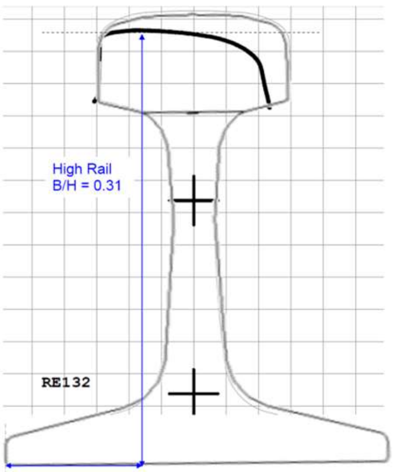
Corrective Grinding of Adverse High Rail Profiles



Brad Kerchof

Director Research & Tests (retired)
Norfolk Southern Railway

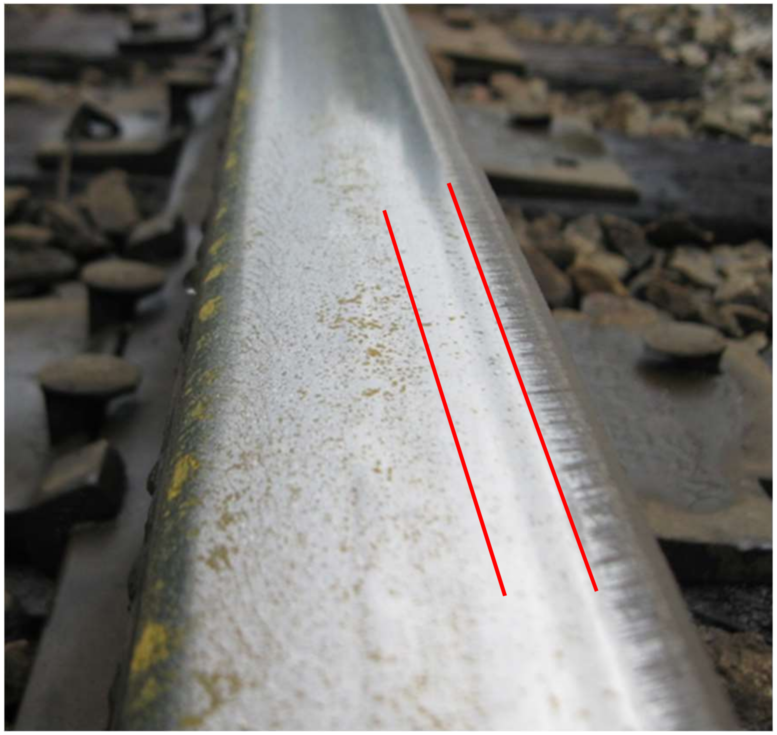
Senior Track Engineer
Advanced Rail Management

Outline

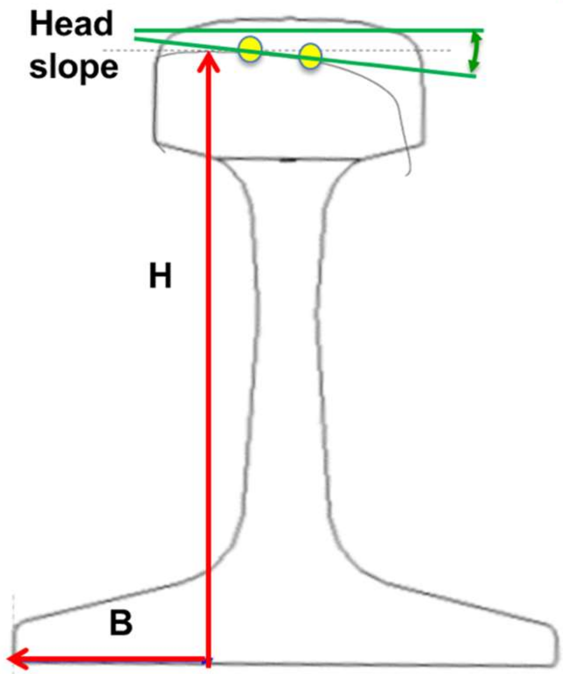
- Adverse high rail profiles:
  - What are they?
  - How do we measure them?
  - Why are they a problem?
  - How do they develop?
  - Consequences
- Corrective grinding field test

What is an adverse high rail profile?

- One that shows significant field-side wheel contact

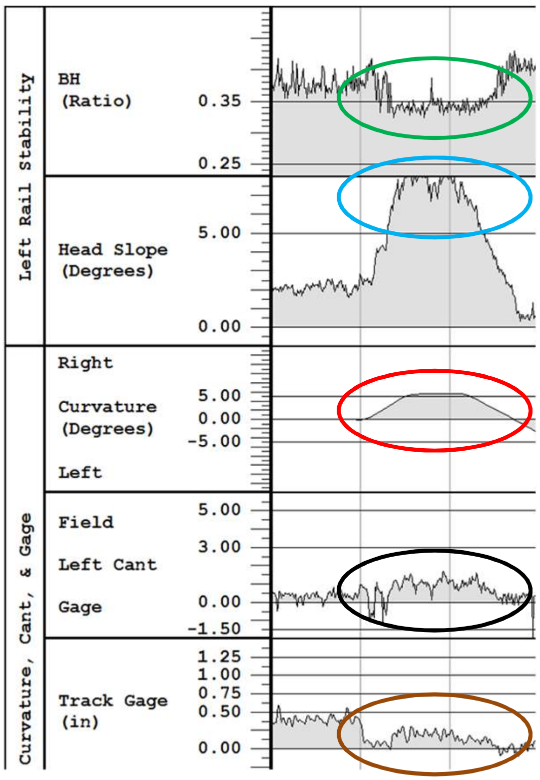


How do we measure an adverse high rail profile?



- B/H is a ratio that includes
  - H, the height of the rail at its highest point
  - B, the horizontal distance between the high point and the field edge of the base
  - New 136# rail: 3" / 7-5/16" = 0.41
  - As high point moves toward field side -> B/H gets smaller
  - Threshold for concern: < 0.35
- Head slope is the angle between horizontal and a line defined by two points one-half inch on either side of rail centerline
  - Steeper slope -> more likely that wheels will run on the field side
  - Threshold for concern: > 5^{o}

Example of an adverse high rail profile

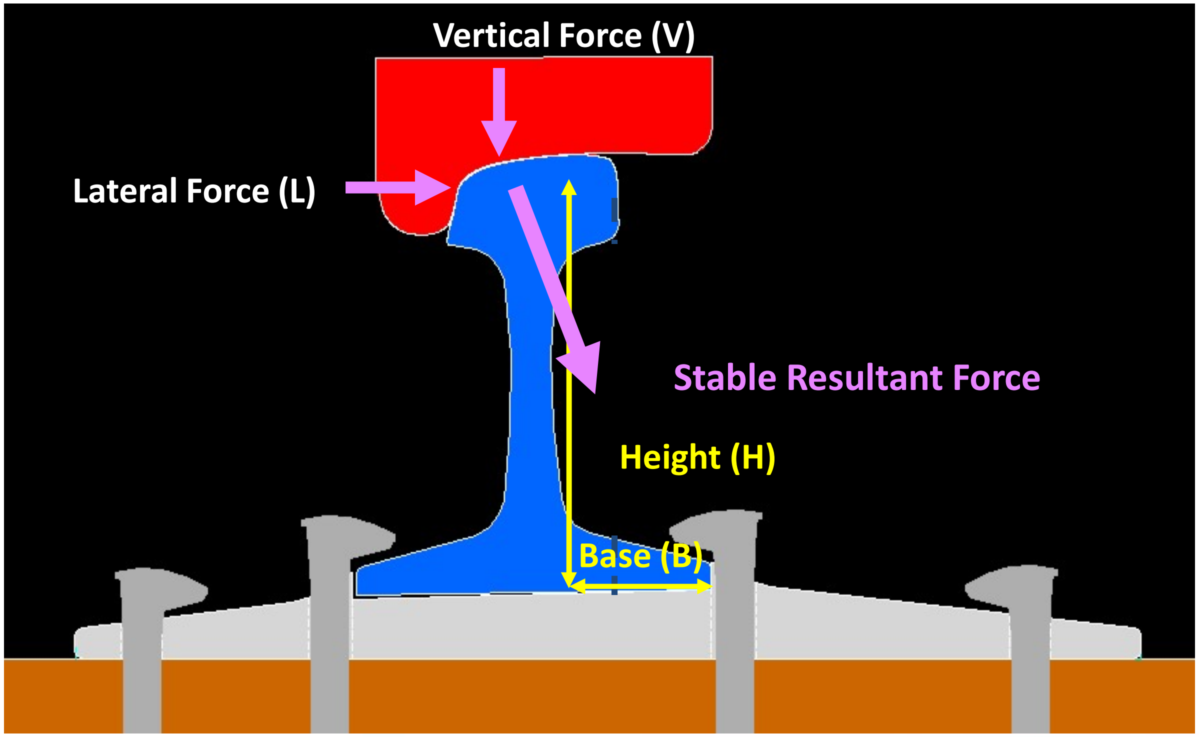


NS rail wear graph

- B/H 0.34
- Head slope 8°
- Curvature 5°
- Rail cant 1°
- Gage ¼”, or 56-3/4”

Primary contact band is on field side

Why is an adverse high rail profile a problem?



Wheel/rail force diagram, stable condition

Lateral & vertical forces produce a resultant directed inside the rail base

This is a stable condition – the rail will not tend to roll

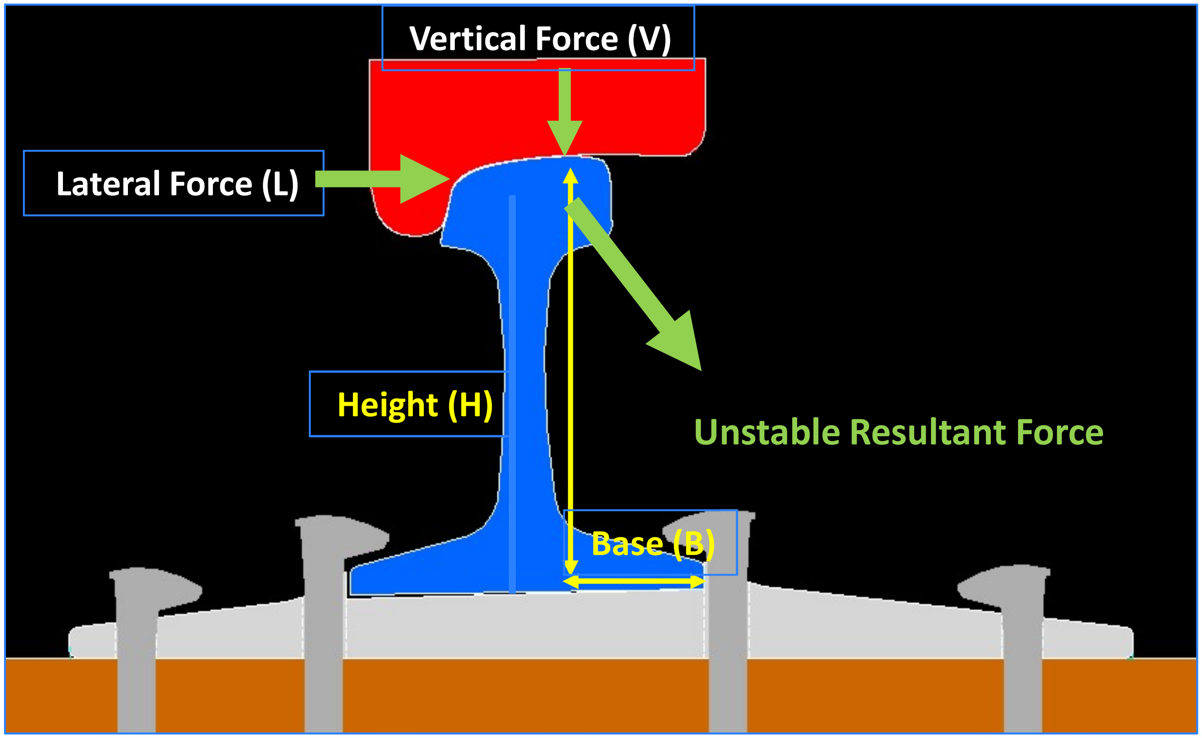
Why is an adverse high rail profile a problem?

Wheel/rail force diagram, unstable condition

Vertical force has shifted toward the field side

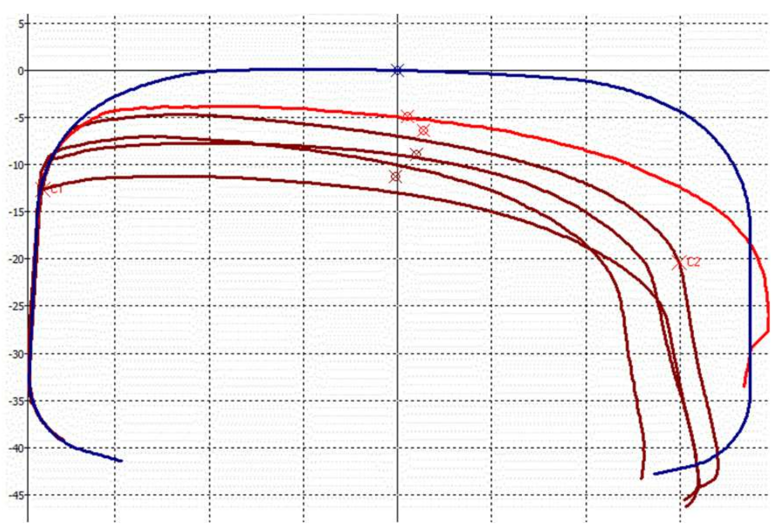
Lateral & vertical forces produce a resultant directed outside the rail base

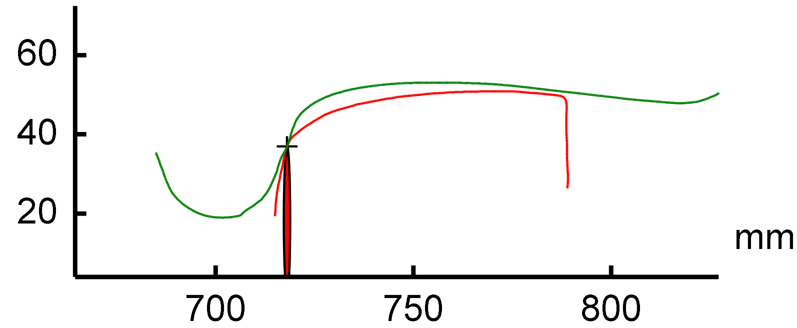
This is an unstable condition - an unrestrained rail will tend to roll outward



Why is an adverse high rail profile a problem?

Below: High rail profiles from five NS rail roll-over derailments (aligned on field side with a new 136RE profile, 1:40 inward cant)





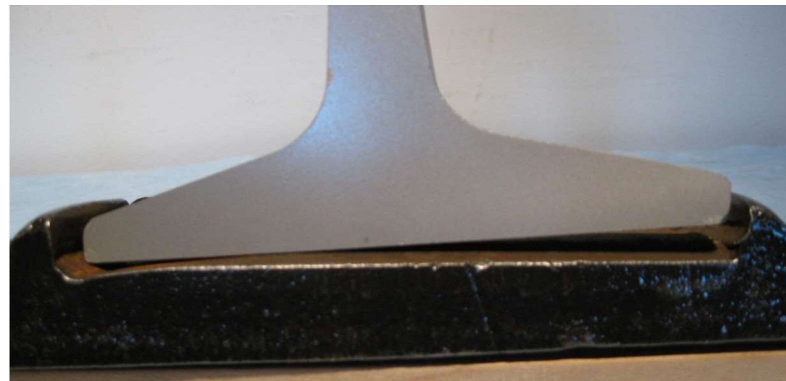
Above: Adverse contact produced by curve-worn rail and 3.5mm hollow-worn wheel. Example of extreme 2-point contact.

Hollow-worn treads are more likely to make field-side contact.

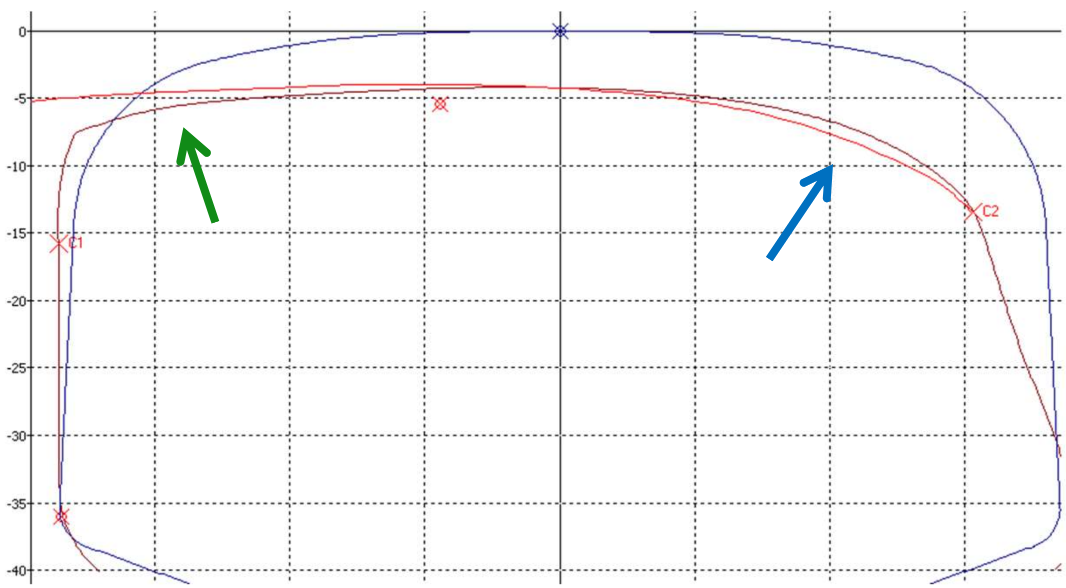
How does an adverse high rail profile develop?

Primary reason: Grinding canted rail

Canted rail (on wood ties) is caused by plate-cut ties or worn tie plate rail seats



How does an adverse high rail profile develop?



Brown profile: a curve-worn high rail with 3° outward cant

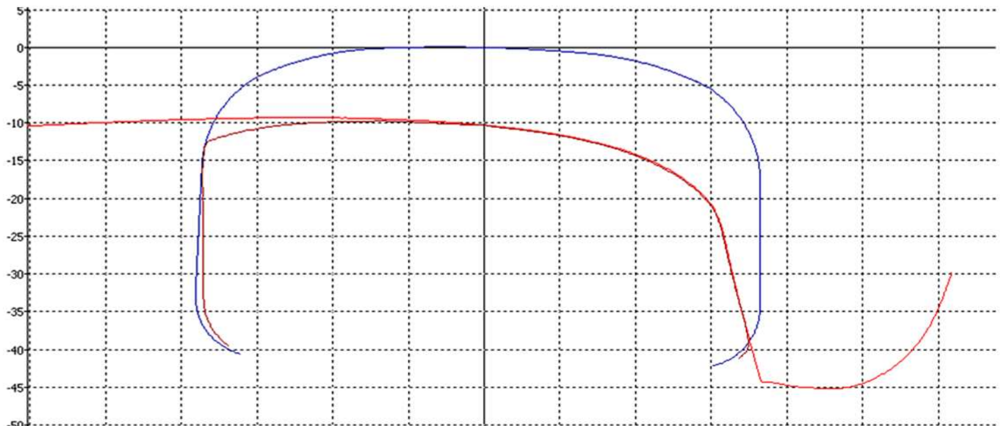
Red profile: high rail template used by Loram & NS

The template can be moved laterally & vertically; it cannot be rotated

What grinding will result?

A: Significant grinding on the gage side (blue arrow) but no grinding on the field side (green arrow)

Why is an adverse high rail profile a problem?

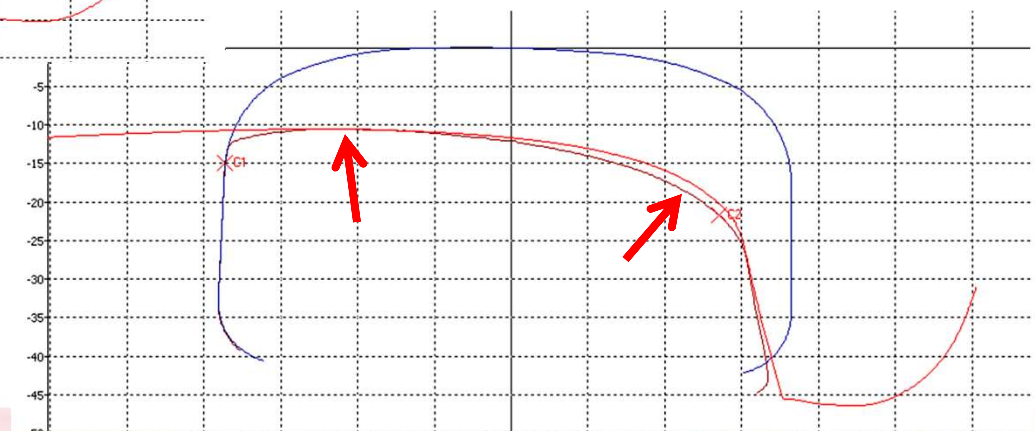


Below: The same slightly-worn wheel and curve-worn rail, but the rail has been set up to 0˚ cant.

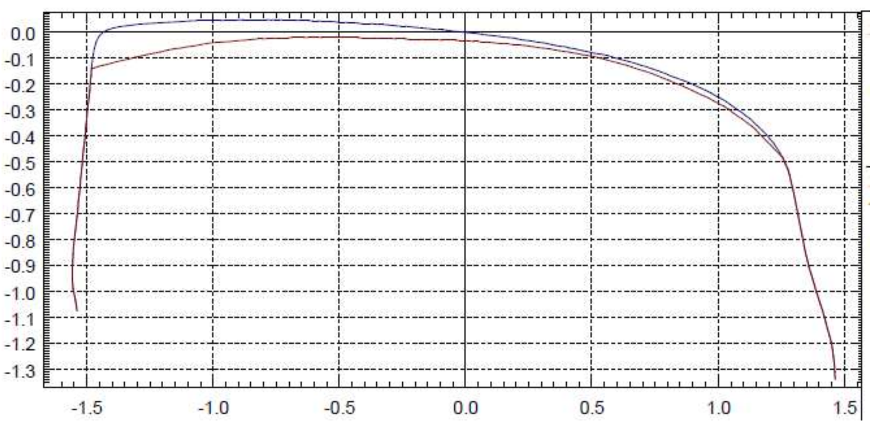
Result: Wheel tread contact has moved toward field side. This is two-point contact, which produces higher-resistance curving.

Above: A slightly-worn wheel on curve-worn rail with 3° cant

This is conformal contact, which produces favorable wheelset steering



An example of high rail corrective grinding



High rail of a 6° curve. The blue profile is pre-grind, and the brown profile is post-grind. A full 1/8-inch was ground off the field-side corner. Both profiles have been rotated to 0° cant.

The same high rail several days after grinding. The primary wheel contact band was moved toward the gage side. (Enough metal was removed from the field side to maintain gage-side wheel contact after the rail was gaged).

Correcting adverse high rail profiles….

- Improves wheelset steering by moving wheel contact toward the gage corner (taking advantage of the larger rolling radius closer to the wheel flange)
- Reduces rail wear, rolling contact fatigue and gage widening
- Improves rail stability by reducing field-side wheel contact

Corrective grinding field test

Objective: Correct adverse high rail profiles using NS's normal grinding program.

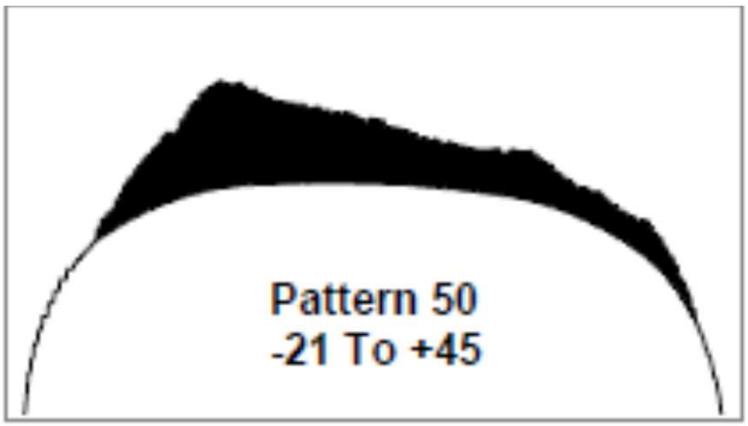
Guidelines: Loram & NS agreed that the number of passes for each curve should be dictated by the metal removal required to correct the worst RCF so that the high rail reprofiling would not add time to the schedule.

Plan: Conduct a field test using grinding patterns recommended by Loram

Corrective grinding field test - phase 1

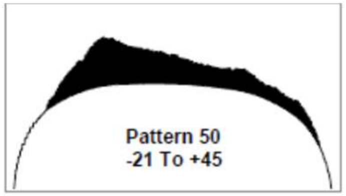
- Former N&W main line between Roanoke, VA and Bluefield, WV
- Pre-grind inspection performed in June 2019 included photos of wheel contact location
- Grind patterns
  - For single pass curves, Loram developed a new pattern 50
  - For three-pass curves, Loram selected pattern sequence 22-28-7
- Loram inserted these patterns manually into the RG 417's grind plan. Grinding was accomplished in early August 2019
- Post-grind inspection in late August 2019 evaluated changes in wheel contact location

Loram's shadow diagrams



- Shows the relative amount of metal removed across the rail head of a new rail.
- Gage side is always on the right
- The numbers on the bottom line (-21 to +45) indicate the range of grinding stone angles
- This newly-developed pattern 50 emphasizes metal removal from the field side

Phase 1 test results - single pass

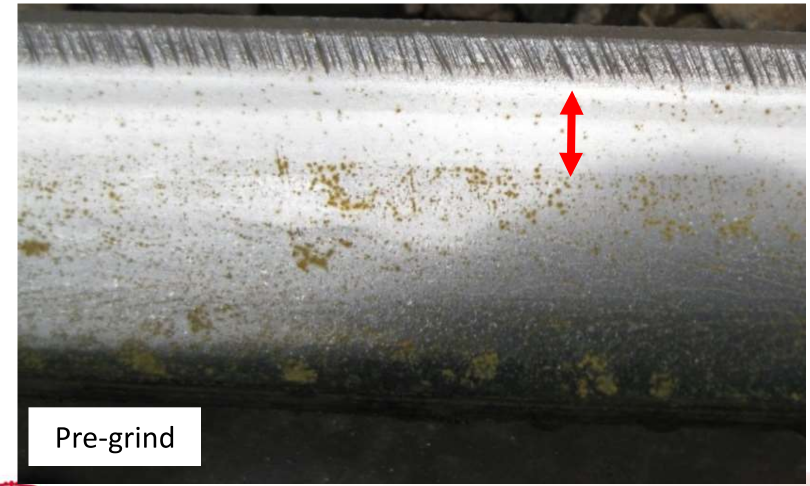


Speed 6 mph

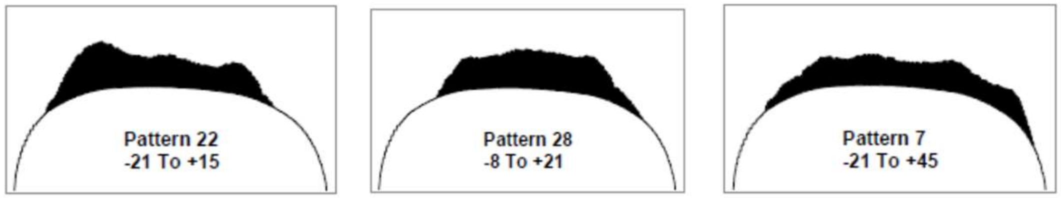
Pre-grind: Primary contact band is on the field side

Side wear 6/16“, cant 1.5°, B/H 0.34, head slope 8°

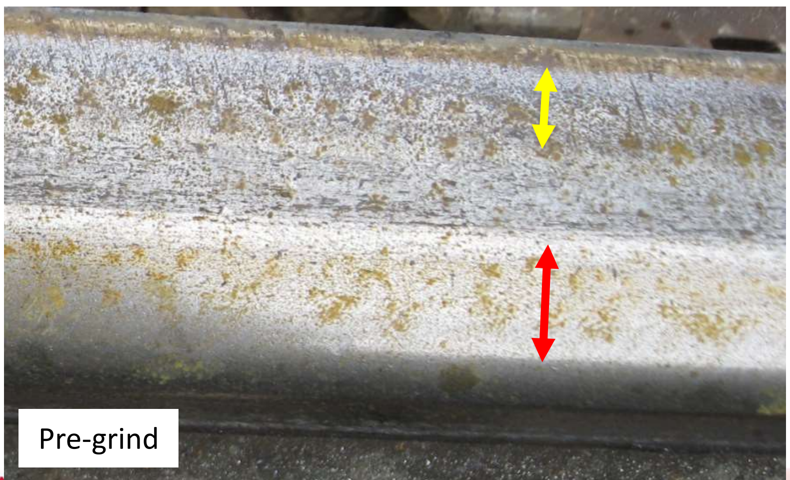
Post grind: Wheel contact shifted toward gage side



Phase 1 test results - 3 passes



Speed 13 mph for all 3 passes



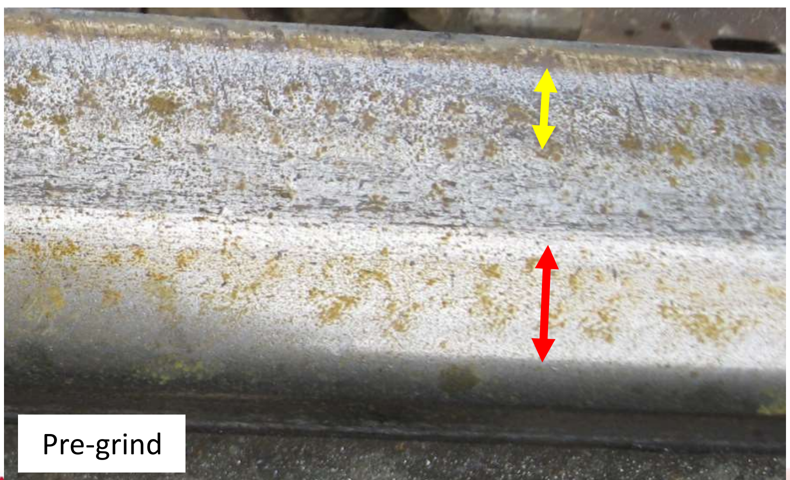
Pre-grind: Primary contact appears to be on gage side (red arrow). There is some field-side wheel contact (yellow arrow), though still-visible grinding marks suggest wheel frequency is low.

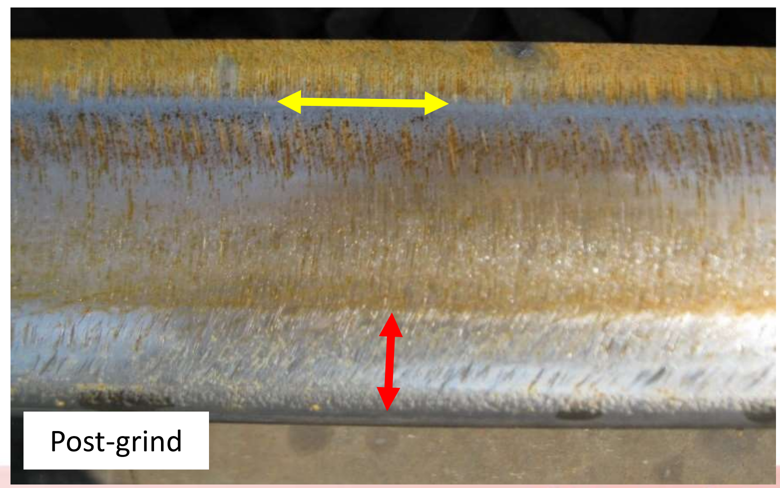
Side wear 6/16“, cant 1^{o}, B/H 0.35, head slope 6^{o}.

Phase 1 test results - 3 passes

Post grind: After 3 passes, the primary wheel contact band is more concentrated on the gage corner (red arrow).

Field-side contact by hollow-tread wheels is still apparent (yellow arrow).

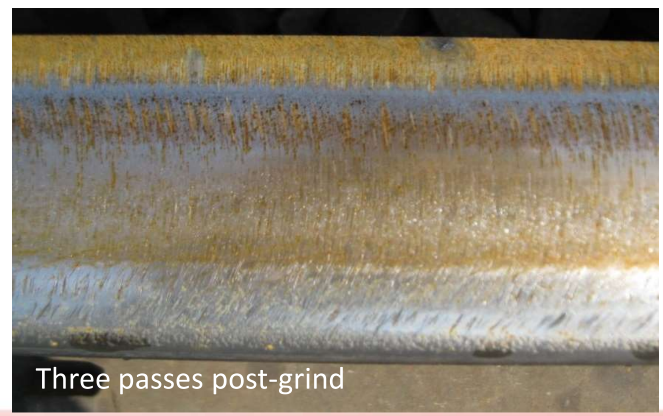




Phase 1 conclusions

- Demonstrated that we could modify an adverse high rail profile and shift wheel contact with our scheduled grinding program.
- On curves that received a single pass, pattern 50 worked well.
- On curves that received three passes, the 22-28-7 sequence did not shift wheel contact as we hoped.
- Agreed that a second field test was needed.

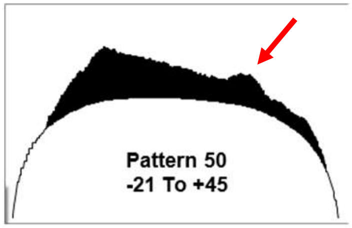
One pass post-grind


Three passes post-grind

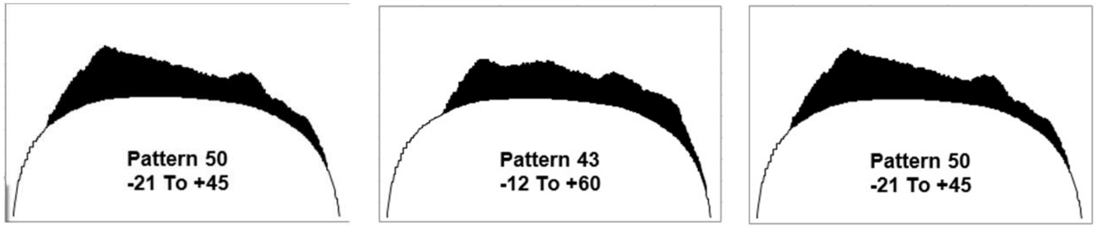
Corrective grinding field test - phase 2

For Phase 2, Loram

- modified pattern 50 to remove more metal between +5° and +15° to address cracks in the gage corner.

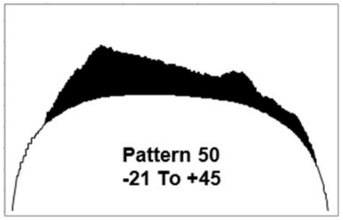


- changed the 3-pass sequence to patterns 50-43-50.



- Former Southern Railway main between Manassas & Riverton Jct, VA

Phase 2 test results – single pass

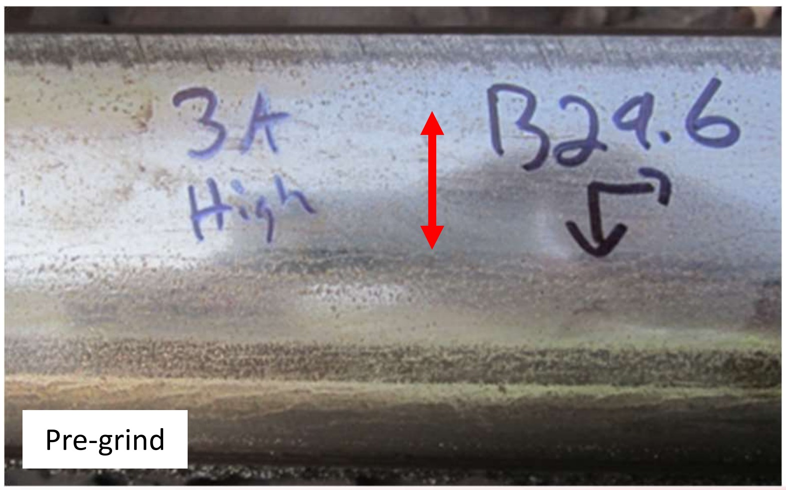


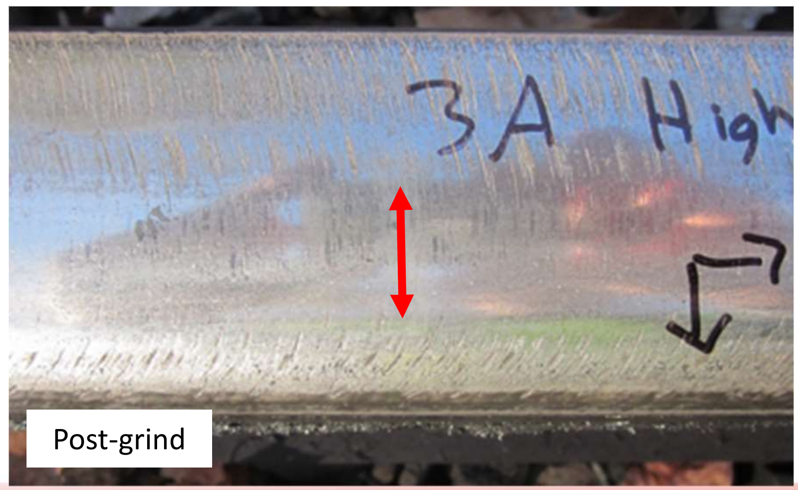
Speed 6 mph

Pre-grind: Primary wheel contact is at the center, though there is evidence of wheel contact over most of the head.

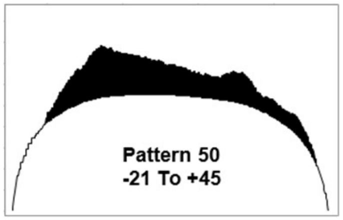
Side wear 7/16", cant 0^{o}, B/H 0.35, head slope 8^{o}.

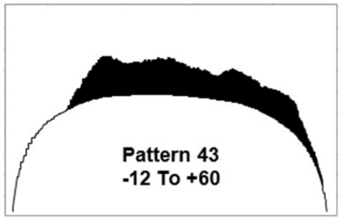
Post-grind: Primary wheel contact has shifted toward the gage side.

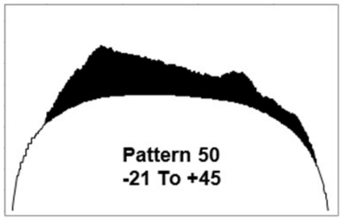




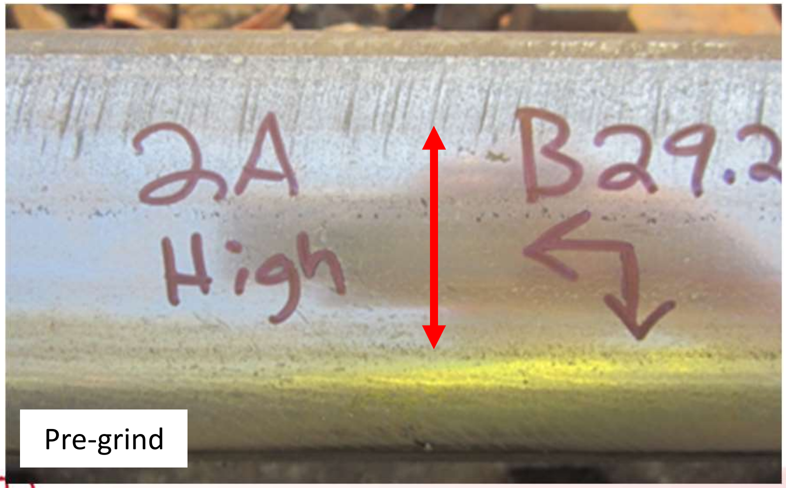
Phase 2 test results - 3 passes







Speed 10 mph for all 3 passes

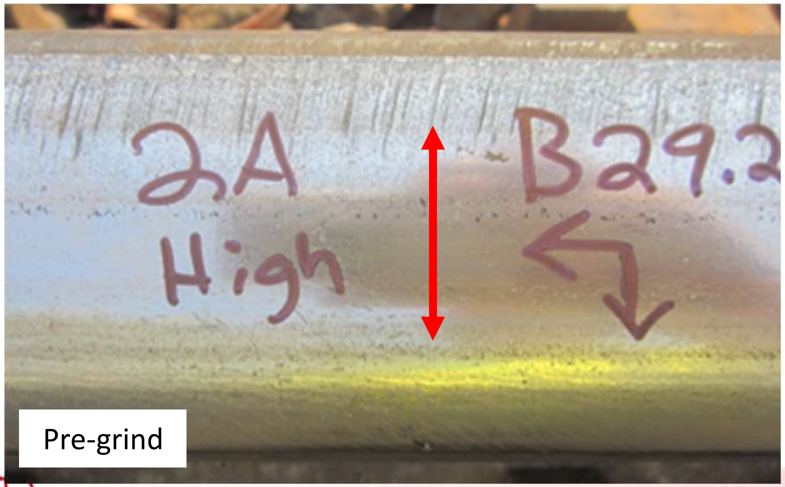


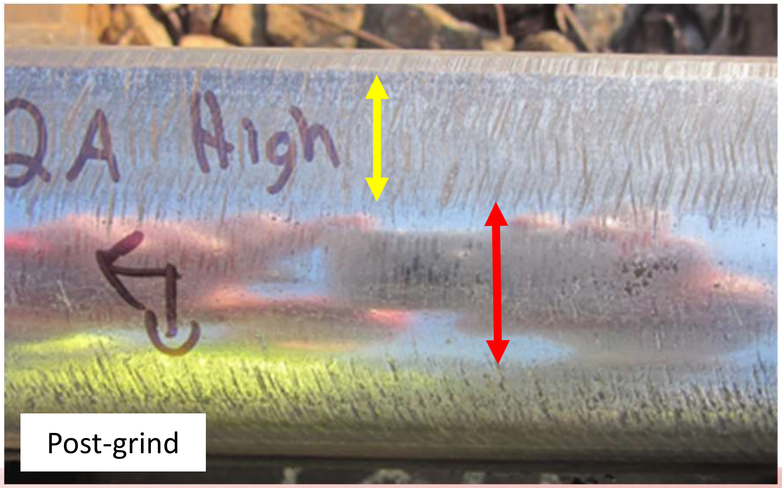
Pre-grind: Primary wheel contact is at the center, though there is significant wheel contact over most of the head.

Side wear 7/16", cant 0°, B/H 0.35, head slope 8°.

Phase 2 test results - 3 passes

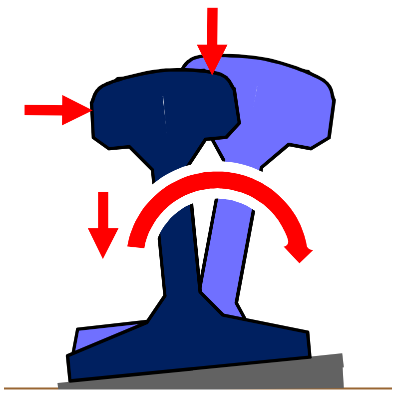
Post-grind: Primary wheel contact has shifted to the gage side of center. Some hollow-tread wheel contact is still evident on the field half of the head (yellow arrow).





Conclusions

1. Curves ground with either the single or 3-pass patterns exhibited a perceptible shift in wheel contact toward the gage side.
2. Field side wheel contact was reduced.

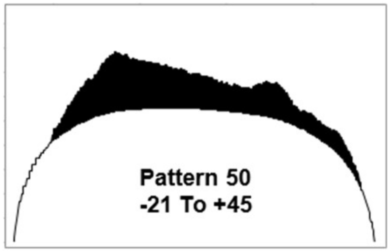


Both observations are significant:

A gage-side shift of the primary contact band indicates that a majority of wheels are taking advantage of a greater rolling radius nearer the flange.

A reduction in field-side contact of hollow-tread wheels suggests a similar steering advantage, but more importantly, indicates that fewer wheels are rolling in a position to cause rail stability problems.

Conclusions



3. The single pattern 50 high rails exhibit more desirable wheel contact bands than the 3-pass 50-43-50 rails.
4. Curves with significant sidewear (> 6/16”) showed a smaller wheel shift. This may have to do with the fact that increased sidewear is accompanied by increased head slope.
5. Multiple cycles will be needed to accomplish the wheel shift objective (which is primary contact on the gage side and minimal contact on the field side).

Next Steps

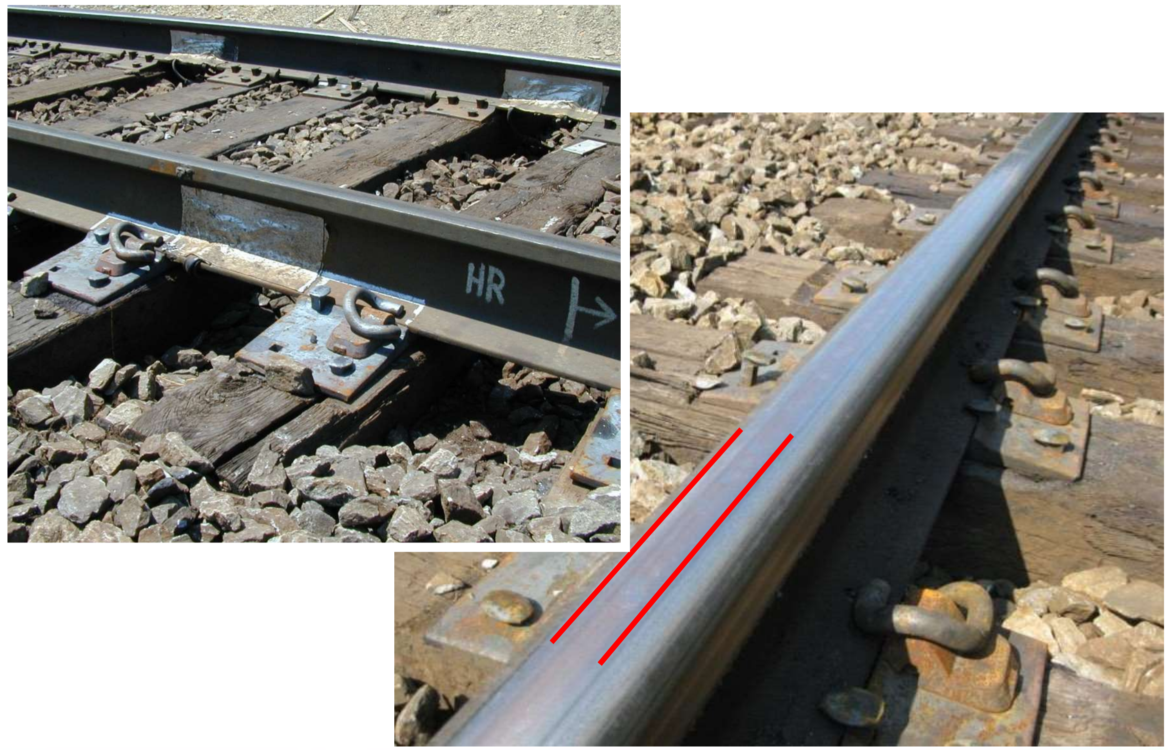
1. NS is applying this corrective grinding system-wide. Local M/W managers are using the wear graphs to identify curves with adverse high rail profiles (head slope > 5°).
2. Loram is adding this pattern to the grind plan manually.
3. High rails with adverse profiles get a single pass pattern 50 at 6 mph.
4. There is talk about trying to automate the identification of adverse profiles.

Thank you!

Consequences of an adverse high rail profile

High rail of 8^{o} curve

- Rail had just been gaged with new plates & e clips
- Gage 57-1/2” to 56-3/8”
- Cant 3^{o} to 0^{o}
- Primary wheel contact moved from gage side to field side



Consequences of an adverse high rail profile

Camera set-up on low rail of this same 8^{o} curve

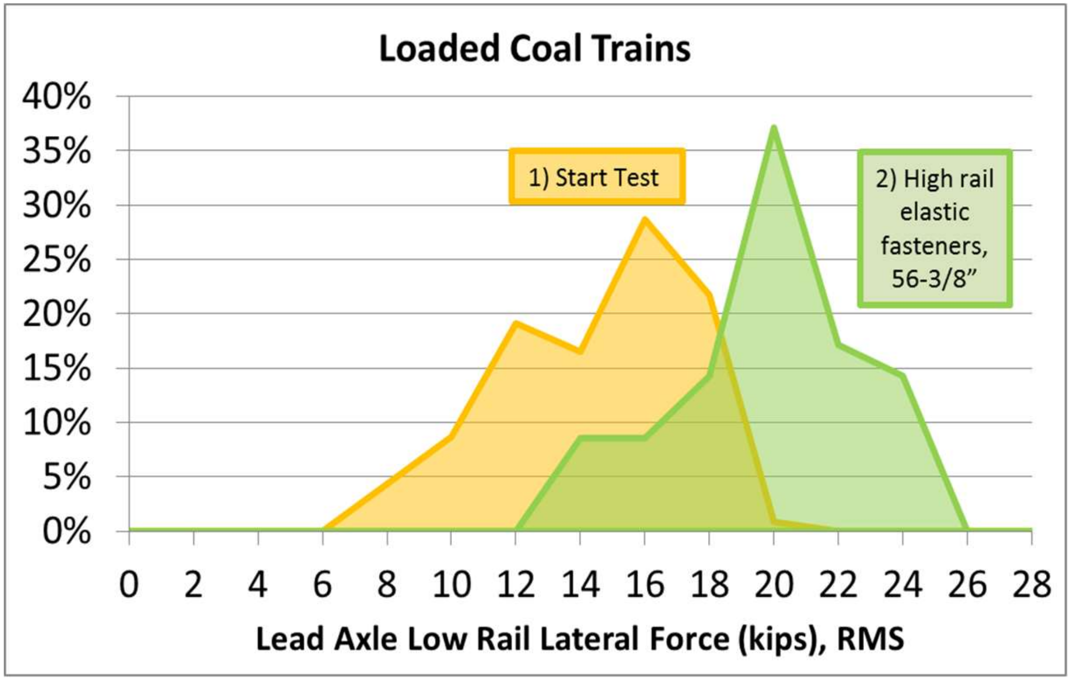
Low rail still has conventional tie plates & cut spikes

Consequences of an adverse high rail profile

Because of a change in wheel contact on the high rail, the low rail is subjected to higher lateral forces

Consequences of an adverse high rail profile

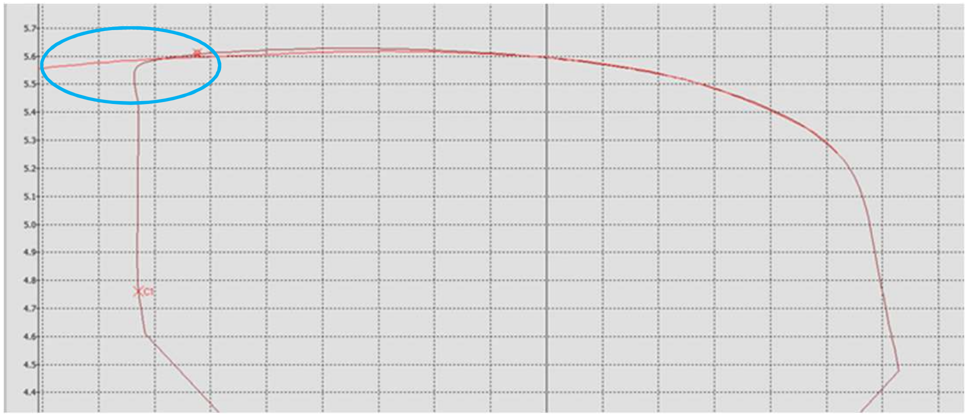
Consequences of adverse high rail profile



Strain gage measurements converted to lateral force

- Start test: cut spikes & 3° cant on both rails, gage 57-1/2”, gage-face lubrication, no TOR
- After trackwork: Victor plates and e clips on high rail, cant eliminated, gage 56-3/8”

How does an adverse high rail profile develop?



Secondary reason:

A curve-worn rail with template applied. As side wear increases, the template is shifted further to the field side, causing the tail of the template to shift off the rail.