

A Derailment Investigation and Broken Spikes

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Research & Tests*



Google Earth image of the derailment site

- Vandergrift, PA, January 2014
- 8.3° curve, river grade (0.3% descending to 0%)
- Timetable speed 30 mph, direction of travel top to bottom on map
- former steel plant located on the outside of the curve
- length of track damage indicated by red line



Looking in the direction of train travel



- looking east at the entrance spiral to the 8.3° curve and at the former steel plant
- signal cut section with insulated joints is at the point of spiral to curve (red arrow)
- track damage began at the insulated joints



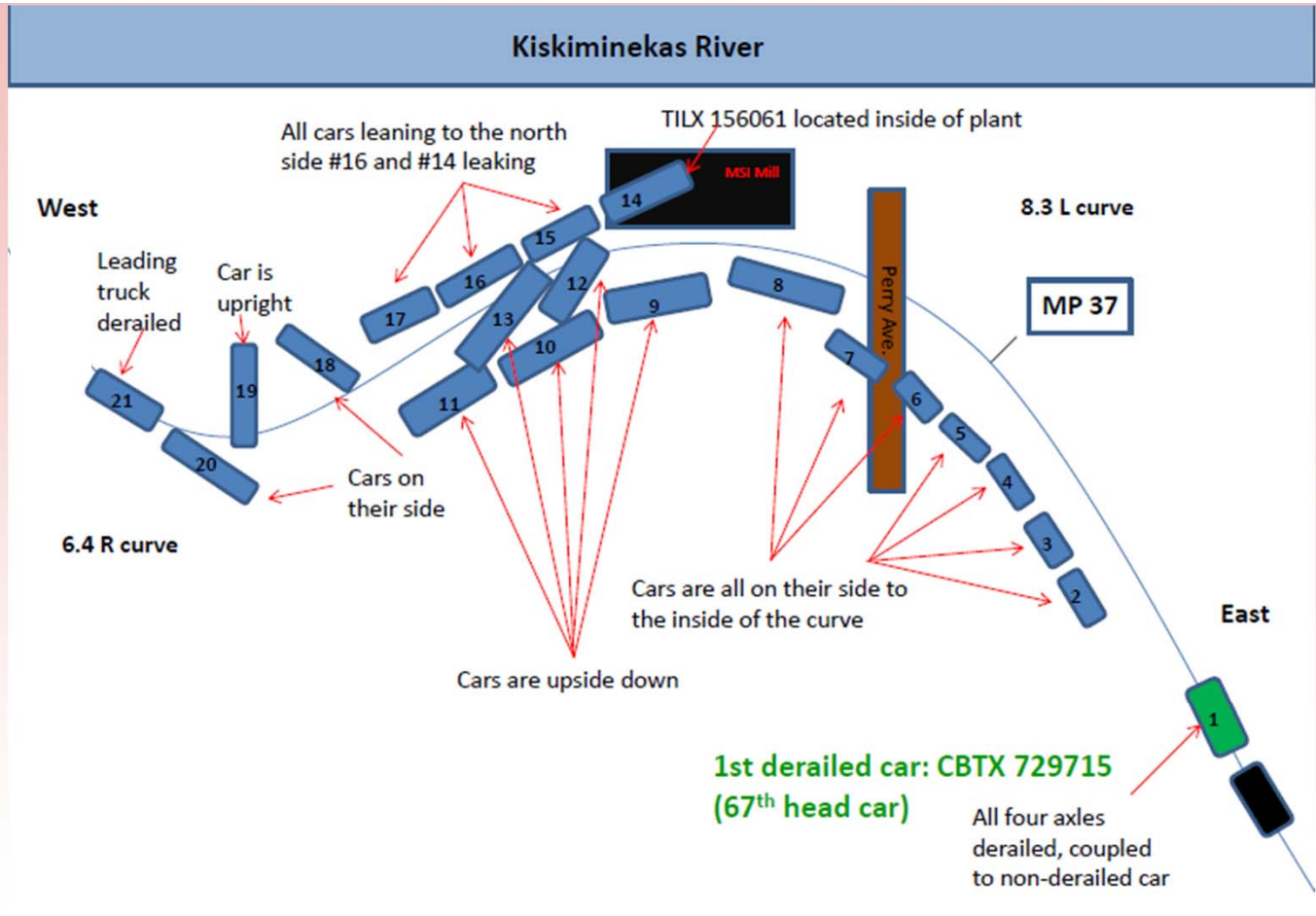
14G, a mixed merchandise train with a cut of 67 loaded crude oil tank cars



21 of those tank cars derailed,
positions in train 67 - 87



A drawing of the derailment site showing positions of the derailed cars



The 14th derailed car ended up inside the building



What causes did the derailment team consider? They looked at the usual suspects

- ~~Train handling~~
 - Mechanical
 - ~~Track~~
- The head end entered the 30-mph curve restriction at MP 38.0 at 36 mph in Run 2. The engineer reduced to Run 1 and had slowed the train to 32 mph when a train line emergency initiated.
 - Only one mechanical defect was found – a broken stub sill on the 11th derailed car.
 - Several broken rails were found, but none had an internal defect (or receiving end batter).
 - Geometry car data was not available because the last test was before June 2013, when new rail was installed and the track surfaced. Track was thought to be in excellent condition due to the recent work.



Derailment investigation fundamentals: What two critical questions must be answered when determining a cause?

1. What was the first car to derail?
 - The team pointed to the 11th derailed car - a broken stub sill on the trailing end
2. What was the point of derailment?
 - ❖ The team did not have a clue

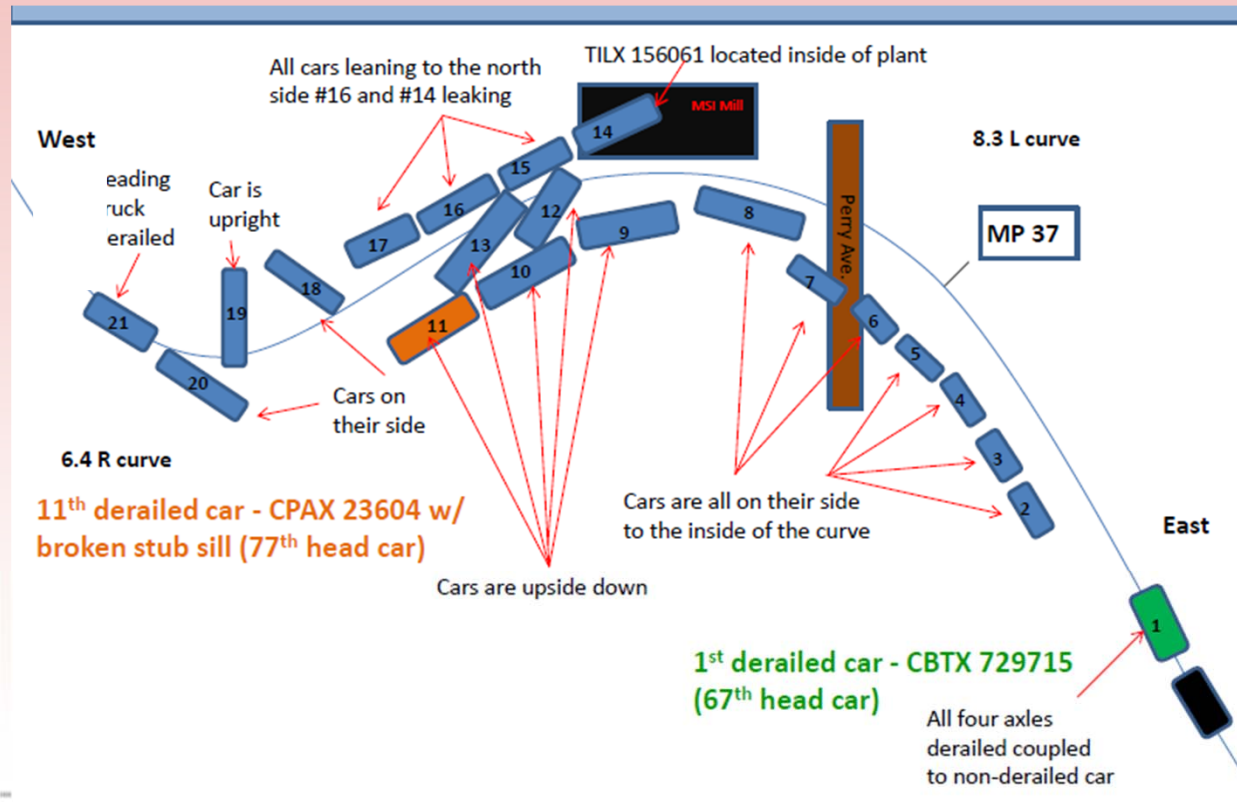


Proposed cause: broken stub sill on 11th head derailed car

The fracture surfaces showed a number of old weld cracks, old fatigue cracks, and large areas of extremely poor weld penetration. But.....



....is there a problem with this cause?



- It is highly unlikely that one car derailed would cause the 10 cars ahead to also derail.
- Typically, the first car to derail is at the head of the line - in position 1 or 2.



Analysis of the stub sill provided additional exculpatory evidence



Based on the fracture pattern, we concluded that the stub draft sill failed due to a high rotational force consistent with coupled cars trying to roll over. Based on the orientation, CAPX 23604 was rolling to its right side (toward the inside of the curve) while the car behind was resisting.

This stub sill separated from the trailing end of the 11th derailed car. The coupler and stub sill were carried by the 12th car and had no marks to indicate that they had struck the track structure.

Conclusion: The failure of the stub sill was a result of the derailment and not the cause.



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The steel plant had security cameras. Could they provide any insight into the derailment?



1. What was the first car to derail?
2. What was the POD?



The security camera included our track in its field of vision



A screen shot from the security camera video shows sparks under the lead truck of this tank car. This was the first indication of wheels on the ground. We identified this car as the first to derail, but we could not read the car's reporting marks.



The security camera video allowed us to identify the first car to derail

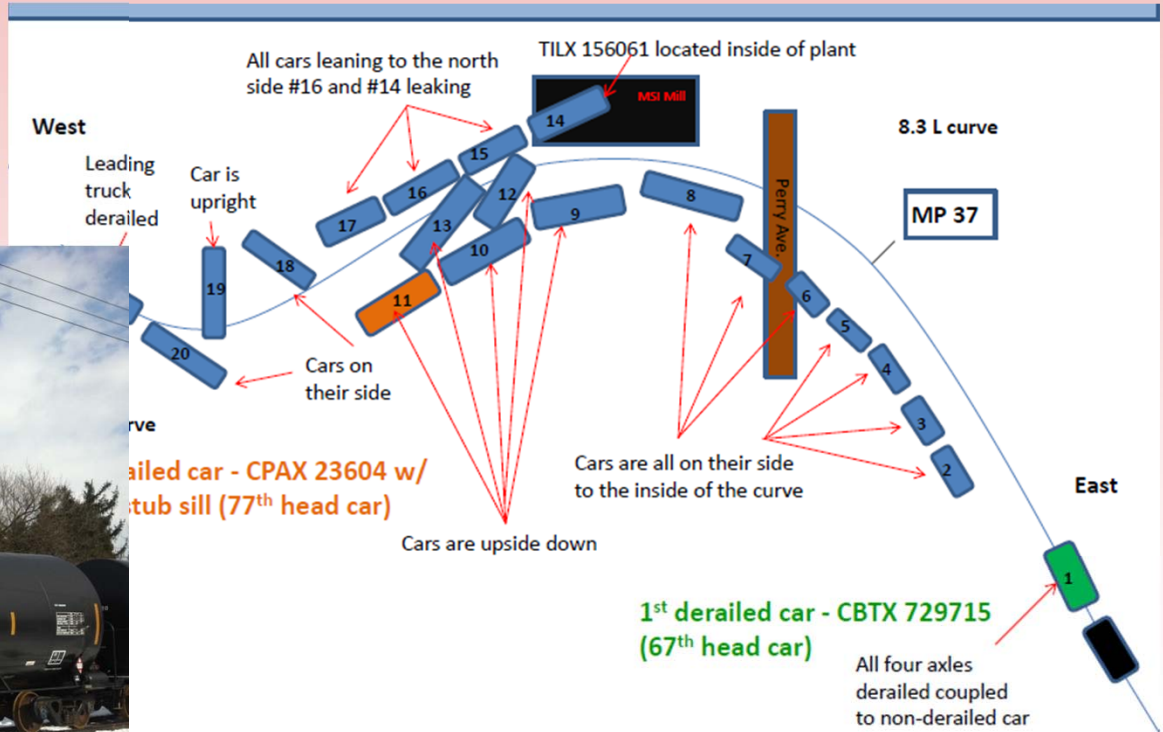


Another screen shot from the security camera video: We were able to read the reporting marks on the car that was two positions ahead of the first car to derail.

This car was consist line 68, or the 65th head car (the consist included 3 locomotives).



The first car to derail was the 67th head car



Does this video also suggest a POD and a derailment explanation?

Yes to both questions:

- POD - likely at the beginning of the track damage
- Explanation - this is likely a wheel climb or wheel drop-in derailment

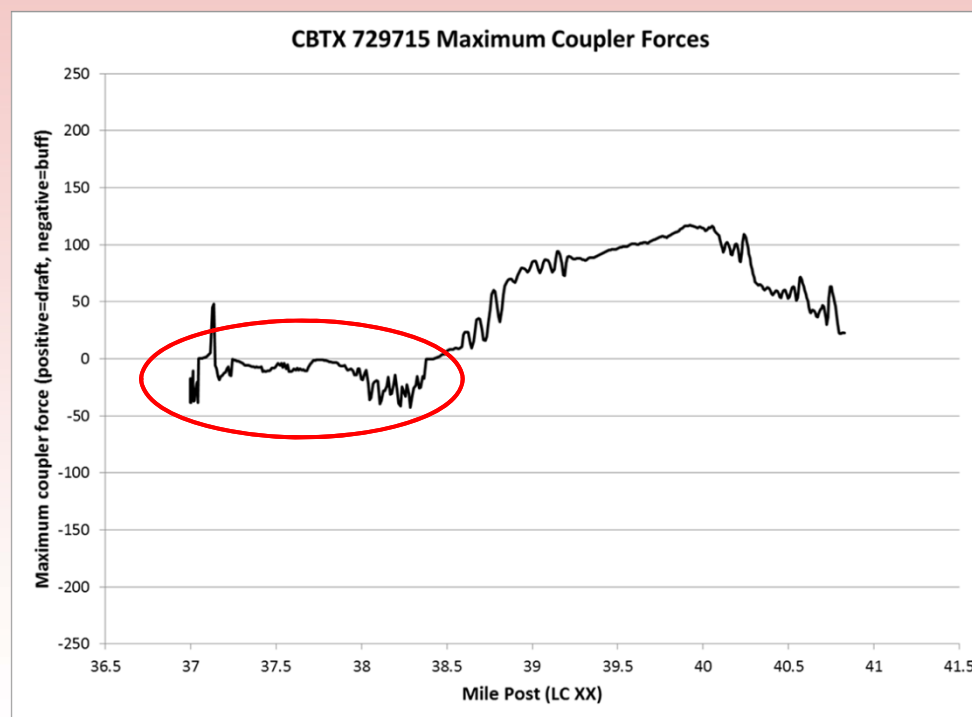
What causes did we consider?

- ✓ Train handling
- ✓ Broken rail
- ✓ Rail rollover
- ✓ Wheel climb
- ✓ Wide gage



How did we evaluate each of these causes?

- ✓ Train handling – no; modeling indicated very low coupler forces

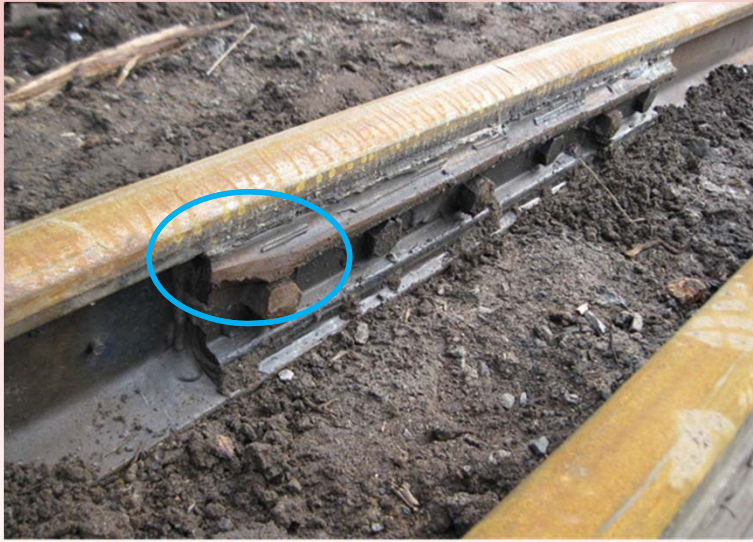


How did we evaluate each of these causes?

- ✓ Train handling – no; modeling indicated very low coupler forces
- ✓ Broken rail – no; the only fractures found were the result of the derailment
- ✓ Rail rollover – no; Pandrol clips
- ✓ Wheel climb, due to a track surface or car problem - would be indicated by flange marks over the top of the rail
- ✓ Wide gage – would be indicated by wheel drop-in marks and a poor tie condition



Back to the derailment site to look for evidence



High-side IJ shows receiving end batter



Low-side IJ also shows receiving end batter

Conclusion: Wheels had dropped in before these joints (on both rails).



Where did the wheel marks begin?

The low rail / gage corner showed four wheel rim drop-in marks, located 3 to 6 feet before the insulated joint.

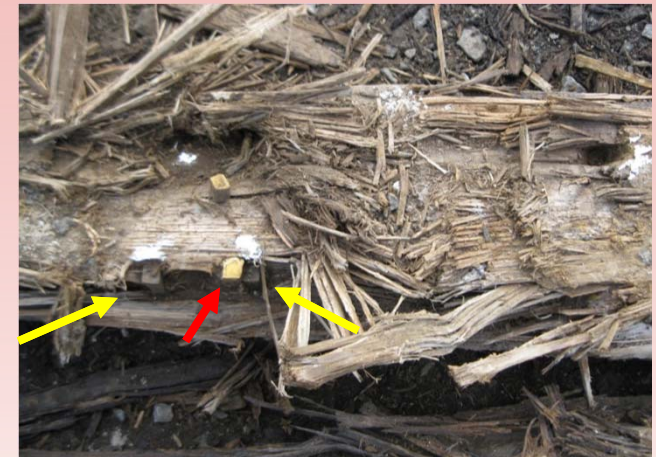


We have a POD. Can we find the ties that were under the insulated joints?

Ties that were close to the POD had been gathered into 4 groups



We looked for evidence of plate movement and broken spikes



Liquid spike hole filler (red arrow)

- No evidence of plate movement (too much tie damage)
- Broken spikes were found (yellow arrows)

Tools of the trade: a screw driver and a long magnet



How did we determine which ties were under the insulated joints?



We looked for a staple that once held a track wire.

We found one.

This indicated we had the correct group of ties.



Ties were cut and brought back to the lab



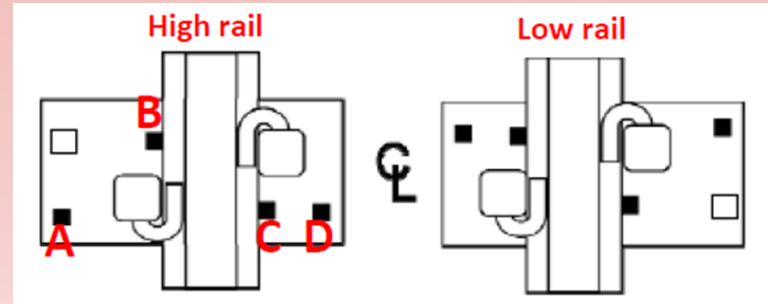
- These tie sections were all from the high side, based on condition of the tie plate seat.
- Wheel mark indicates that these were likely adjacent ties
- We believe that these ties were positioned under the high-side II, immediately east of the tie with the staple.



Cross-sectioning of ties revealed broken spikes



Broken spike inventory from the four tie ends



7 broken spikes were found in the 4 tie ends

Tie	Location "A"	Location "B"	Location "C"	Location "D"
#1	Broken spike	Spike missing from hole	Spike missing from hole	Broken spike
#2	Broken spike on top of old broken spike	Spike missing from hole	Spike missing from hole	No spike or hole, old broken spike nearby
#3	Broken spike	Broken spike	Spike missing from hole	Spike missing from hole
#4	No hole or spike (old broken spike in alternate field hole)	No hole or spike	Broken spike	Broken spike



Official cause determined

“High-side wheels of 67th head car, loaded tank CBTX 729715, ruptured gage by shoving the high rail out in a 8.3° RH curve account broken spikes under high rail IJ, and allowing low-side wheels to drop inside the low rail.”



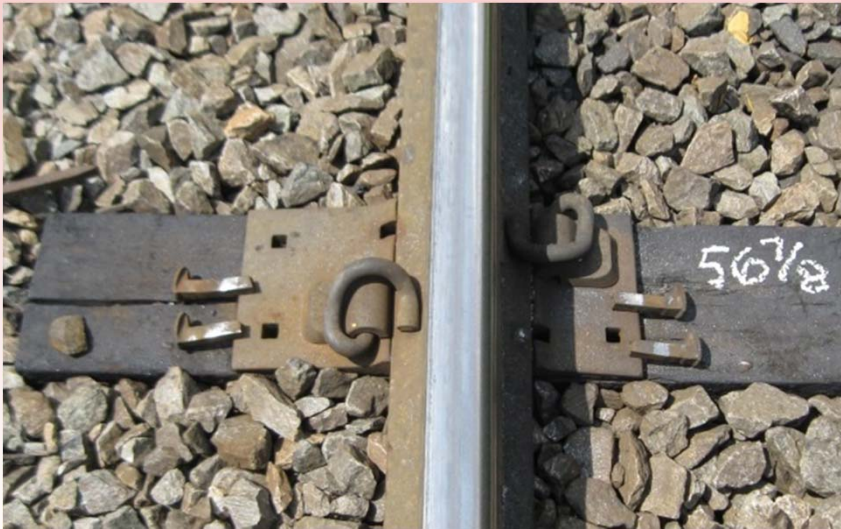
Broken spikes (fasteners): How big a problem?



- On NS, we have found broken spikes in over 70 different curves
- Maximum number of broken spikes found in one curve during one inspection – 150
- Number of broken-spike derailments - 2



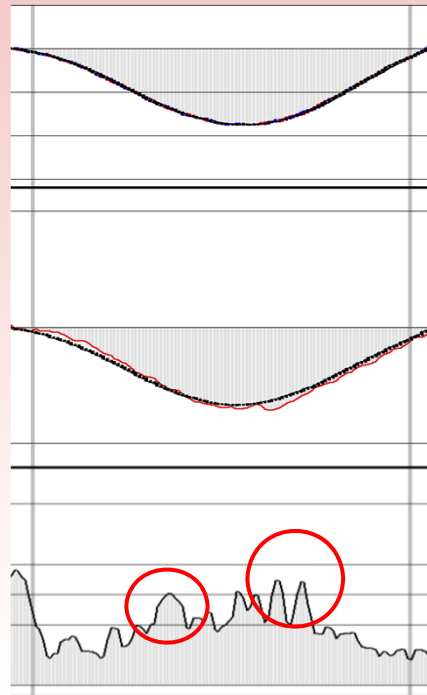
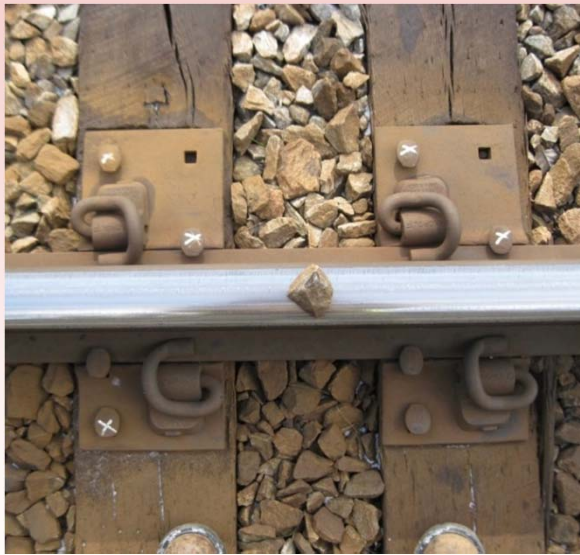
What has NS discovered about broken spikes (1)?



1. Broken spikes are found on the high rail, on both gage and field sides, in both rail spike and anchor spike positions.
2. They are found in solid ties – including new ties.
3. Some broken spikes have been found in curves with our standard 8X18 tie plates, though the problem appears to be much more severe in curves with Victor plates.
4. Spikes typically break 1-1/2” below the top of the tie (which makes finding them difficult).



What has NS discovered about broken spikes (2)?

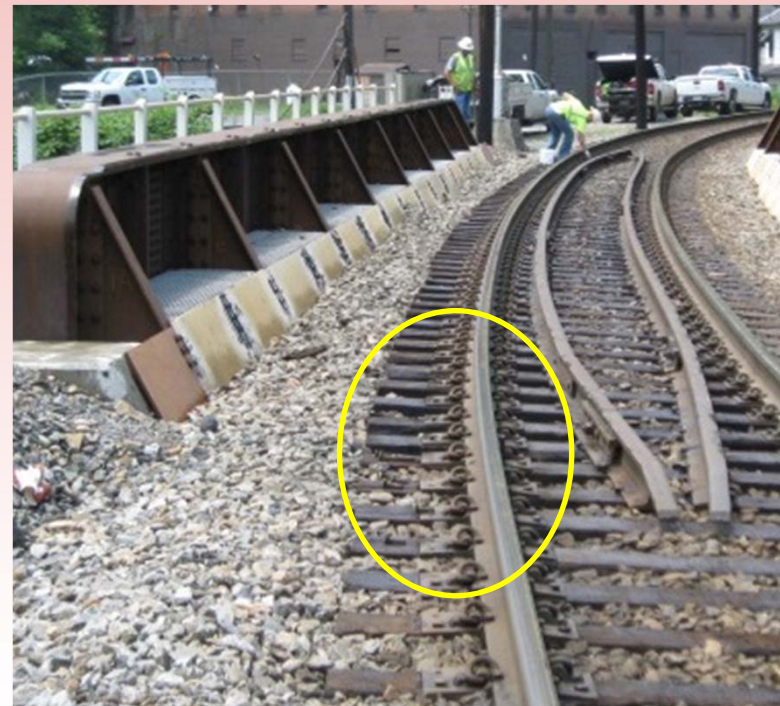
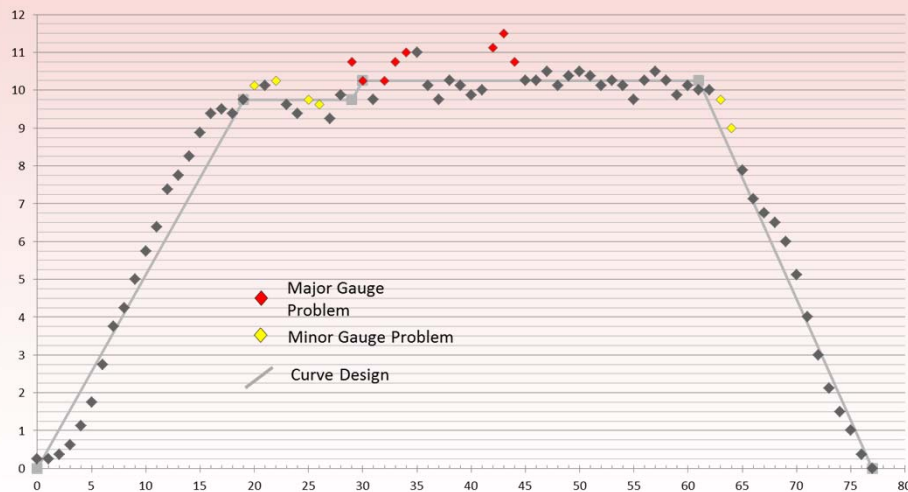


5. Tie plate movement can be minimal until a cluster of ties with broken spikes develops. Still, a gage spike is often recognizable on the TGC graph at locations with just a few broken spikes.
6. The curves are all over 6° and have a Timetable speed < 35 mph. Most locations have traffic exceeding 30 MGT.



What has NS discovered about broken spikes (3)?

- Broken spikes are often associated with non-uniform alignment in the high rail; these line spots may be very difficult to detect by eye.



What has NS discovered about broken spikes (4)?



8. Longitudinal force is believed to be a significant contributing factor. This force can be generated by trains in heavy braking (air or dynamic), or by locomotives generating high tractive effort. A substantial grade is often the reason for these high locomotive forces.
9. The increase in broken spikes over the past three years coincides with our increased use of AC locomotives.

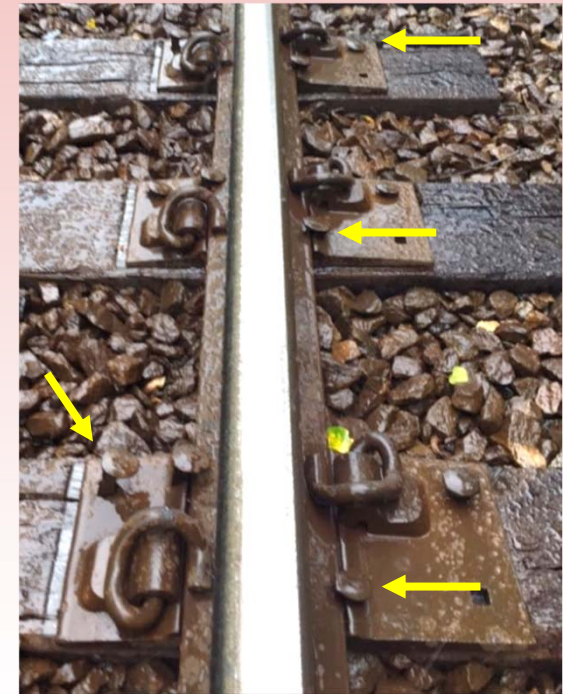
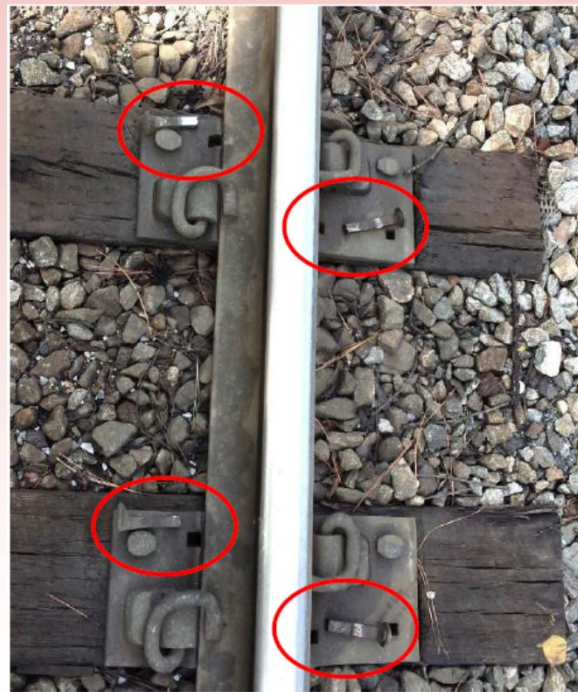
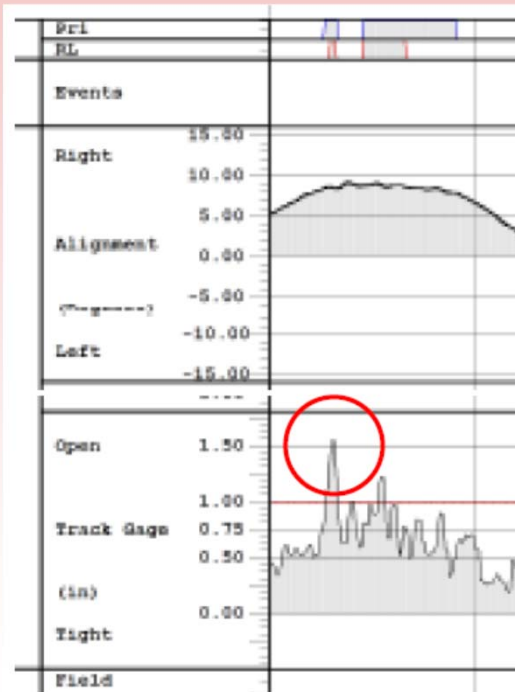


How do we find broken spikes?
We investigate a derailment caused by ruptured gage



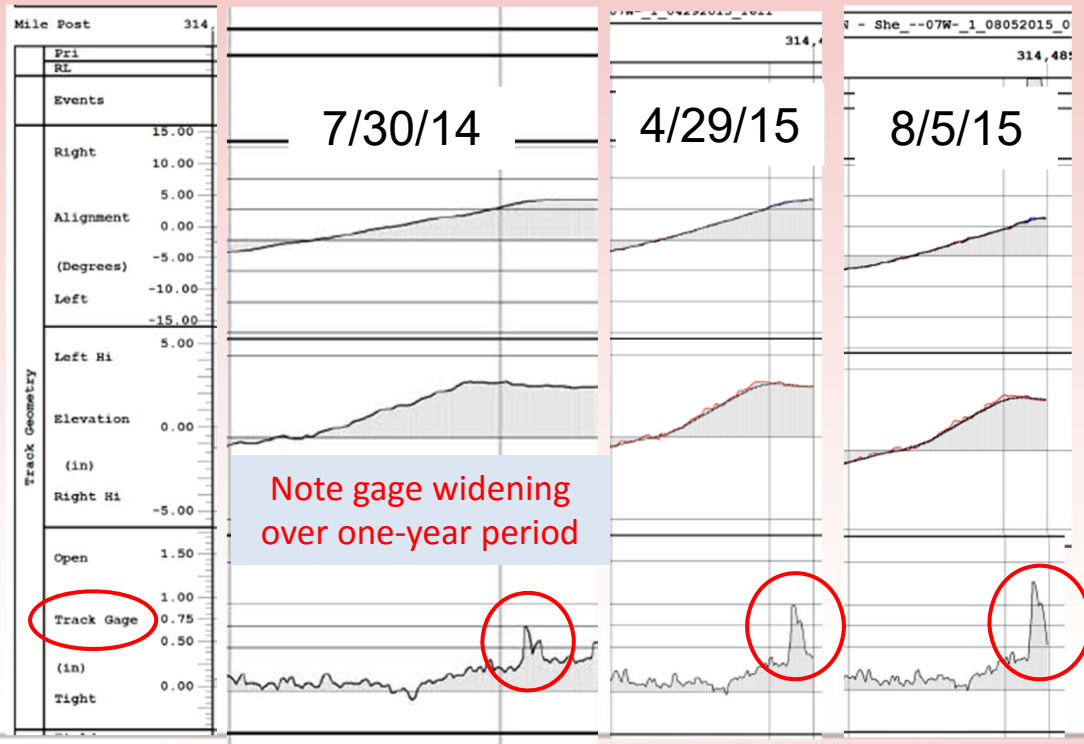
How do we find broken spikes?

We find ruptured gage before it causes a derailment



How do we find broken spikes? We find gradual gage widening

Over one year, gage widened from 57-1/4" to 57-3/4"; broken spikes were found to be the reason



False-flange contact on the head of the low rail is another clue of gage widening



How do we find broken spikes? By hand, one spike at a time



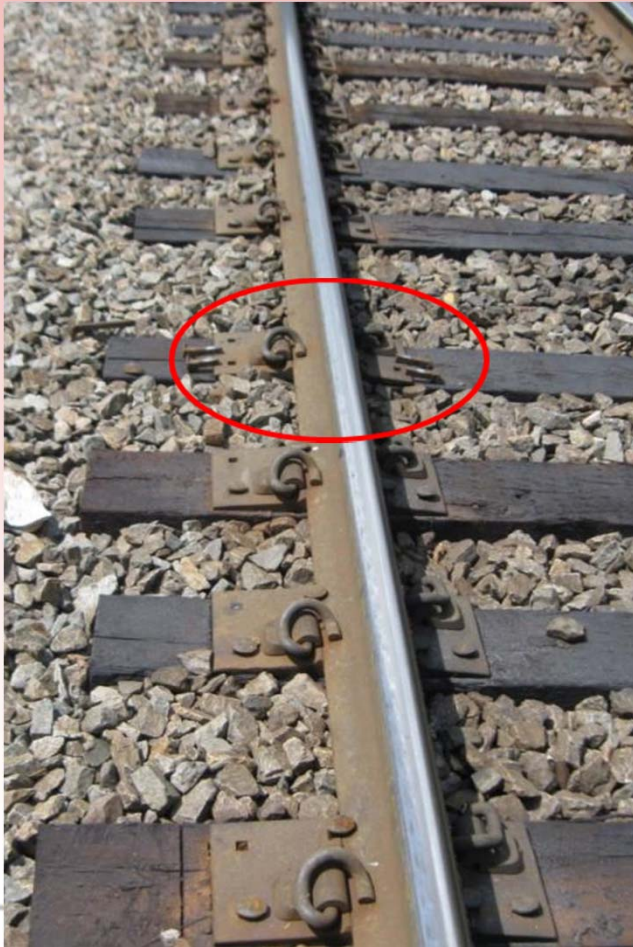
Step 1: Hit the heel of the spike to see if it is loose or makes an unusual sound.



Step 2: Attempt to pry the spike up. If it is broken, the top half will pull out.



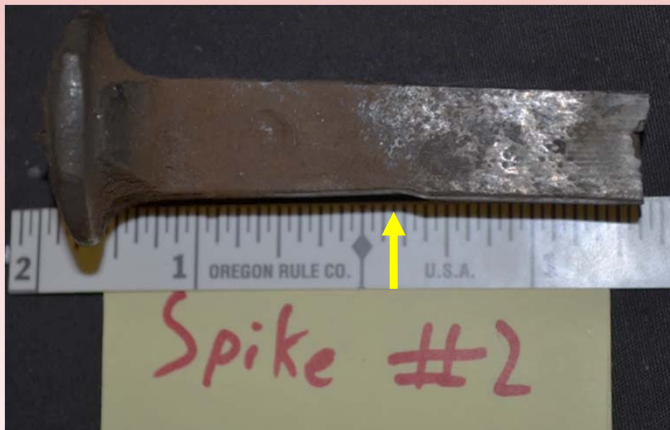
Let's look at a broken spike



- High rail of a 10° curve
- Descending 1.2% grade (loaded unit trains use air brakes, all other trains use dynamic)
- Tie condition was exceptional – most had been installed within the past 2 years.



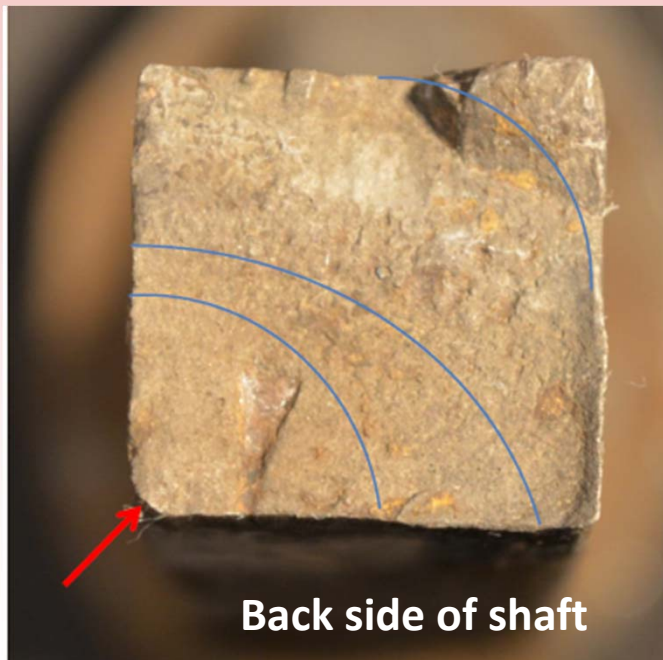
Analysis of the broken rail spike – front and back views



- Yellow arrows - note deep groove on uphill side of shaft, caused by longitudinal (downhill) force applied by the tie plate.
- Red - fatigue fracture originated in uphill back corner.



Analysis of the broken rail spike - cross-section



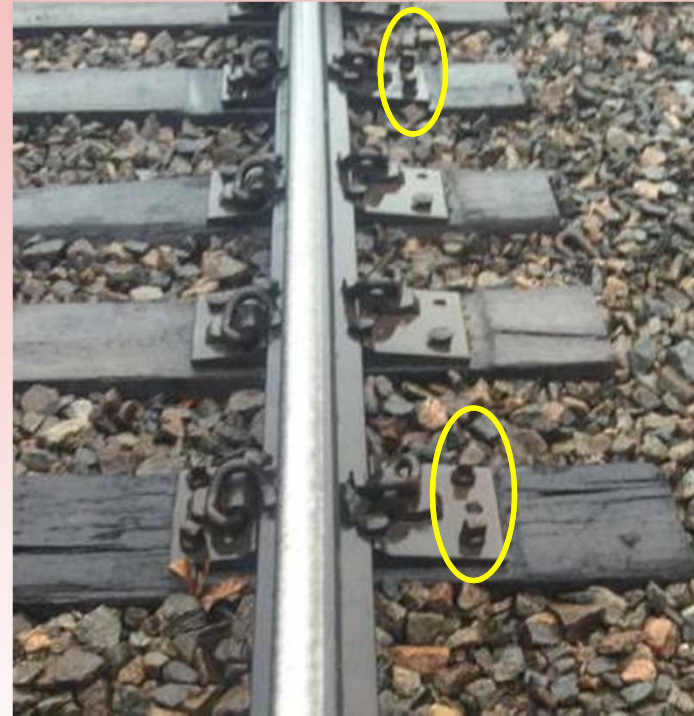
- The fatigue fracture originated in the corner marked with the red arrow, and propagated along a pattern indicated by the blue lines.
- The primary load was due to lateral forces, however, significant longitudinal force is also indicated.



Remedies



Adding anchors to the high rail has reduced the frequency of broken spikes significantly.



Installing "bridge" Victor plates every third tie has eliminated broken spikes... so far. The plates have round holes for 15/16" Evergrip screws.



Questions?



5 consecutive ties have 13 broken spikes in 20 spike positions, yet no tie plate movement!

