RAIL CORRUGATION ISSUES AT BART

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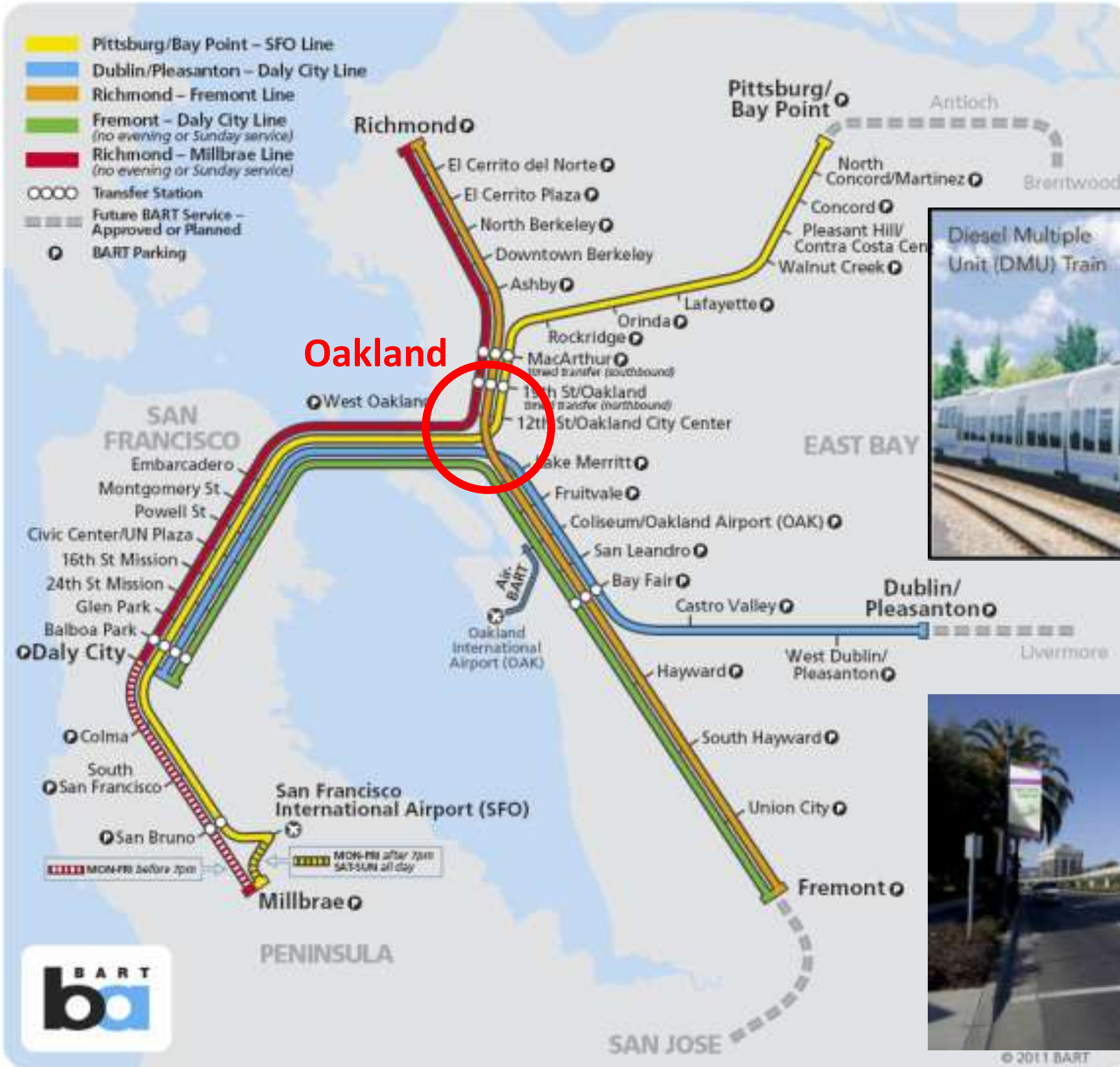
Outline

- System Description
- Track Structure
- Rolling Stock
- Rail Corrugations on BART
- Contributing Factors
- Rail Lubrication
- Rail Grinding
- Questions

BART SYSTEM DESCRIPTION

- BART serves 4 counties in the San Francisco Bay Area - soon to be 5 (SVBX Extension)
- Operate 700 point-to-point trains per day
- Fleet of 669 passenger cars
- Average weekday ridership: 366,565 (2012)
- Maximum Authorized Speed: 80 MPH
- Automatic Train Control



BART System Map

BART INFRASTRUCTURE

- 105 Route Miles of Main Line Trackage:
  - 29 Miles of Aerial Direct Fixation Track
  - 27 Miles of Subway Direct Fixation Track
  - 47 Miles of At-Grade Concrete Tie Track
  - 49 Interlockings / 289 Main Line Switches
  - 44 Passenger Stations
  - Minimum Curve Radius 500ft
  - Maximum 4% Grade

MAINLINE TRACK STRUCTURE

- ***224*** Mainline Track Miles
- 119 RE Continuous Welded Rail
- Track Gage: ***66 inches (1676mm)***
- ***103*** Track Miles of Ballasted/Concrete Tie Track
  - Tie Spacing: ***30 inches***
- ***121*** Track Miles Direct Fixation
  - Fastener Spacing: ***36 inches***
- Traction Power: ***1000 VDC Third Rail***

ROLLING STOCK

- 4 Types of cars:
  - A Cars: Feature a mainline control cab; can operate *only* as lead or end car in revenue service
  - B Cars: Operate mid-consist *only* in revenue service

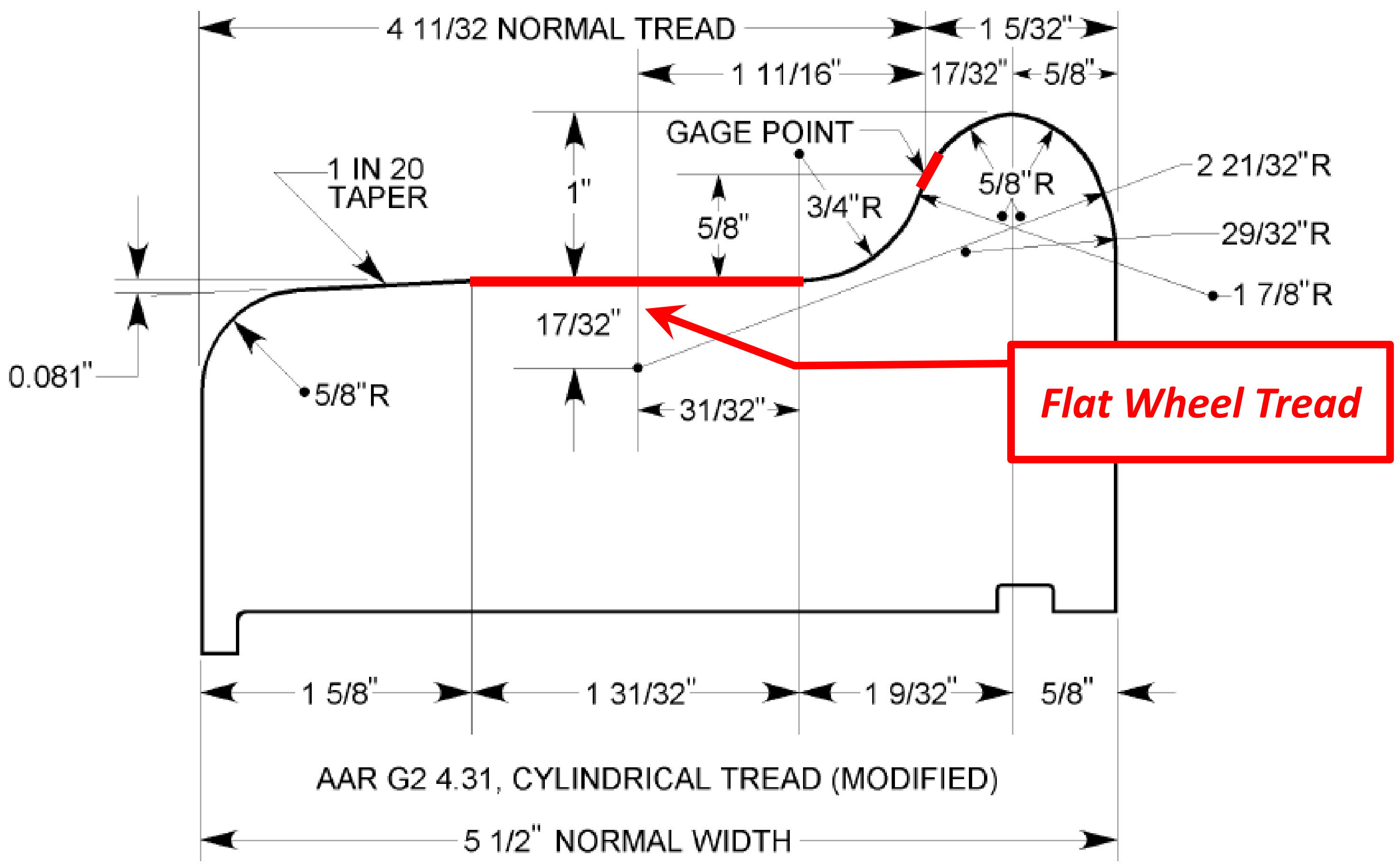
Rolling Stock

- C1 & C2 Cars: Features mainline control cab; operates as a lead, middle, or end car in revenue service

CAR CHARACTERISTICS

- Length: 70 ft (75 ft A-cars)
- Truck Spacing: 50 ft / 20 ft (between coupled)
- Truck Wheel Base: 7 ft; Wheel Diameter: 30 in
- Weight: ≈ 64,000 lbs (empty)
- Maximum Axle Load: 27,500 lbs (crush load)
- All Axles Driven by 150 hp Electric Traction Motors

Cylindrical Wheel Profile



Rail Corrugations at BART

- Occurrence:
  - on tangents and curves
  - all track forms
  - heaviest on aerial, subway & other DF track forms
- Curves:
  - more pronounced on low rail
- Tangents:
  - Heaviest where acceleration/deceleration occurs
  - Interlockings experience severe corrugations

Examples: Tangent Track - Aerial Interlocking

Examples:

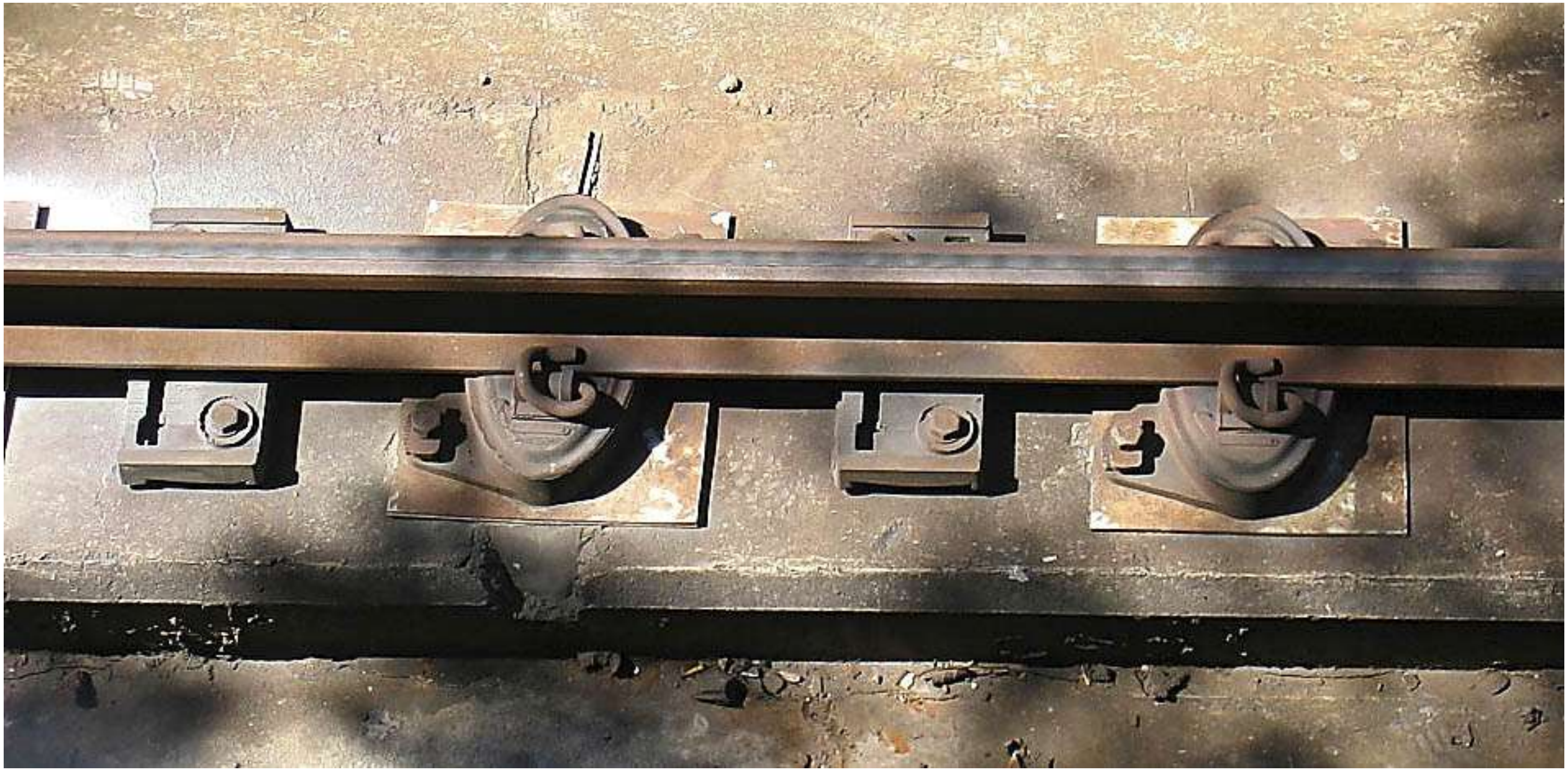
10 RBM Frog Tangent, Ballasted Track

Possible Cause:

Numerous joints, field welds and other discontinuities in the rail head initiate wheel load vibration leading to corrugation growth

Severe short wavelength corrugations on low rail of curve.

Curvature: 3°
Superelevation: 8in
Design Speed: 80mph
Avg. Speed: 48mph
Cant Excess: 2.5in



Egg fasteners installed between original Landis pads (shown disconnected)

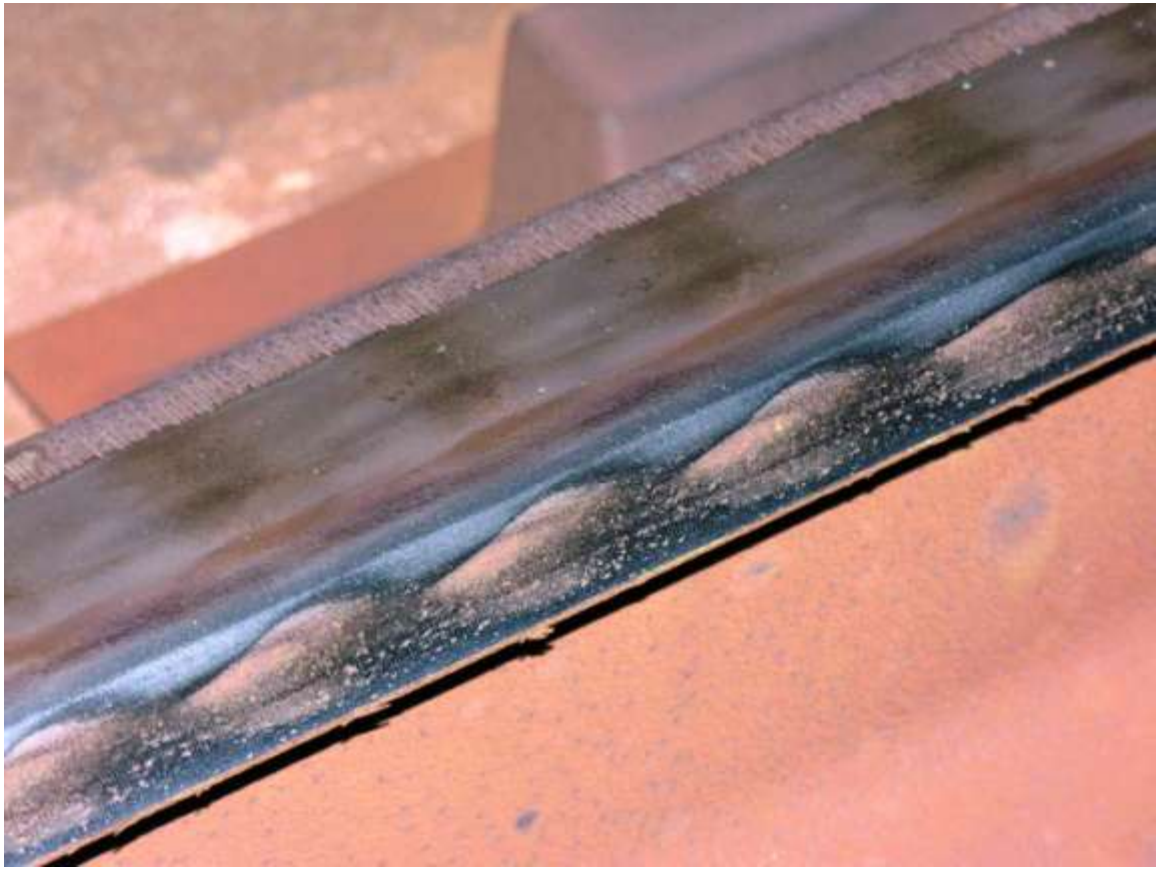
Same Location as Previous Slide

Maintenance Access Points – Problem Areas

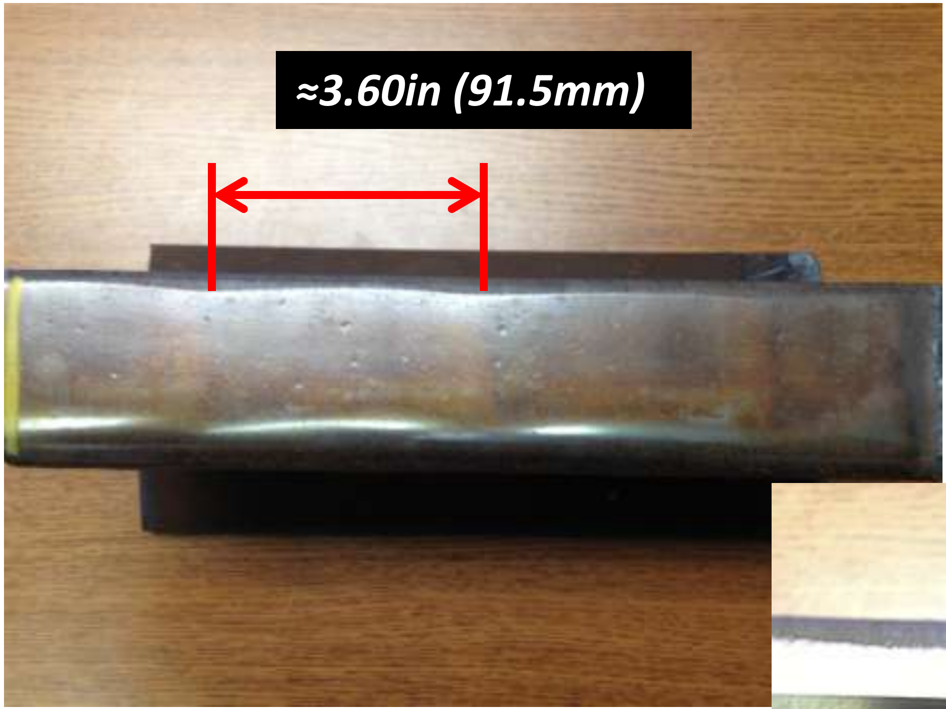
Tangent track descending into Trans-Bay Tube

Difficult to grind through crossing panels; operators often skip these locations, resulting in…

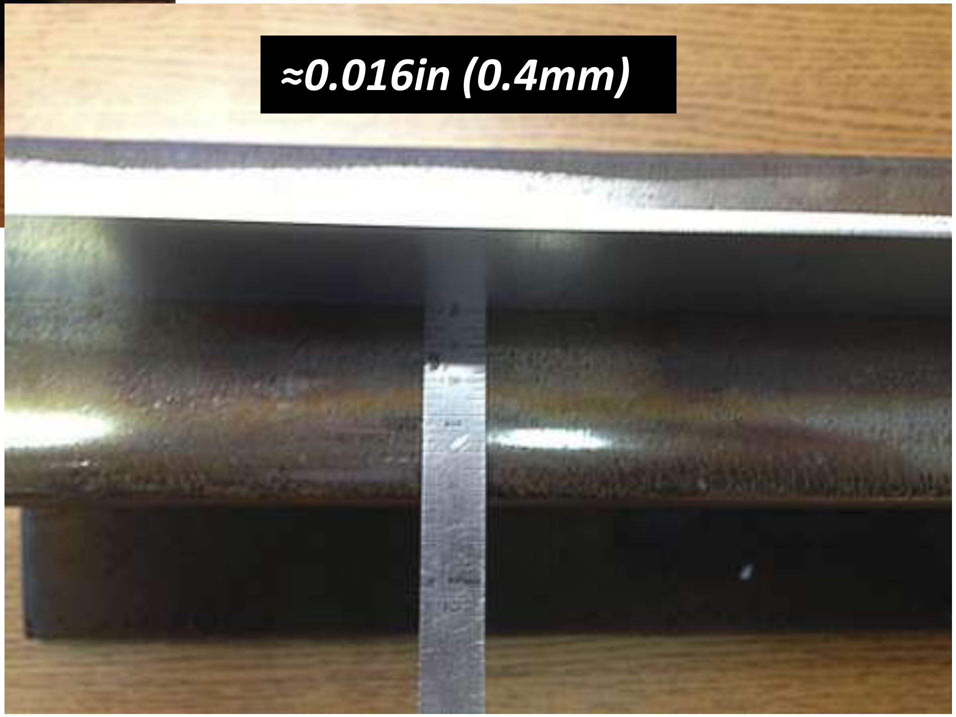
Extreme Corrugations / Broken Clips



Corrugations on Gage-Face!



Rail from previous slide was removed from track



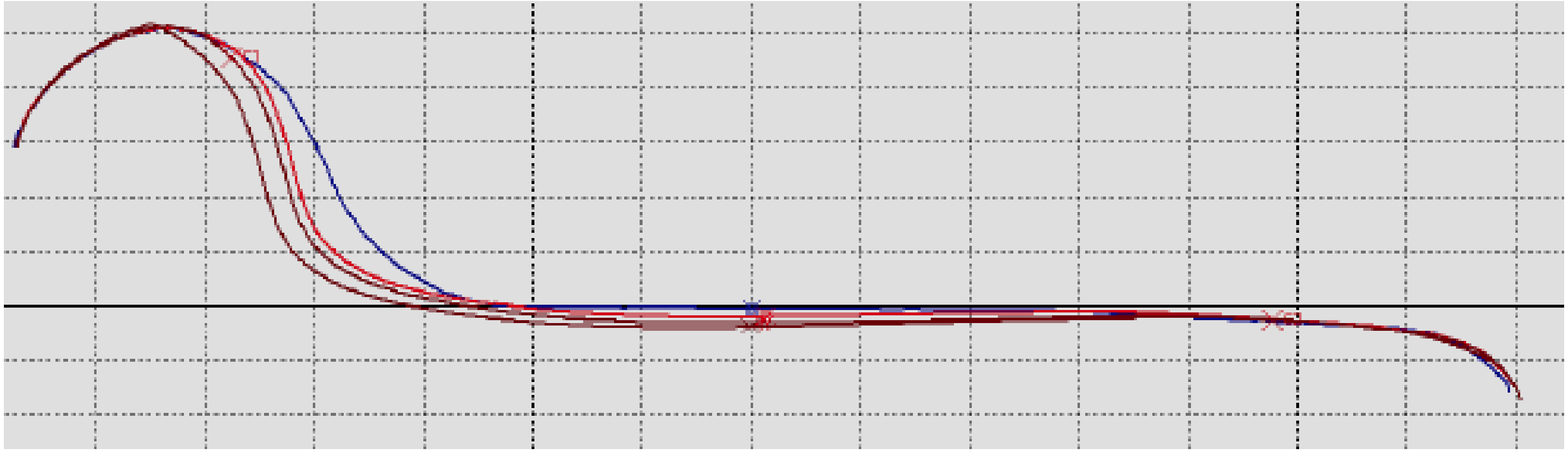
Examples:

- Low rail of 1° curve
- 2.75 in of superelevation
- Vipa fasteners
- Design Speed: 80 mph
- Average Speed: 65 mph
- < 1/2in Cant Deficiency

Some of the factors that may influence rail corrugation growth on BART

- Cylindrical wheels/poor steering/wheel tread hollowing
  - insufficient rolling radius difference
- High track support stiffness coupled with low damping characteristics on DF track
- All axles are driven
- Insufficient/ineffective rail lubrication
- Lack of optimal rail profile design(“seat-of-pants” grinding)
- Excess superelevation in many curves
- Rail cant inconsistent on DF track
- Uniform traffic loading: same wheel, same speed, same direction

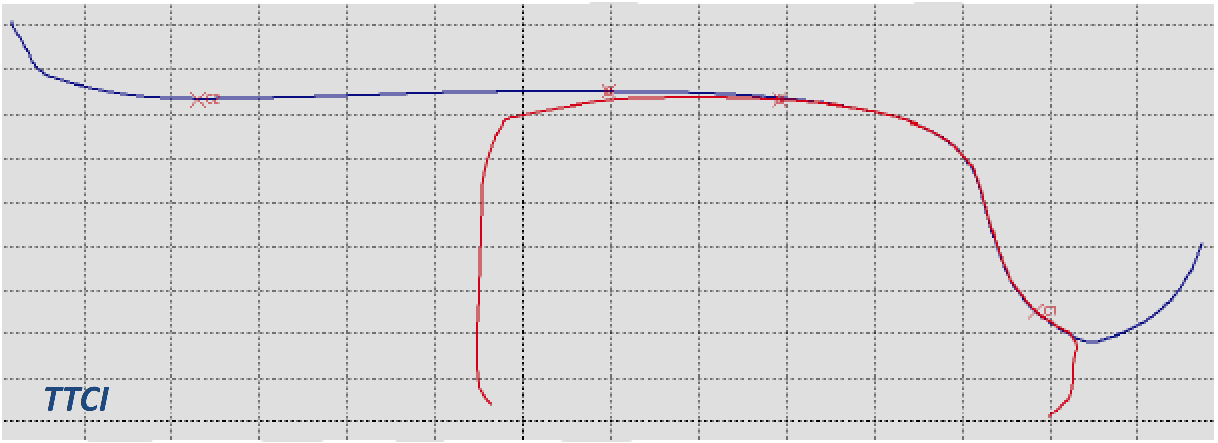
Cylindrical Wheels / Tread Hollowing



Overlay of measured wheels at different stages aligned on non-wearing surfaces (courtesy of TTCI)

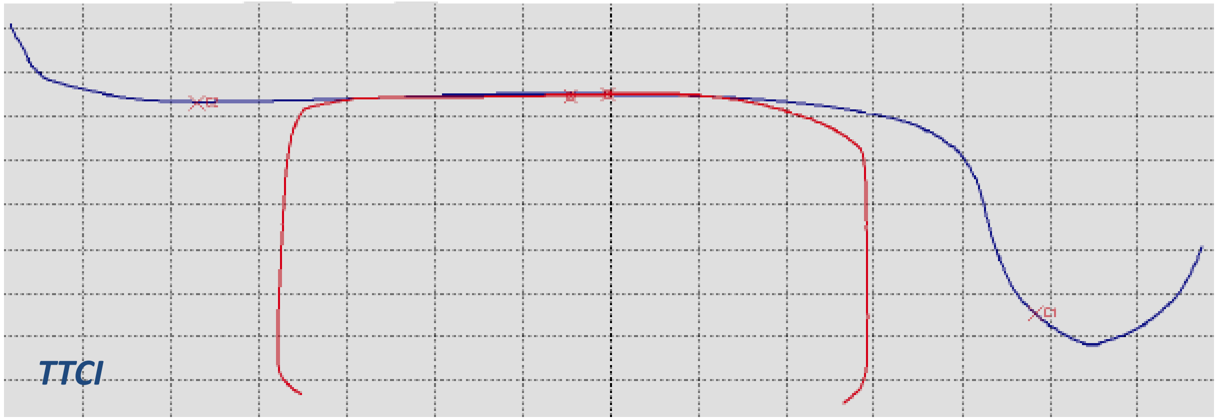
Wheel treads quickly hollow - partly because they start out as cylindrical

Wheel/Rail Interaction at BART



Worn wheel on worn high rail of curve

Worn wheel on worn low rail of curve



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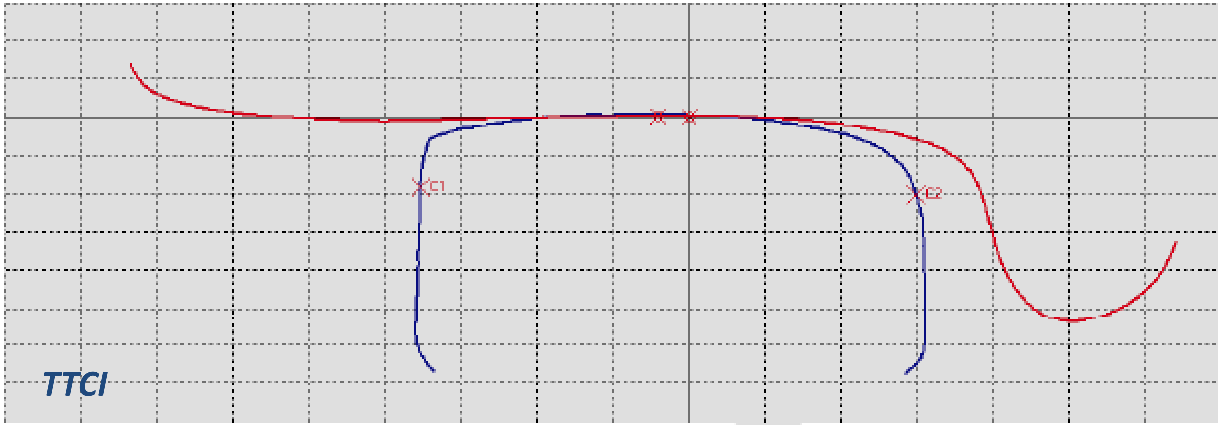
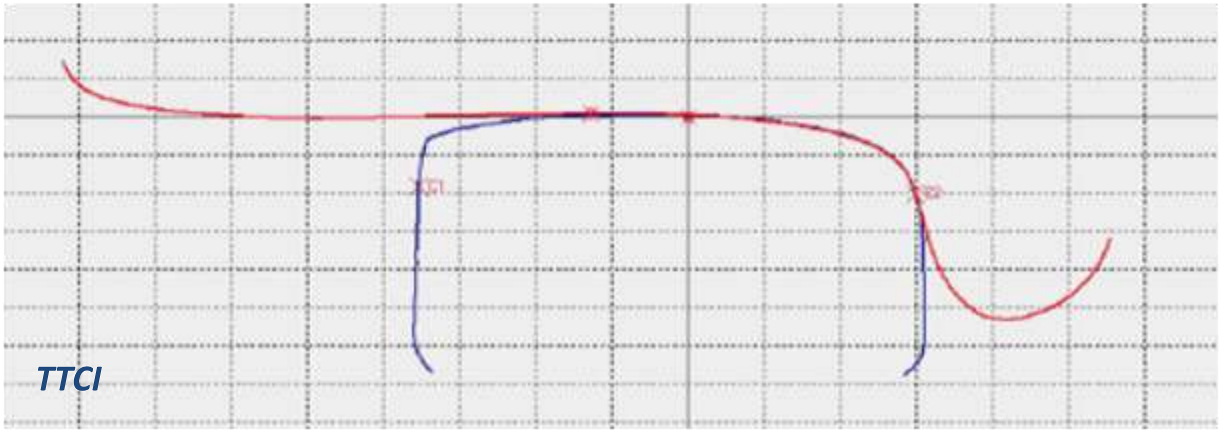
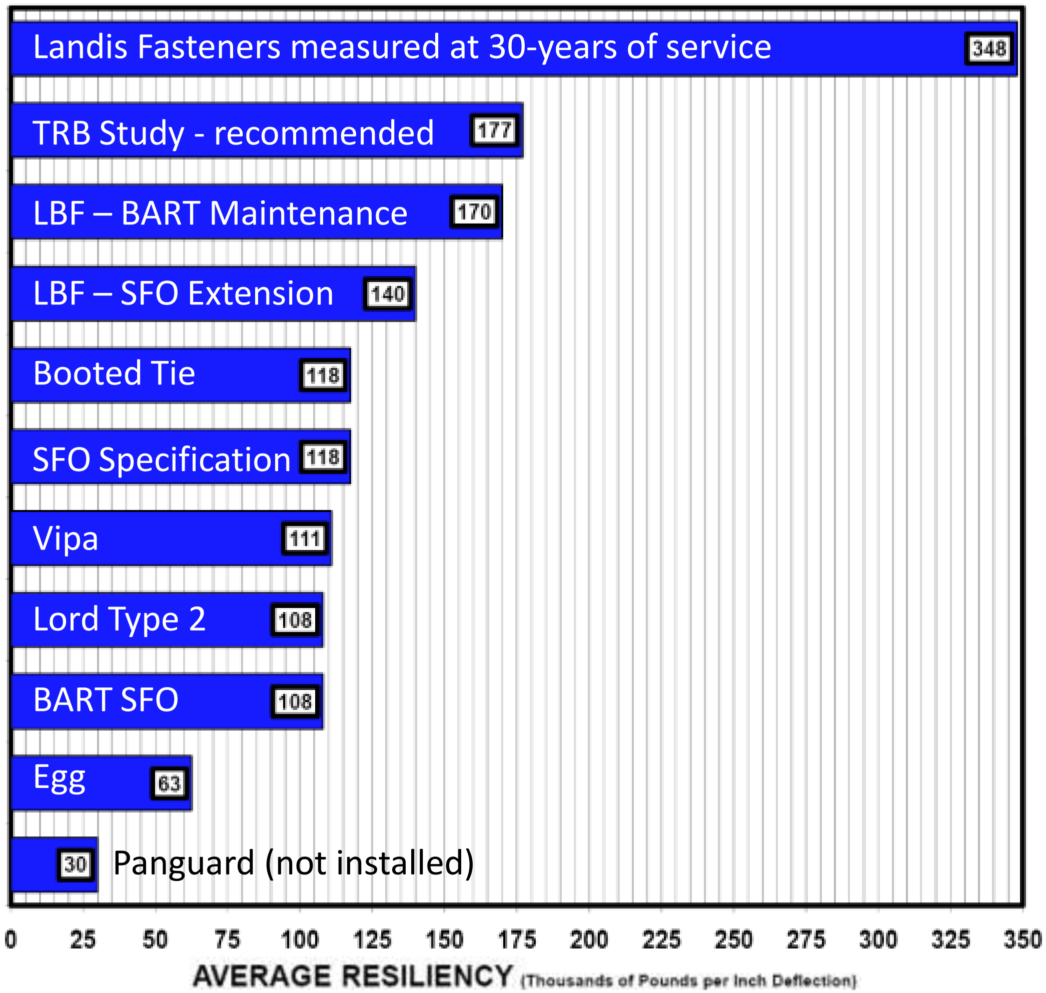


Tangent Track Contact

Contact Similar to Low Rail in Curves



Trials and Tribulations with Fastener Stiffness



Different Fastening Systems in use or proposed on BART

A systematic study of corrugation growth versus fastener stiffness has not been performed for the various fastening systems in use at BART.

The only metric available to date is frequency of grinding to reduce noise.

Interpretation of this data is too subjective to be reliable.

Rail Lubrication at BART

- BART’s standards prescribe gage-face lubricators for all curves of radius 3000 ft or less
- 173 curves in this category, but only 50 lubricators on the system (11 in Yards), many not functioning properly
- No lubricators found on aerial structures – the primary source of noise affecting our neighbors
- No lubricators in the TBT – the primary source of noise complaints from passengers
- We need to repair/replace non-functions units
- We need to add new units – aerials and subways

Working (but leaking) hydraulic unit

Partially working mechanical unit

Gage Face? Top-of-Rail? Both?

- One study claims gage-face lubrication alone is sufficient to slow corrugation growth and reduce noise
- More recent reports claim substantial reductions in noise and growth of corrugations can be realized with top-of-rail friction modifiers.
- Effects on traction/braking and the train control systems specific to BART cars needs to be determined.

Rail Grinding at BART

- Done exclusively in-house
- Operator experience varies
- Limited maintenance windows (2-1/2 hrs)
- 12-stone machine / multiple passes required
- Need to educate operators/supervisors on wheel/rail interaction and eliminate "seat-of-the-pants" grinding
- Need to implement optimal rail profiles
- Need to implement "managed" program

BART Owns/Operates 2 - LORAM LRG 12-Stone Rail Grinders

- Delivered 2008
- Work 5 – 7 Nights/Week
- Positive Shunting
- Travel to/from Work Site During Revenue
- Full Utilization of Work Window
- Requires 6 – 12 Passes to Re-Profile Rail
- Averages 1/2 mi/night

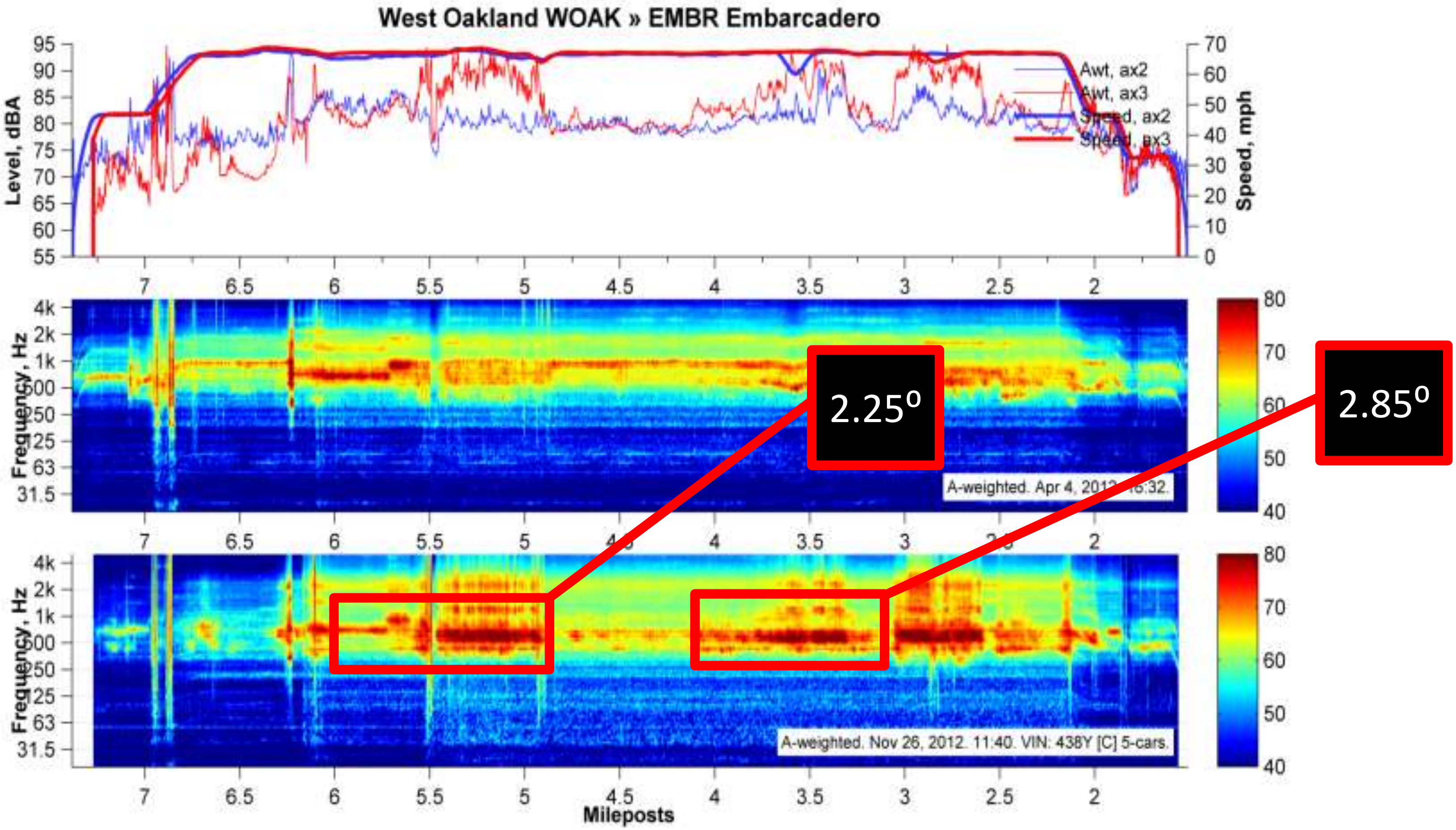
We Have the "Power Tools" but lack the "Precision Measuring Tools"

- First things first – Rail Profile Measurements
  - *BART does not have in-house equipment to measure rail profiles periodically – system wide*
- TTCI has nearly completed the wheel/rail interaction study
  - New wheel and rail profiles recommended
- Need to develop a strategy to implement recommendations.
  - *Measuring rail profiles periodically will be essential to monitoring rail grinding effectiveness*

Prioritize

- Tools are available to measure corrugations accurately; push-behind not suitable for system-wide measurements
- Automated/on-board equipment is expensive
- Need a cost-effective method to obtain a measure of rail corrugations that can be used to prioritize and monitor grinding program
- BART has chosen on-board sound level mapping as a cost-effective method to obtain rail surface roughness data.

Noise Spectra – Trans-Bay Tube



That's it!

Questions?