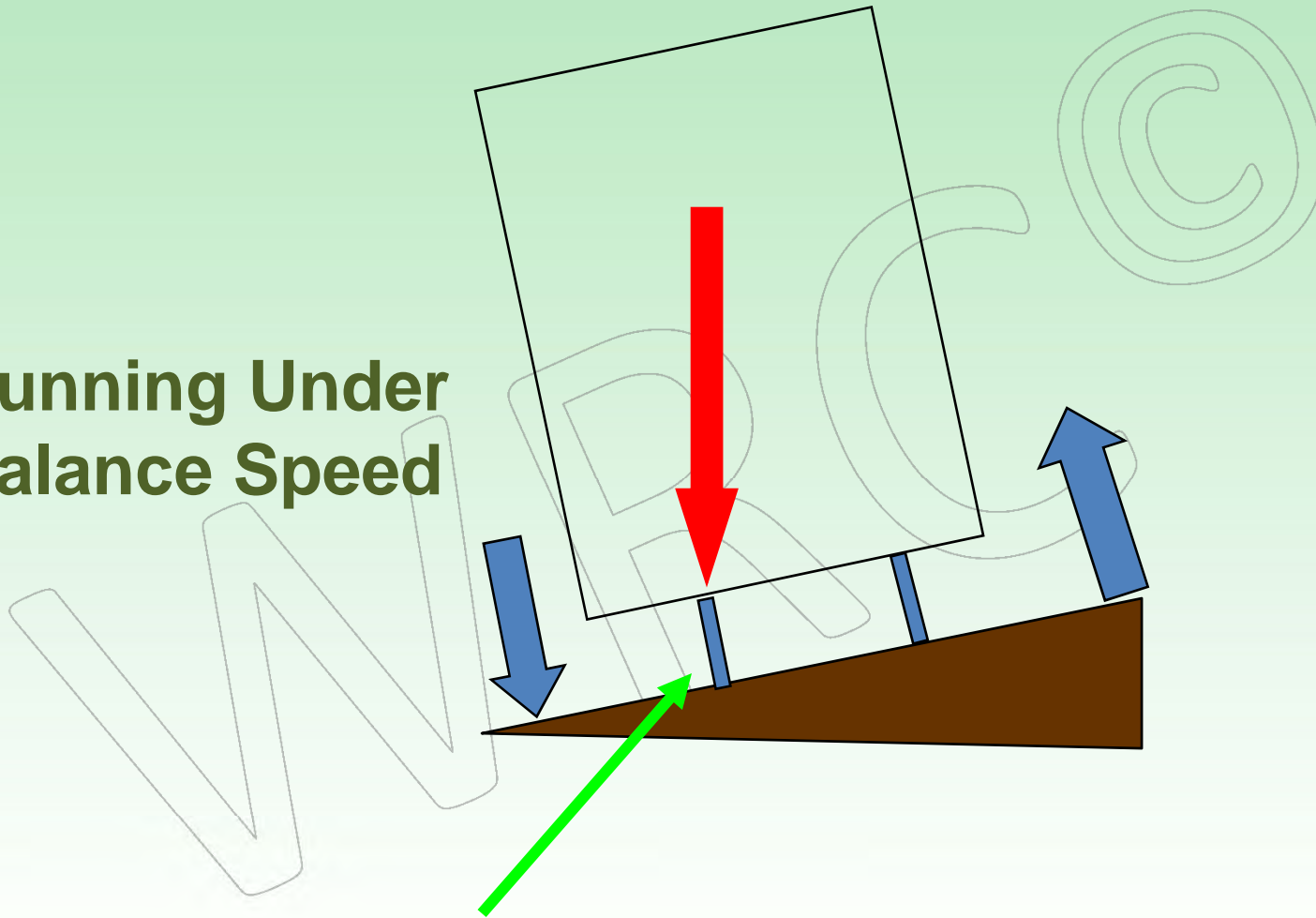
- Traditionally maximum superelevation put into curves
- Allowed for fast train speeds
- No clear understanding of wheel/rail interface mechanics



**At Equilibrium;
Equal Vertical Load
on High & Low Rail**

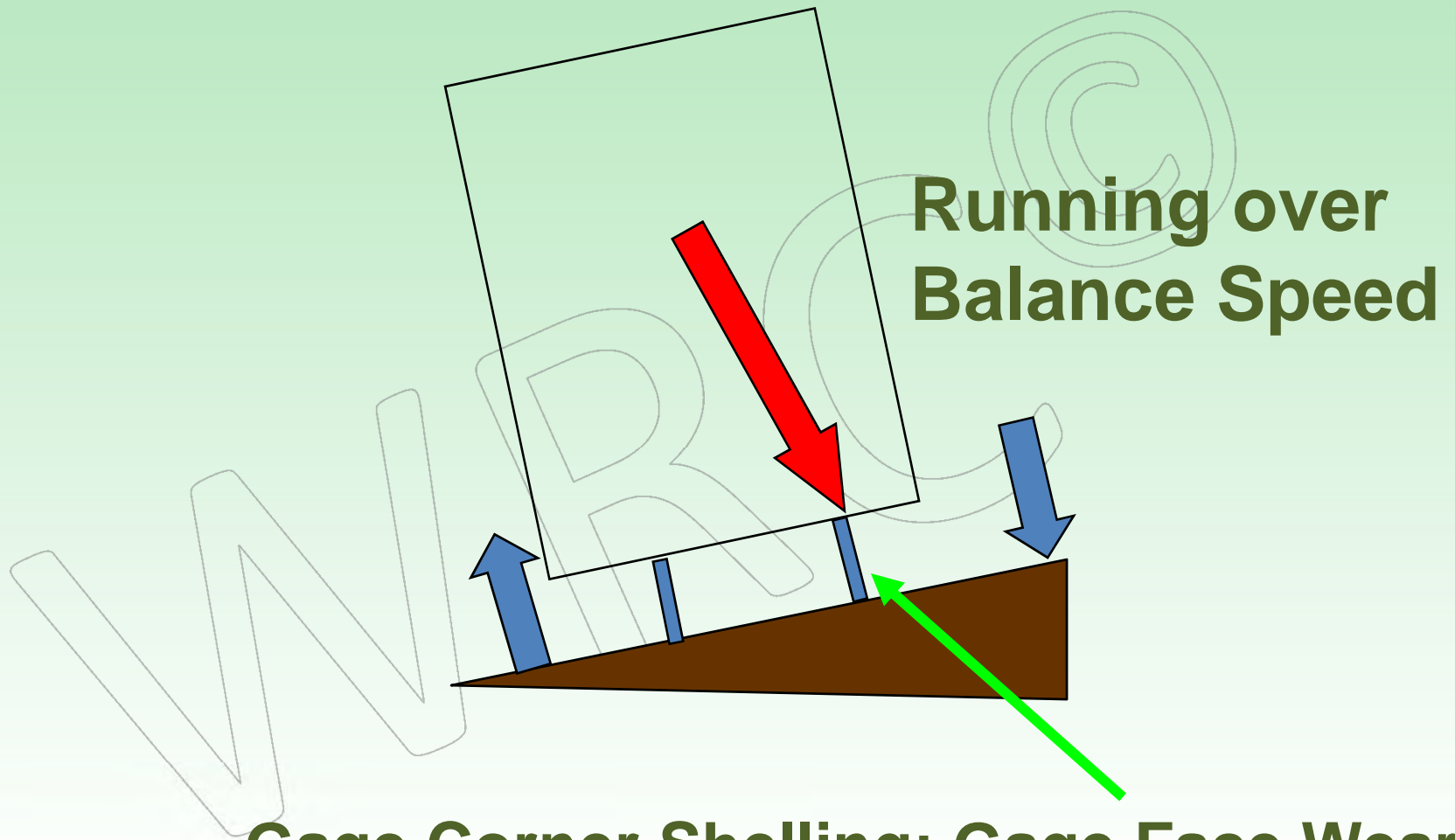


**Running Under
Balance Speed**



Spalling on Low Rail; Pumping at Joints





Gage Corner Shelling; Gage Face Wear



The Problem with Excess Superelevation

- Increased Vertical Loads on **Low Rail**
 - Increased lateral creep forces
 - Increased spalling on low rail
 - Increased derailment potential due to low rail rollover/gage widening derailments
- Increased potential for wheel climb on **high rail** due to rocking and track twist



Low Rail Spalling

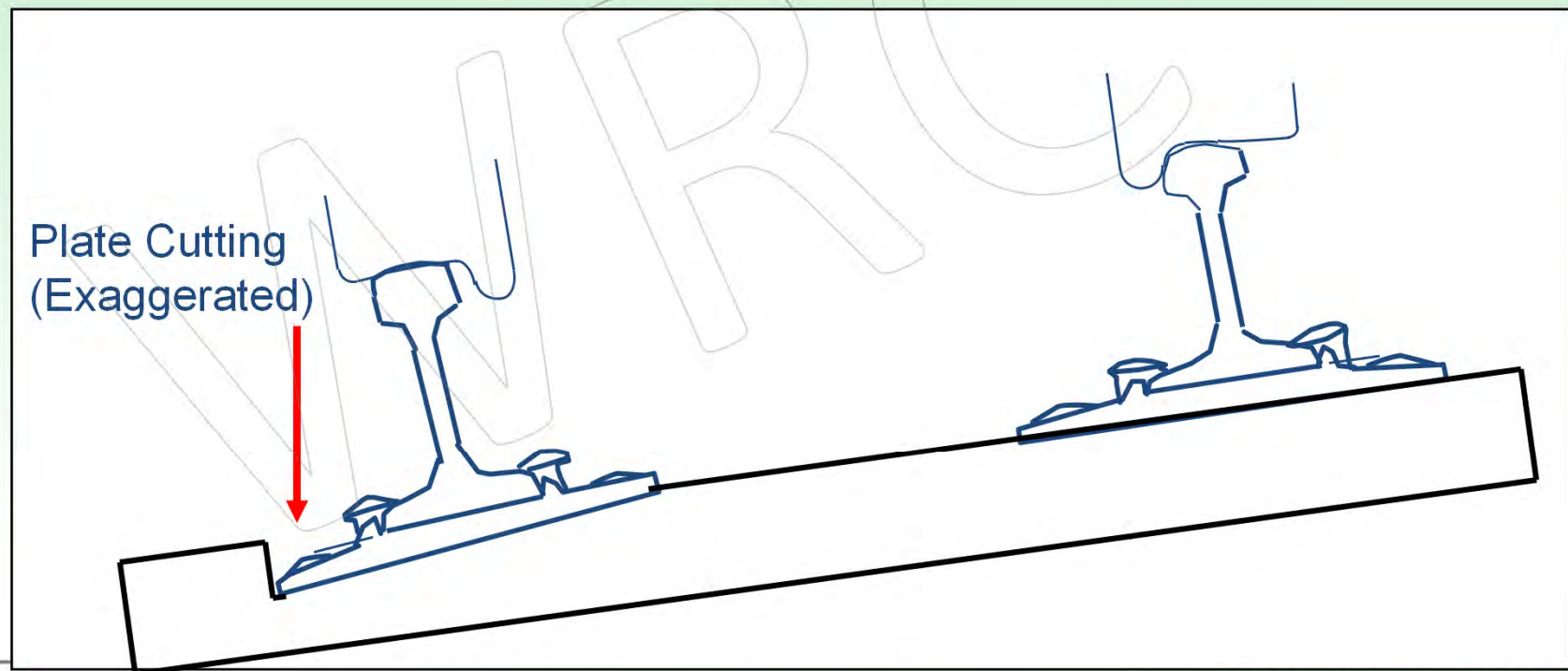


Low Rail Rollover/Gage Widening



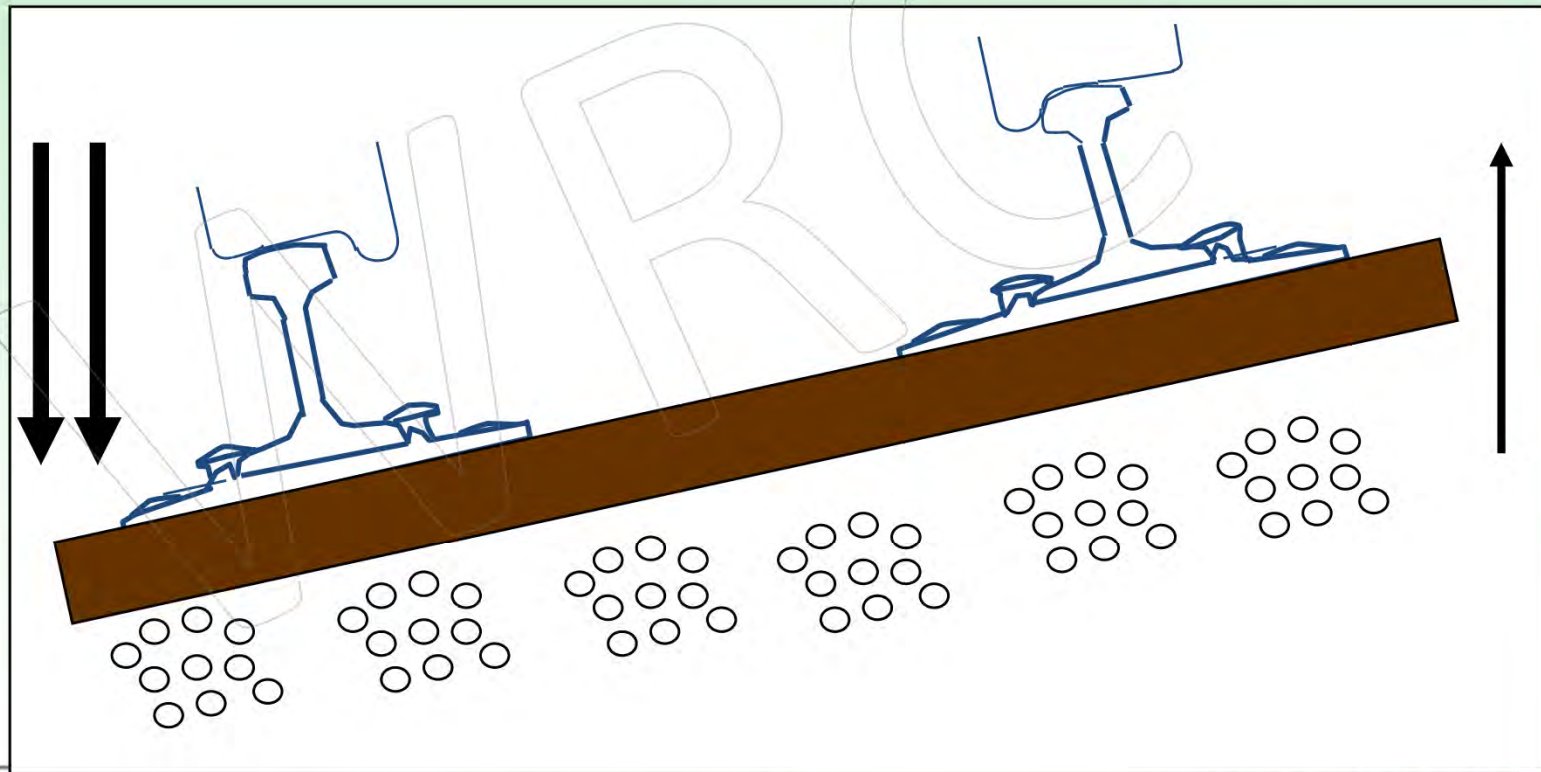
The Problem with Excess Superelevation

Excessive cutting on the low side due to too much elevation actually increases elevation and worsens situation



The Problem with Excess Superelevation

A curve with too much elevation will also gain even more due to excess ballast pressures on low side



Not Enough Superelevation...

- Increased high rail gage face wear
- Increased derailment potential due to wheel climb (High Lateral Pressure)
- Increased potential of car overturning
- Increased gage corner shelling



Gage Corner Shelling



Typical Scenarios to Watch For:

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



Elevation for Amtrak vs. Freight

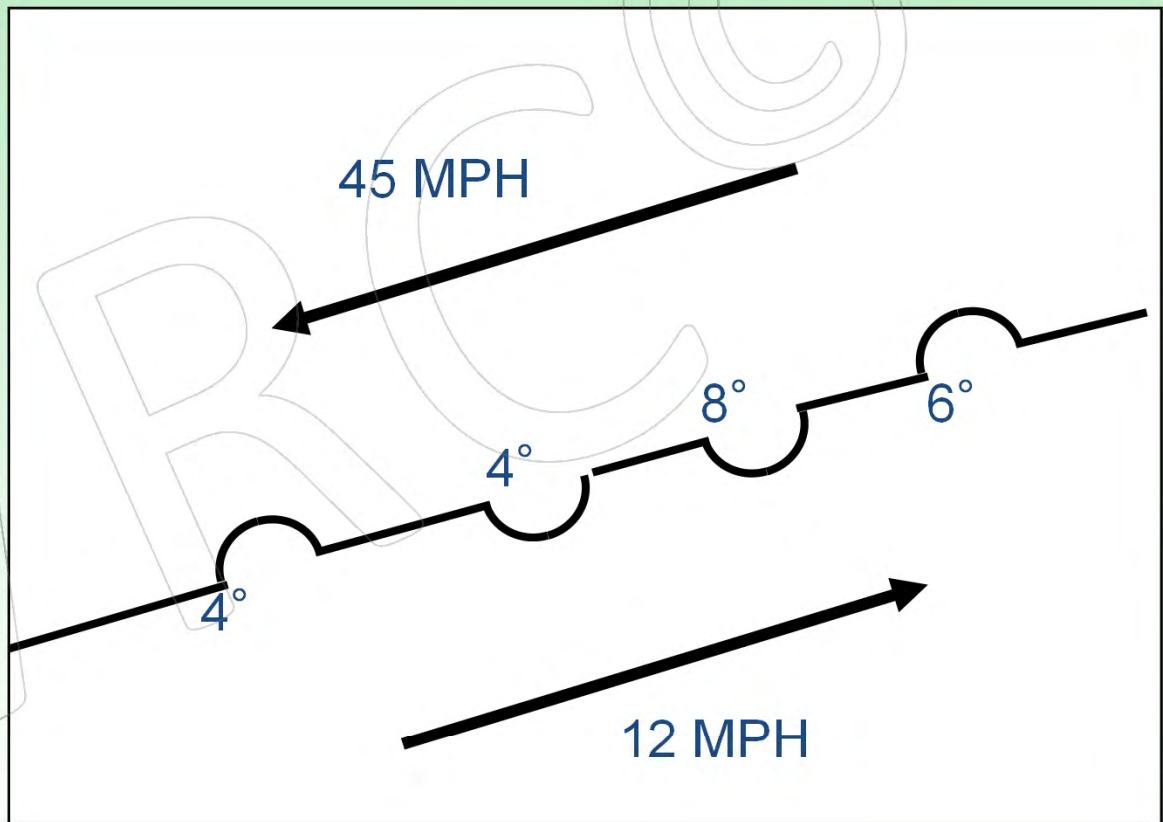
For a 2 Degree Curve:

Amtrak 79 MPH = 6" SE

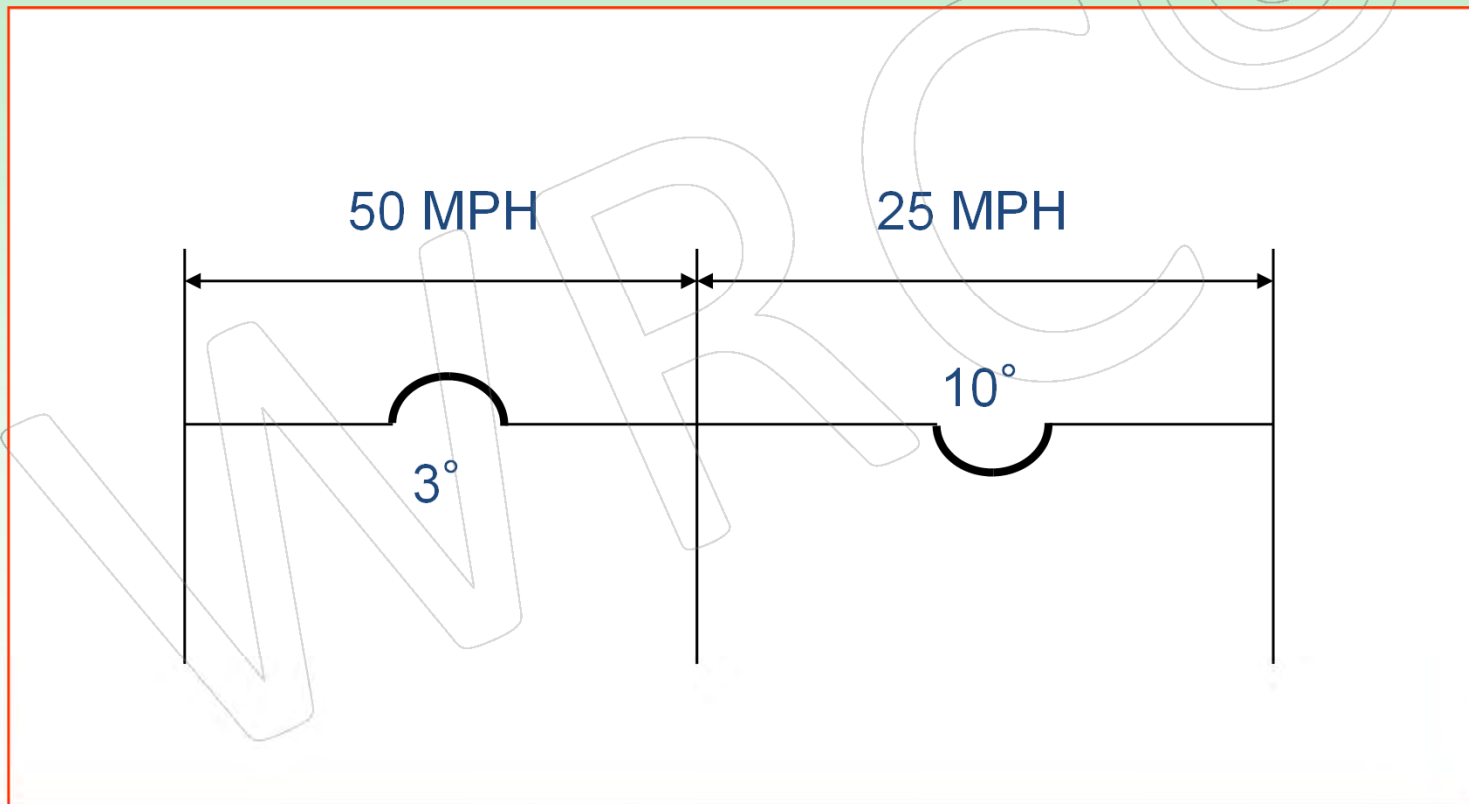
Freight 50 MPH = 2 1/2" SE



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.

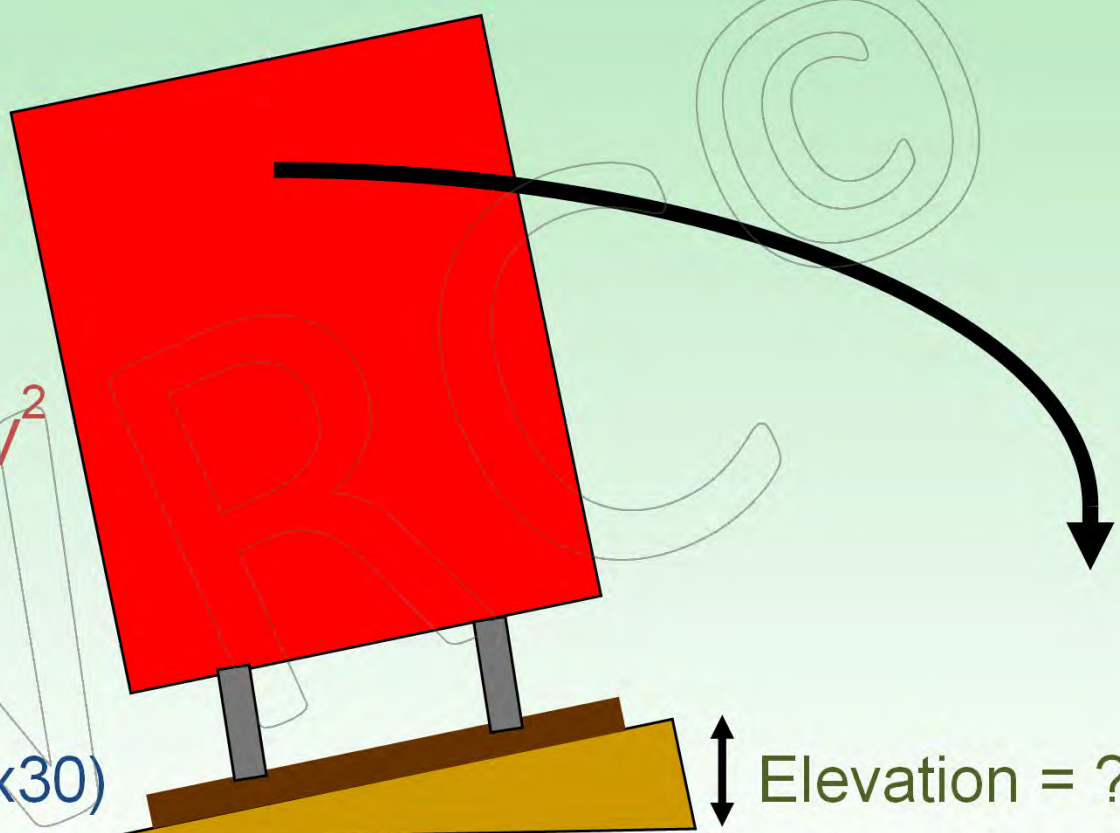


The Key Question...

What speed do you use to adjust
superelevation?



Correct Superelevation for Curve & Velocity



The diagram shows a red rectangular sign tilted to the right, mounted on two posts on a yellow-tinted road surface that is sloped to the right. A black arrow curves from the top of the sign towards the right, indicating the direction of travel. In the background, there are faint concentric circles representing a curve. A vertical double-headed arrow on the right side of the road surface is labeled "Elevation = ?".

$EL_{EQ.} = .00067 DV^2$

4 D. Curve

$V = 30 \text{ MPH}$

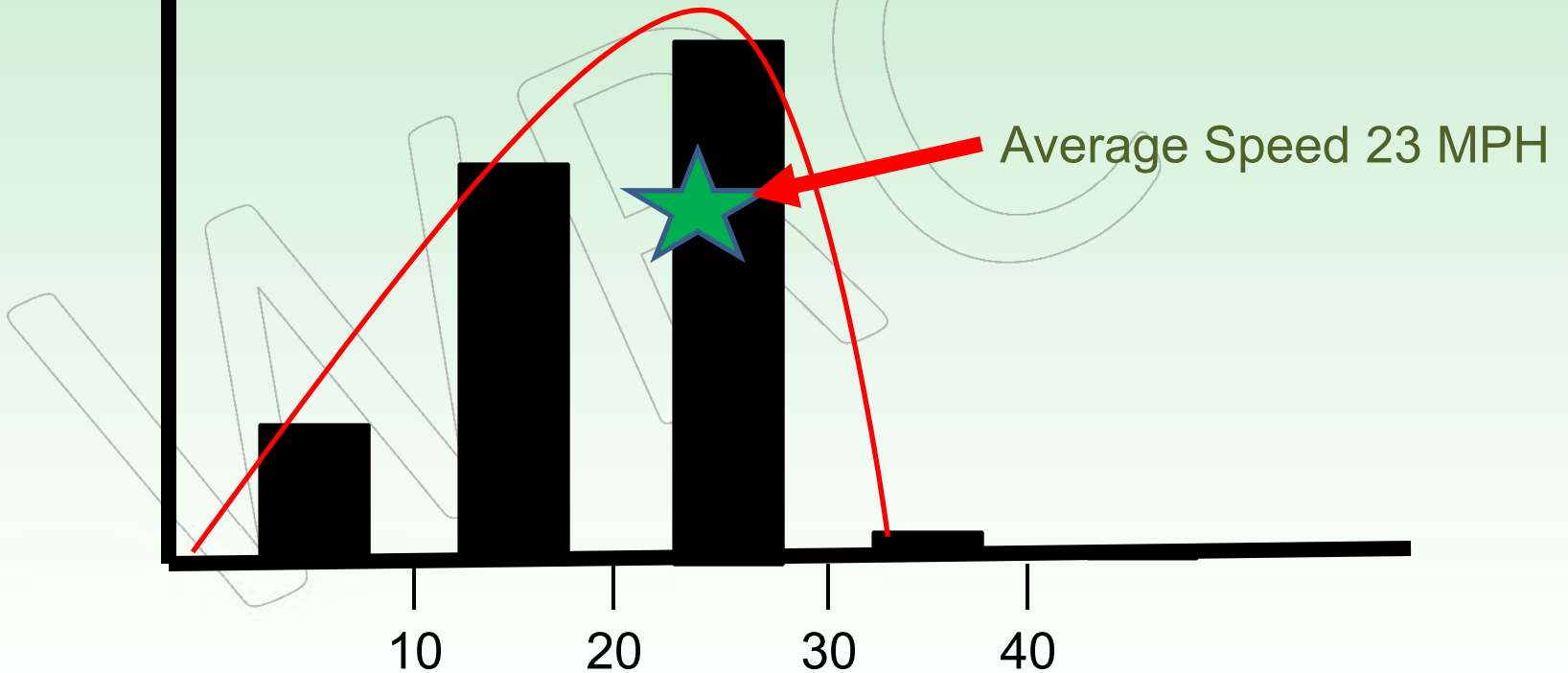
$EL = .00067 (4) (30 \times 30)$

$EL_{EQ.} = 2.4 \text{ "}$



Number of trains

Typical train speed distribution over a given territory with 30 MPH maximum speed



Correct Superelevation for Curve & Velocity

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

4 D. Curve

V = 30 MPH

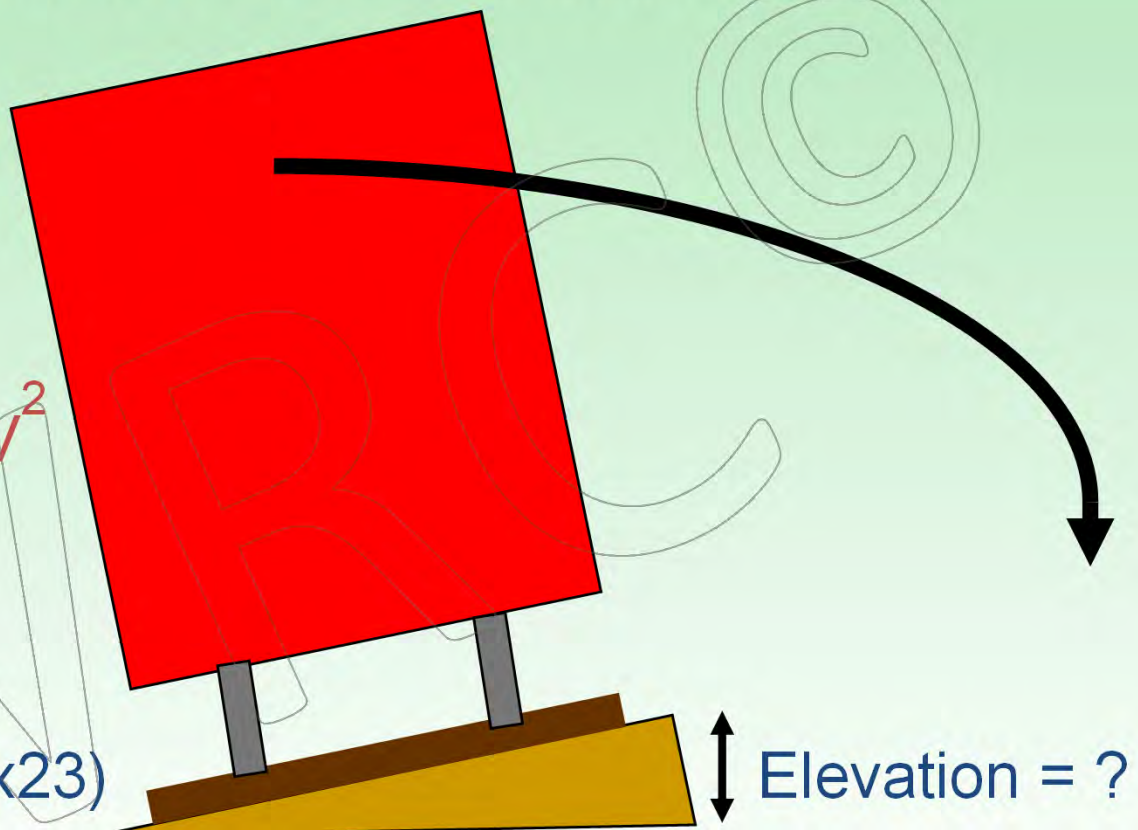
$$EL = .00067 (4) (30 \times 30)$$

$$EL\ EQ. = 2.4''$$

$$1''\ \text{Unbalance} \rightarrow 2.4'' - 1.0'' = 1.4''$$



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



The diagram shows a red rectangular train car tilted on a brown track that is banked to the right. A black arrow indicates the direction of travel along the curve. A vertical double-headed arrow on the right side of the track is labeled "Elevation = ?".

$EL_{EQ.} = .00067 DV^2$

4 D. Curve

$V = 23 \text{ MPH}$

$EL = .00067 (4) (23 \times 23)$

$EL_{EQ.} = 1.4 \text{ ''}$



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 Derailment Issues

- **Superelevation is added to curves to allow trains to operate at normal track speed without placing abnormally high lateral and vertical forces against the high rail.**
- **Insufficient elevation can lead to overturning of cars**
- **Excessive elevation places adverse vertical forces on the low rail of curves, which can result in broken rails, broken joints, low rail rollover, and wheel climb on high rail**
- **Many curves in North America are currently over-elevated given operating train speeds. Short lines are especially vulnerable to this condition.**
- **When operating in over-elevated curves, derailment risk increases when encountering significant track perturbations which may be FRA/TC compliant.**



Superelevation Derailment Check List

- Determine actual train speed, timetable train speed, and design speed for curve.
- Calculate equilibrium elevation for actual speed of train.
- If train was operating at 3" or more of over-elevation, elevation may be primary cause of derailment, or major secondary cause.
- In general, curves in excess of 4" of elevation are at risk when operating at 10 MPH or lower.
- Over-elevated curves can contribute to following type of derailments:
 - Wheel lift-off on high rail when encountering marginal track twist
 - Harmonic rock and roll
 - Low rail rollover; wide gage
 - Broken low rail or joint bar
- Under-elevation of curves can contribute to the following types of derailments:
 - Wheel climb or rail rollover of high rail of curve
 - Car Overturning



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

Degree of curvature	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
	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.

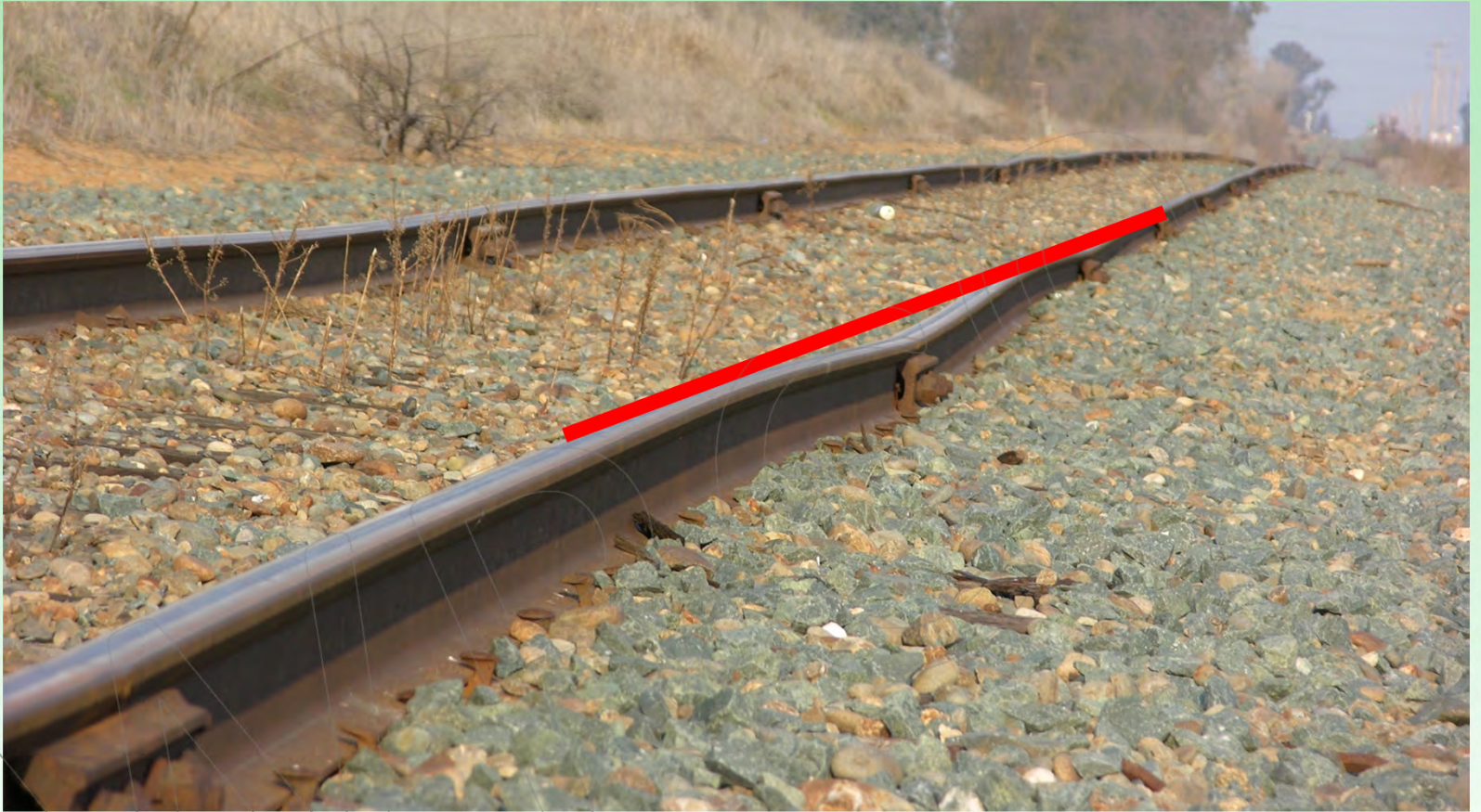
(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

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 ^{* 12}	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

¹Except 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 1 1/2 inches.

²However, 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 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

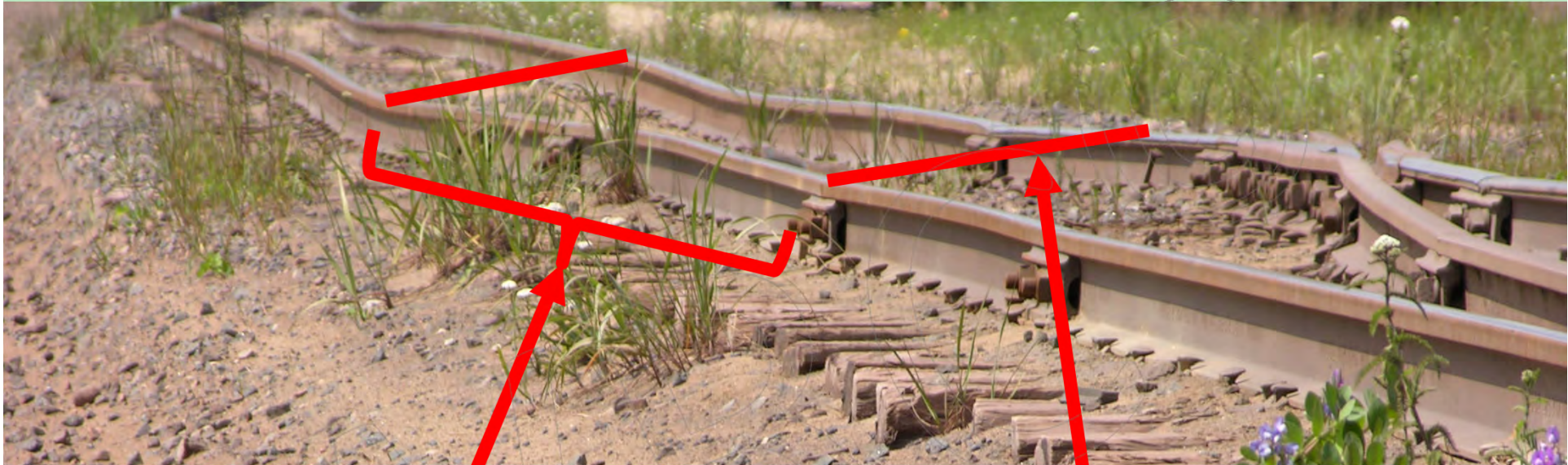


2 Key Words used in the FRA Regulations

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				
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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

¹Except 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 1 1/2 inches.

²However, 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 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.

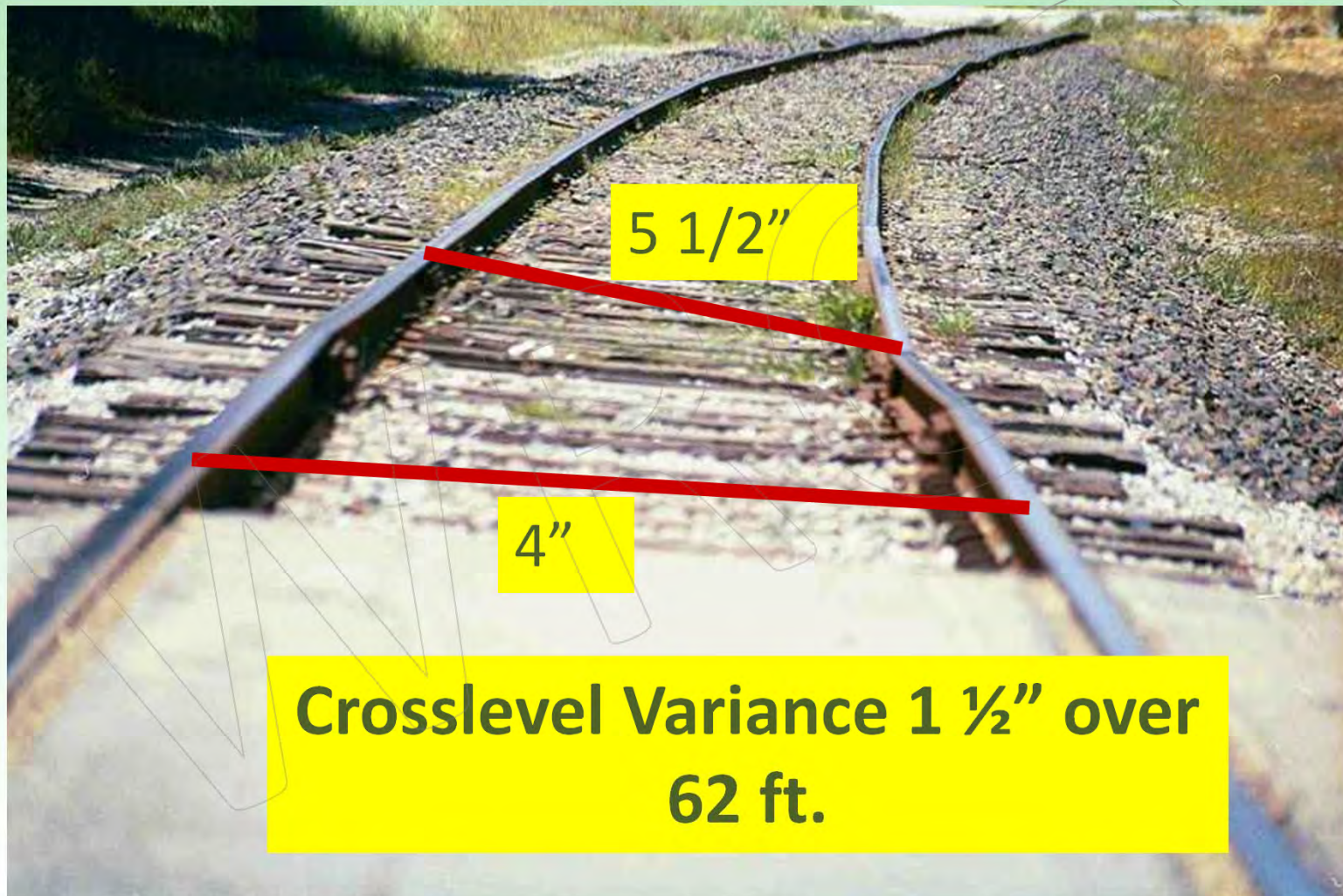


Crosslevel Variations

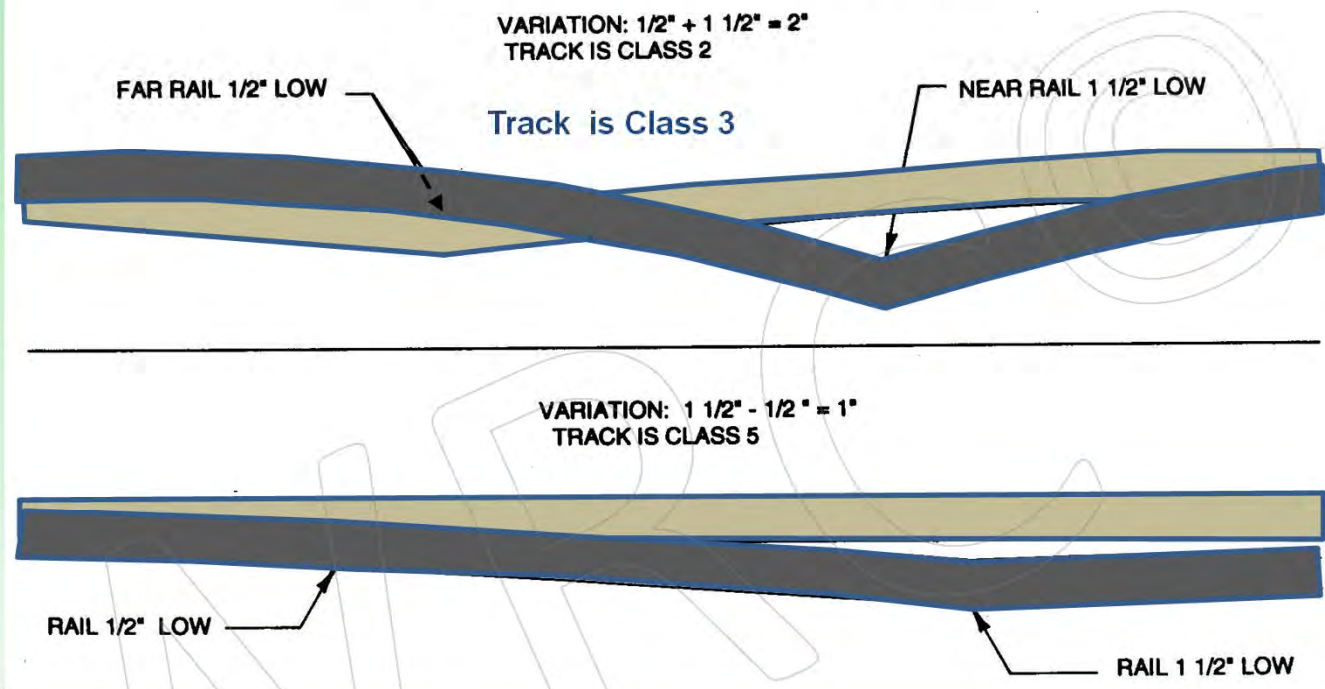


Any two Crosslevel measurements less than 62' apart

Crosslevel Variations



CROSSLLEVEL VARIATIONS ON TANGENTS & CURVES



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

1	2	3	4	5
3"	2 1/4"	2"	1 3/4"	1 1/2"

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:

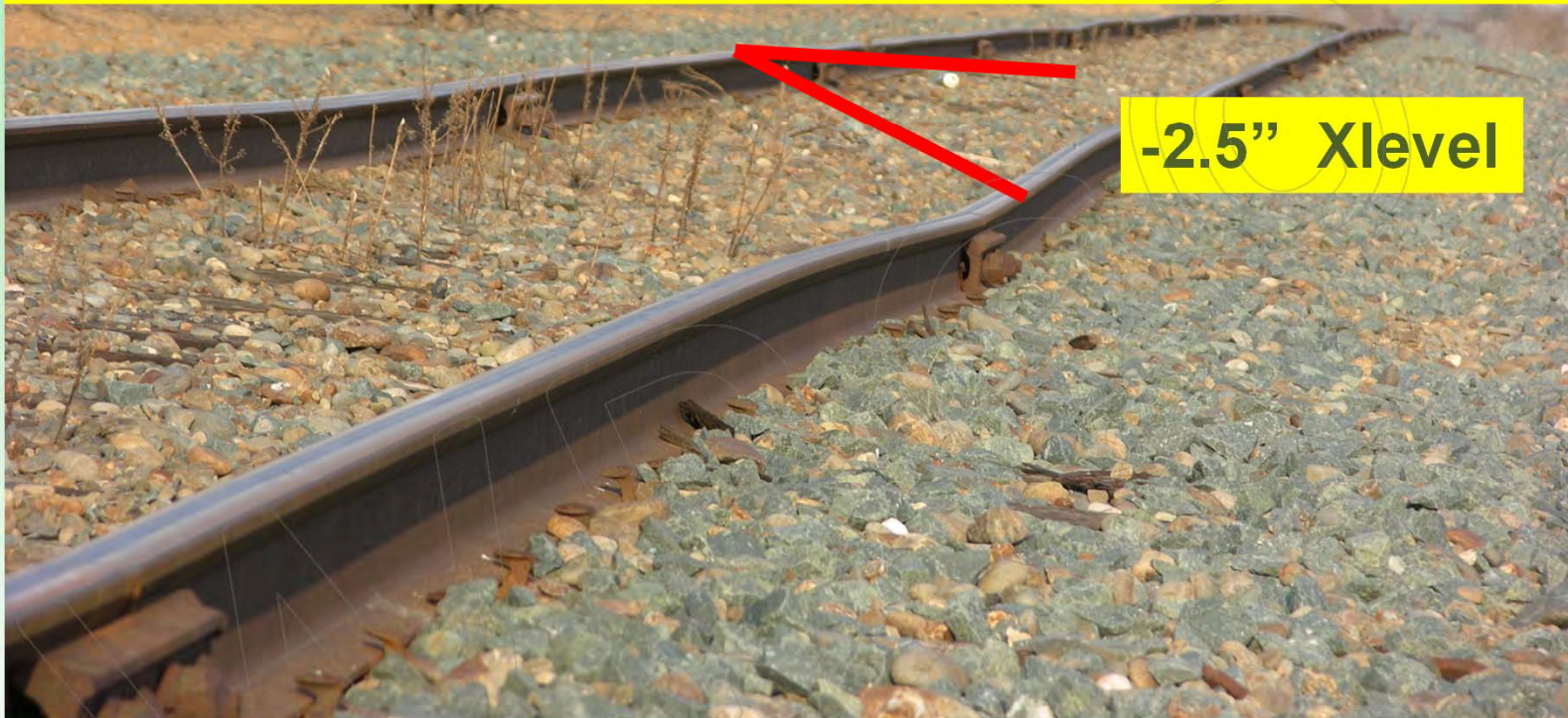
Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero 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

¹Except 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 1 1/2 inches.

²However, 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 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.



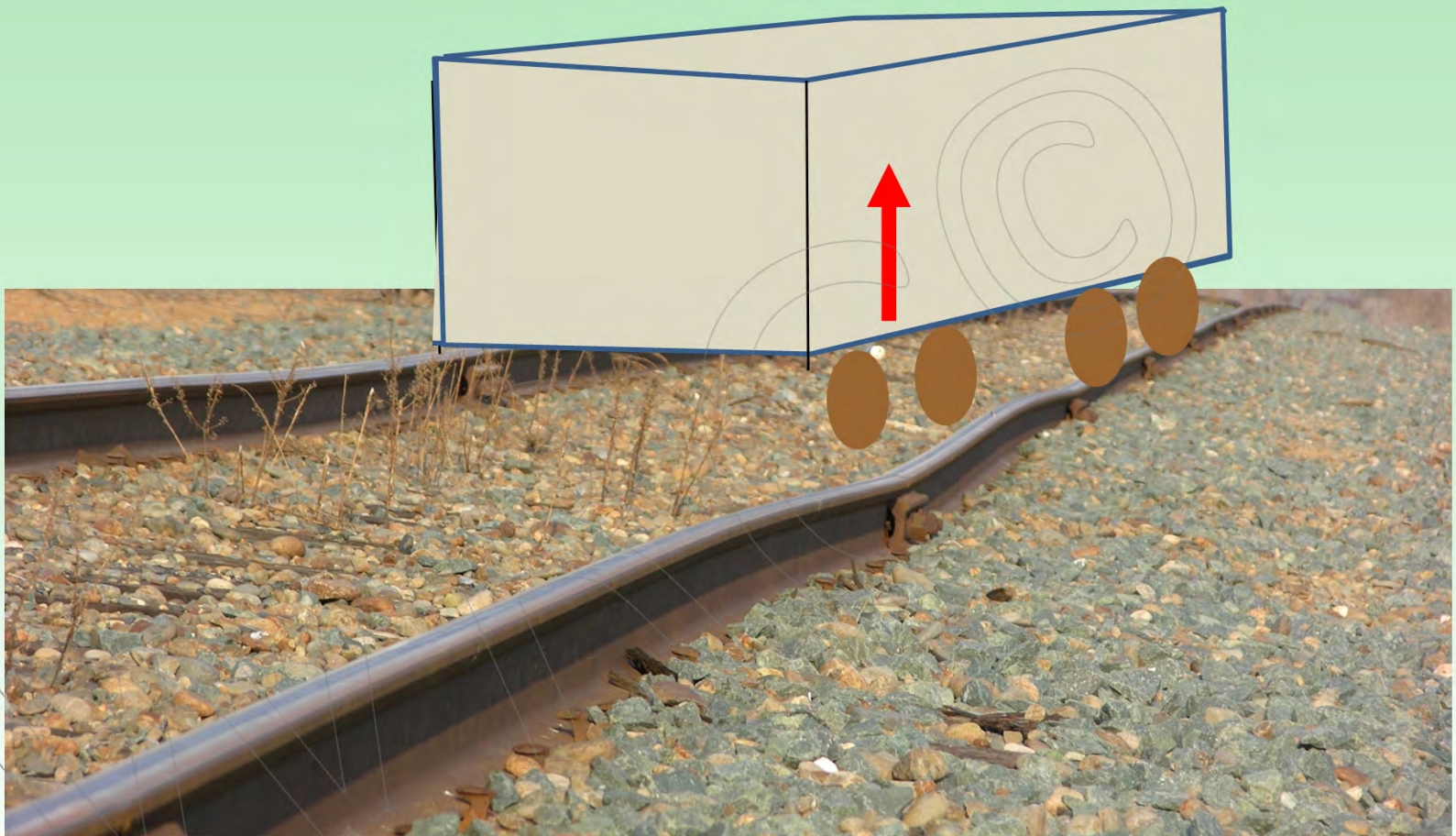
Crosslevel Deviations



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

1	2	3	4	5	Class
3"	2"	1 3/4"	1 1/4"	1 "	Deviation

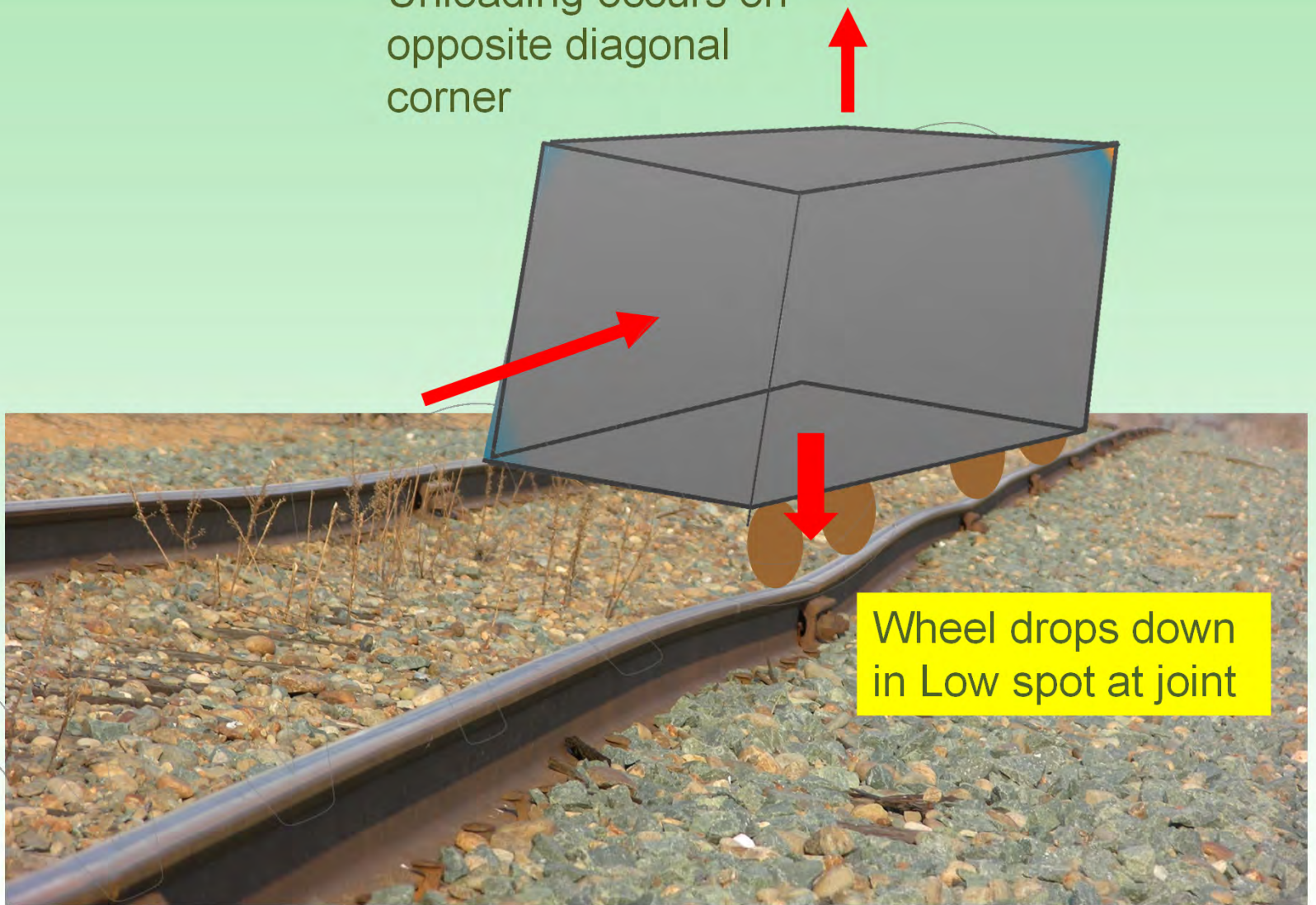




**Wheel Unloading/Lift due to Crosslevel Variation
Between rear and front trucks**



Unloading occurs on
opposite diagonal
corner

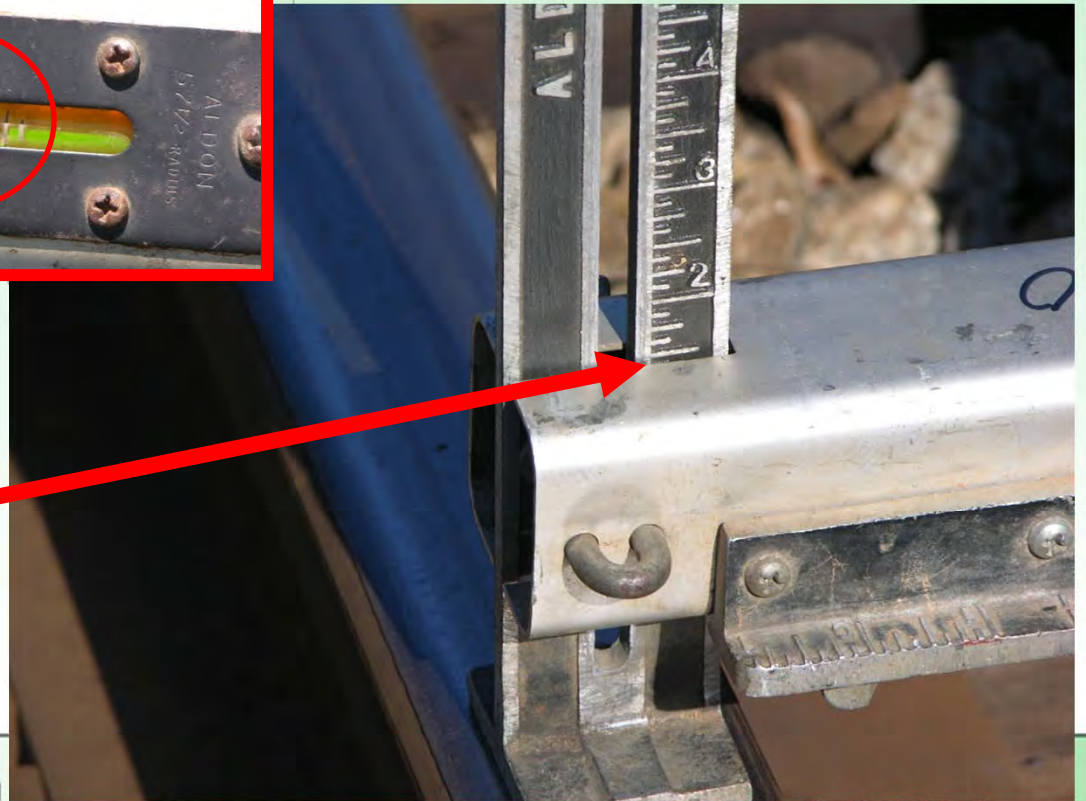
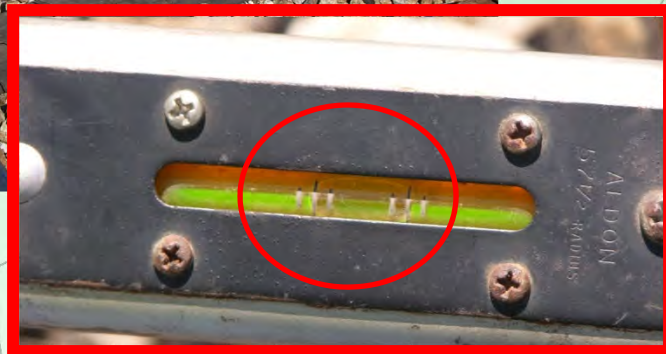


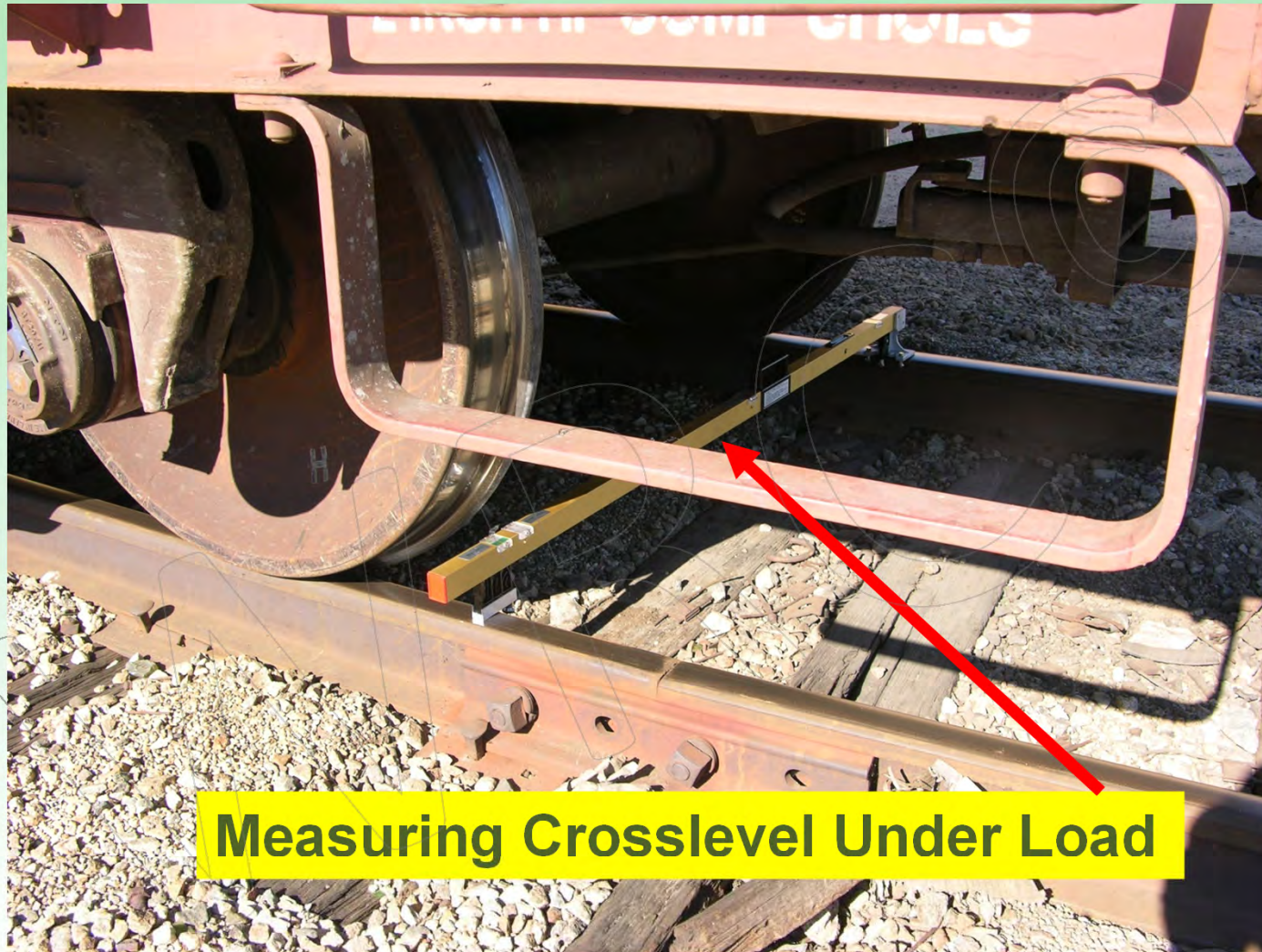
Wheel drops down
in Low spot at joint

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



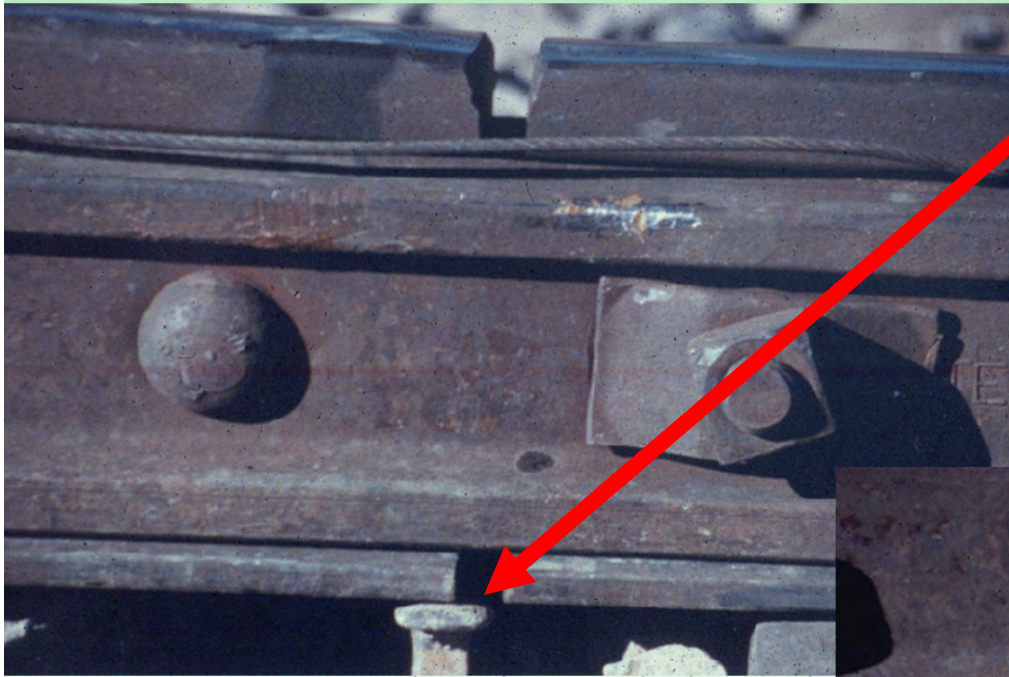
Measuring Crosslevel with level board





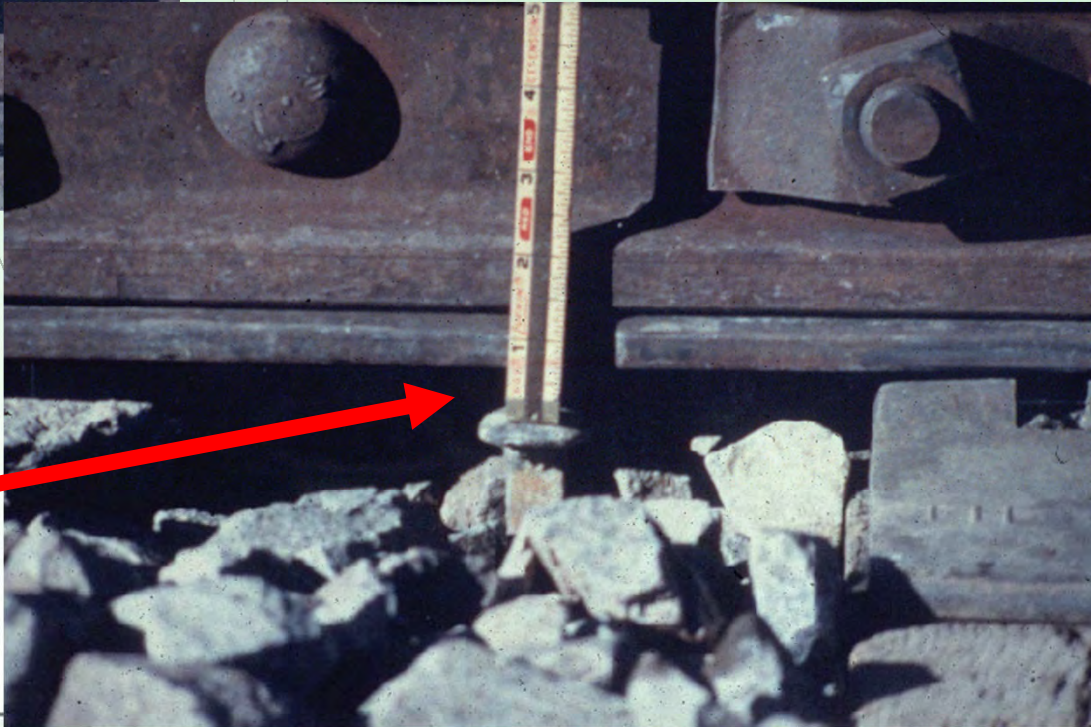
Measuring Crosslevel Under Load





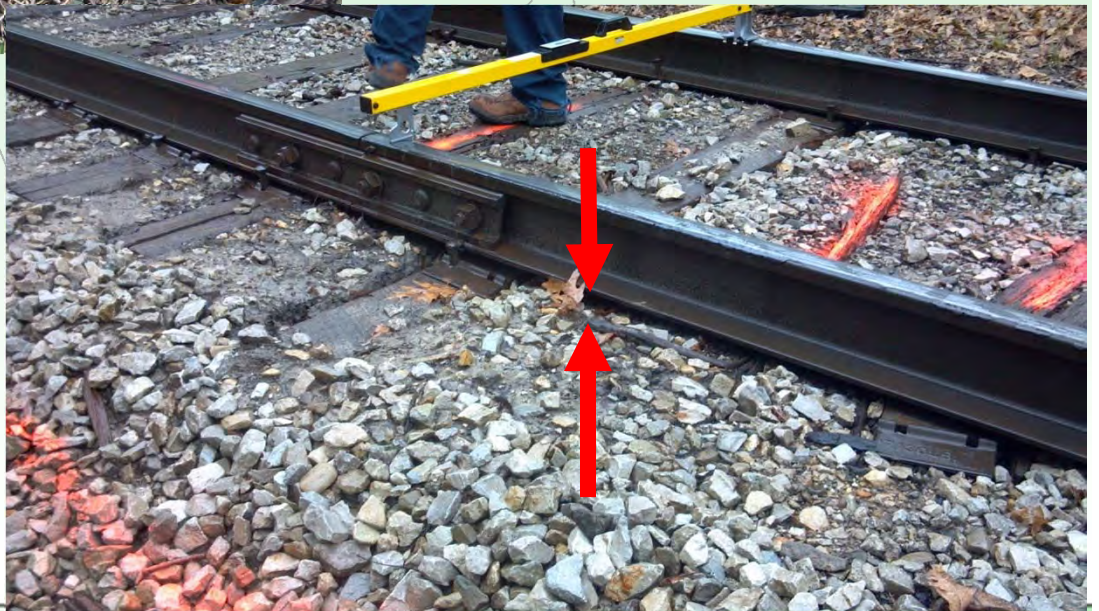
Tamp Spike up Under Base of Joint

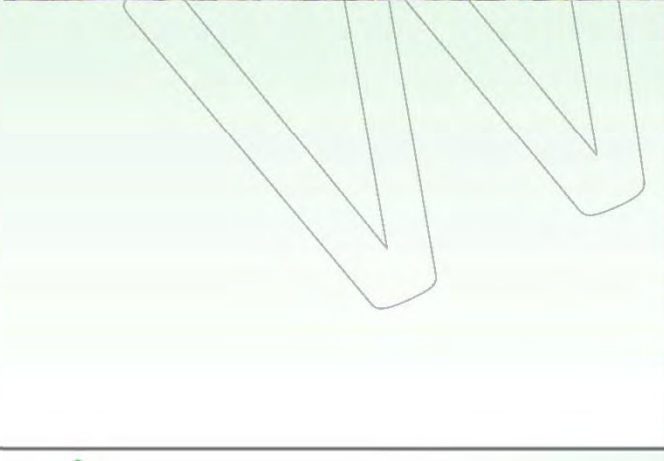
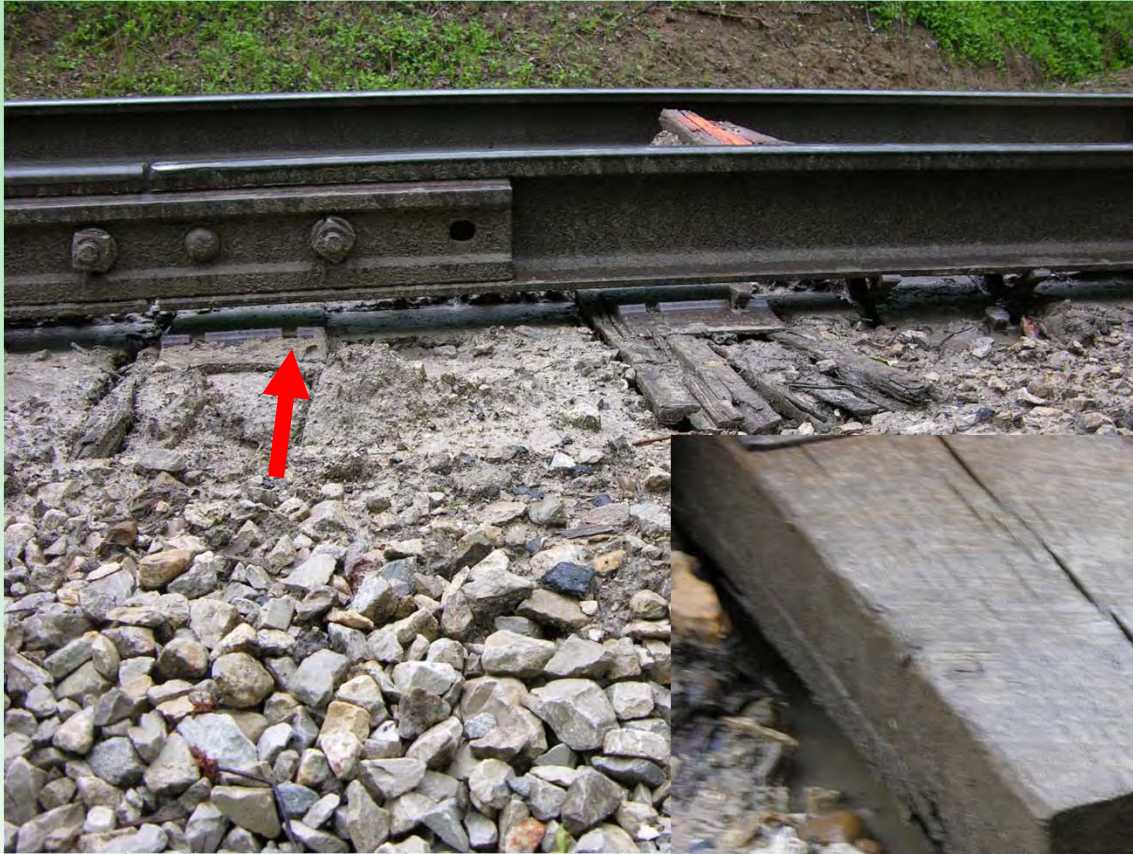
**Run Train over Joint;
Measure Maximum
Deflection**



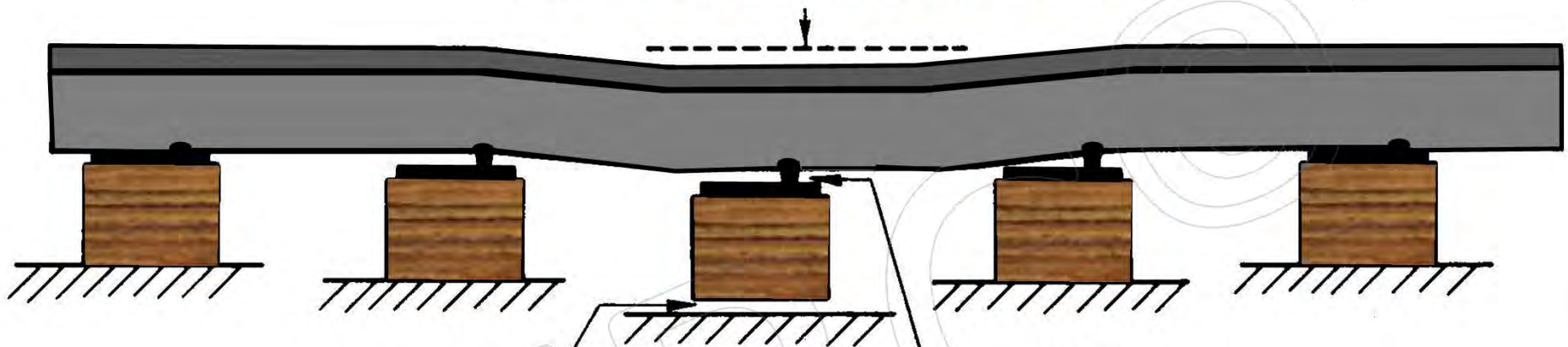


Hanging Ties





MEASURED CROSSLEVEL 1"



1/2" SPACE (Hanging Tie)

3/8" SPACE

MEASURED CROSS LEVEL
SPACE UNDER TIE PLATE
SPACE UNDER TIE

1"
3/8"
1/2"

ACTUAL CROSSLEVEL UNDER LOAD

1 7/8"

MEASURING CROSSLEVEL NOT UNDER LOAD

MEASURING CROSSLEVEL NOT UNDER LOAD

§ 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.

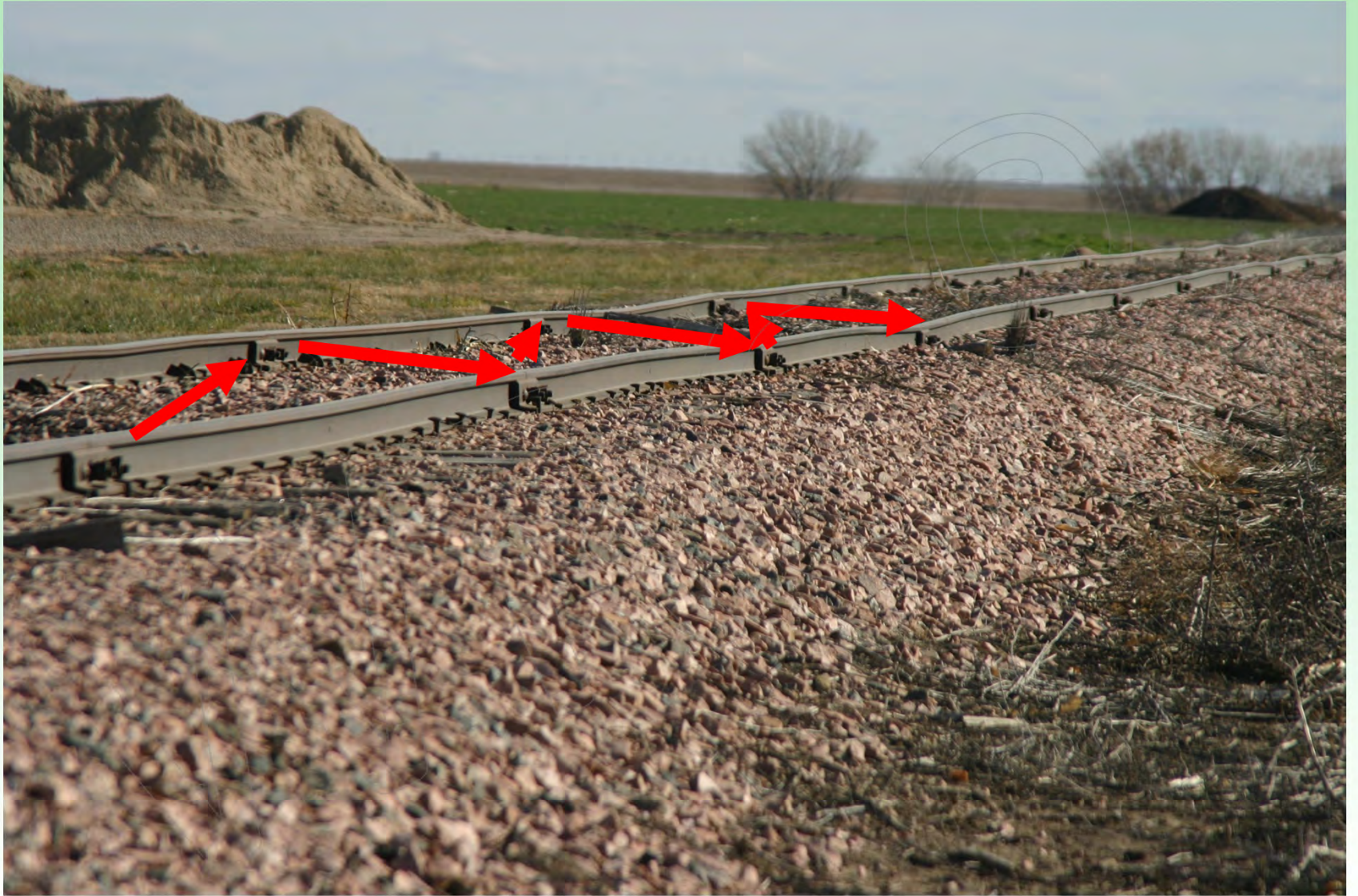
(a) Except as provided in paragraph (b) of this section, each track owner shall maintain the surface of its track within the limits prescribed in the following table:

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 ^{* 12}	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

¹Except 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 1 1/2 inches.

²However, 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 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.



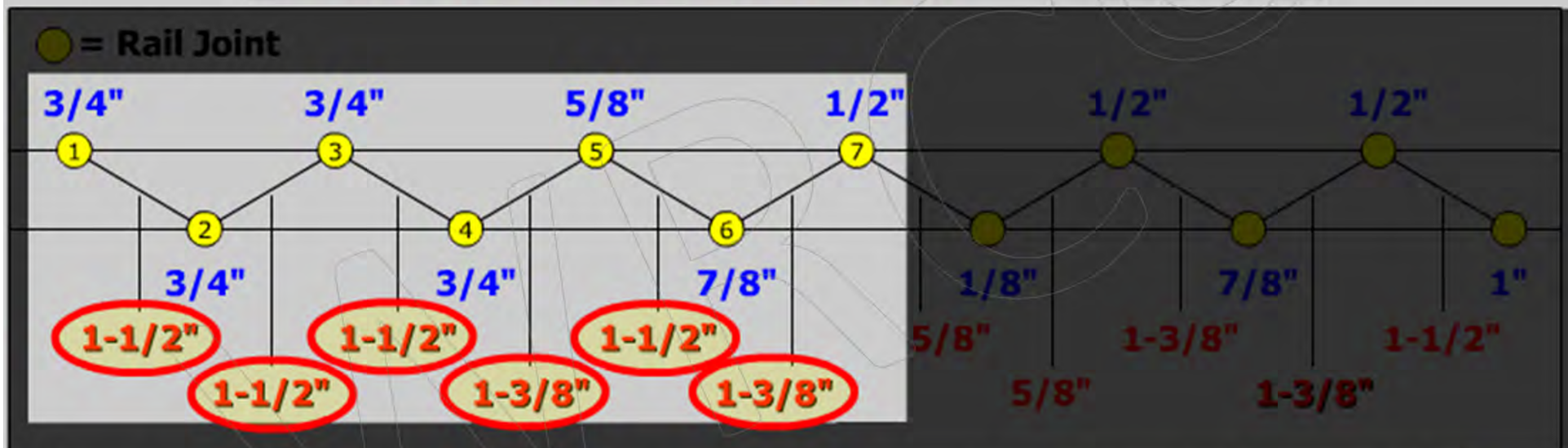


Staggered Jointed Rail



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.)



§ 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:

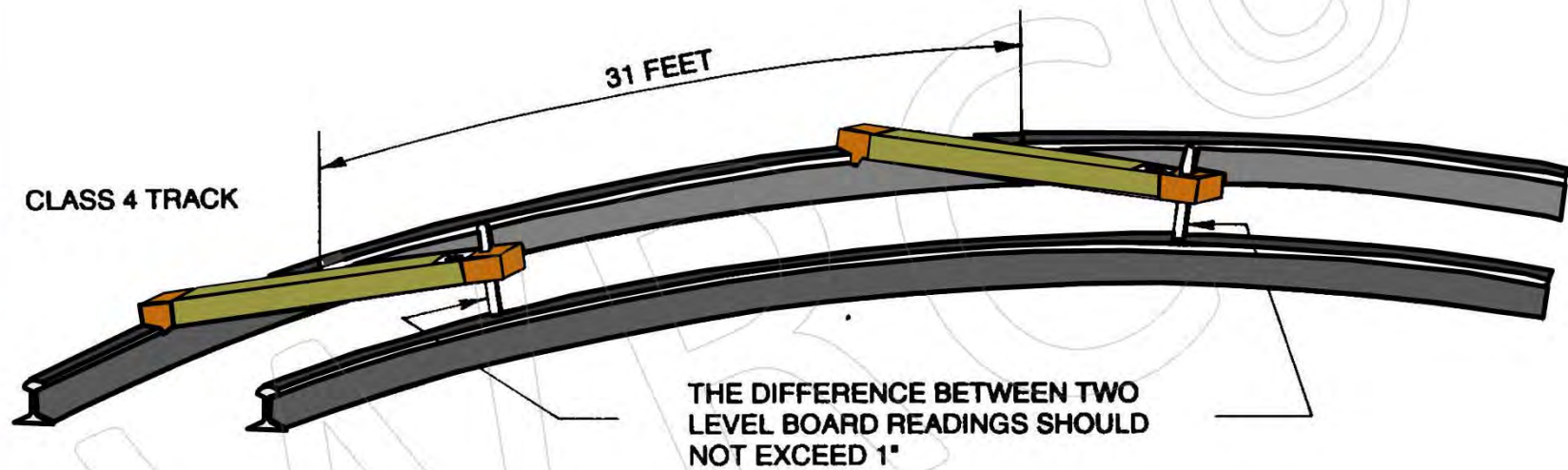
Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero 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 ^{* 12}	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

¹Except 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 1 1/2 inches.

²However, 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 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



VARIATION IN CROSSLEVEL ON SPIRALS IN ANY 31'
MAY NOT BE ANY MORE THAN

CLASS OF TRACK				
1	2	3	4	5
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	1/2"	3/8"	3/8"
3	1"	3/4"	3/8"
4	1 1/2"	1"	1/4"
5	2"	1 1/8"	1/8"
6	2 1/2"	1 7/8"	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:

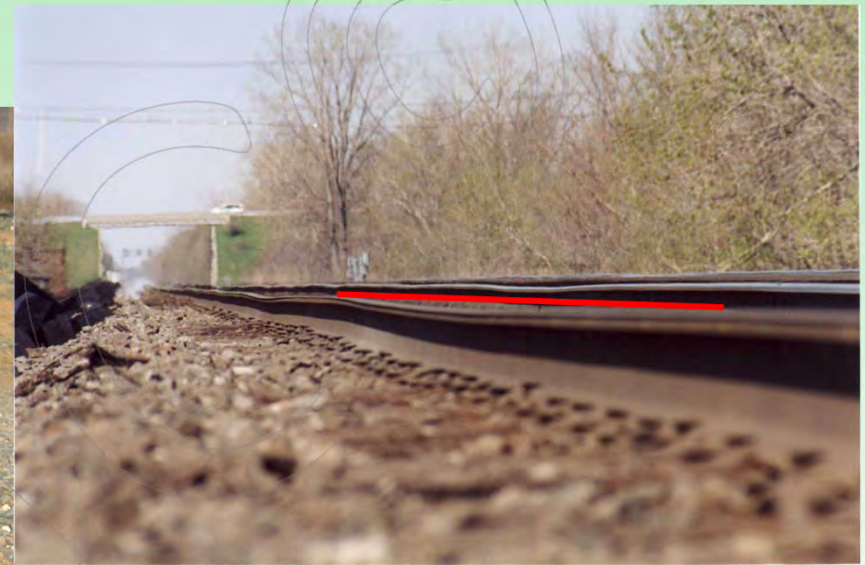
Track surface (inches)	Class of track				
	1	2	3	4	5
The runoff in any 31 feet of rail at the end of a raise may not be more than	3 1/2	3	2	1 1/2	1
The deviation from uniform profile on either rail at the mid-ordinate of a 62-foot chord may not be more than	3	2 3/4	2 1/4	2	1 1/4
The deviation from zero 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 ^{* 12}	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

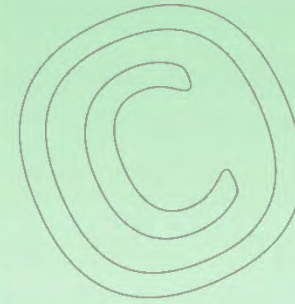
¹Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 1 1/2 inches.

²However, 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 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.

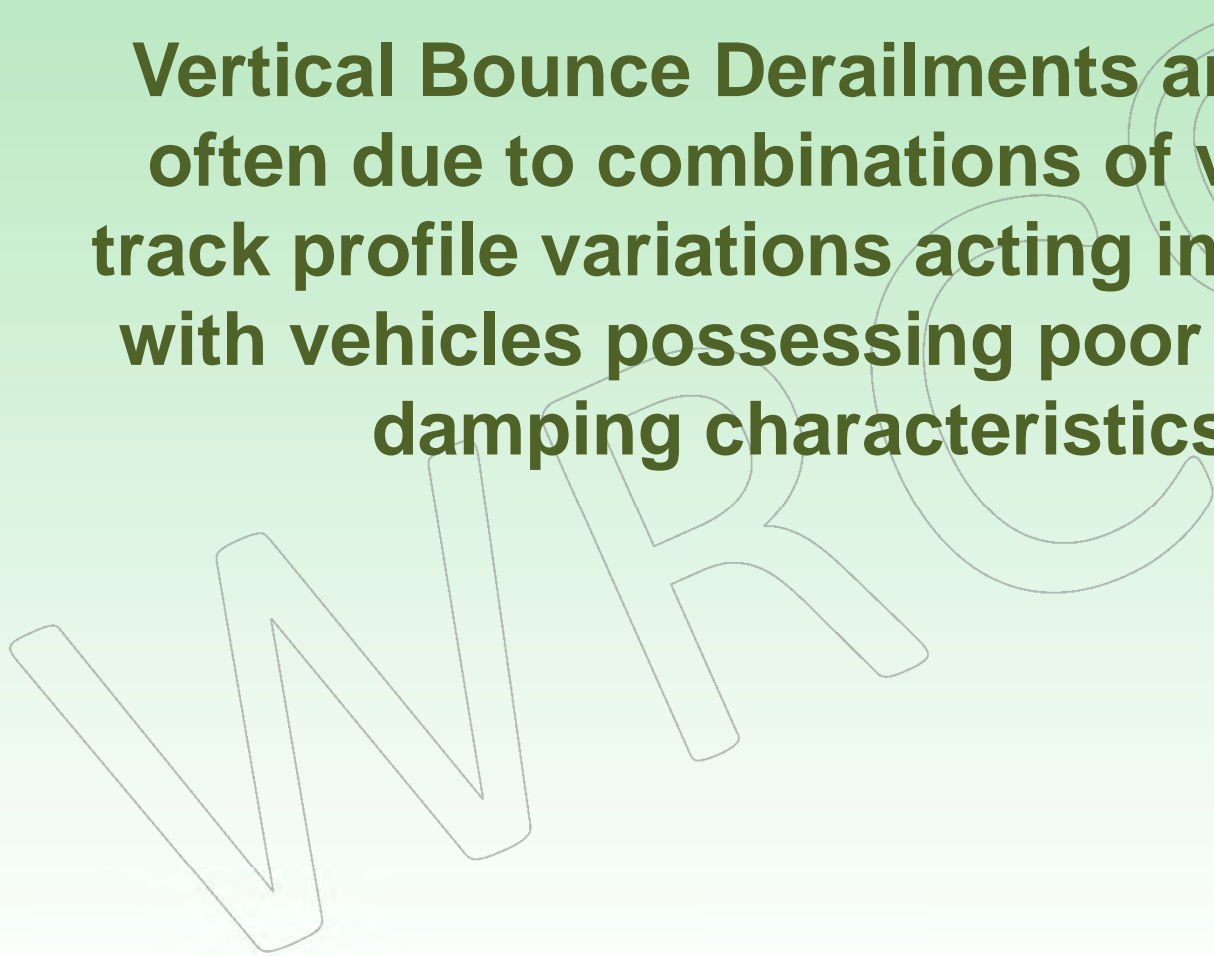


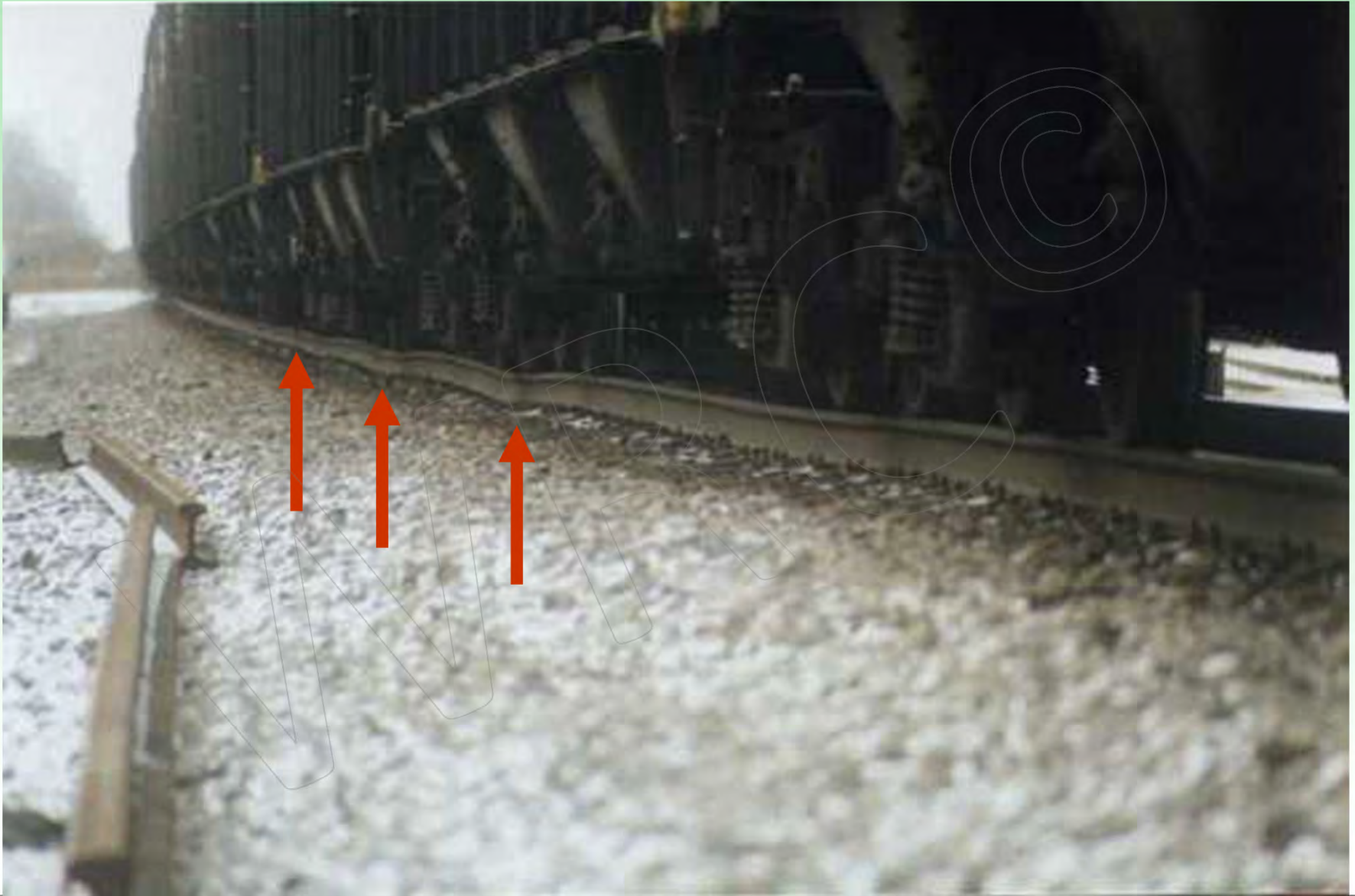
Vertical Profile Deviations





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





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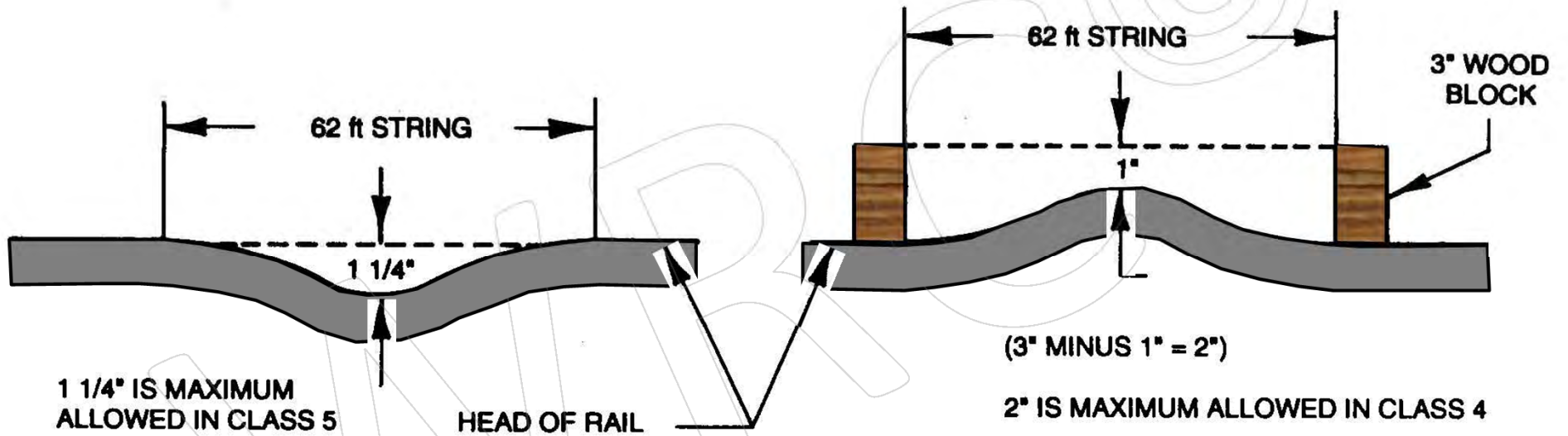
Vertical profile deviation caused by poor subgrade



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



DEVIATION FROM UNIFORM PROFILE



THE DEVIATION FROM UNIFORM PROFILE ON EITHER RAIL AT THE MID-ORDINATE OF A 62' CHORD MAY NOT BE MORE THAN

CLASS OF TRACK				
1	2	3	4	5
3"	2 3/4"	2 1/4"	2"	1 1/4"



Checking Vertical Profile with 62' Chord



§ 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 ^{* 12}	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

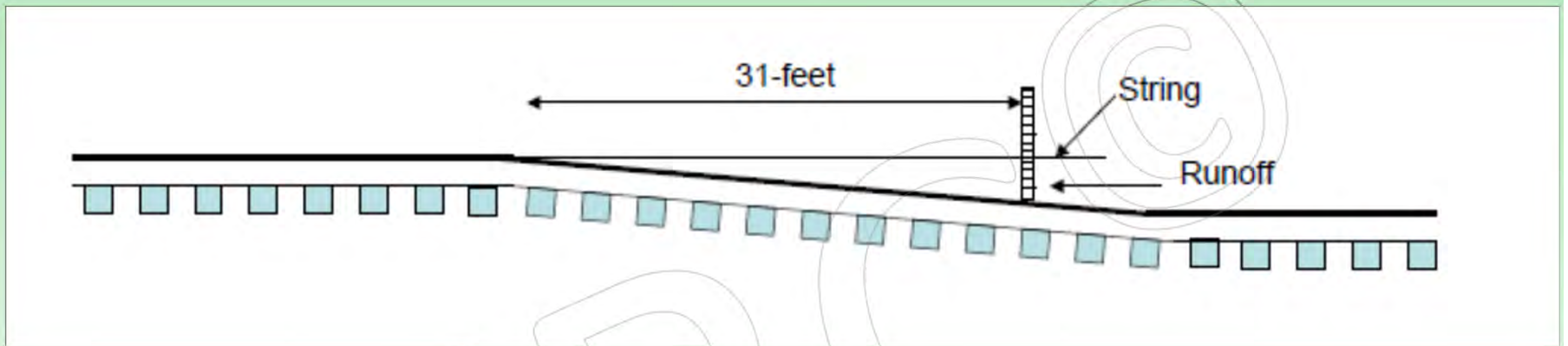
¹Except as limited by § 213.57(a), where the elevation at any point in a curve equals or exceeds 6 inches, the difference in crosslevel within 62 feet between that point and a point with greater elevation may not be more than 1 1/2 inches.

²However, 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 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

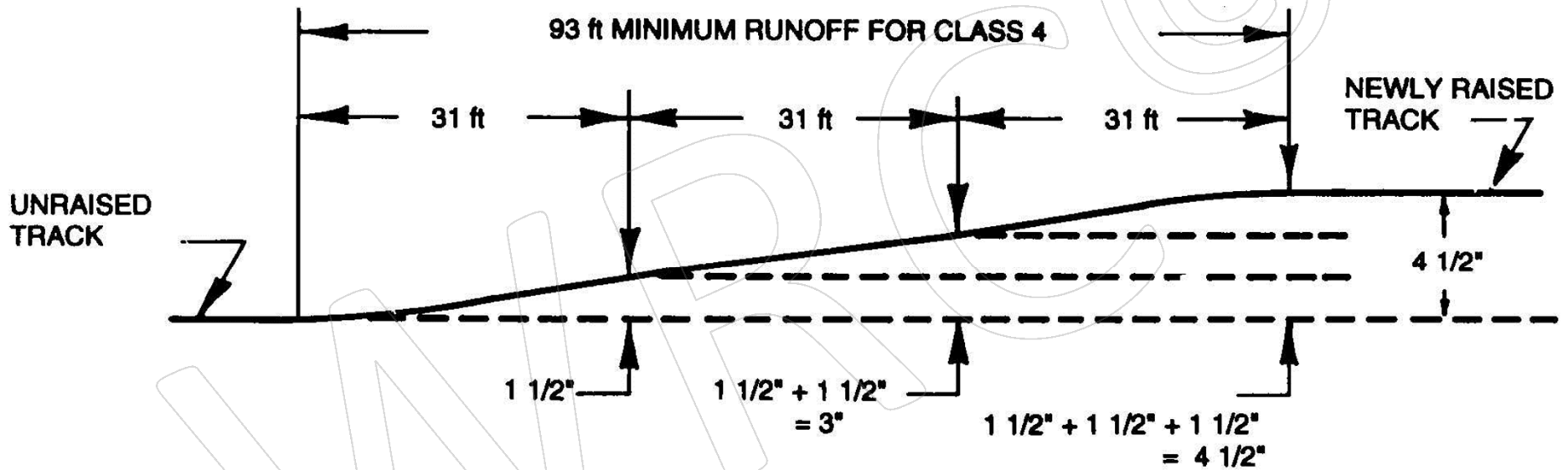




Rate of Runoff over 31 feet



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



THE RUNOFF IN ANY 31' OF TRACK AT THE END OF A RAISE MAY BE NO MORE THAN

CLASS OF TRACK				
1	2	3	4	5
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

WVRR

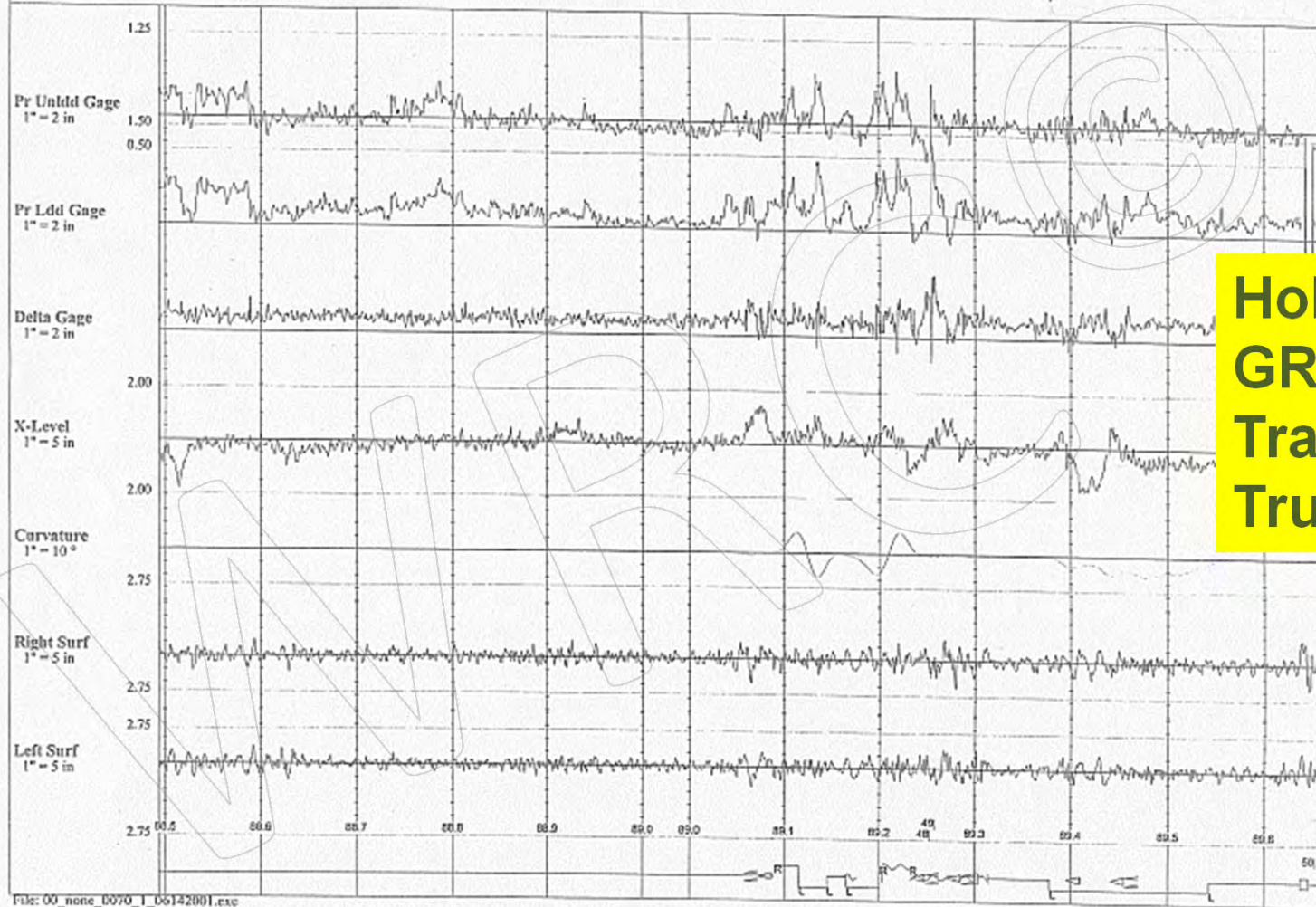


Client Name:
Date: 6/14/2001
Division:
Subdivision:
Track: 1

FRA Class: 2
Milepost:
Increasing Milepost Counter
Direction: South
Operator: .

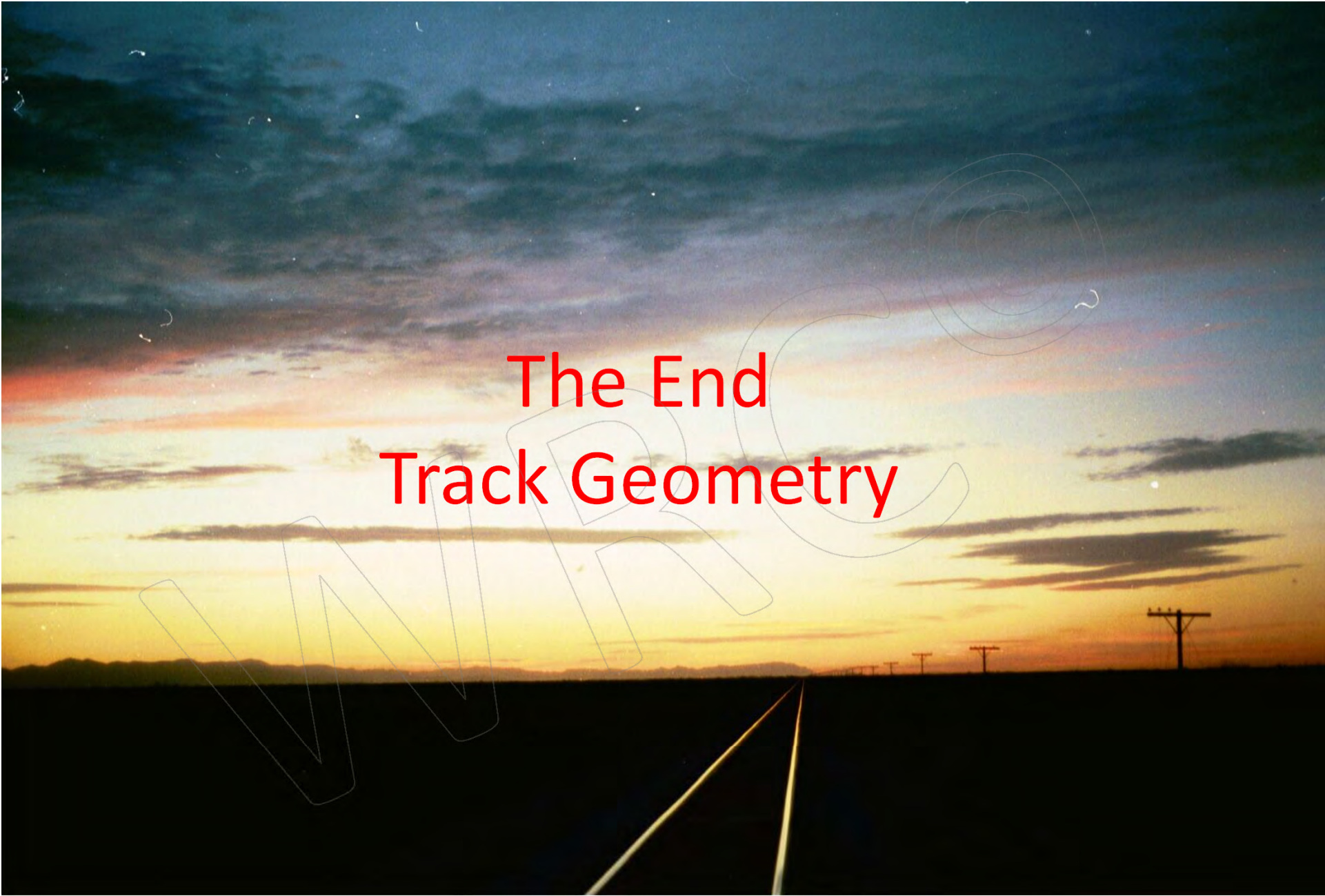
RR Personnel:
Lateral Load (kips): 9.000
Vertical Driver Load (kips): 15.000
Vertical Passenger Load (kips): 15.000
L/V Ratio: 0.60

STAR Strip Chart for



Holland
GRMS
Trackstar
Truck





The End Track Geometry



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