The PSR Operating Environment and Potential Effects on Derailments and Track Maintenance

This ain't your grandfather's railroad anymore…the times, they are a changing

Presented by:

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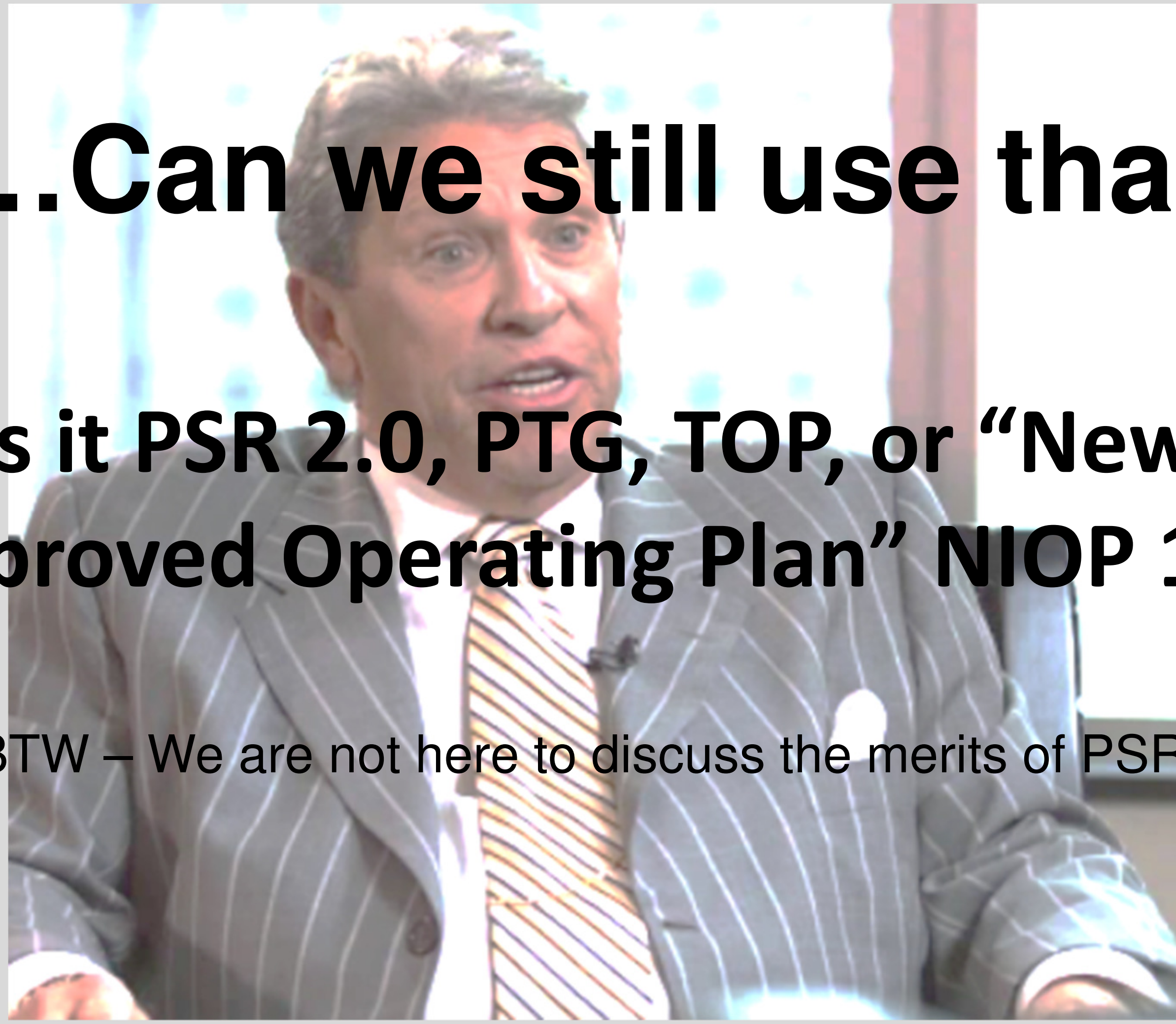
PSR…Can we still use that term?



Or is it PSR 2.0, PTG, TOP, or “New and Improved Operating Plan” NIOP 1.0 ?

(BTW – We are not here to discuss the merits of PSR)

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Tenets of PSR and Variants

- Less touches per car – less switching, more destination blocking
- Focus on car performance; less on train performance
- Car/train velocity important; less terminal dwell
- Less Unit trains; more complex blocking
- Optimizing network, not just single divisions/terminals
- Longer full tonnage trains; filling out tonnage enroute
- Running on Schedules; more predictability
- Less fire fighting; knowing what to expect
- More flat switching; less humping
- Drive decision making to local level; less bureaucracy

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PSR Summary

- Will see a change in train lengths(+/-) and speeds (+/-)
- Will see a change in traffic (Coal↓; Intermodal↑)
- Do more with Less…
  - ✓Fewer locomotives
  - ✓Fewer crews
  - ✓Less staff
  - ✓Fewer cars
  - ✓Less yards
  - ✓Less track (where not needed)

Higher utilization of assets means accelerated degradation of those assets, both physical and human.

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“All of the Class I systems regularly operate trains that reach or exceed 12,000 feet. Systemwide averages on the big six systems range from a low of 6,900 feet at BNSF Railway to a high of 9,359 feet at Union Pacific, according to recent data. UP’s train length is up about 30% since late 2018, when it adopted a Precision Scheduled Railroading operating model. UP aims to get its average train length beyond 10,000 feet”

Source: Trains Article, Bill Stephens, November 2021

Source: STB railway service dataset

Potential Impacts of PSR on Derailments and Track Maintenance

- Curve elevation issues
  - ✓ Higher train velocity may increase speeds on certain curves; insufficient elevation
  - ✓ Longer trains may operate slower on certain portions of the track; excessive elevation
  - ✓ Effect on rail grinding and RCF
- Higher speeds
  - ✓ More truck hunting; effect on equipment and track
  - ✓ Change from slow coal/oil/ore trains to fast intermodal trains
- Possible changes in train blocking; Block swaps; pick up on line of road
  - ✓ More slack action; effect on equipment and track
  - ✓ Higher steady state coupler forces with longer trains
- Longer trains = more heat into the rail
  - ✓ Implications for track buckling
  - ✓ Effect on gage face and TOR lubrication retention rates

Potential Impacts of PSR on Derailments and Track Maintenance Cont'd

- Longer trains = more locomotive horsepower
  - ✓Effect on rail anchoring; ballast sections
  - ✓Larger drawbar forces = larger lateral forces in curves
- Longer trains; more air brake problems (especially cold weather)
  - ✓Sticking brakes; flat wheels; wheel impacts on rail
- Less track time available for maintenance; penalties for impacting schedules; might need more slow orders
- Increased switching volumes in flat yards; More degradation of flat yard tracks and turnouts

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PSR and derailments/maintenance… the bottom line (or, WTBD)

Operating precision and reliability cannot coexist with derailments, maintenance interruptions, disruptions, slow orders, signal malfunctions, and human failure.

To operate a reliable precision/scheduled network we must eliminate disruptions/outages.

Changes in Locomotives and Train Lengths

- ✓ Higher Adhesion Rates (Traction/DB)
- ✓ Slower trains = higher in train forces
- ✓ Bigger trains = higher in train forces
- ✓ DPU Trains – Locomotive Placement Issues
- ✓ Higher traction/dynamic braking forces into smaller footprint on the track

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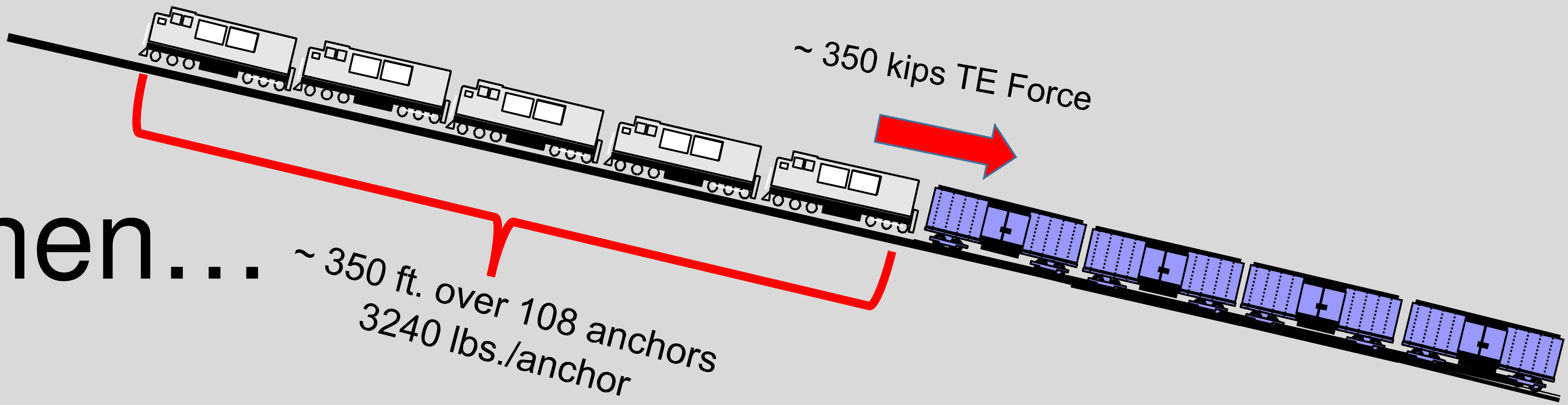
Then…



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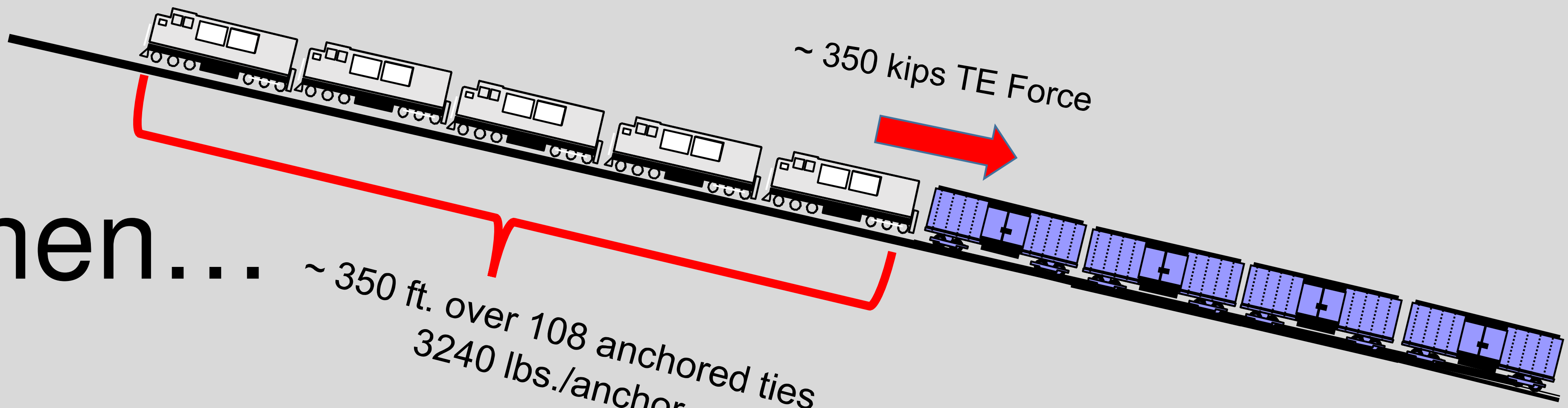
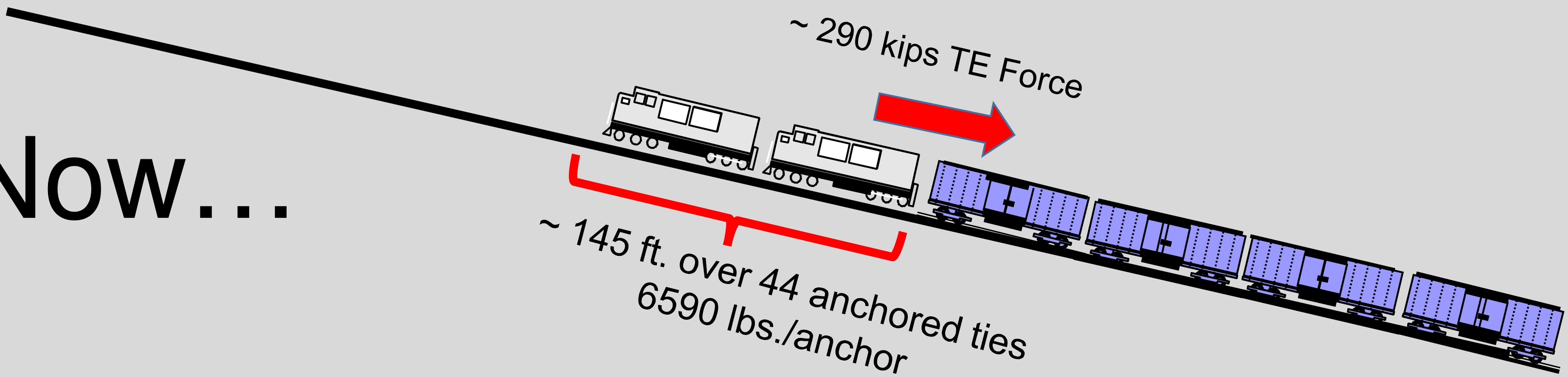
Then…


~ 350 kips TE Force
~ 350 ft. over 108 anchored ties
3240 lbs./anchor

Now…


~ 290 kips TE Force
~ 145 ft. over 44 anchored ties
6590 lbs./anchor

Let’s discuss the effects of increased longitudinal rail forces on anchoring and fastener life

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Rail Anchors

- Prevents Longitudinal Rail Movement
- Resists Movement due to Tractive/Braking Effort
- Resists Movement due to Heat Input
- Prevents Track from Buckling
- And we are learning they can help Prevent Sheared Spikes

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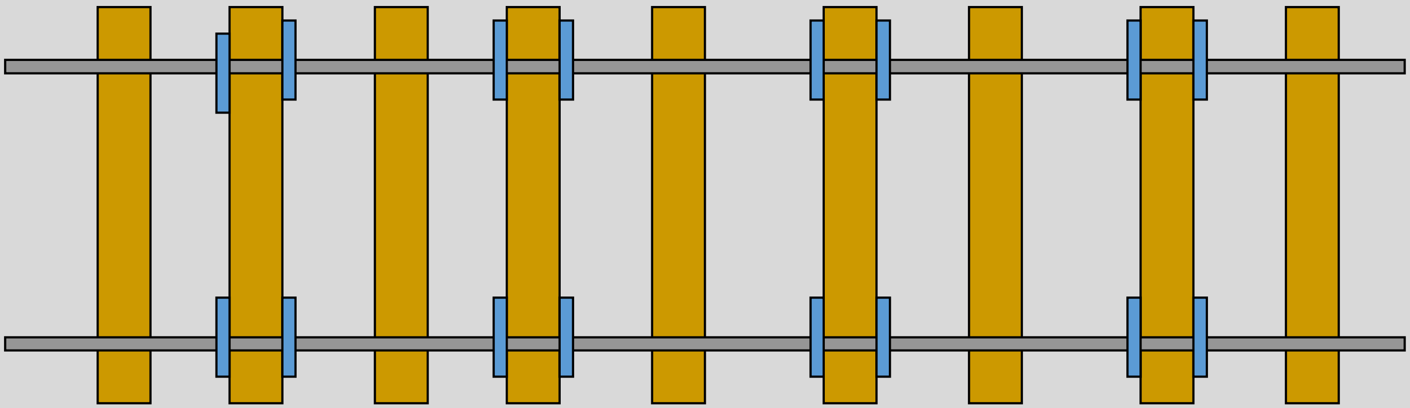
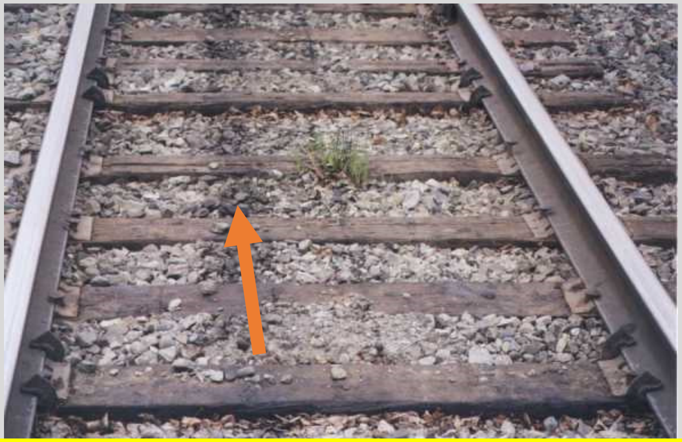
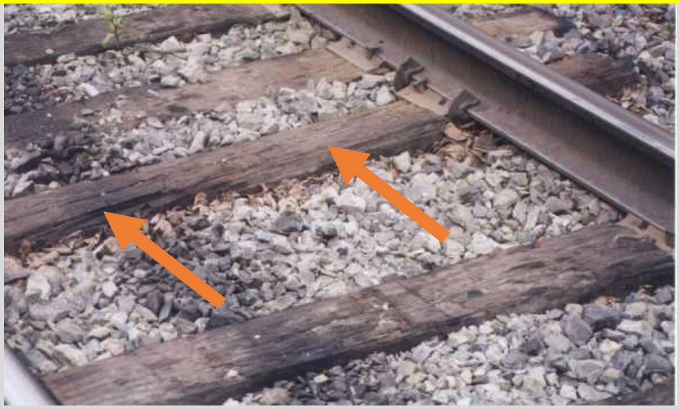
Anchoring Strength



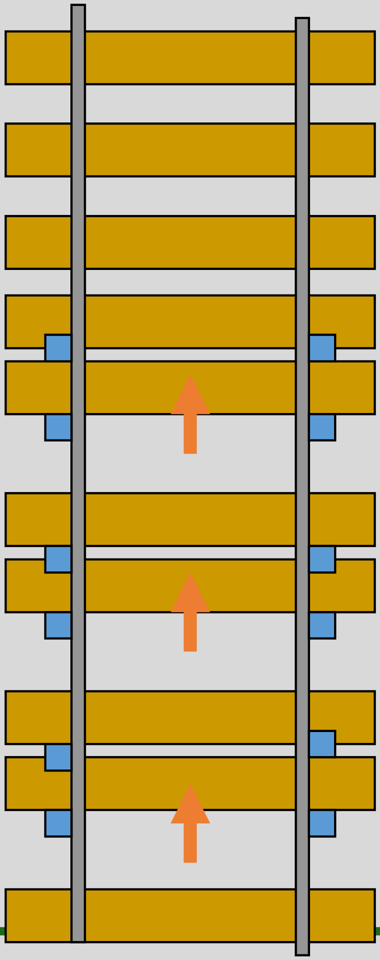
Each box anchored tie provides approximately 5,000 lbs. of clamping force/anchor per side



Effect of Poor Ballast Section and High Traction Forces



Tie Bunching against non-anchored ties



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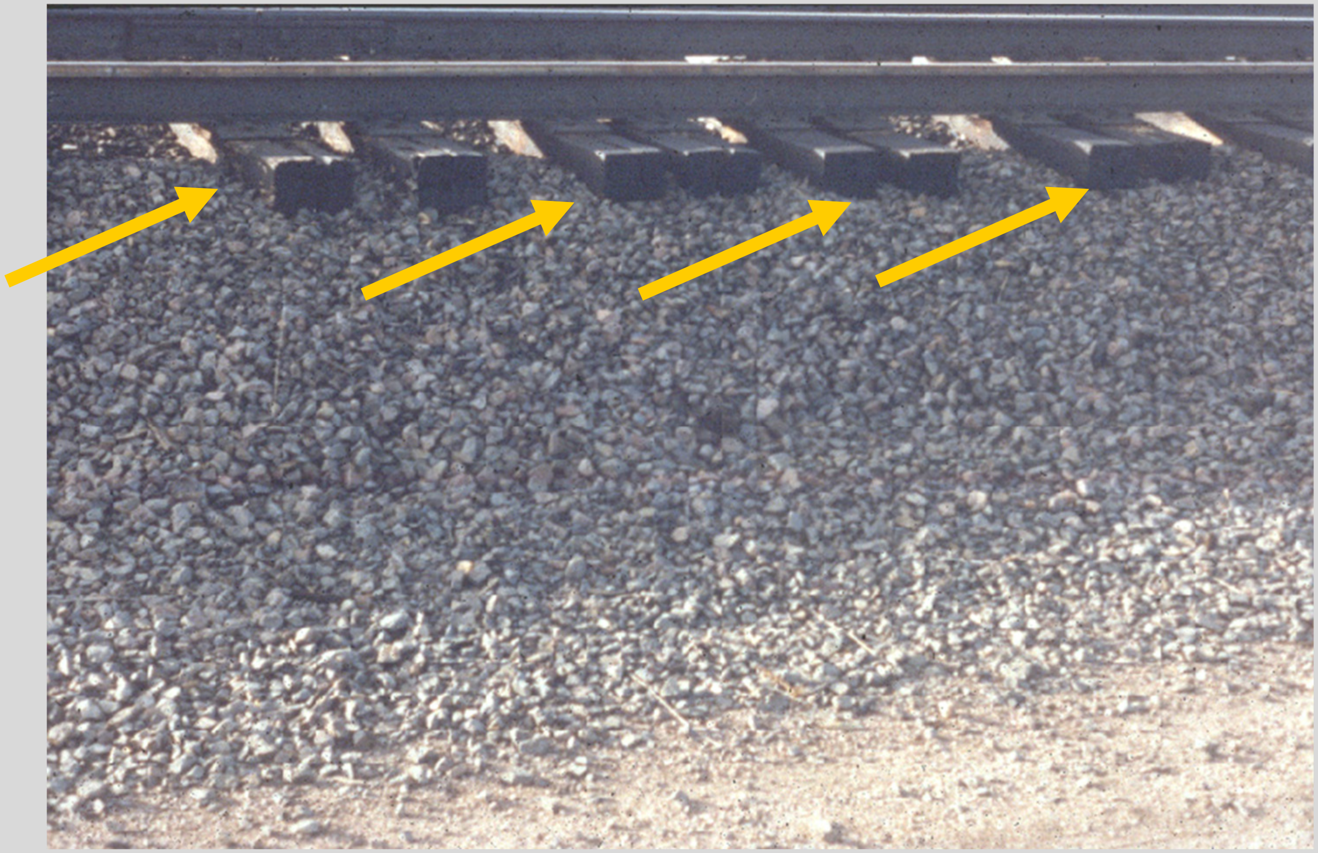

Tie Bunching due to Poor Ballast Crib, High Traction/Thermal Forces

Check Special Anchor Patterns as called for in CWR Territory based on your CWR Plan

And check critical locations of heavy Traction/braking Forces…

Watch Bridge Approaches

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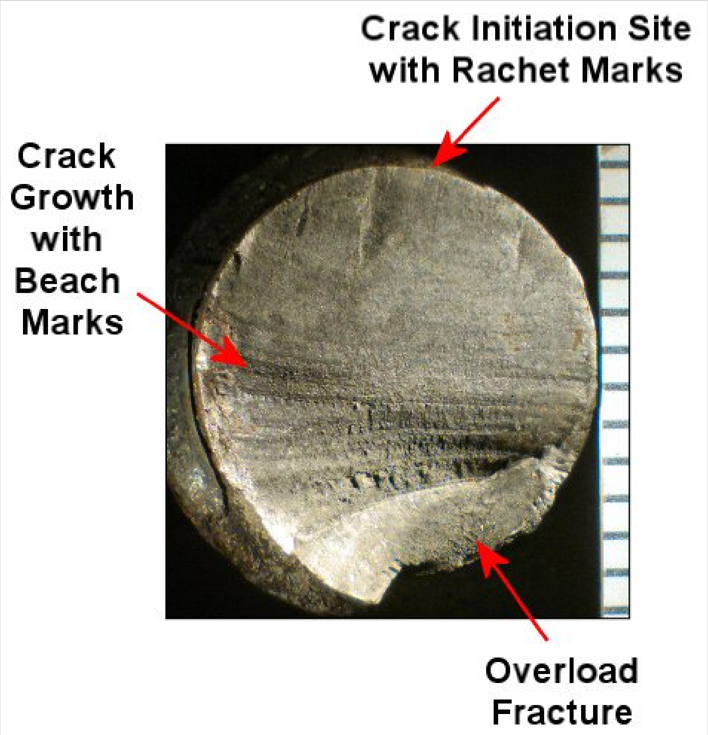
Sheared/Broken Spike Issue

History of Sheared/Broken Spikes

- Problem was first identified in the early 2000’s on several class 1’s
- Most locations of sheared spikes were in curves on steep grades where high traction and braking forces were present
- Initial research showed asymmetrical lateral forces on different spikes in the tie plate created bending stresses that initiated fatigue cracks below the spike head; once one failed, they go is succession
- A derailment at Mosier Oregon in 2016 brought the issue to the forefront again. At POD found ~ 80 broken spikes in a cluster.
- Later research showed high longitudinal rail stresses were another major factor in initialing failure at other sites

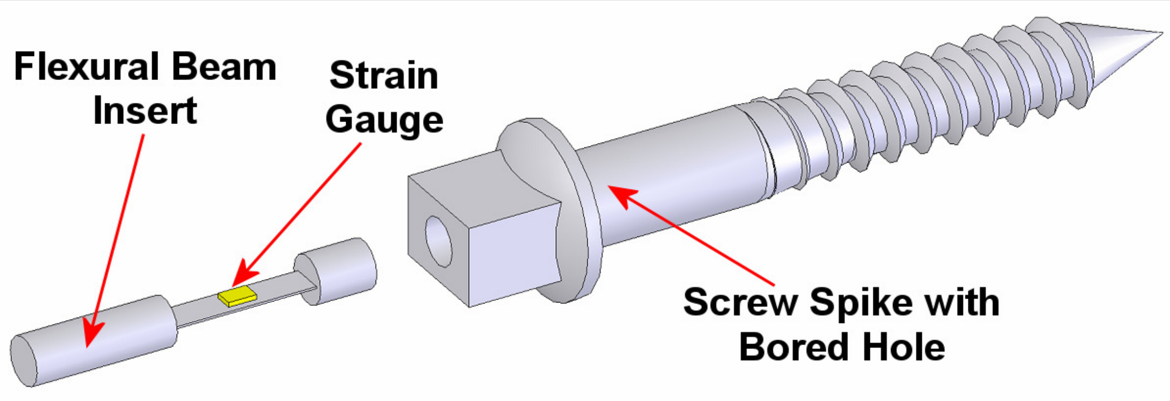
Background of Problem

- Screw spikes failure due to bending fatigue from lateral wheel loads.



Development of Instrumented Screw Spike

- It was desired to measure the lateral bending load applied to an instrumented screw spike.
- This was accomplished using a flexural beam insert with an installed strain gauge.
- This provided the microstrain and corresponding force output resolution needed, with a rugged, reliable design.
- Spikes were calibrated for bending force in MTS Machine at RSI Lab



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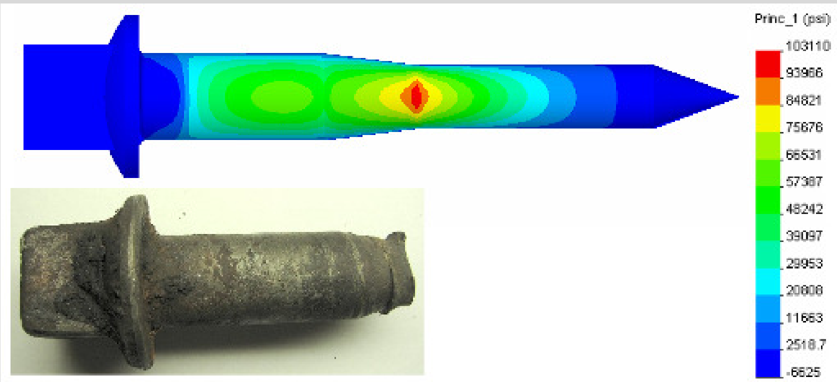
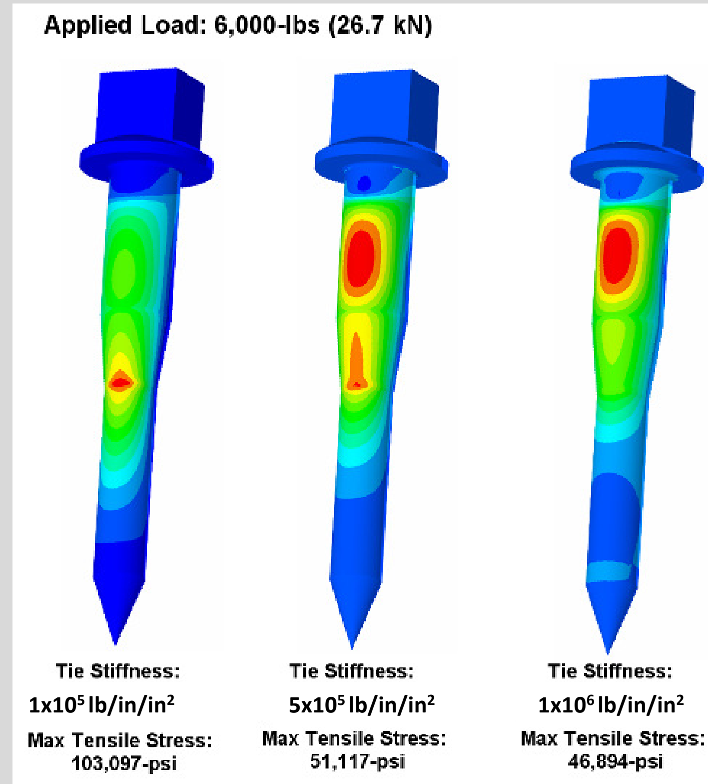
Finite Element Analysis



Comparison of FEA model to failed screw spike.



Stress locations for various wood tie stiffness.

Conclusions

- One screw spike was found to carry 63.1% while another only carried 1.0%. Interestingly these two spikes were opposite of each other of the field and gage sides, respectively.

- Finite element analysis indicated that lateral loads exceeding 8,000-lbs were needed to create stresses to cause fatigue. Only one instrumented screw spike measured loads that high, which was the same screw spike that carried 63.1% of the load within its tie plate.
  - ✓ Square and Round beams are not suited to prevent bending

- It can be concluded that screw spike failures can be attributed to uneven division of lateral wheel loads among screw spikes within a tie plate.

- Test only measured lateral bending, not longitudinal.

- It was noted that rail temperature swings also introduced additional bending stress into the spikes.

Additional Research into spike failures after 2016 Mosier derailment

- NS, UP, and other railroads continued to see spike failures, especially in clusters.
- Many failures were occurring on wood ties, with cut or screw spikes, and elastic fasteners.
- Failures are difficult to find, usually more observable when clusters appear in a concentrated area. Can find by watching gage channel on TGC. Sometimes lateral plate movement is an indicator.
- It was noted that most failures occurred on high rail of curve, and in heavy grade locations.
- FRA funded research proceeded at TTCI, U of Illinois, and NS (Brad Kerchoff), to name a few

Where we are now with broken spikes

- New test data suggests longitudinal loads may be important factor in creating adverse bending stresses in spikes (cut and screw)
- NS correlated broken spike problem coincided with introduction of new high adhesion AC locomotives on certain routes.
- The transfer of longitudinal loads thru elastic fasteners into the tie plate is exacerbating the problem. Asking spikes to carry loads traditionally resisted by the anchors bearing against the tie sides.
- Additional conventional rail anchors may be required in areas of high tractive efforts to supplement the toe load restraint of elastic fasteners.
- Locations of alignment irregularities also contribute to excessive lateral bending loads into cut and screw spikes.

Additional rail anchors may assist in lowering longitudinal bending

Evidence of false flange contact on field side of low rail another way of finding wide gage and broken spikes

Sheared Spikes Remedial Actions

- On TGC data, observe not only gage magnitude, but also the change in gage over short time intervals (Δ).
- Use of Autonomous (ATIP) frequent geometry testing (with quantification) will likely spot incipient spike failures due to changes in gage. Better than visual hy-rail inspection.
- Consider use of additional conventional anchoring in areas of broken spikes
- Make sure incorrect elevation is not contributing to increases in lateral rail forces
- Consider TOR Lubrication/FM in known areas of broken spikes
- Insure good tie quality and all spikes equally sharing the loads
- Tap with hammer/maul on inspections, hard to spot visually.

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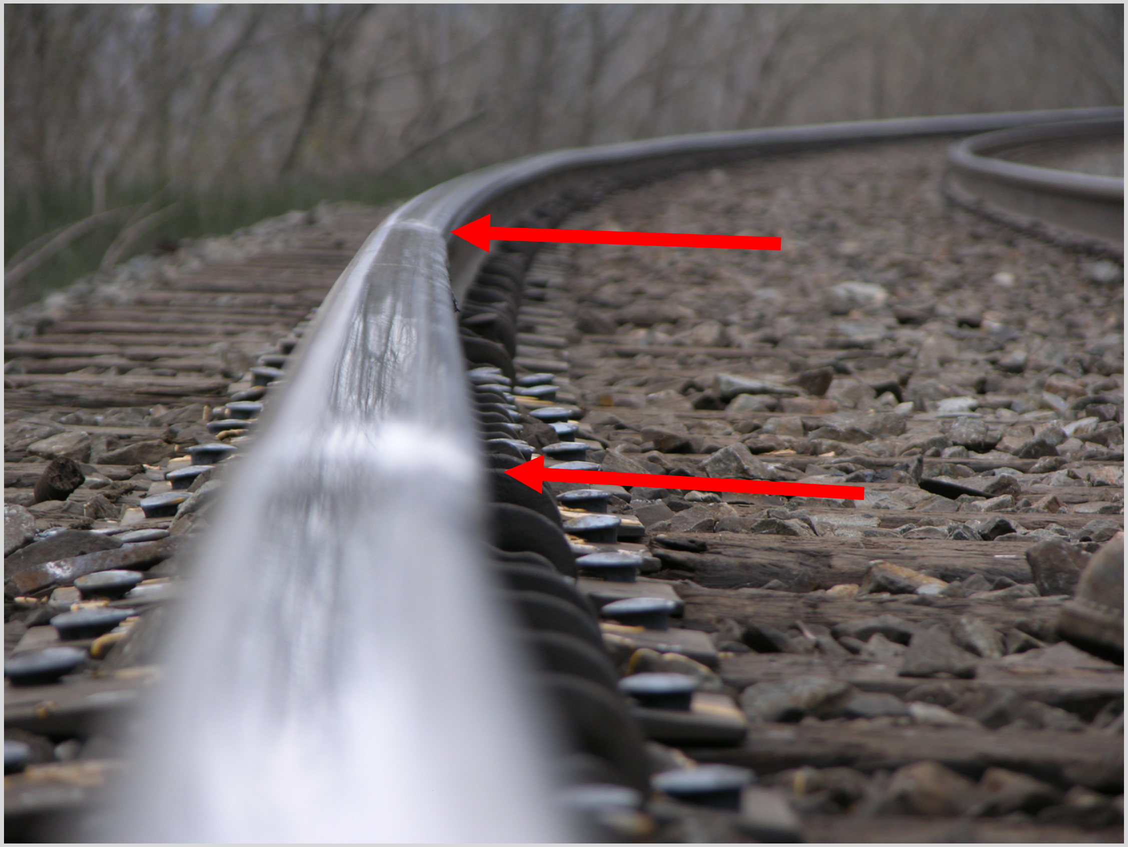
Alignment Irregularities can increase incidents of sheared/broken spikes

- Alignment changes (non-condemnable) increase wheel flange forces.
- Watch TGC alignment channel for small increases in alignment irregularities; with increasing gage.
- Bridge approaches key locations for alignment changes.
- Check after cold winter season for curve pull-in/alignment changes
- Check in heat season for alignment changes



Alignment irregularity due to insertion of plug rail causing increase in lateral flanging force and lateral bending stress into spikes

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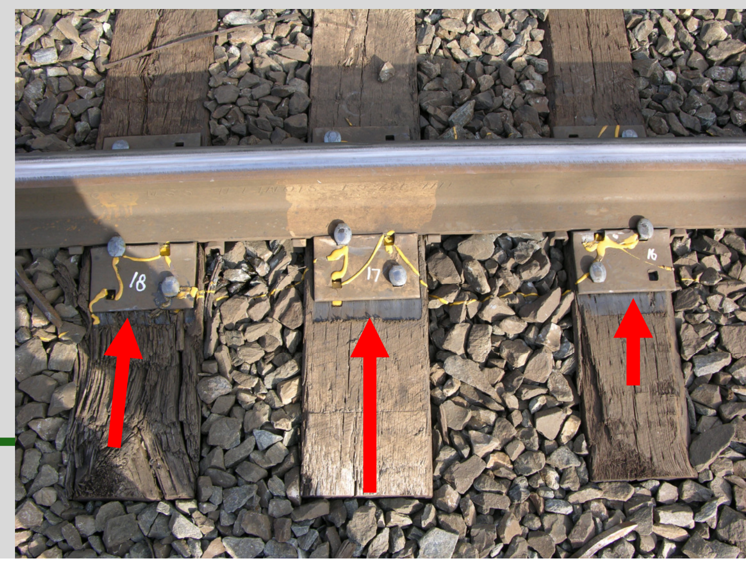

Alignment irregularity location showing spikes and obvious lateral plate movement

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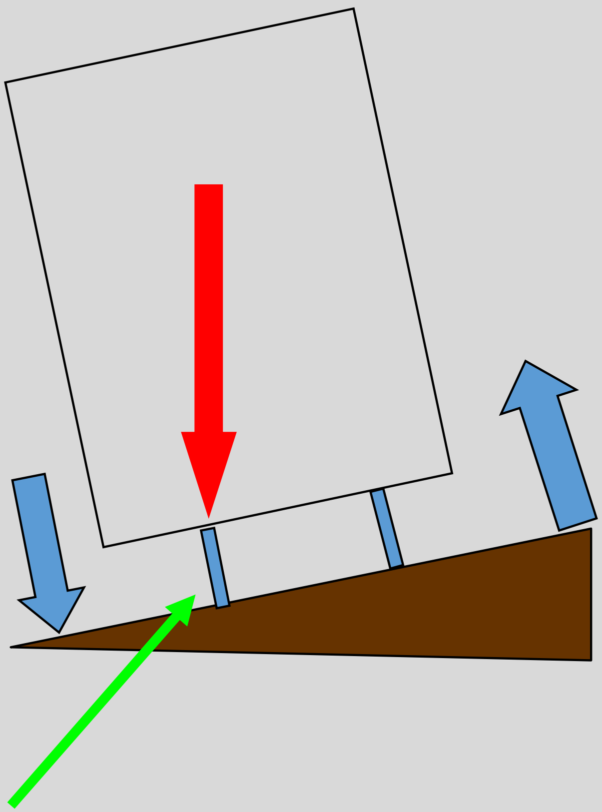
Curve Elevation Issues

- Changes in train speeds with operational changes due to PSR; can be an increase or decrease in speed.
- With longer/heavier trains speeds on ruling grades train speed may decrease
- As speeds drop, the curve becomes over-elevated, increasing the vertical loads and lateral creep forces on the low rail of curves.
- With shorter, more frequent trains, speeds may be increasing in curves, causing under-elevation of existing curves
- Track maintenance personnel must be vigilant against under/over elevation issues.

Running Under Balance Speed develops more vertical and lateral force into the low rail



Spalling on Low Rail; Pumping at Joints

The Problem with Excess Superelevation

- Increased Vertical Loads on Low Rail
  - Increased lateral creep forces
  - Increased spalling on low rail
  - Increase plate cutting on low rail; also increase in rail cant
  - 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

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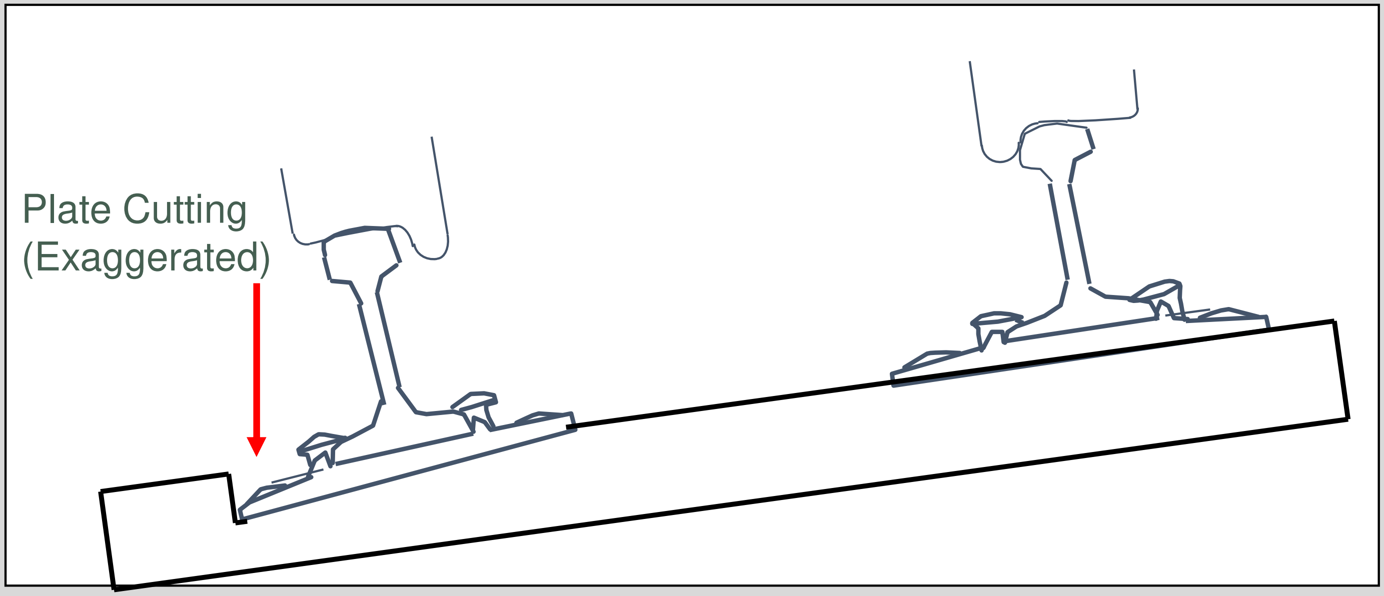
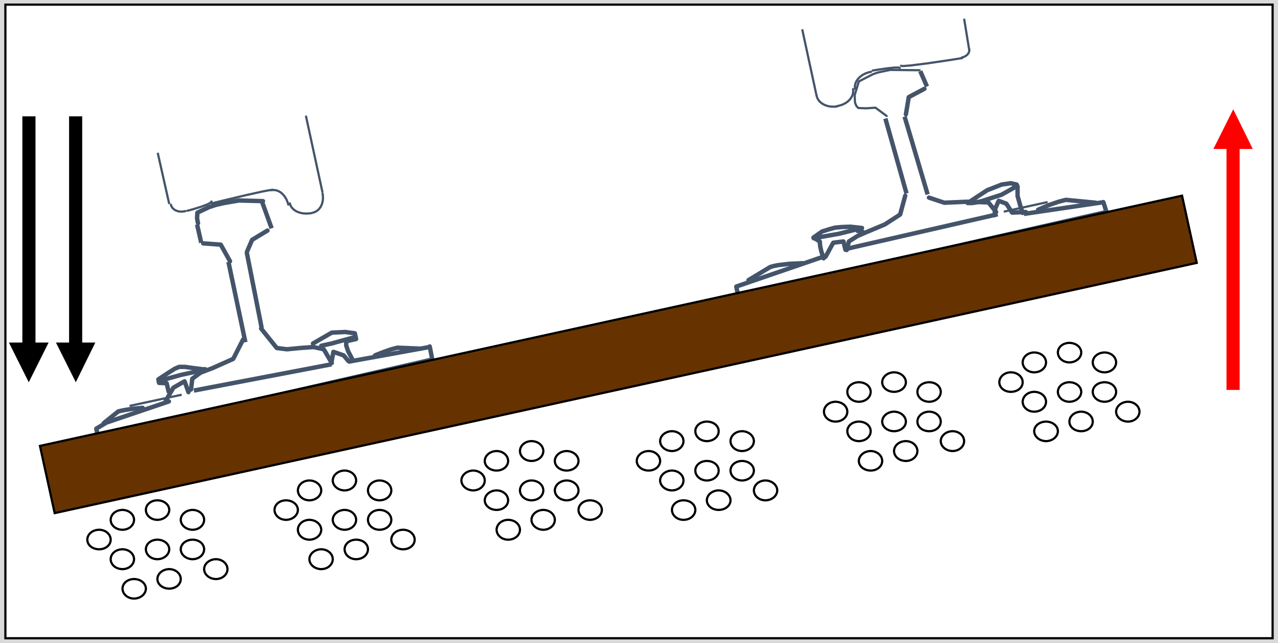
The Problem with Excess Superelevation

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



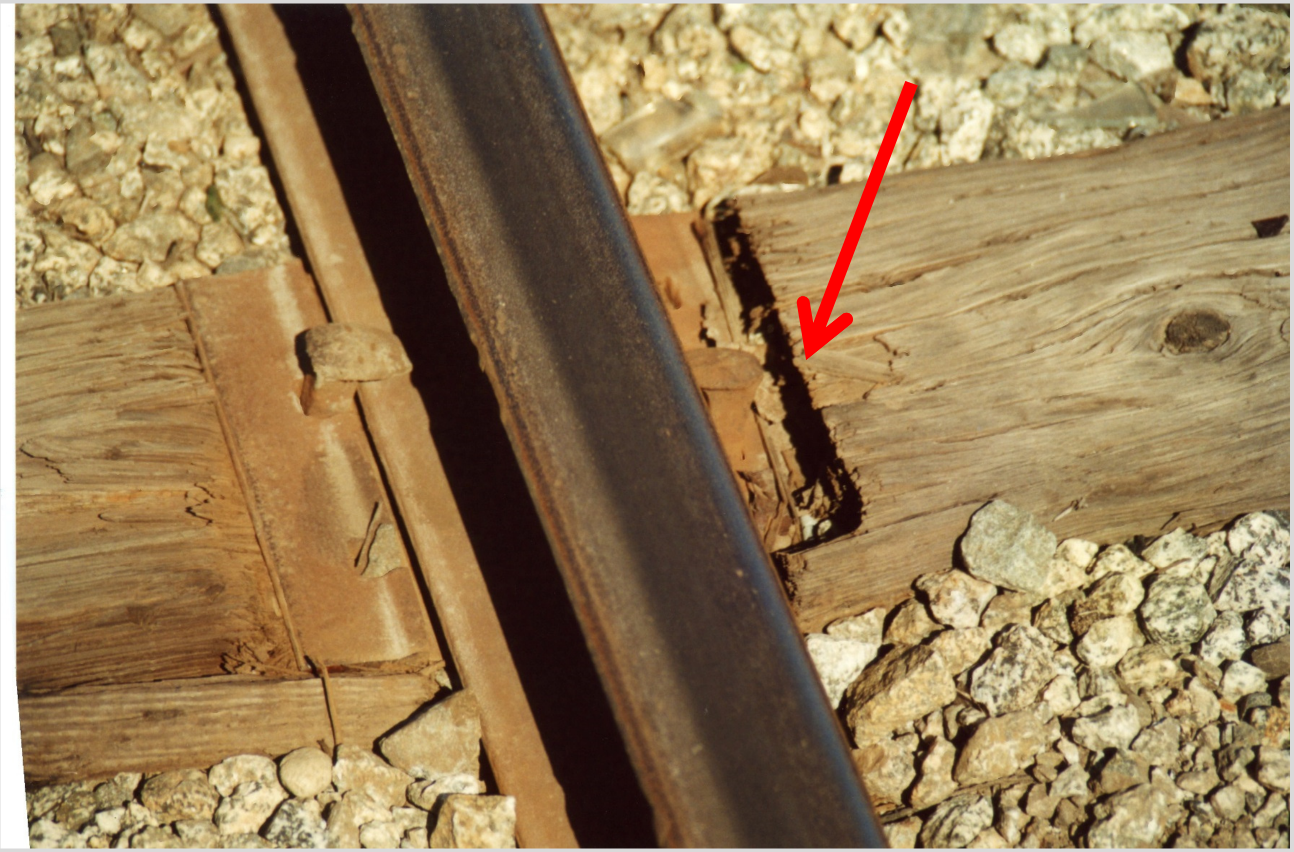
The Problem with Excess Superelevation

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



Low Rail Spalling

Low Rail Rollover/Gage Widening



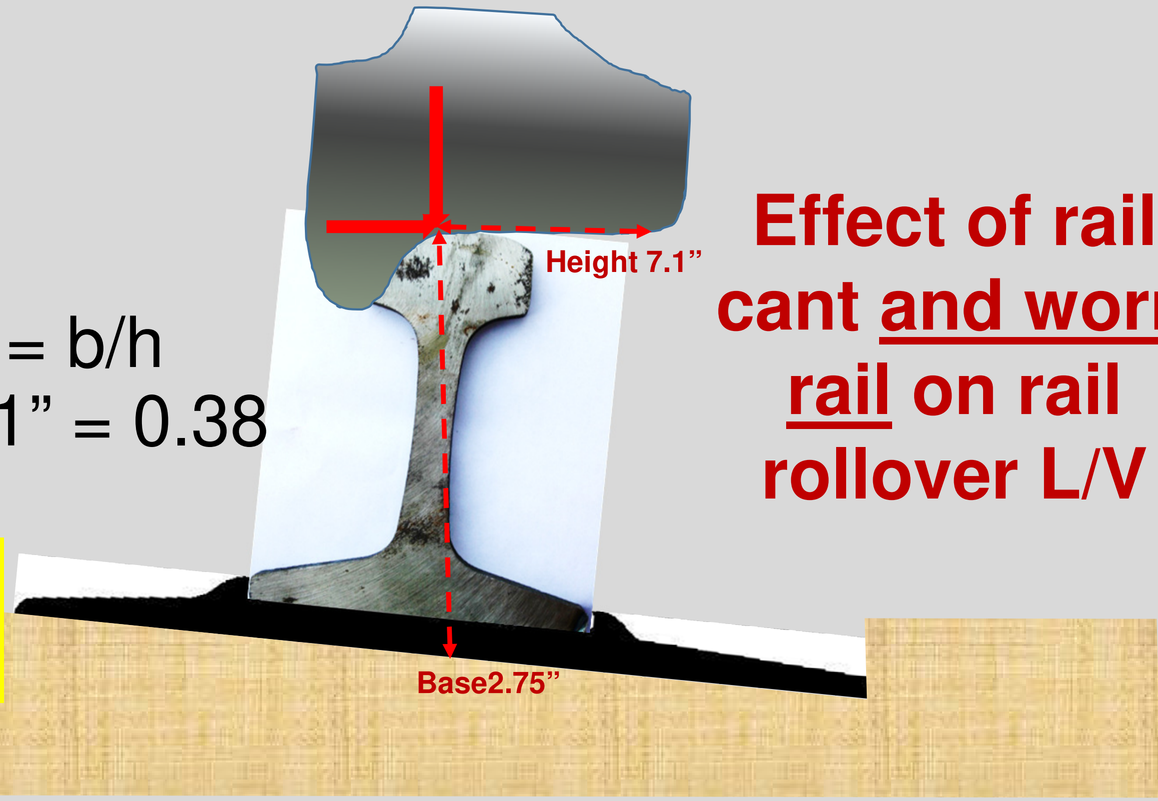
Effect of rail cant on rail rollover L/V

High Rail in Curve

Effect of Worn Rail and Outward Rail Cant

L/V = b/h

2.75”/7.1” = 0.38



Effect of rail cant <u>and worn rail</u> on rail rollover L/V

Double Jeopardy !!

Summary Rail Cant Issues...

- Rail cant can be caused by improper curve elevation due to changes in train speeds (PSR effects).
- Running on over-elevated track will increase rail cant on low rail of curve.
- Rail cant lowers the required L/V ratio (B/H ratio) for rail rollover to extremely low levels. It can greatly enhance probability of low rail rollover.
- During inspection, be observant for increases in rail cant.
- Correct elevation problem and remediate with adzing, shimming, or new ties.

A note on rail lubrication/FM

- Longer trains, with more axles, will increase rail heat in curves due to friction.
- Higher rail heat, along with additional wheel forces, may reduce the retentivity of greases and friction modifiers, causing less carry forward down the track.
- Need to closely monitor rail friction levels (gage face and TOR) to make sure that lubricator spacing and output rates are proper for longer/heavier trains.

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A note on rail grinding

- Longer, heavier, slower/faster trains, with higher wheel loads, may change wear patterns on high and low rail heads.
- An increase in rail cant can adversely affect rail wear patterns
- Insufficient lubrication coverage can also increase rail wear rates
- Rail wear rates (gage face and top) may change dramatically
- Make sure grinding intervals are keeping pace with rail wear rates and you are staying in preventive grinding mode vs. corrective grinding

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One Final Issue – Switch Yards

- Switching operations are moving from hump yards to flat yards with PSR.
- Many flat yards are old, with lighter weight rails, and marginal fastener/tie condition
- Many turnouts in flat yards are <#10 increasing difficulty in curve negotiation through the turnout. Watch for wear/tear on switch points, heel blocks, frog points, and guard rails.
- Handling long blocks of cars in block swapping moves can increase the potential for heavy slack action due to improper use of independent brake, or rapid throttle manipulations.
- The extra traffic levels moving to flat yards, and lighter infrastructure, can increase the rate of track degradation, with an attendant increase in derailment risk.
- Keep a close eye on track conditions in flat yards.

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Summary of PSR Effects

- Changes in speeds with PSR will change wear patterns on rail, fasteners, ballast, and crossties.
- Keep an eye on how train speeds in curves, especially on ruling grades, are affecting the track geometry and strength.
- Increases in drawbar forces due to bigger trains will exert higher lateral and vertical forces on the track structure.
- Higher wheel stresses into the rail may affect rail lubrication effectiveness
- Keep a close eye on track conditions in flat yards.
- Longer, slower trains may reduce track capacity and maintenance windows. Ensure you have adequate windows to perform required maintenance.

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Summary of PSR Effects con't

- Special problems to be aware of include:
  - ➢Increase in track buckles due to higher longitudinal rail stresses
    - ✓Inspect for anchor movement, ballast churning, tie bunching, weak shoulders/cribs
  - ➢Increase in sheared/broken spikes
    - ✓Inspect for increases in Δ gage, low rail grooving, lateral plate movement, curve mis-alignment
  - ➢Monitor curve elevation to be sure it is consistent with current trains speeds
    - ✓Check for gain in elevation, increase in plate cutting and rail wear rates
  - ➢Increase in rail cant and rail rollover due to improper curve elevation
    - ✓Inspect for rail cant, worn rail, plate movement

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Summary of PSR Effects con't

- Special problems to be aware of include:
  - ➢Monitor effectiveness of rail lubrication/FM
    - ✓Gage face and top of rail (TOR)
  - ➢Monitor rail profile wear rates and patterns
    - ✓Both high and low rails
  - ➢Enhance Inspection of flat yards especially low number turnouts (<#10)
    - ✓Switch points, frogs, heel blocks, braces, guard rails

Remember…

- The only thing constant in the world is change; nothing stays the same
- Be vigilant to changes in operating practices during PSR, and its variants, that can and will affect track maintenance and derailment risk
- "If you do what you've always done, you'll get what you always got!" W. Edwards Deming

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The End