# *Origins and Dynamics of Wide Gage Derailments*


**Presented by:**

**Gary Wolf**

**Wolf Railway Consulting**

**Atlanta GA**

**www.wolfrailway.com**

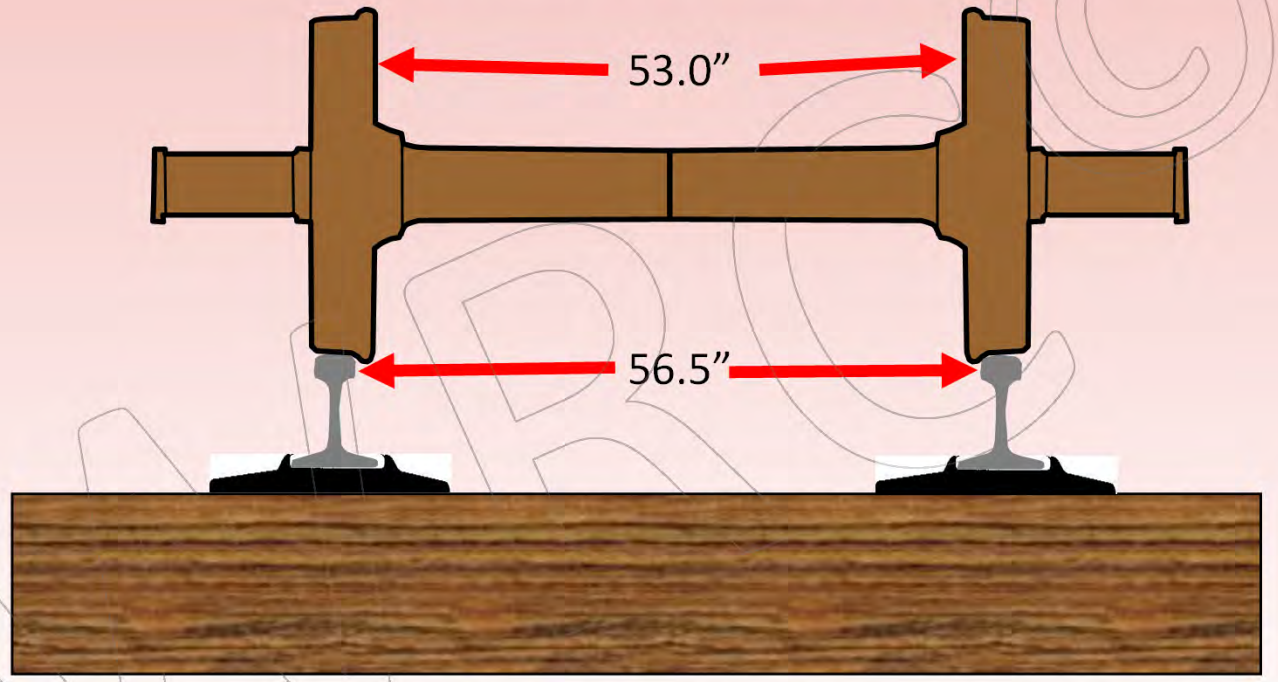
# Why A Presentation on Wide Gage Derailments?

- Most used cause code in the FRA Accident Database
- ~20% of all track caused derailments attributed to T110, T111 Wide Gage
- Many derailments listed as “wide gage” incorrectly blamed on “wide gage”.
- Other Causes such as mechanical and train handling often not listed.

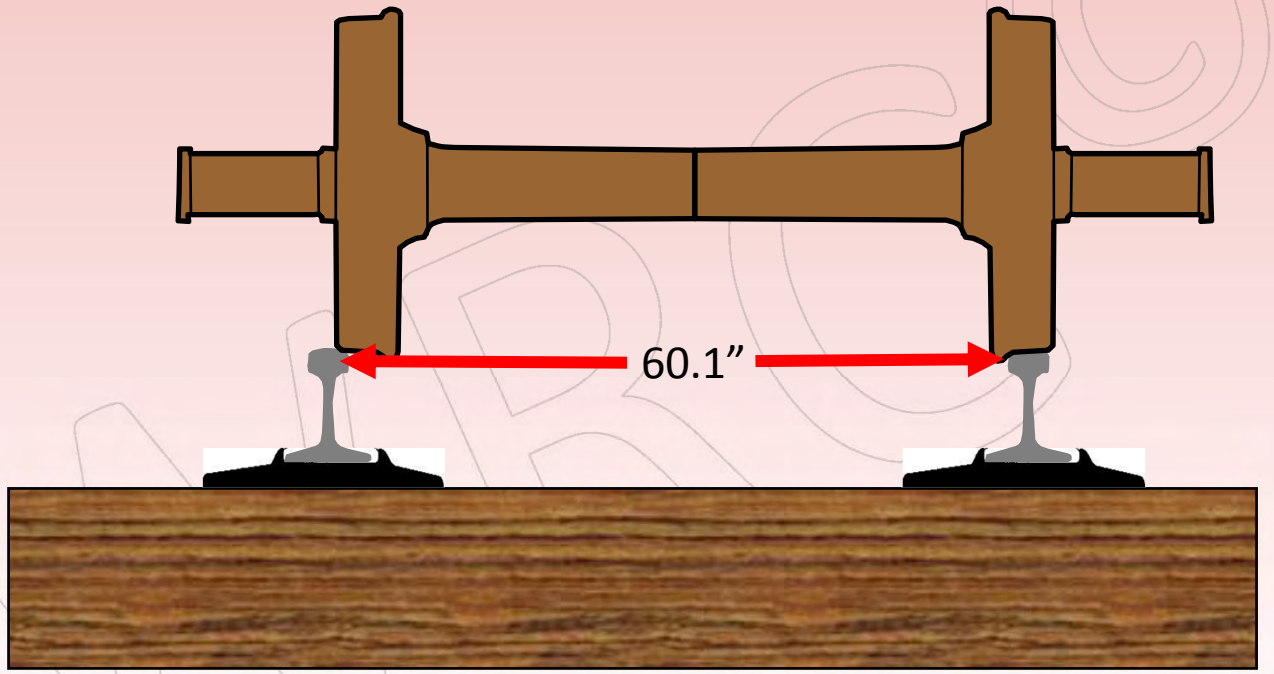
*"Wide Gage description possibly the least understood of all derailment causes"*

*"The true root causes of wide gage are generally not reported. Not all 'wide gage' derailments are track caused. Many 'wide gage' derailments have mechanical and train operations root causes"*

## Nominal gage of 56.5” with 53” Wheel back to back

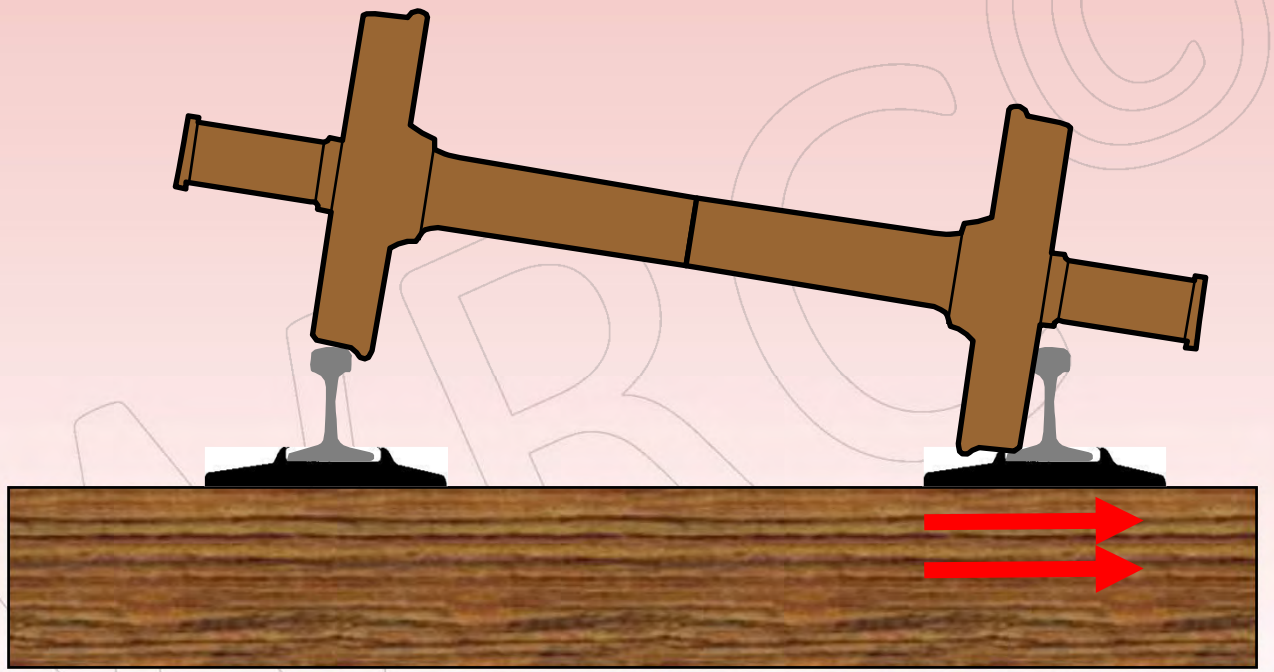


## Point of incipient wheel drop
## Due to widening of gage

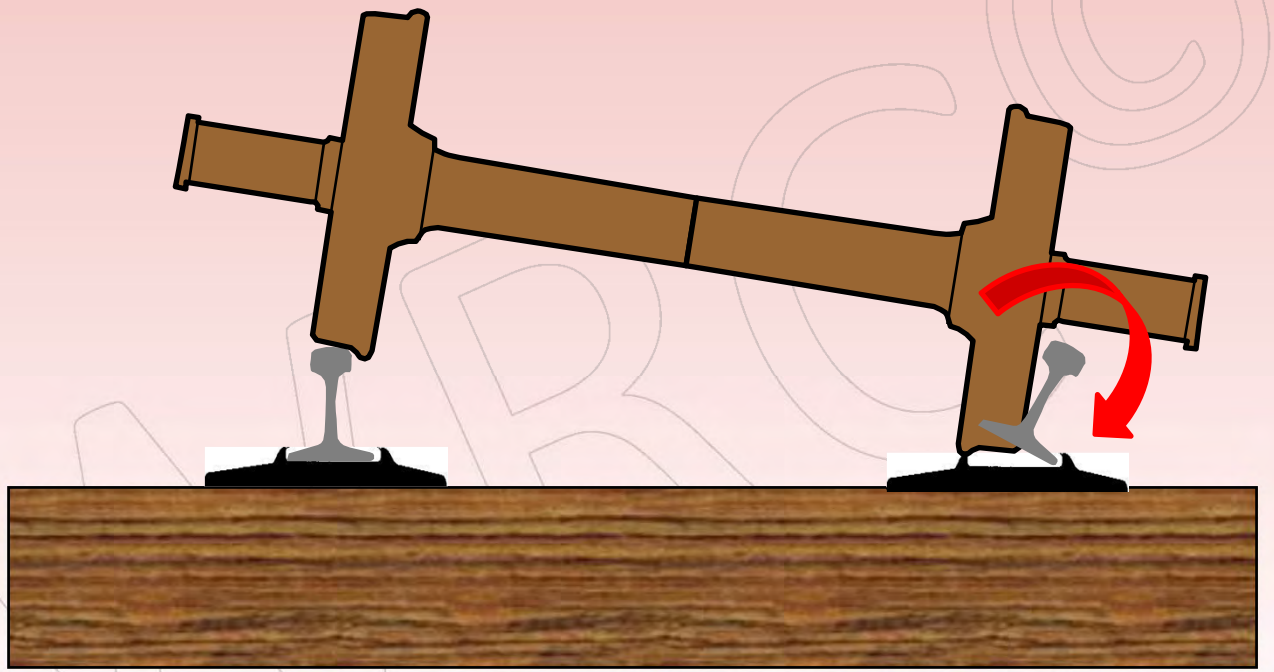



Wheel/Rail Geometry with 60.1” Gauge
Note: This is gauge point at which wheel drop becomes likely due to radius of wheel intersecting radius of rail head

## Wide Gage due to lateral Translation of rail



## Wide Gage due to rail Rolling outward



# Wide track gage is caused by:

- Lateral translation of one or both rails, due to:
  - Deformation of wood fibers holding spikes; elongated spike holes; spike kill
  - Broken screw spikes or cut spike fasteners
  - Worn shoulders on tie plates
  - Gage face wear on the rail
- Rail rolling outwards, due to:
  - Differential tie plate cutting; rail cant
  - Loose fasteners; weak spiking; insufficient spiking
  - Poor wheel contact geometry toward field side of rail head
  - Hollow worn wheels contacting field side of rail head
- A combination of lateral translation and rail roll

# How does Gage Widen?

- Progressive failure (fatigue) over weeks or months
  - *"Death by a thousand small cuts…"*
    - ✓ Spike kill/ tie deformation over time
    - ✓ Fastener failure
    - ✓ Differential plate cutting; rail cant
    - ✓ Geometry defect
- *Singular catastrophic event*
  - *"Death by a single blow to the head…"*
    - ✓ Bypassed couplers during switching
    - ✓ Excessive buff (compressive) force
    - ✓ Use of non-aligning couplers
    - ✓ Truck warp; locked bolster on truck

# What causes gage to widen?

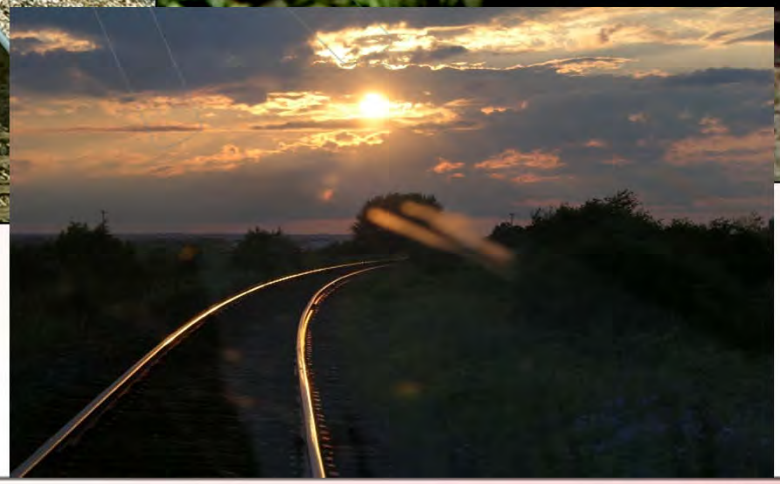
- Excessive lateral pressure against the rail due to:
  - Incorrect curve elevation
    - Insufficient elevation causing pressure of high rail
    - Excessive elevation causing pressure on low rail
  - Pre-existing wide gage allowing greater wheelset angle of attack
  - Horizontal alignment kinks causing increase in flanging force
  - Lack of rail lubrication, particularly top of rail extremely dry
  - Poor steering due to poor wheel – rail contact geometry

# What causes gage to widen (con't)?

- Excessive lateral pressure against the rail due to:
  - Excessive compressive buff force in train
    - Excessive dynamic braking
    - Excessive independent braking
    - Excessive shoving amperage
    - Bypassed couplers
  - Stiff truck condition; excessive turning moment locking up bolster rotation
    - Centerbowl not lubricated
    - Centerbowl rim contact or fouling
    - Tight side bearings
    - Improper centerplate repairs
  - Warped truck condition
    - Lack of truck squaring force due to wedge rise; bolster pocket wear; column plate wear

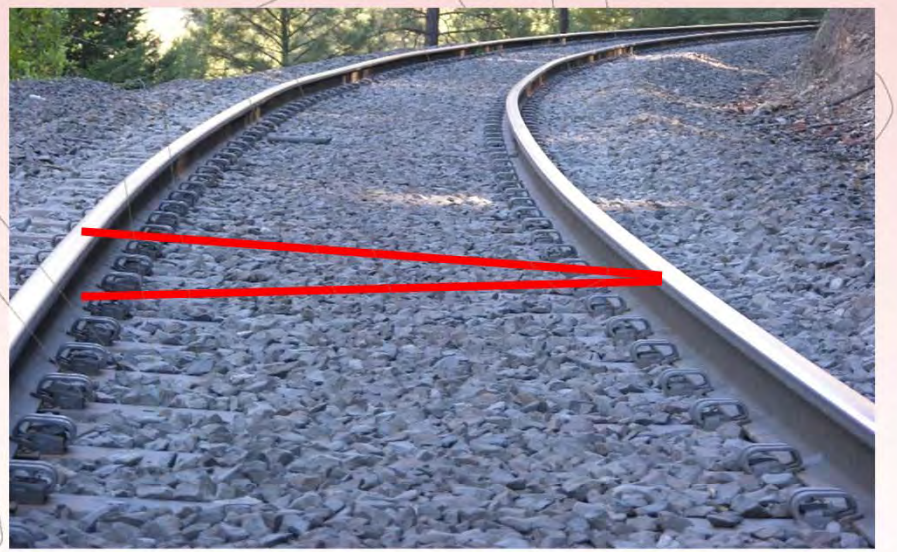
Let’s review how our maintenance strategies and operating procedures can contribute to increased lateral pressure against both the high and low rail of curves…

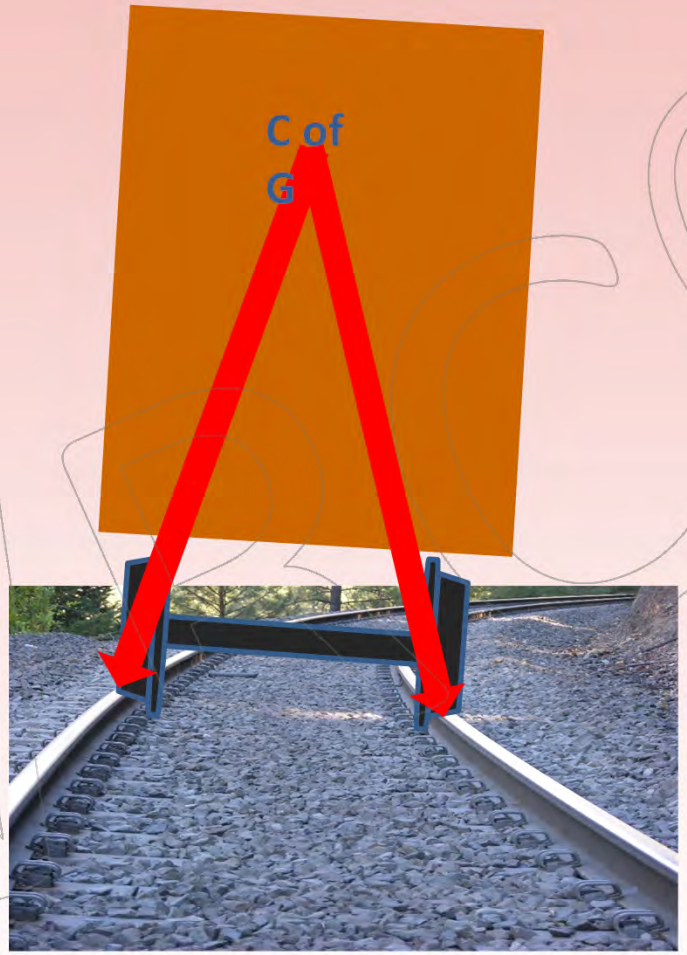
# Curve Superelevation Issues

## 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.**






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

# To determine Equilibrium Speed for Curve

Eq. Elevation = .00067 (D) ($V^2$)

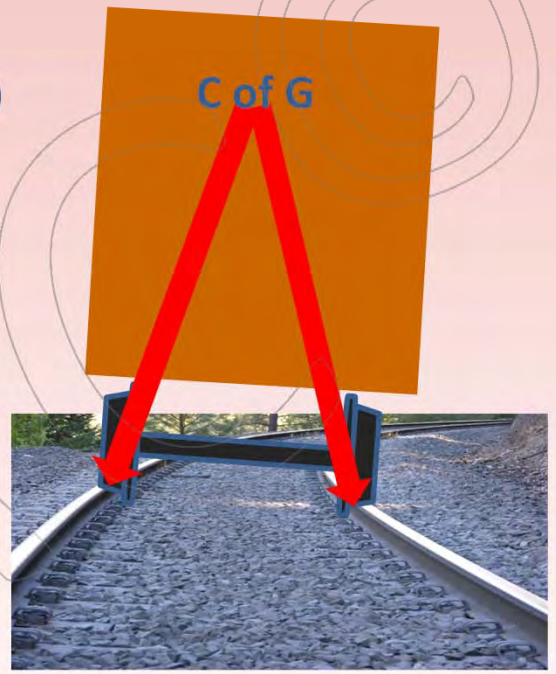
For 5 degree curve; 30 MPH

Eq. El. = .00067 (5) ($30^2$)

Eq. El. = .00067 (5) (900)

Eq. El. = 3.00 “

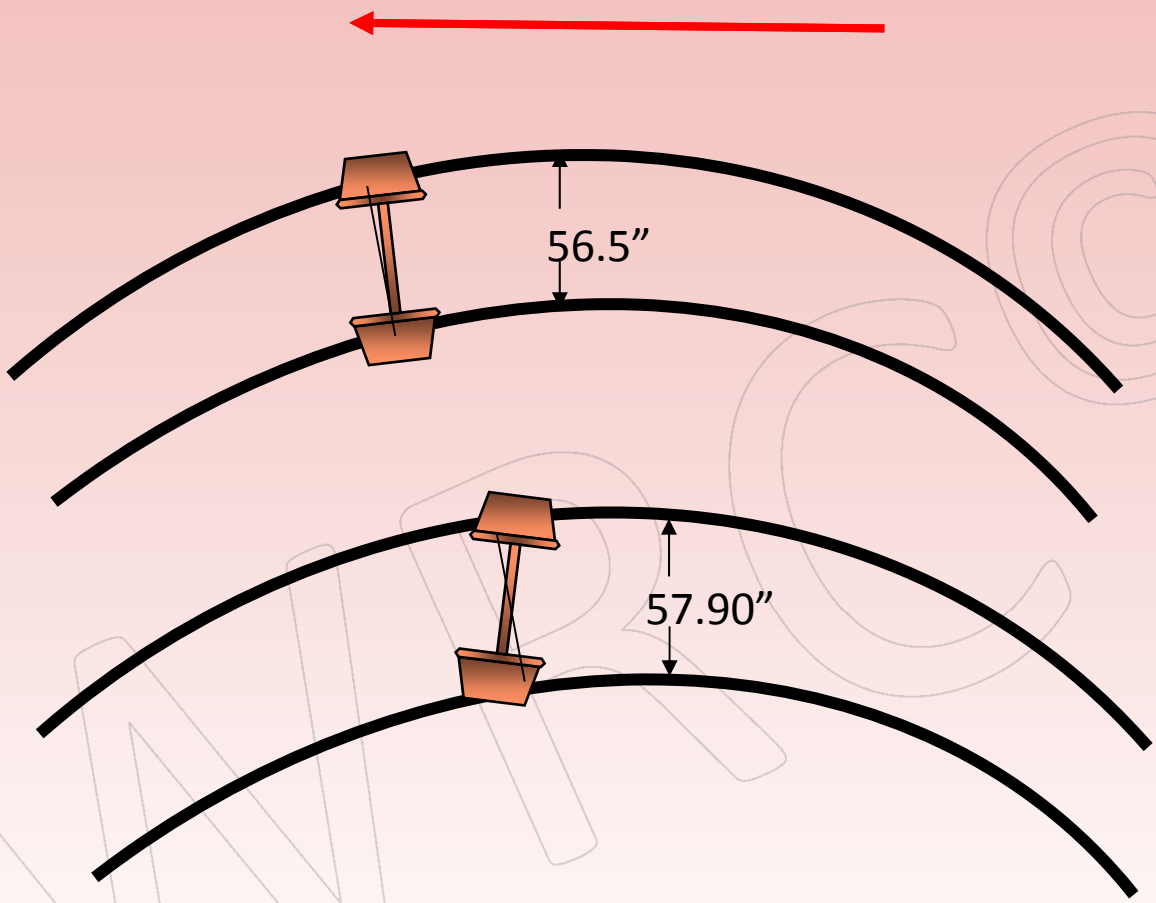
1” Unbalance = 3.00 – 1.00 = 2.00”



# Superelevation and adverse lateral forces

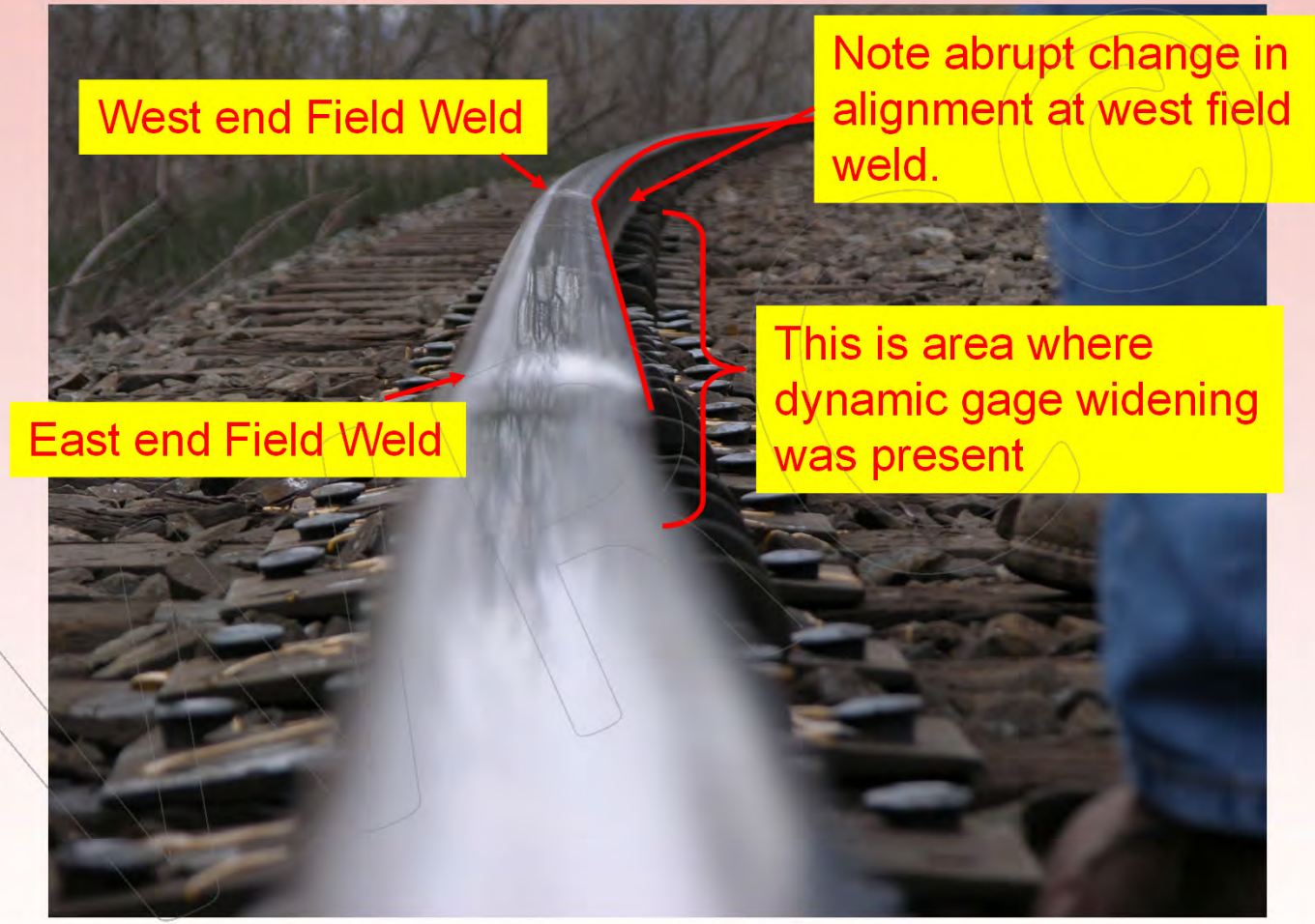
- Superelevation is added to curves to allow trains to operate at normal track speed without placing abnormally high lateral and vertical forces against the high rail.
- Insufficient elevation can lead to excessive lateral pressure against the high rail in curves
- Excessive elevation places adverse vertical forces on the low rail of curves. Excessive vertical forces on the low rail of curves also increases the development of large lateral creep forces toward the field side.

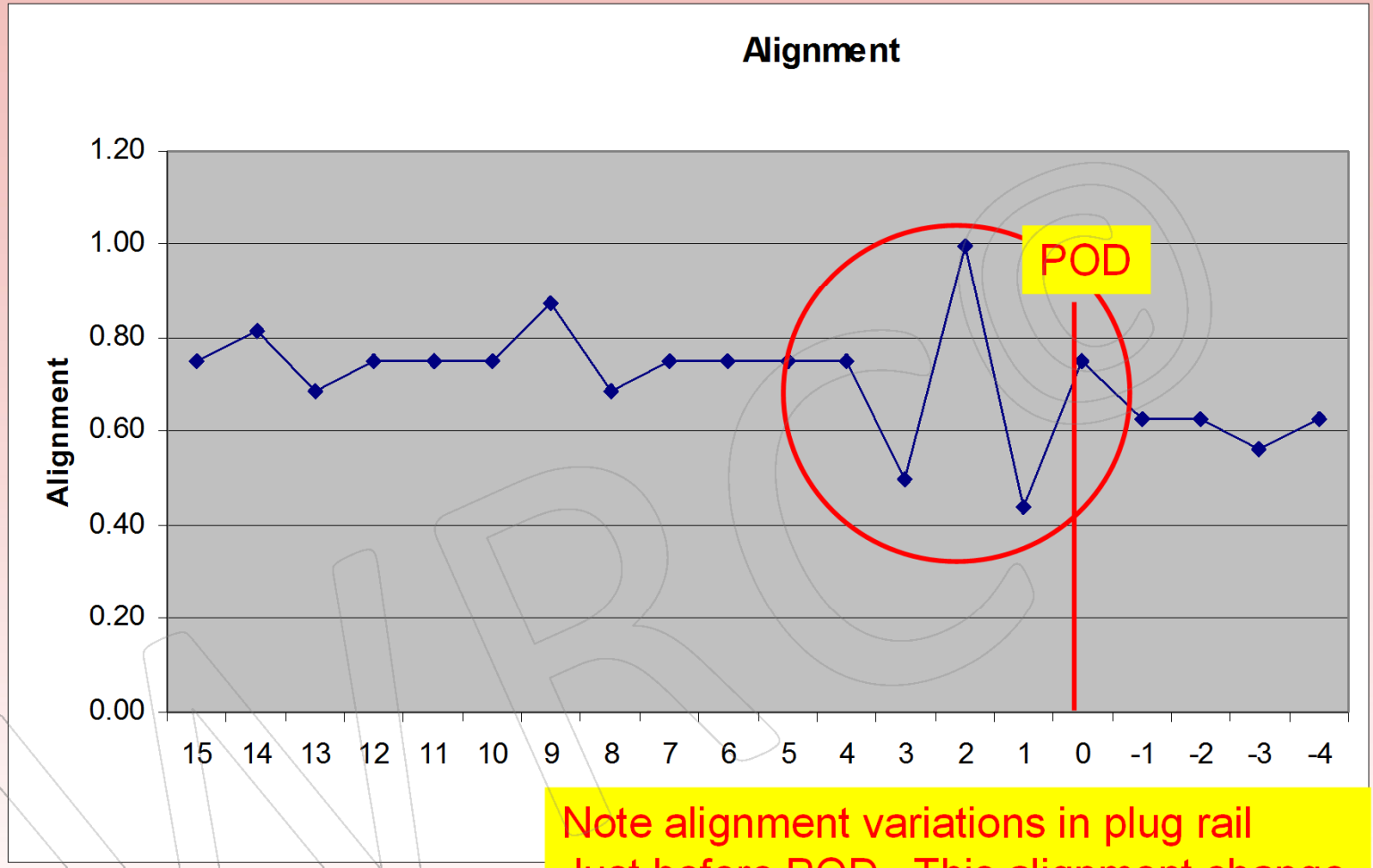
# Pre-Existing Wide gage




**Pre-existing Wide Gage can allow greater wheelset angles of attack;**
**Greater angles of attack can cause greater lateral creep forces.**
**Wide gage also can lead to poor wheelset steering and adverse contact geometry**

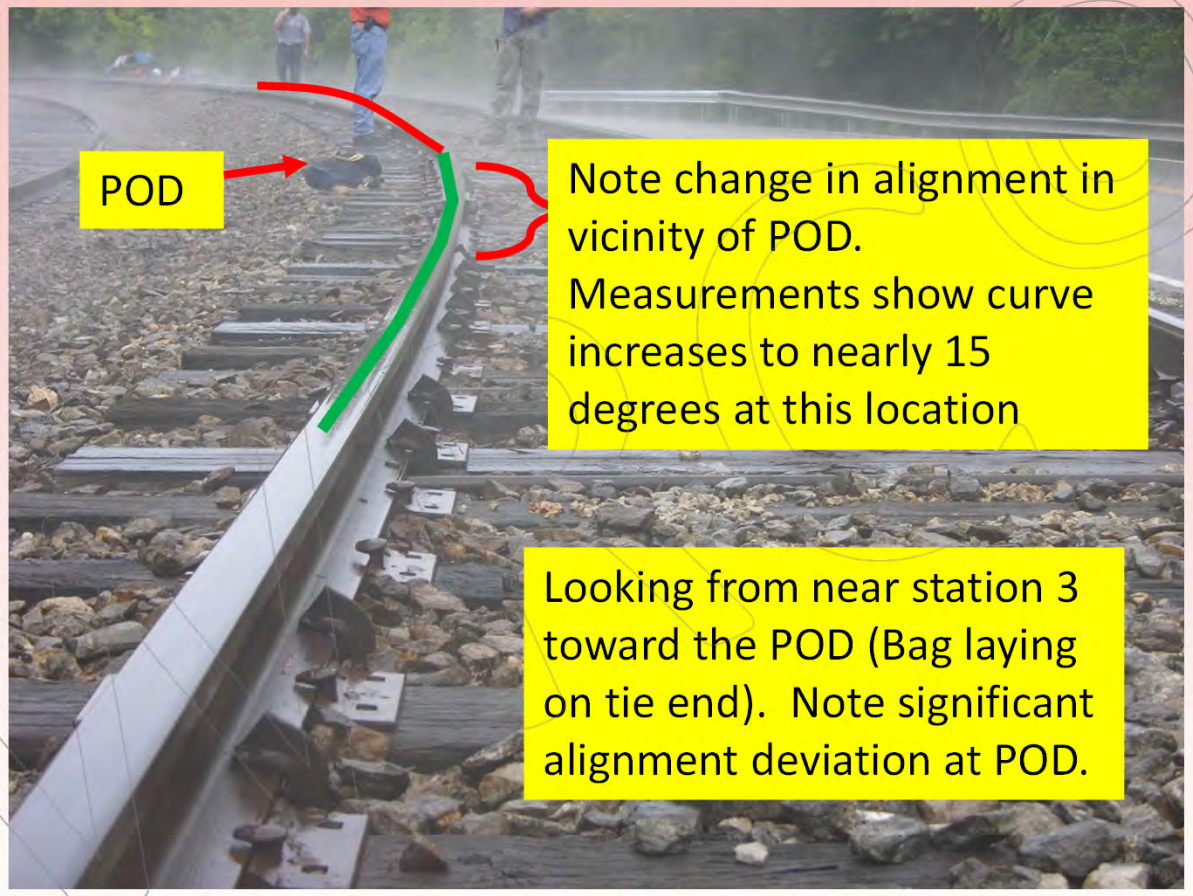
# Curve Alignment Kinks/Irregularities

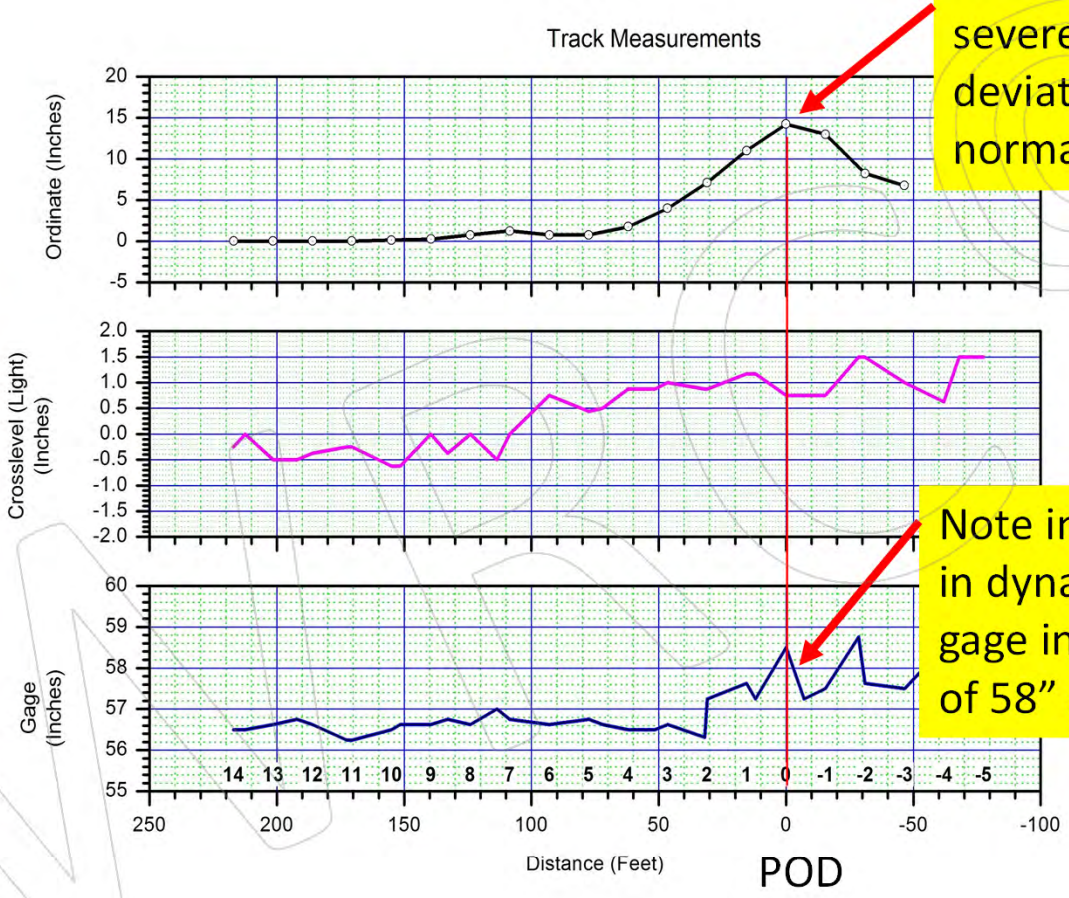

West end Field Weld
Note abrupt change in alignment at west field weld.
East end Field Weld
This is area where dynamic gage widening was present




Note alignment variations in plug rail Just before POD. This alignment change Is evident in photos in report.

**This chart prepared by using the actual ordinates from a 31 ft. chord**


POD
Note change in alignment in vicinity of POD. Measurements show curve increases to nearly 15 degrees at this location
Looking from near station 3 toward the POD (Bag laying on tie end). Note significant alignment deviation at POD.

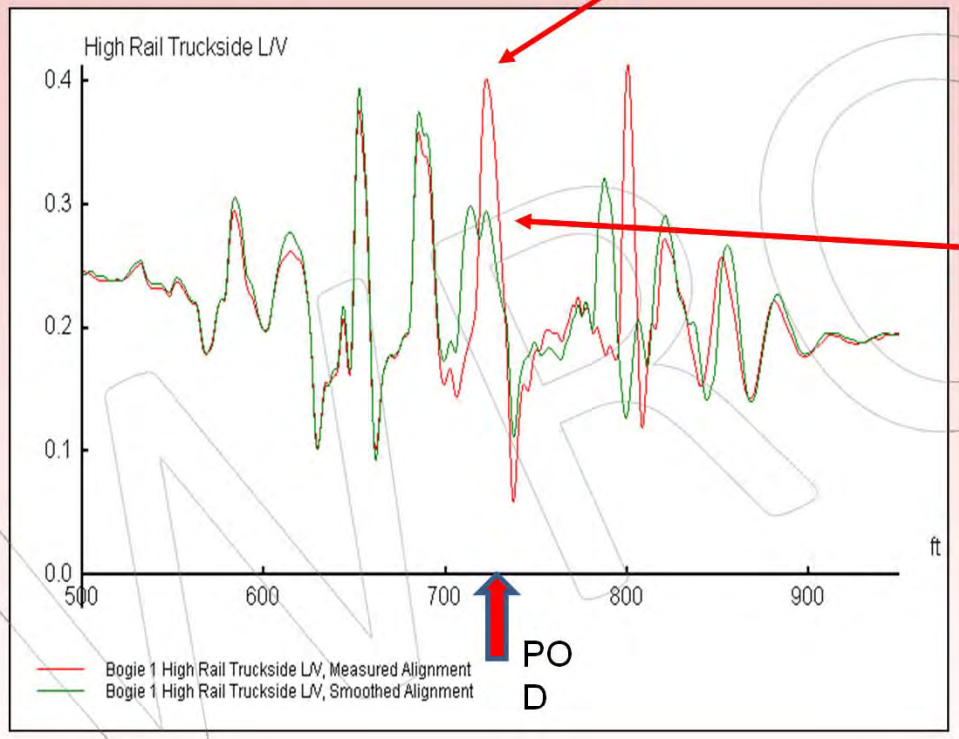



Note sharp increase in degree of curve at the POD due to severe alignment deviation from normal.

Note increase in dynamic gage in excess of 58” at POD

## Truckside L/V Results: Measured vs. Smoothed Alignment

Note, peak L/V Ratios at the POD

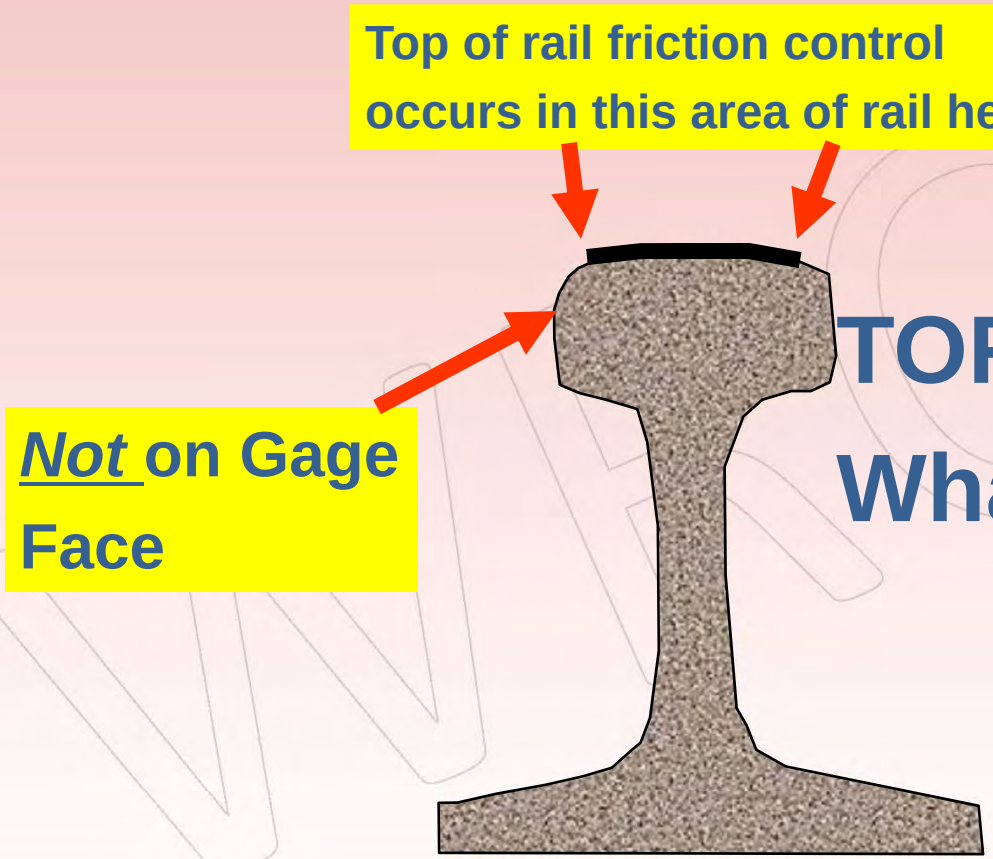



Truck Side L/V at POD:

Measured Alignment = 0.40

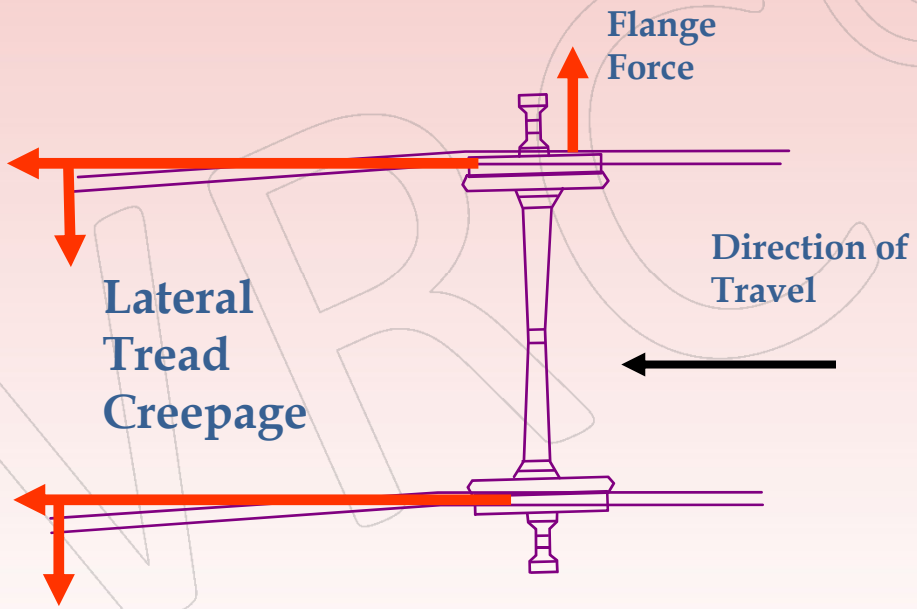
Smoothed Alignment = 0.29

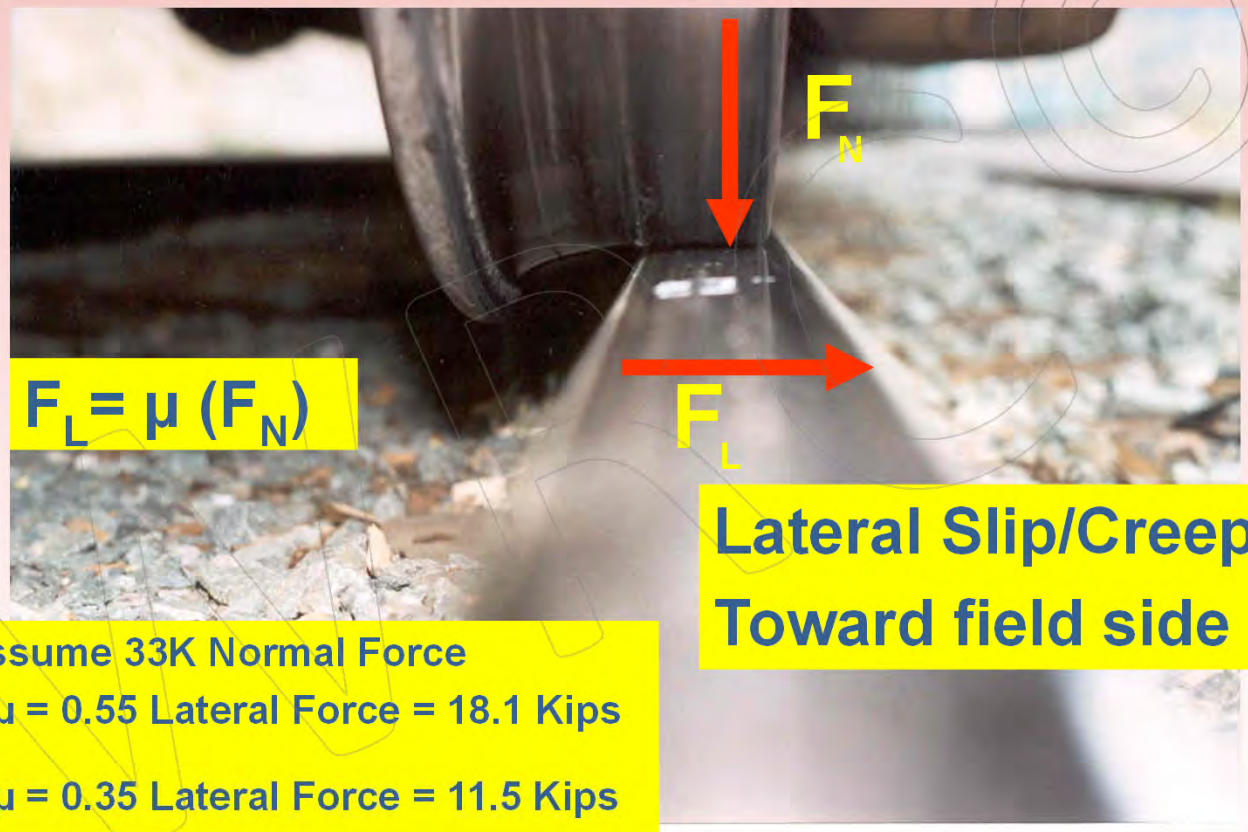
# Inadequate top of rail lubrication




# TOR What is it???

# How do we develop lateral forces on top of rail toward the inside of a curve?






$F_L = \mu (F_N)$

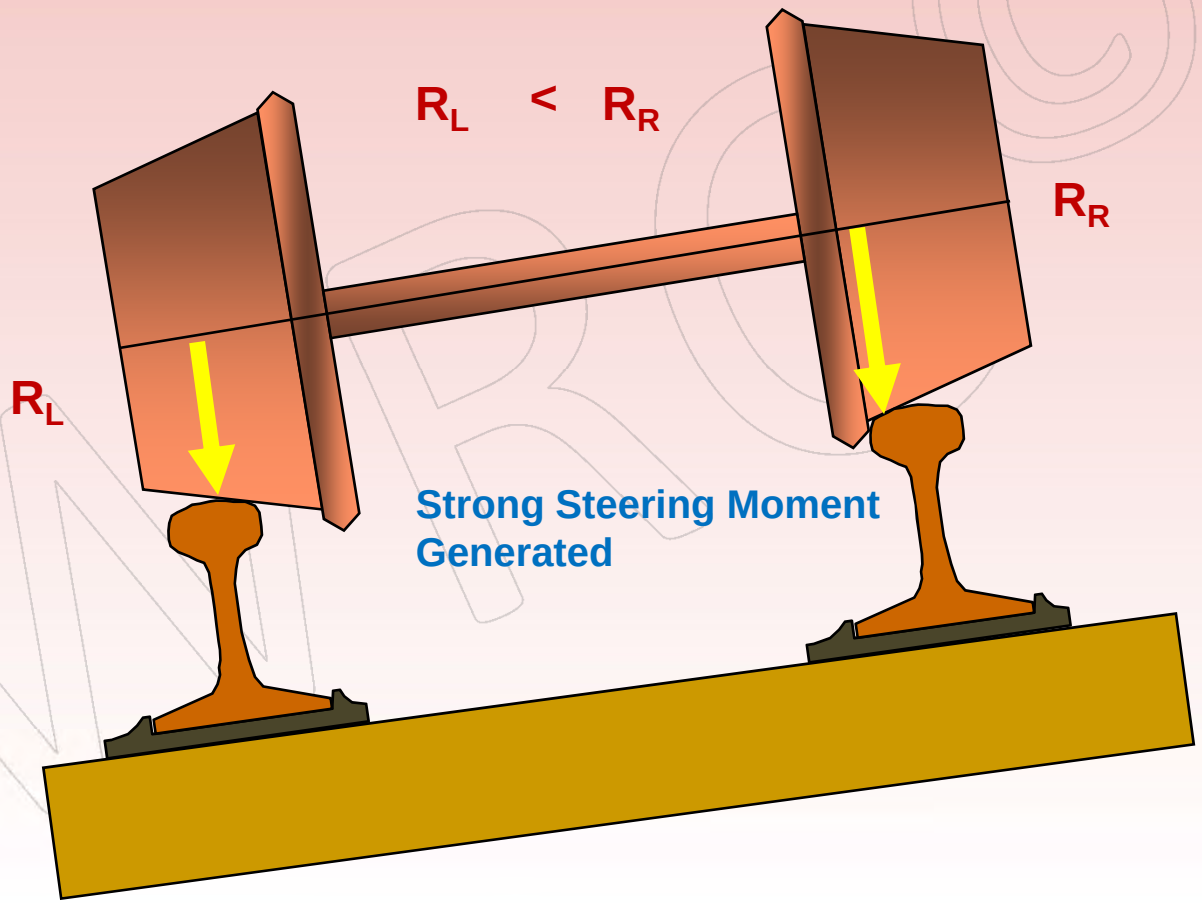
Lateral Slip/Creep
Toward field side

Assume 33K Normal Force
If μ = 0.55 Lateral Force = 18.1 Kips

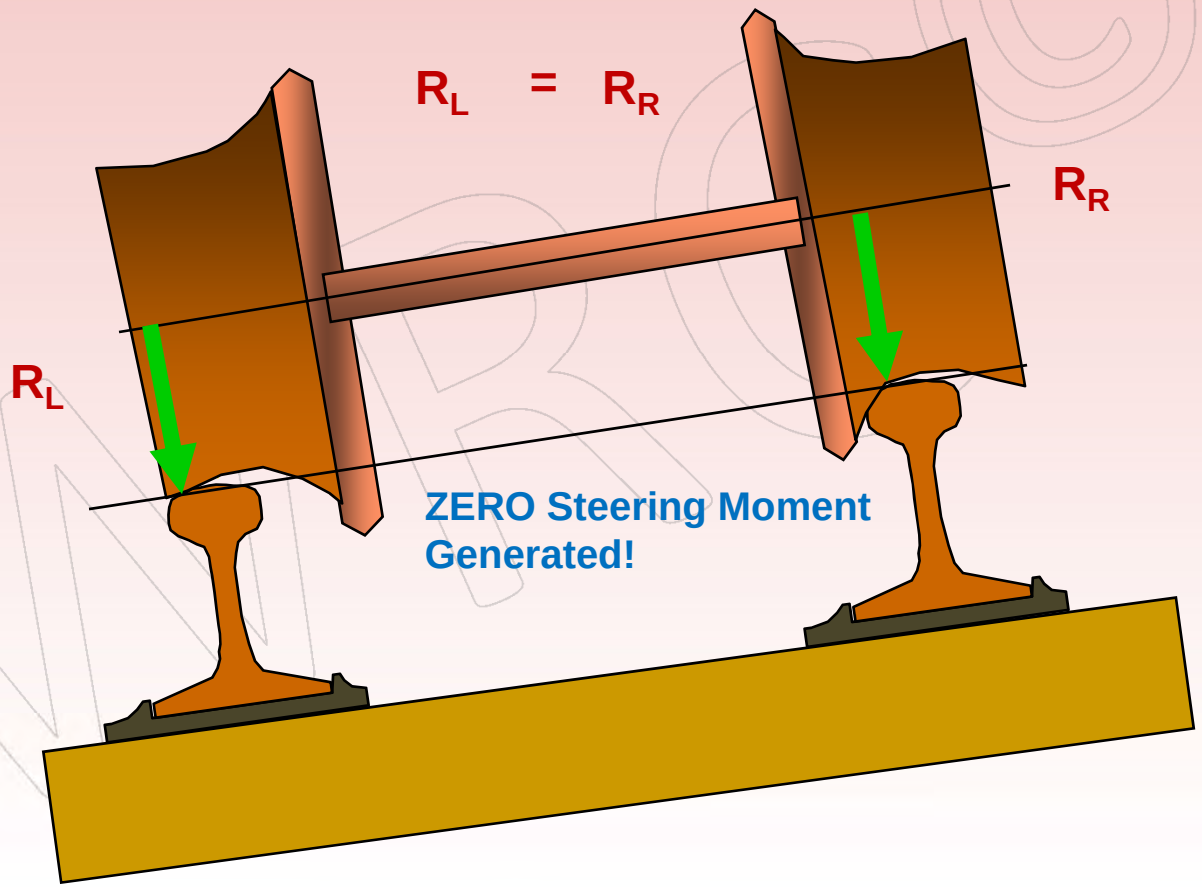
If μ = 0.35 Lateral Force = 11.5 Kips

# Poor wheel rail contact geometry

# Normal Curving

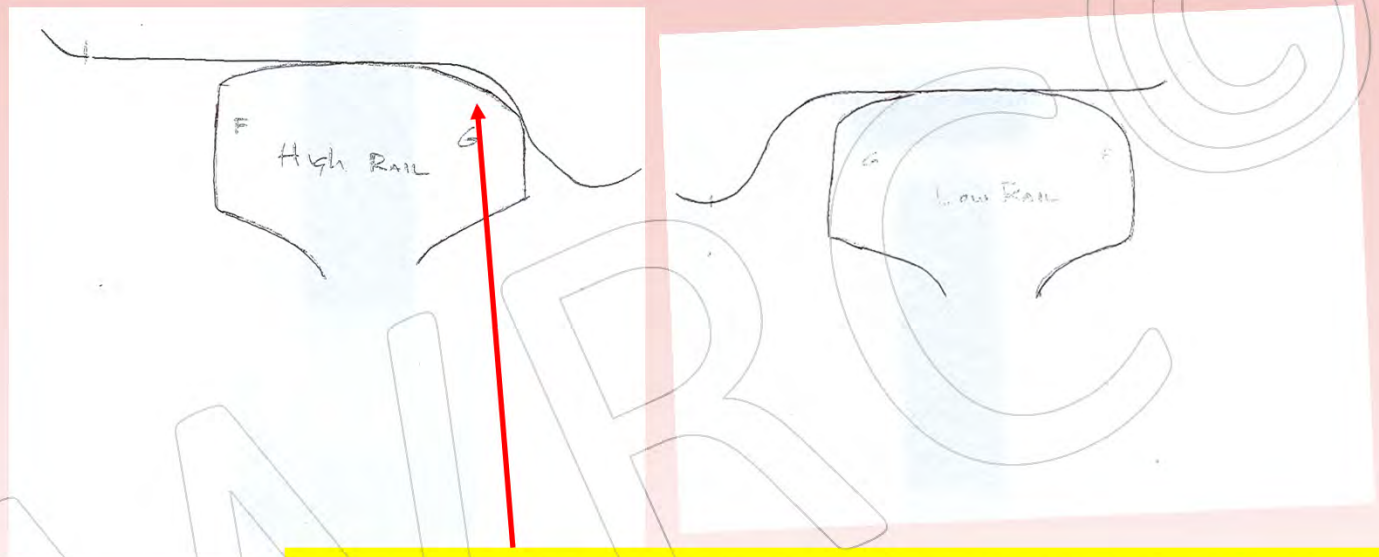


# Hollow Wheel Curving



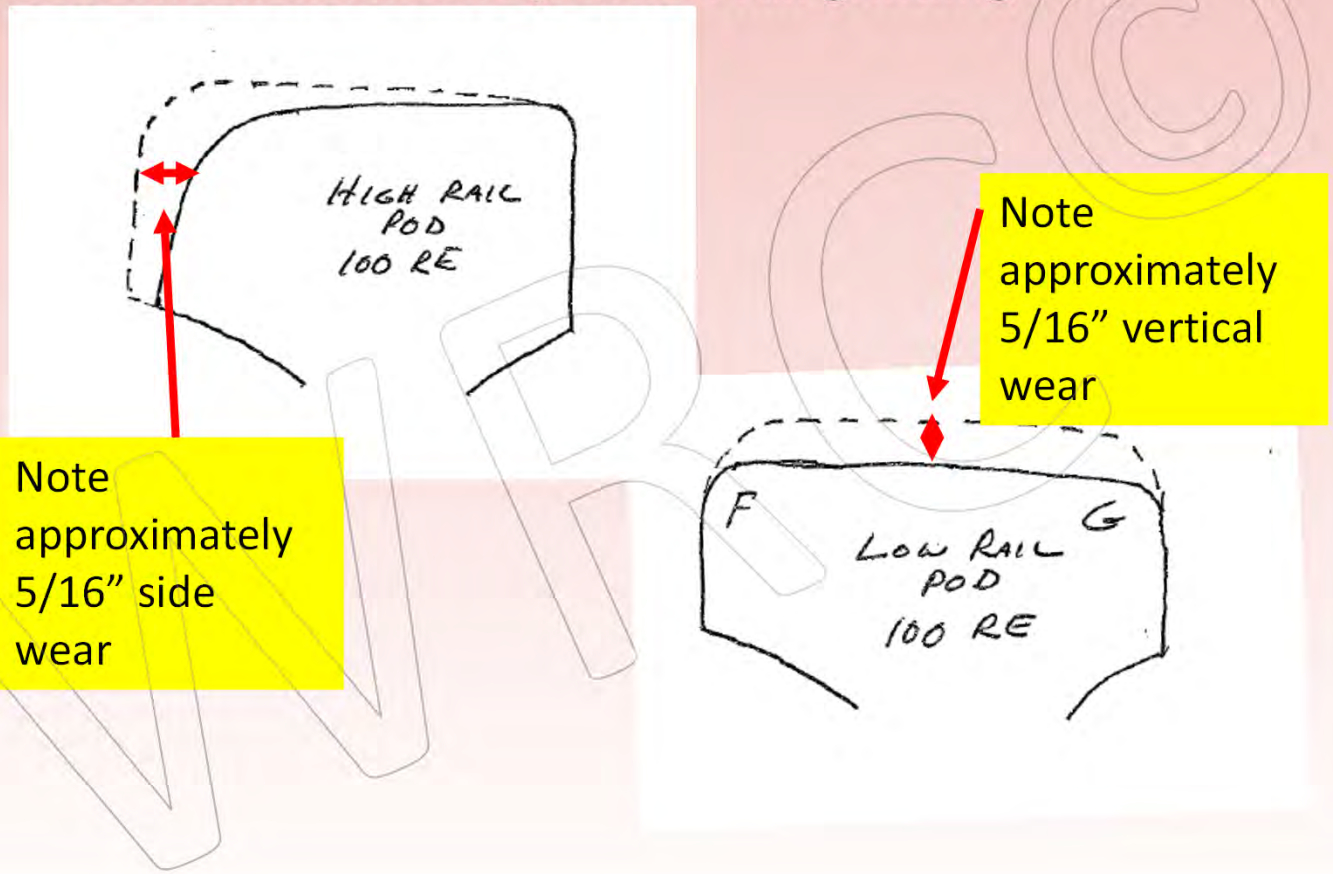
## Hollow Worn Wheels

## Poor Rail Profile maintenance; Lack of rail grinding

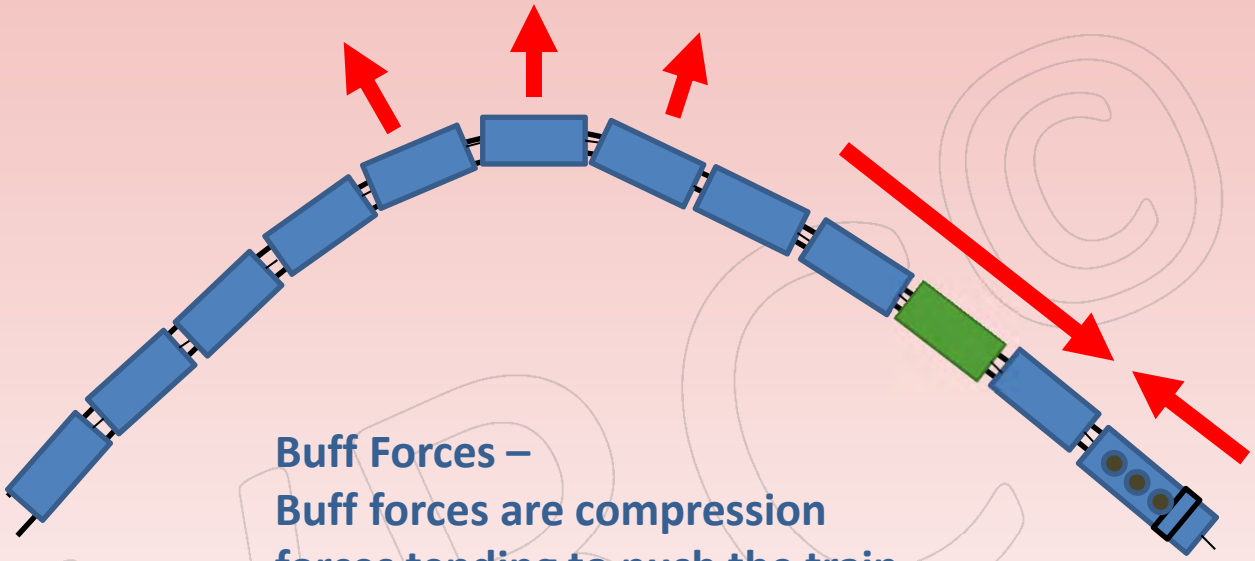



Approximate wheel/rail contact at POD on low and high rail of curve. Note severe two-point contact on high rail due to gage corner wear and new wheel profile. This two point contact will compromise steering of wheelset.

## Poor Rail Profile maintenance; Lack of rail grinding

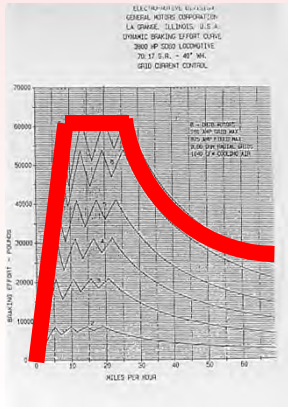


# Excessive compressive buff force in train



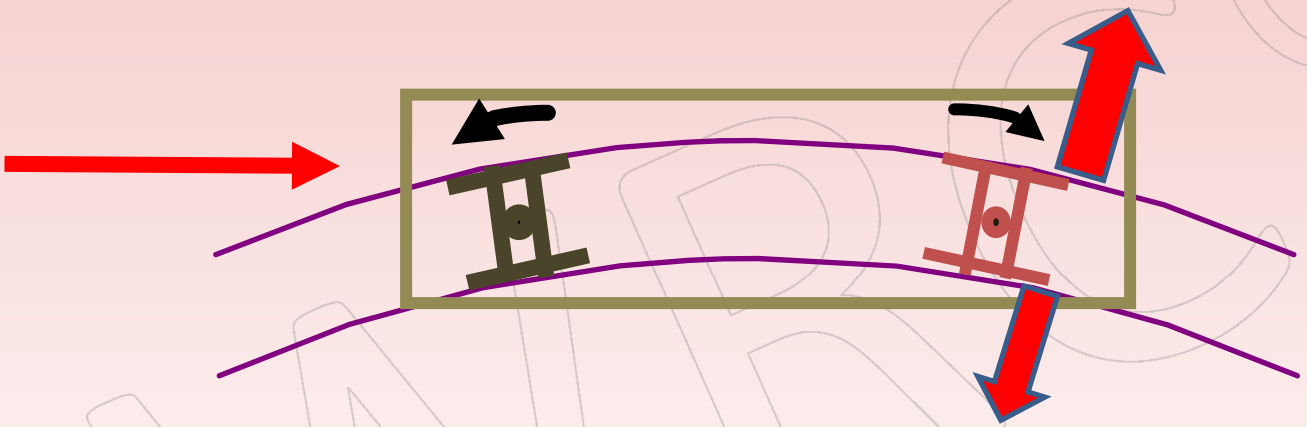
**Buff Forces –**
**Buff forces are compression forces tending to push the train outward in a curve. Often called "jackknifing" forces**

**Locomotive**



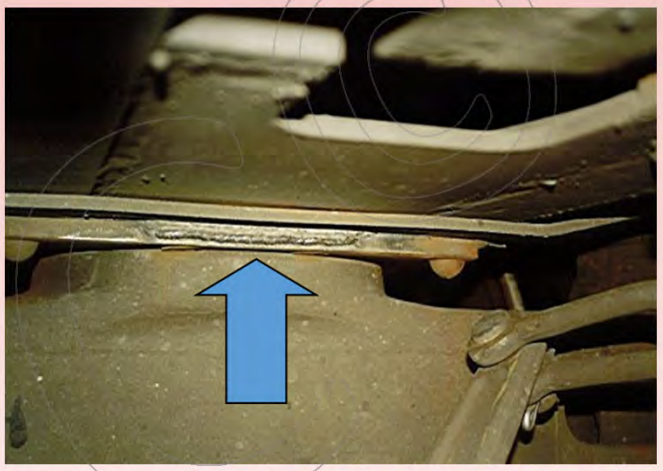
# Stiff truck condition; bolster not steering

# Truck Bolster Position During Curve Negotiation



**Lead and Trailing Truck Bolsters must pivot in opposite directions**

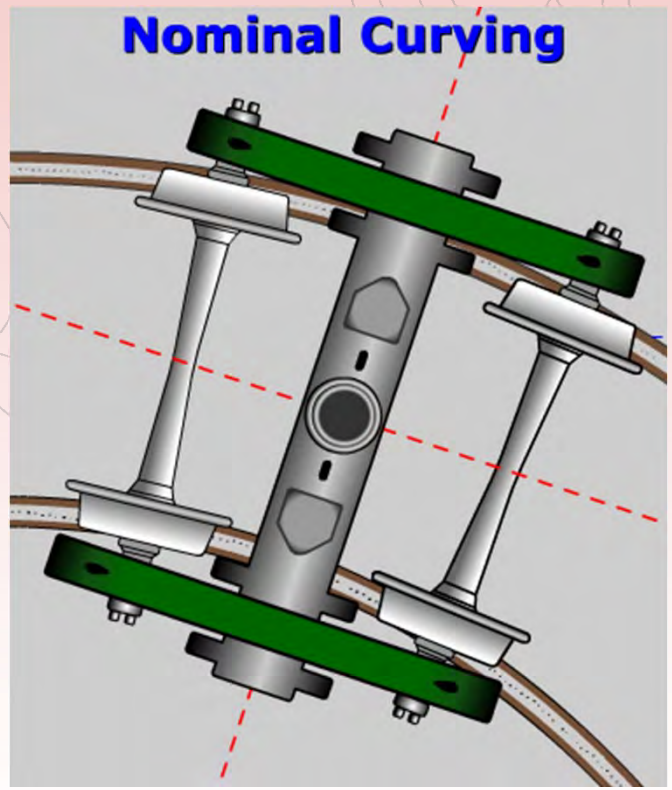
- ✓ Improper centerplate repair
- ✓ Lack of bowl lubrication
- ✓ Insufficient side bearing clearance
- ✓ Fouling between bowl and rim

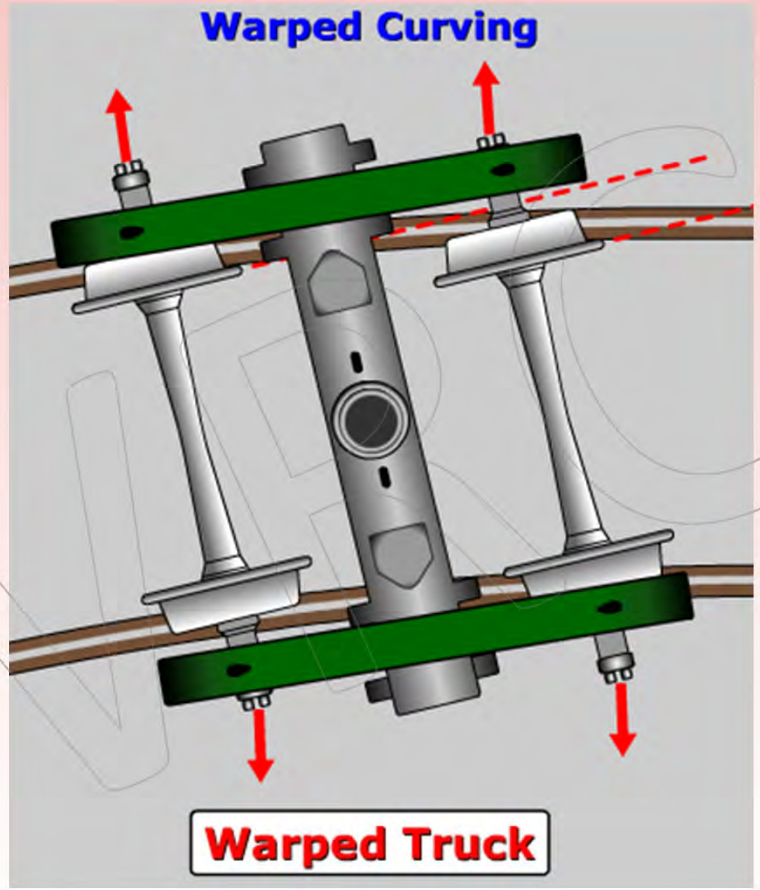



# Truck Warp Condition

# Truck Warp Restraint

**Ideally, a truck should remain "Square" during curving to allow radial alignment of wheelsets with curve**




Warped Curving
Warped Truck

OK, we now understand that progressive and catastrophic gage widening is caused by excessive lateral force against both the high and low rail of curves.

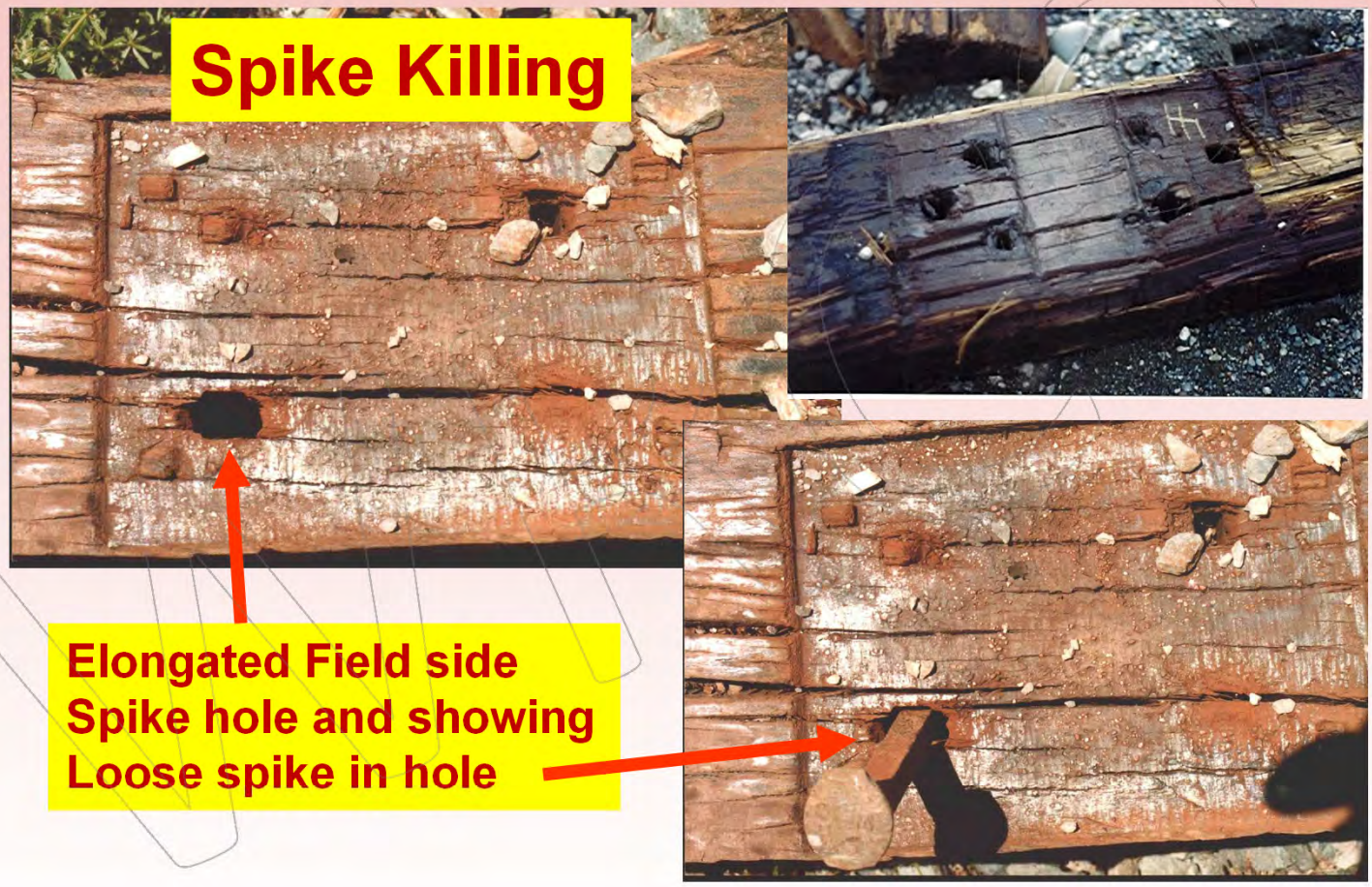
Now let's review various track conditions that precipitate widening of the gage….

# Wide track gage is caused by:

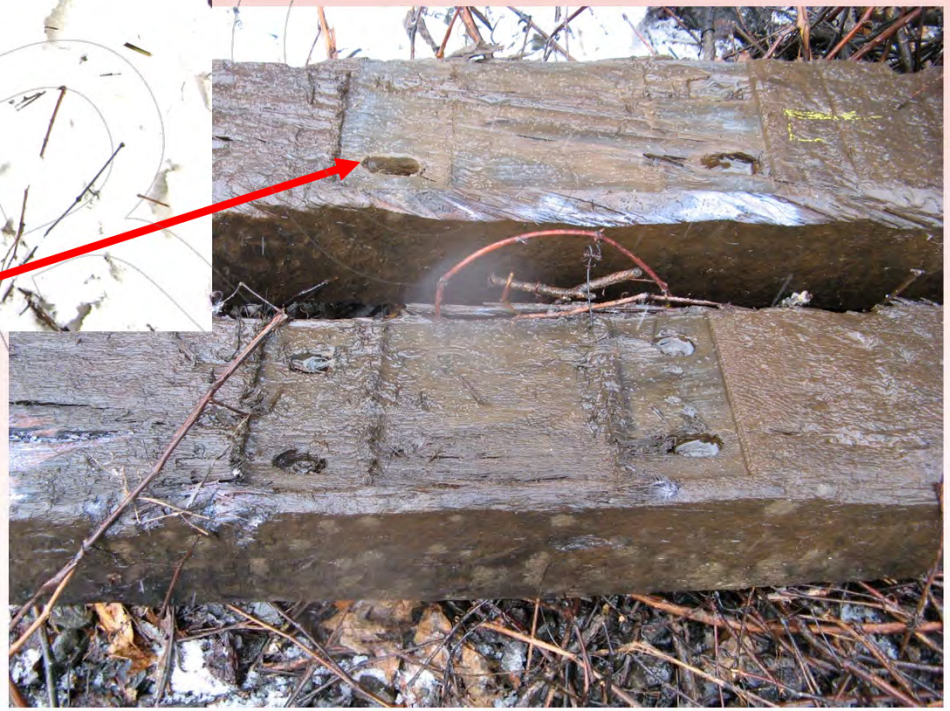
- Lateral translation of one or both rails, due to:
  - Deformation of wood fibers holding spikes; elongated spike holes; spike kill
  - Broken screw spikes or cut spike fasteners
  - Worn shoulders on tie plates
  - Gage face wear on the rail
- Rail rolling outwards, due to:
  - Differential tie plate cutting; rail cant
  - Loose fasteners; weak spiking; insufficient spiking
  - Poor wheel contact geometry toward field side of rail head
  - Hollow worn wheels contacting field side of rail head
- A combination of lateral translation and rail roll

# Deformation of track components

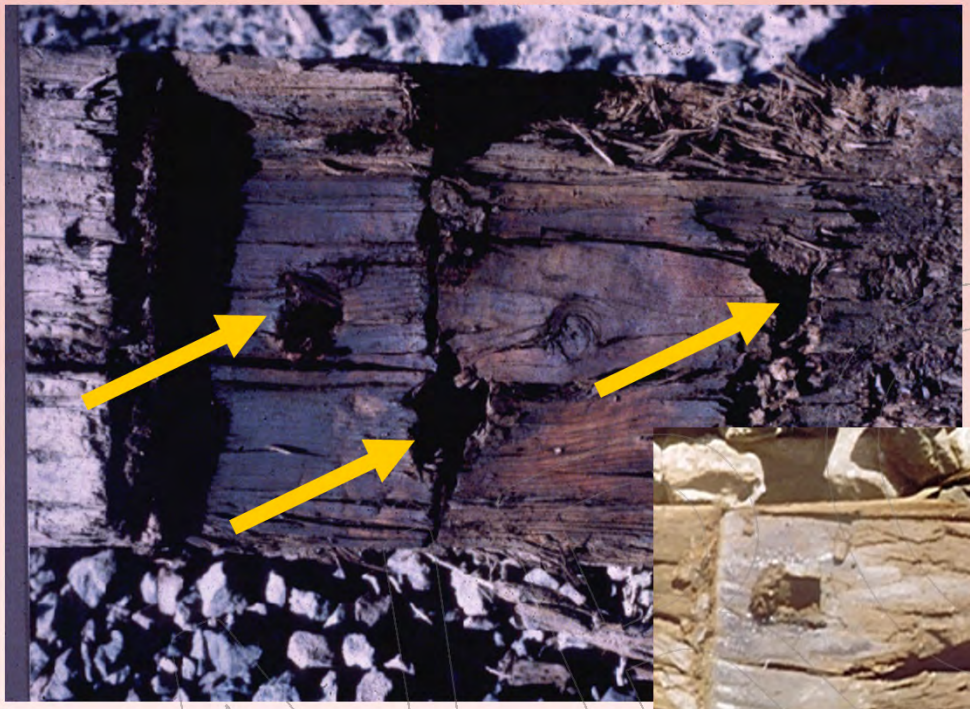
# Spike Killing

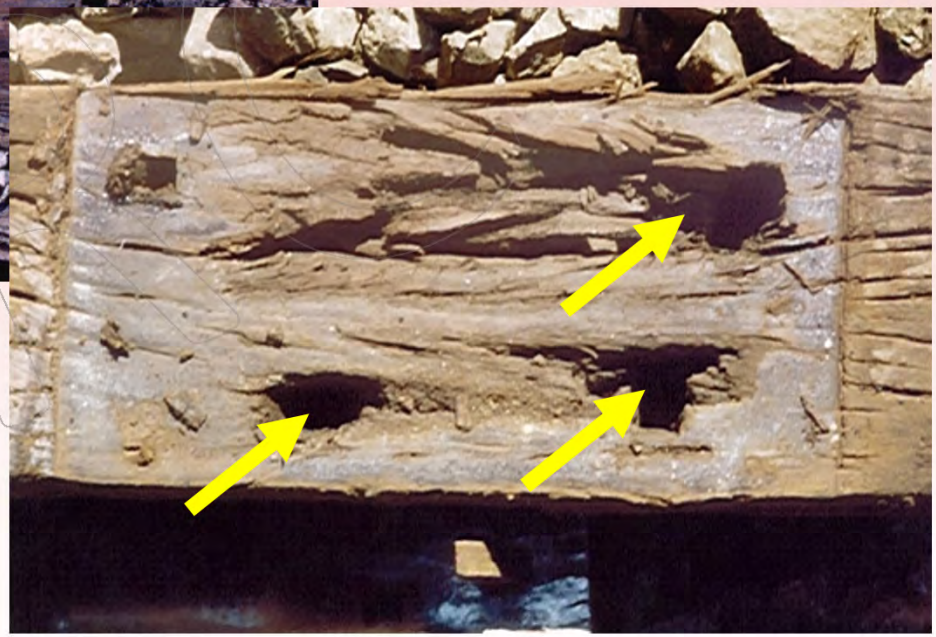


Elongated Field side
Spike hole and showing
Loose spike in hole



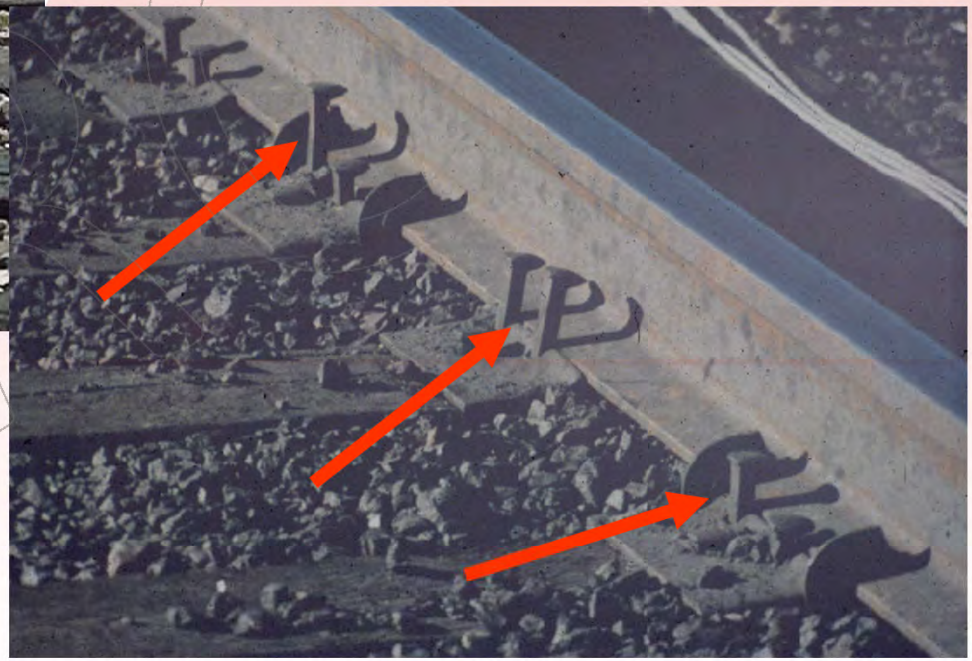
**Elongated Spike holes**



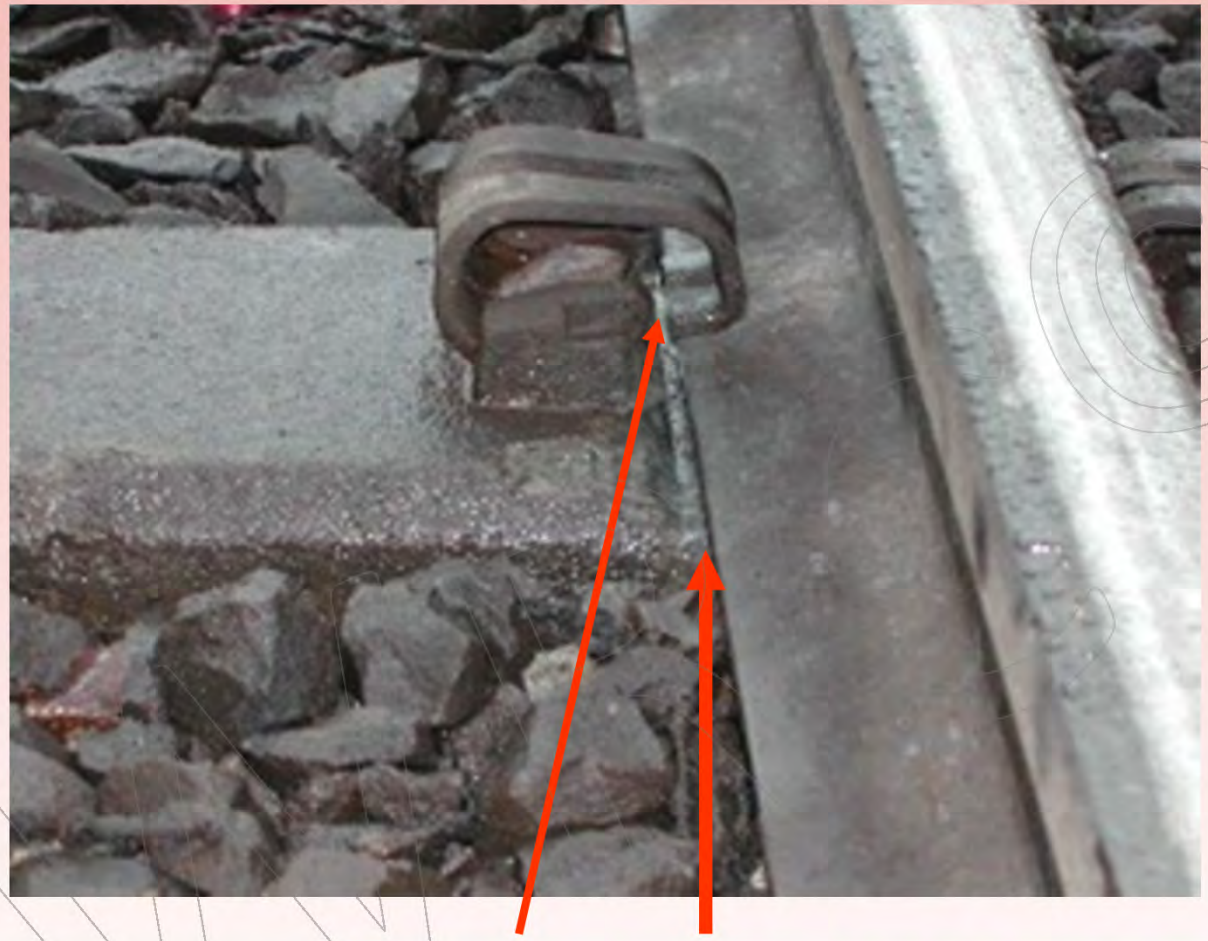


Spike Kill

# Raised Spikes

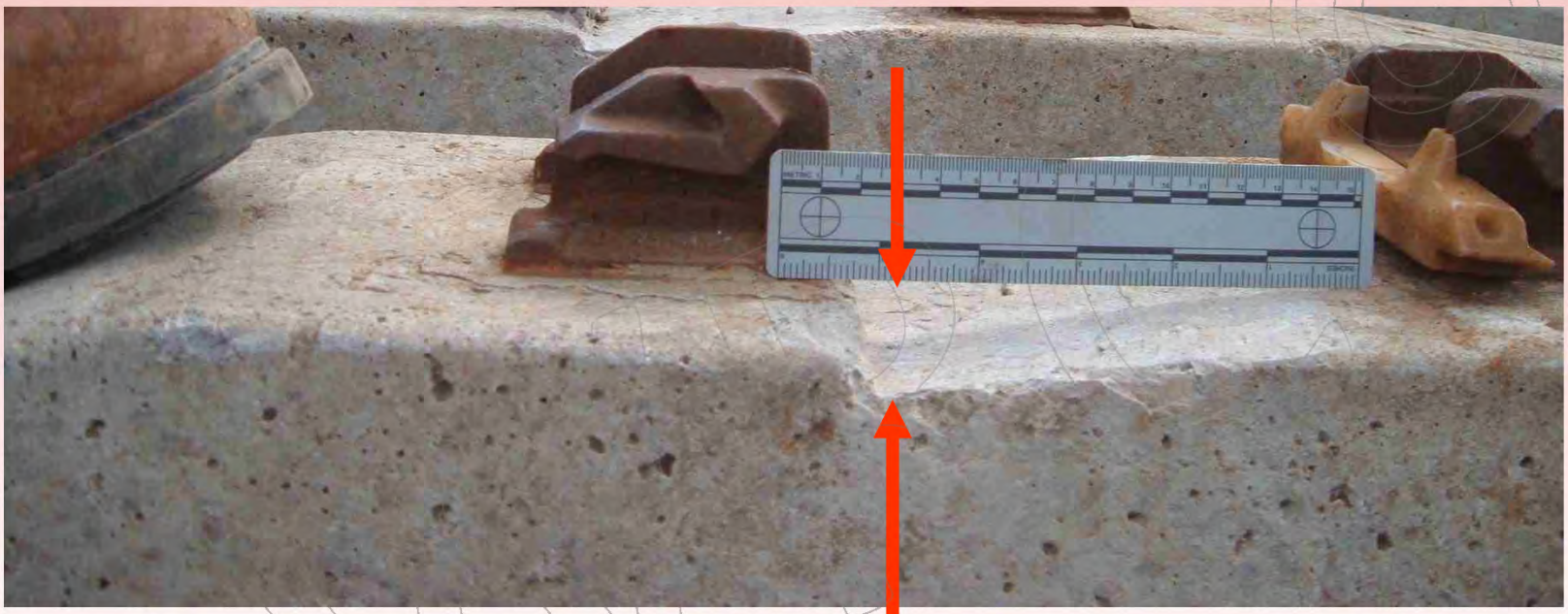



Concrete Ties
Watch for Tie Seat Abrasion
under Rail and Pad



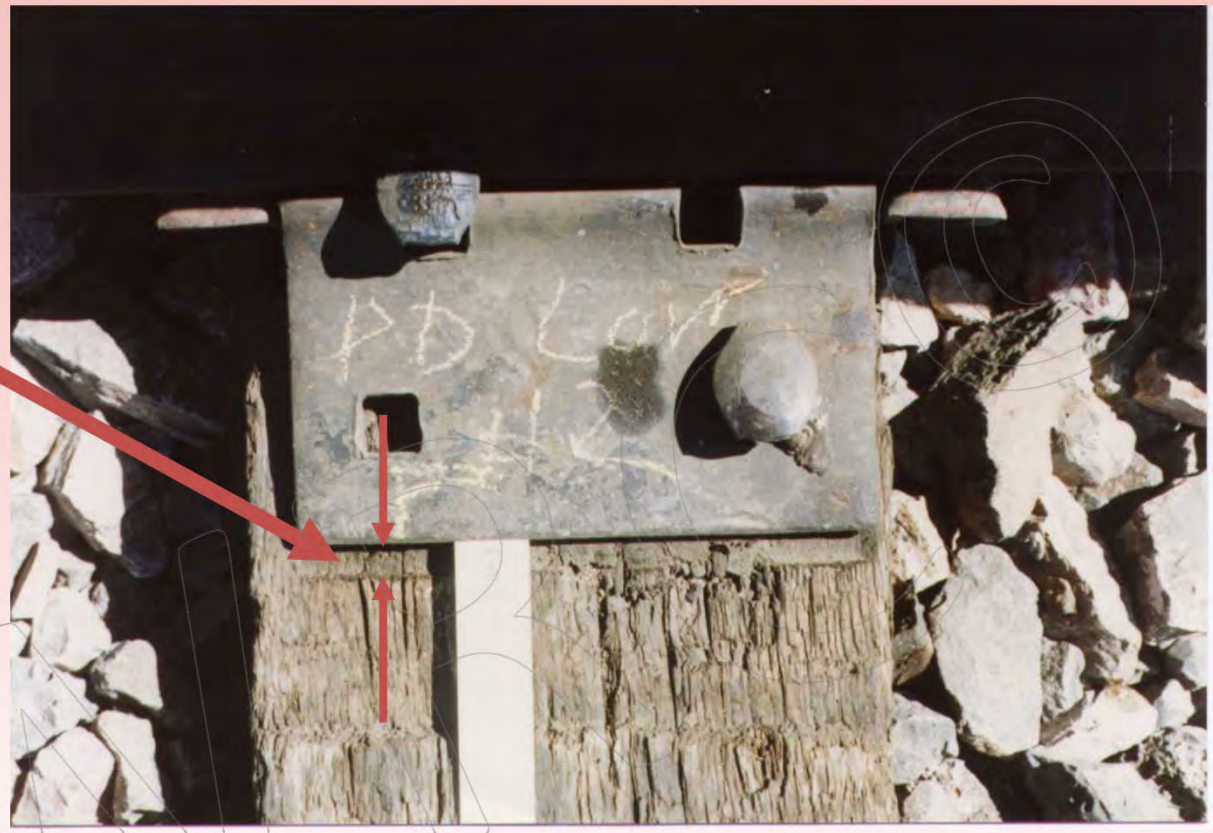
**Watch for Tie Seat Abrasion under Rail**


Watch for Tie Seat Abrasion
under Rail

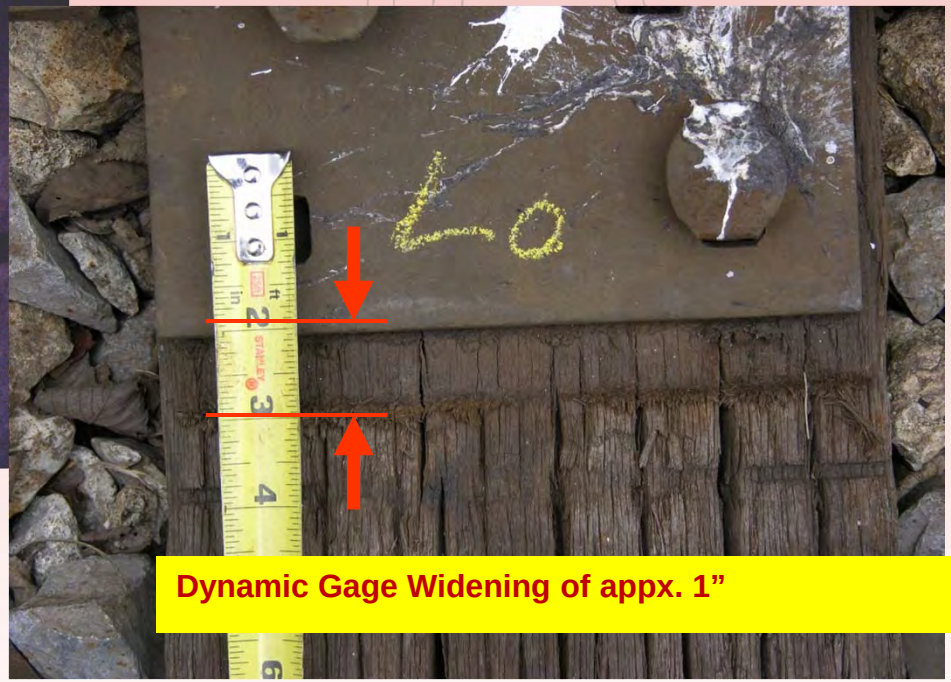


Tie Seat Abrasion under Rail and Pad

**Dynamic Gage Widening**



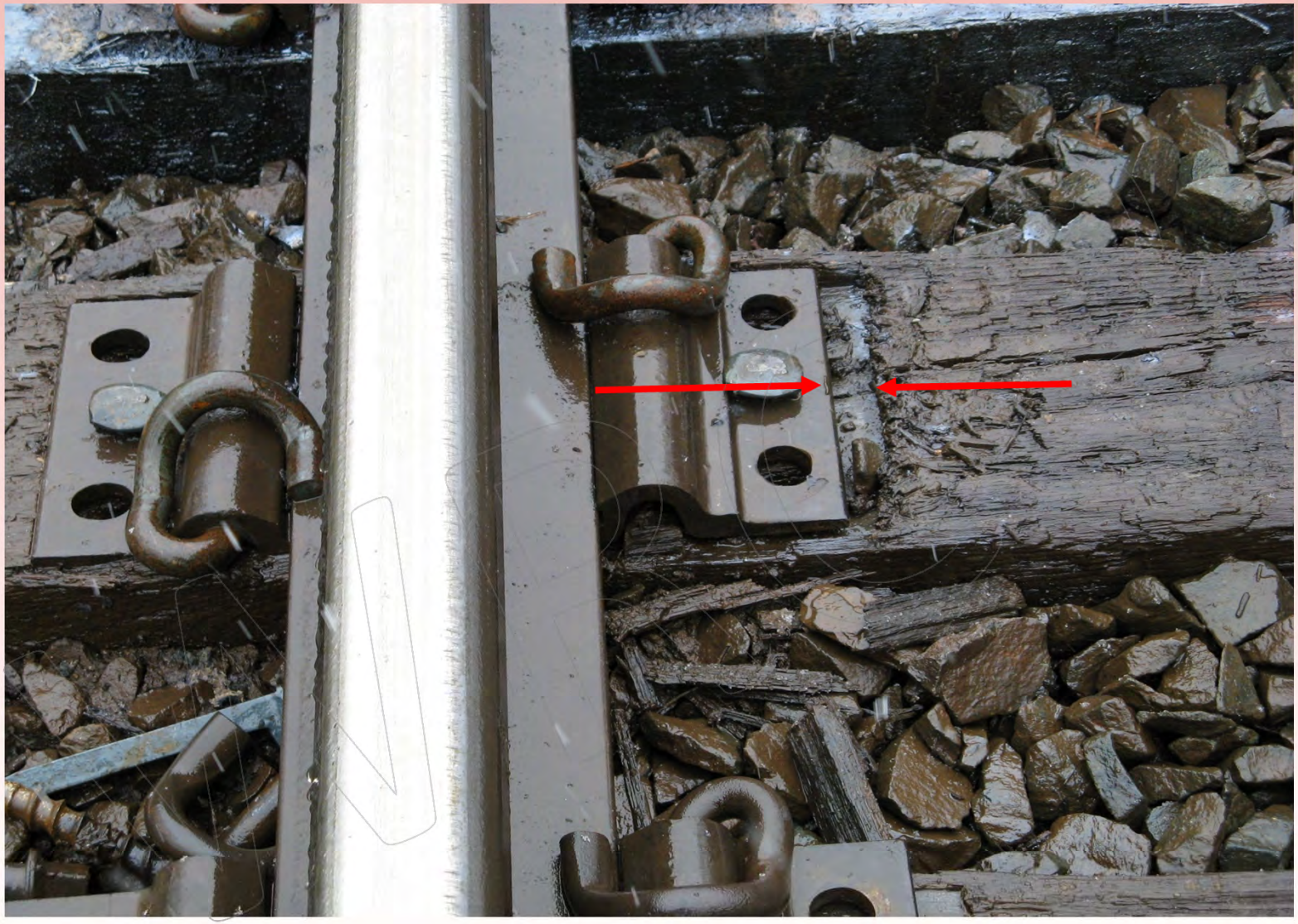
**No more than 1/2” lateral movement per FRA**

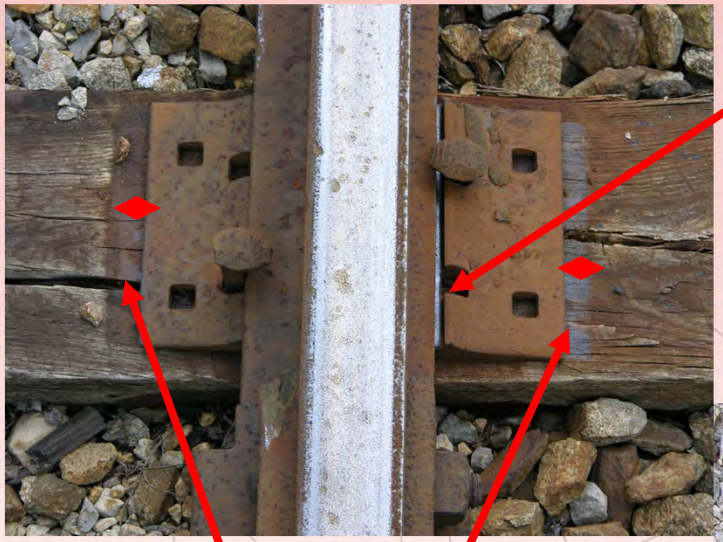



# Dynamic Gage Widening

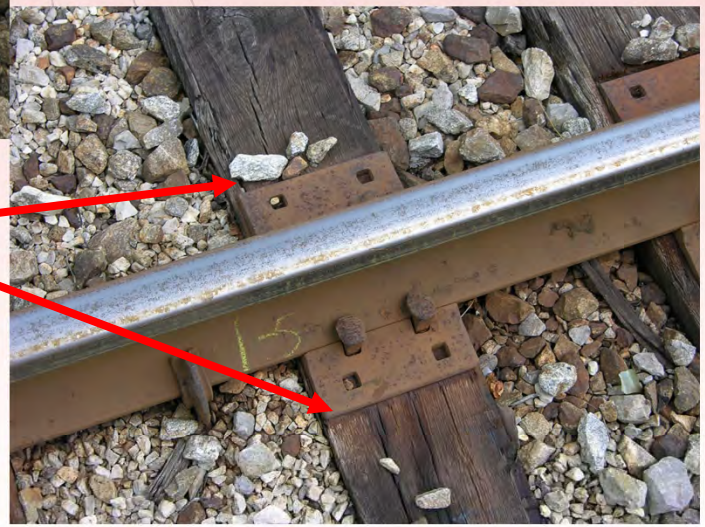
## No more than 1/2” lateral movement per FRA

## *Closeup showing amount of dynamic plate movement*





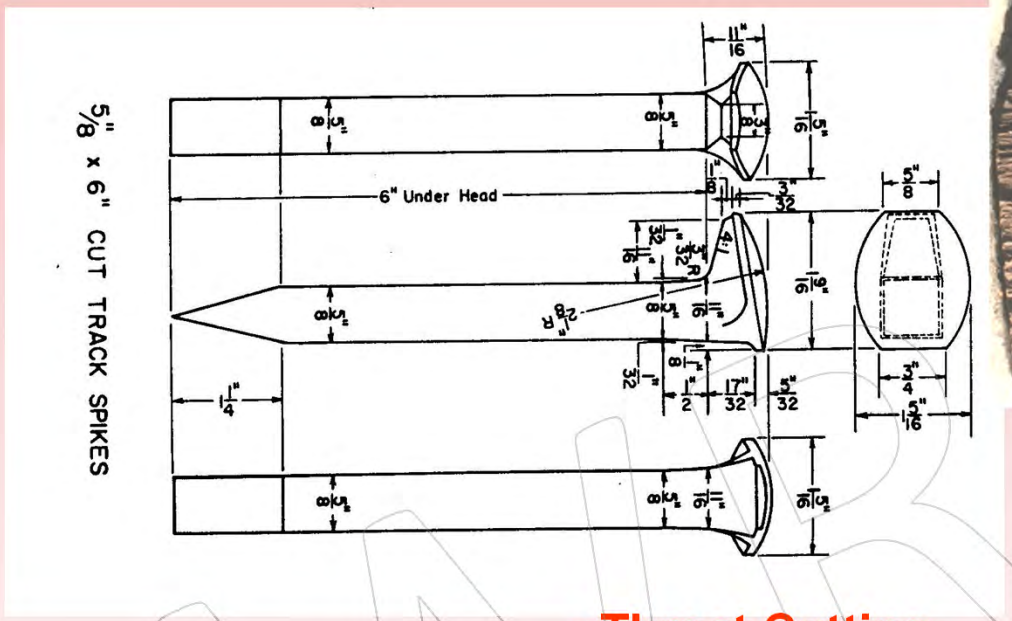
Note wear in shoulders of tie plate allowing additional rail movement under dynamic load.



Note significant dynamic gage widening under load.

# Broken Fasteners

# Cut Spike




Sheared Spikes

Throat Cutting

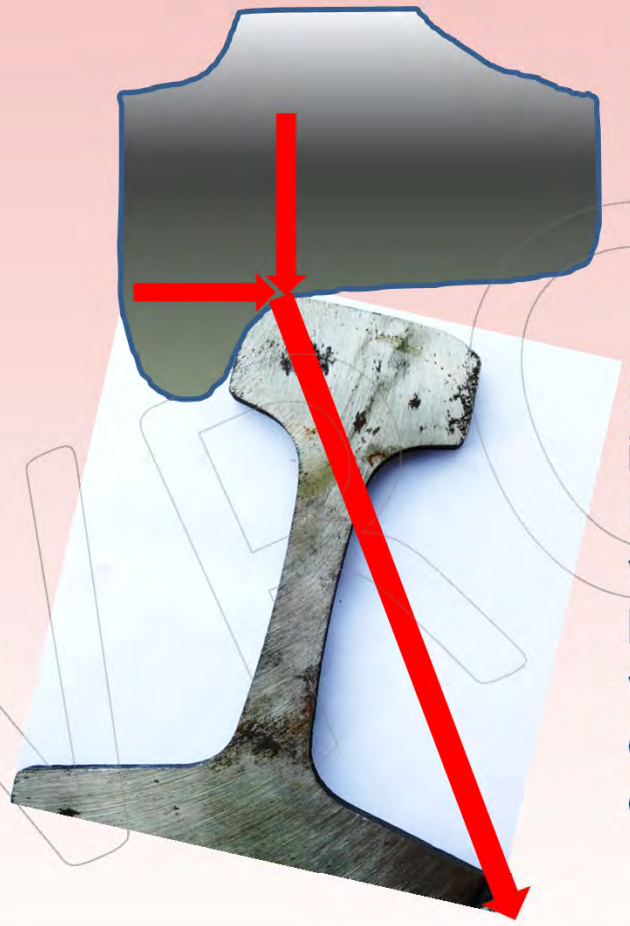
Sheared Screw Spikes


Random broken spikes from vicinity of POD. Note fatigue, rust, and polish on surface indicating not brand new break.

Fracture surfaces on three random broken spikes in Vicinity of POD. Note breaks appear to be “old”.

Random broken cut spikes and screw spikes from wide gage derailment.
Note fatigue, rust, and polish on surface indicating not a brand new break.

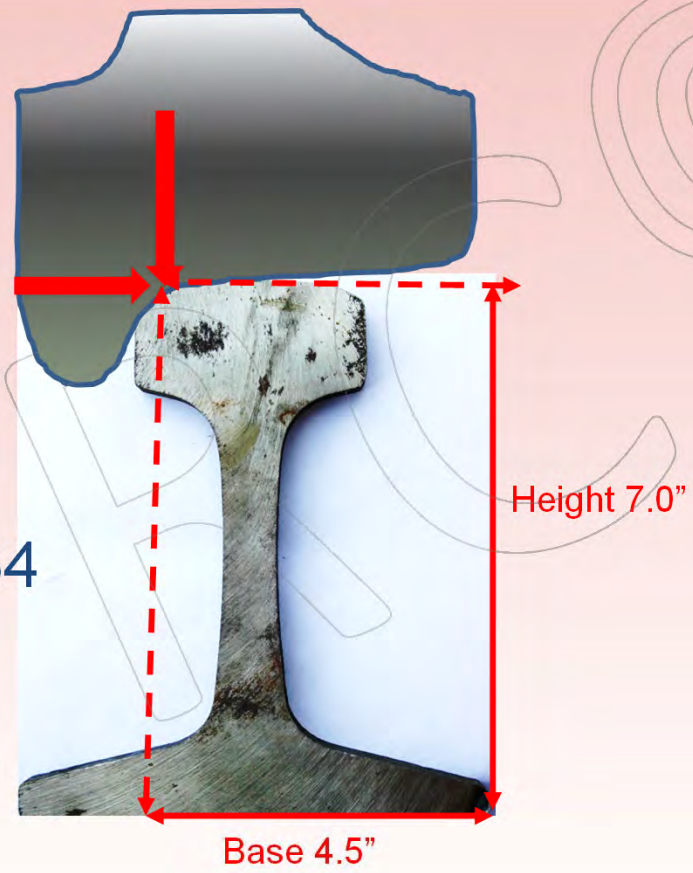
# Why rail rolls over



For rail rollover to initiate, the resultant of the vertical and lateral force vectors must fall outside the base of the rail

L/V = b/h

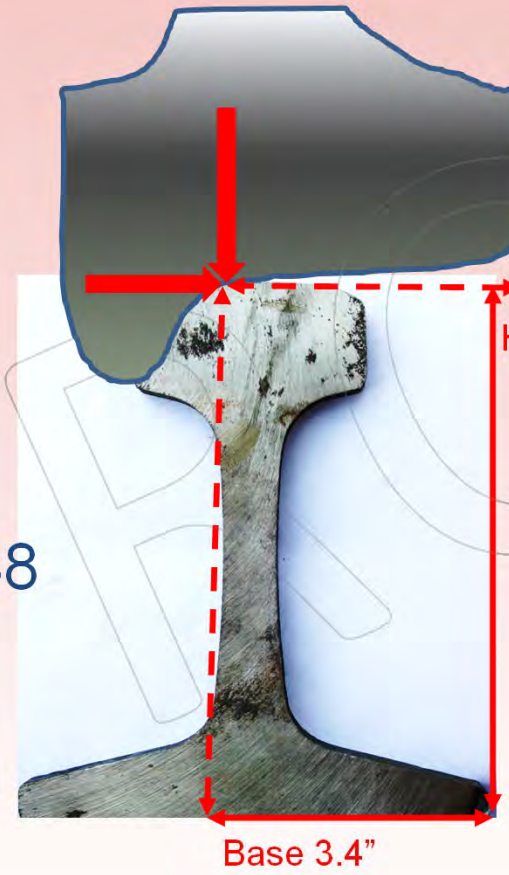
4.5”/7.0” = 0.64



# Effect of Worn Rail on Rail Rollover

$$L/V = b/h$$

$$3.4”/7.0” = 0.48$$

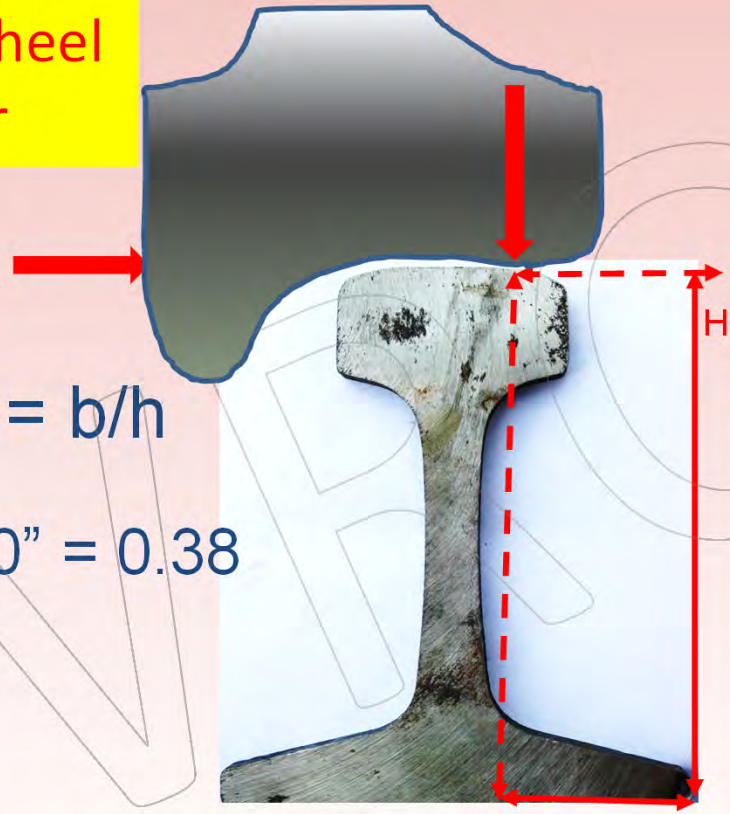



Gage face wear has the effect of moving the vertical load (base dimension) closer to the field side of the rail. This reduces the required L/V threshold for rail roll


L/V = b/h

2.75”/6.8” = 0.40

# Effect of Hollow Wheel on Rail Rollover

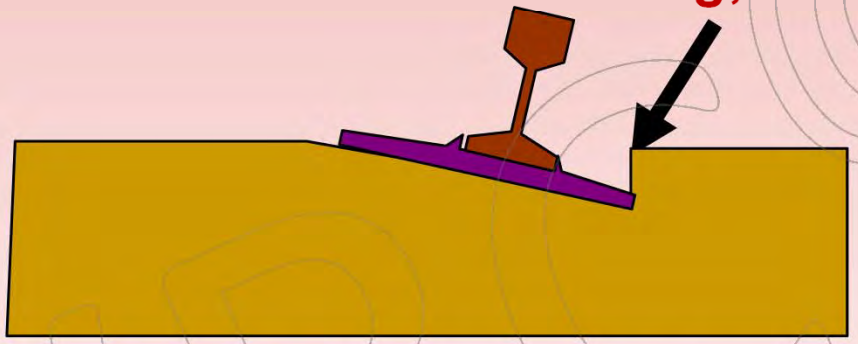



$$L/V = b/h$$

$$2.8”/7.0” = 0.38$$

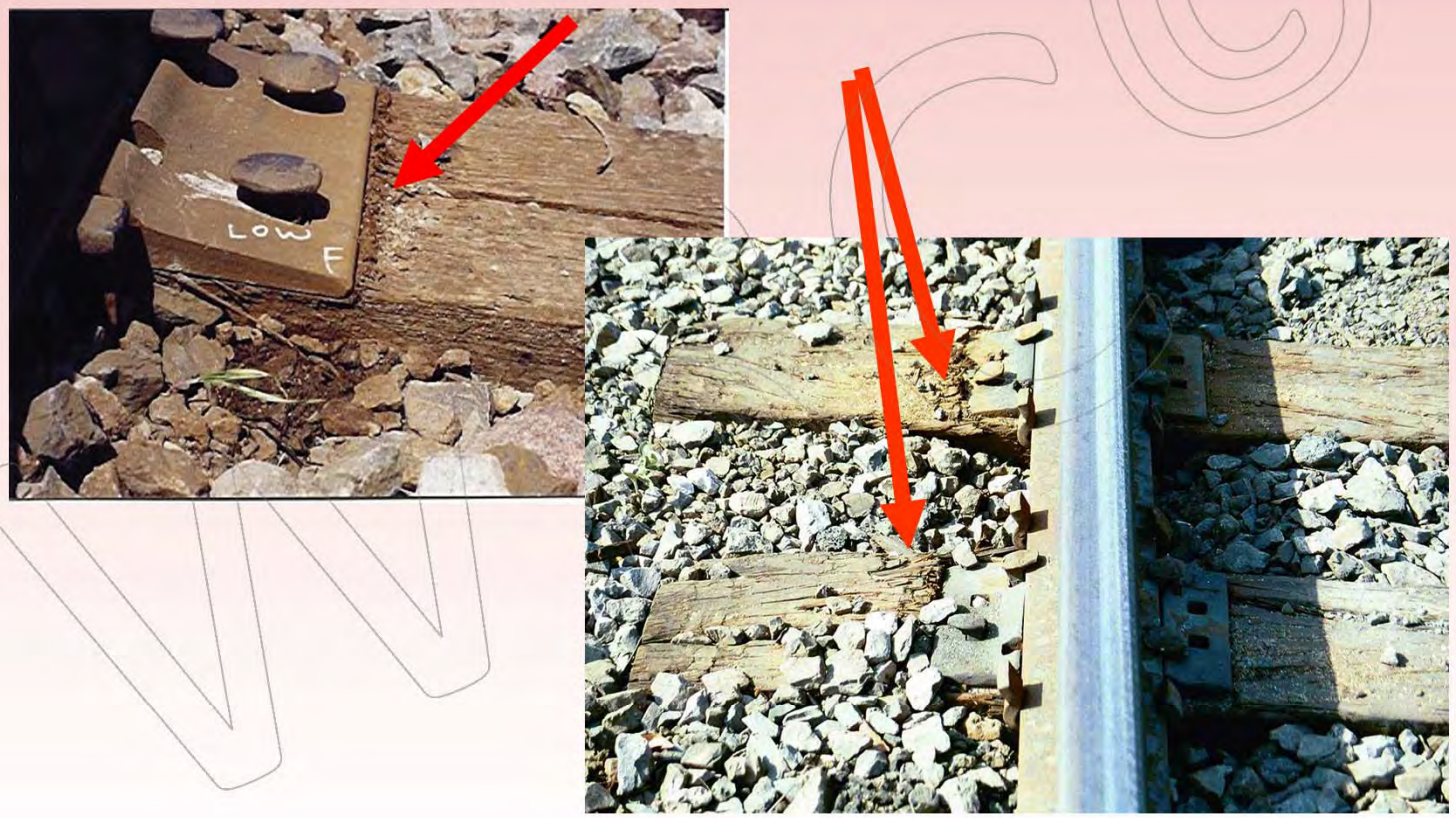
Gage face wear has the effect of moving the vertical load (base dimension) closer to the field side of the rail. This reduces the required L/V threshold for rail roll

# Differential Plate Cutting; rail cant

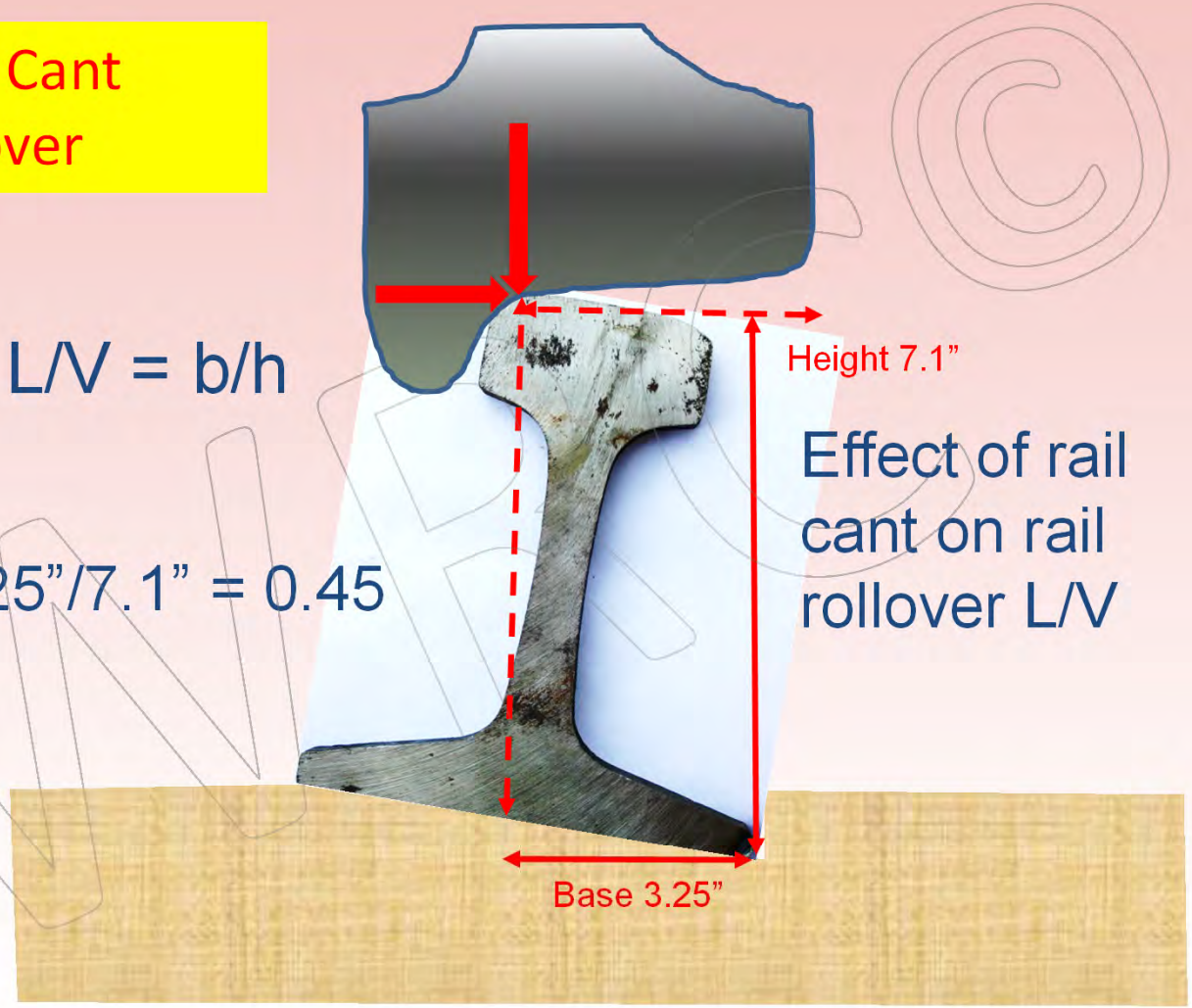


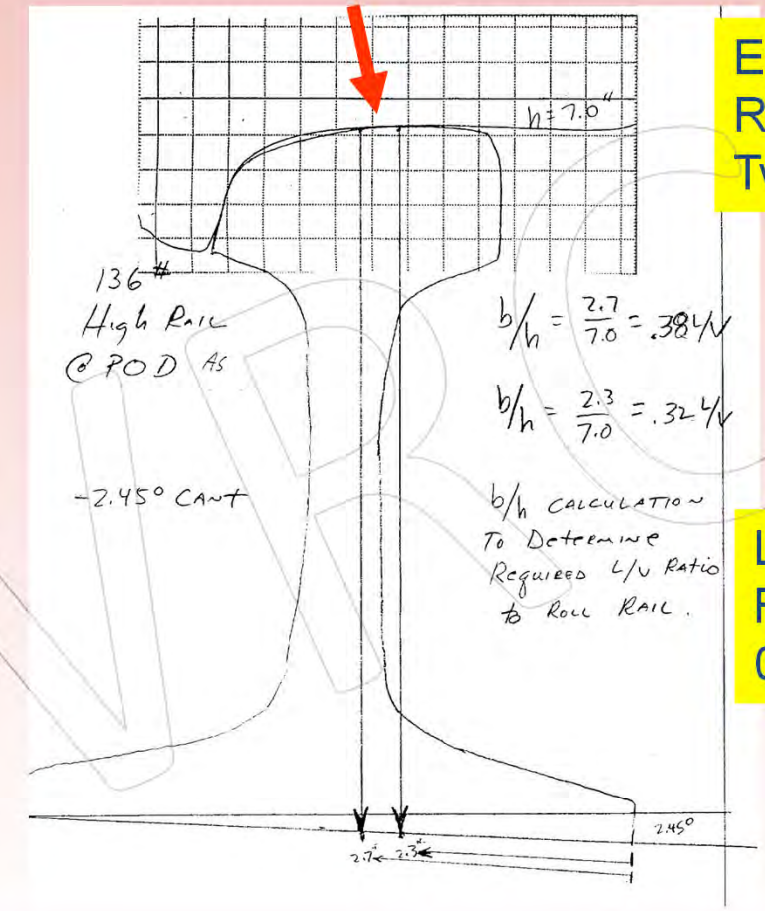

1.5”
.25”
Differential Plate Cutting

# Field Side Plate Cutting



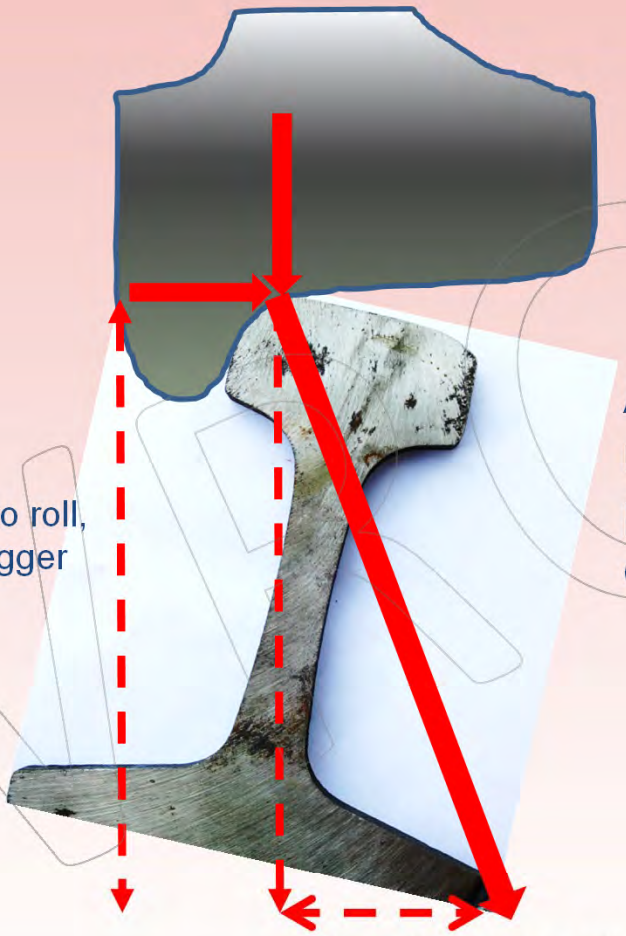
# Effect of Rail Cant on Rail Rollover






Effect of Negative Rail Cant and Two-point Contact

Lowers L/V ratio For rollover to 0.38 – 0.32



As rail starts to roll, height gets bigger

As rail starts to roll, it becomes progressively easier

As rail starts to roll, base gets smaller

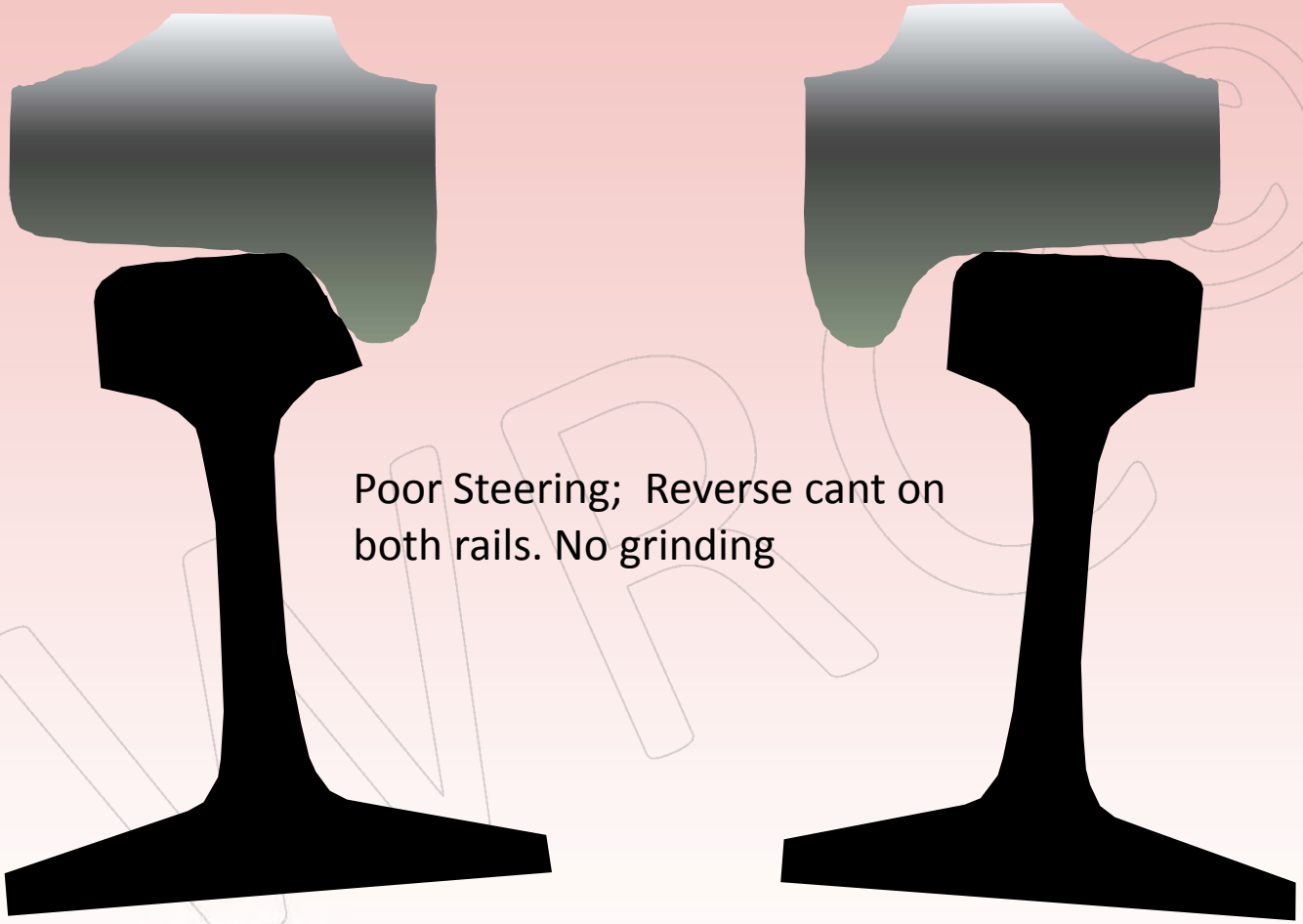

**Why Low Rail is More Prone to Rail Rollover Especially with Hollow worn wheels**

B/h Ratio

2.5”/7.0”

L//V for rollover = 0.35

How maintenance practices, particularly incorrect restoration of rail cant, and lack of grinding can affect the steering forces developed

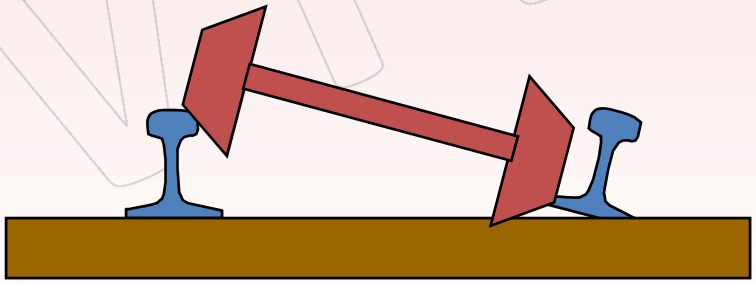


Poor Steering;  Reverse cant on both rails. No grinding

Very Poor Steering; High Rail Positive Cant restored; Low rail still has reverse cant. No grinding

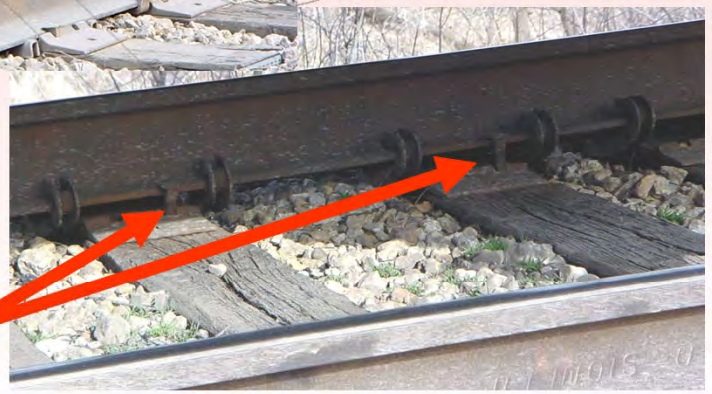
# Wide Gage Derailments
# T110, T111 - Symptoms

- Wheels found dropping in the gage
- May find wheel Drop-in Mark on gage corner of rail at POD
- Pre-existing Wide Gage or Evidence of Dynamic Gage Widening
- Either Rail May be Rolled Outward

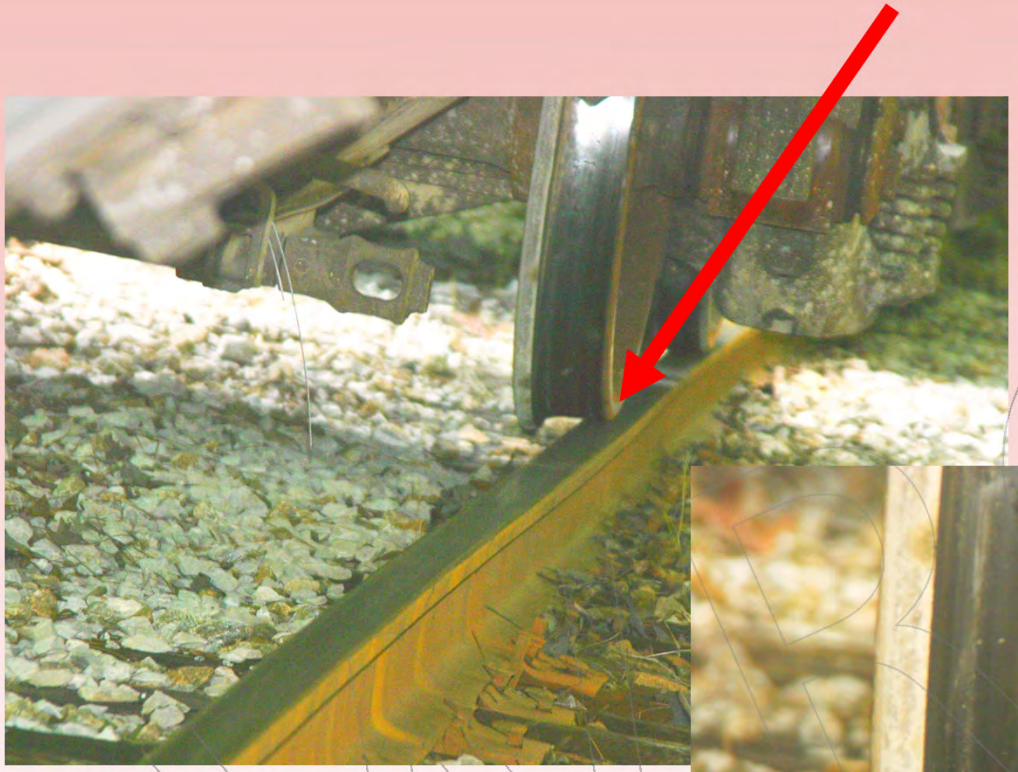


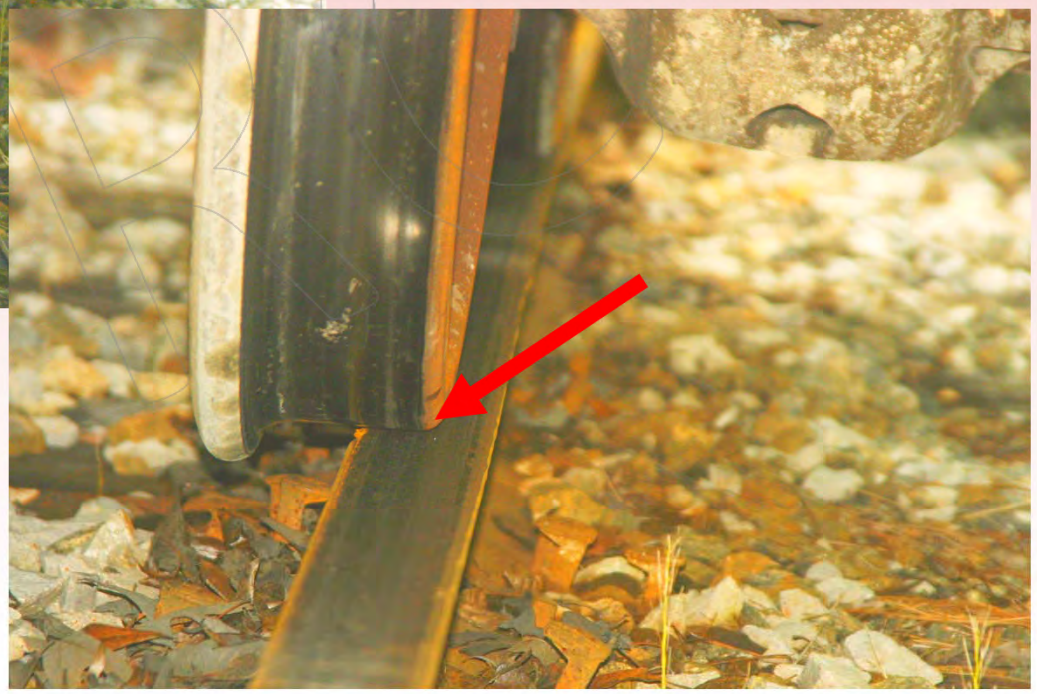
## Anatomy of a Wide Gage Derailment
## T110, T111

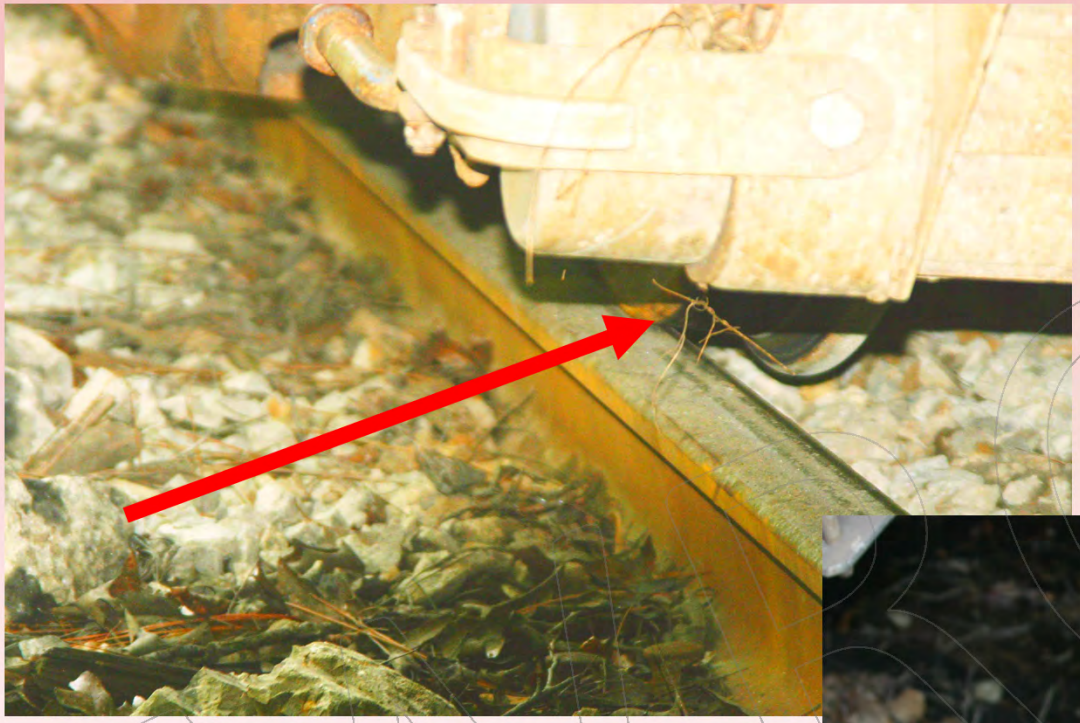
One or both rails rolled outward under train



Evidence of raised spikes leading into POD








COMP SHOES
70


Wheel Drop In Mark due to rail rolling outward

# Wide Gage Summary

- Wide gage derailments involve complex interaction between the track, rail, vehicles, and operating parameters.
- The investigator must determine if the gage widened progressively or catastrophically.
- Each component of the system must be evaluated
  - Ties, fasteners, wheel-rail contact, wheelset steering, rail wear, track geometry, speed, wheel wear, vehicle condition, operating factors
- Only after a detailed investigation can a true root cause(s) be developed.
- Not all wide gage derailments are due to weak track!

# The End