Tracking the Evolution of Rail Grinding and Milling

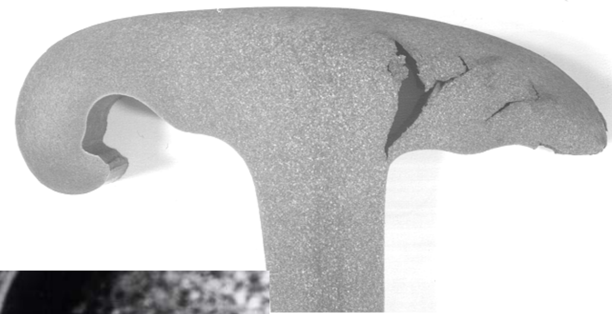
Mike Roney and Dan Hampton

Agenda

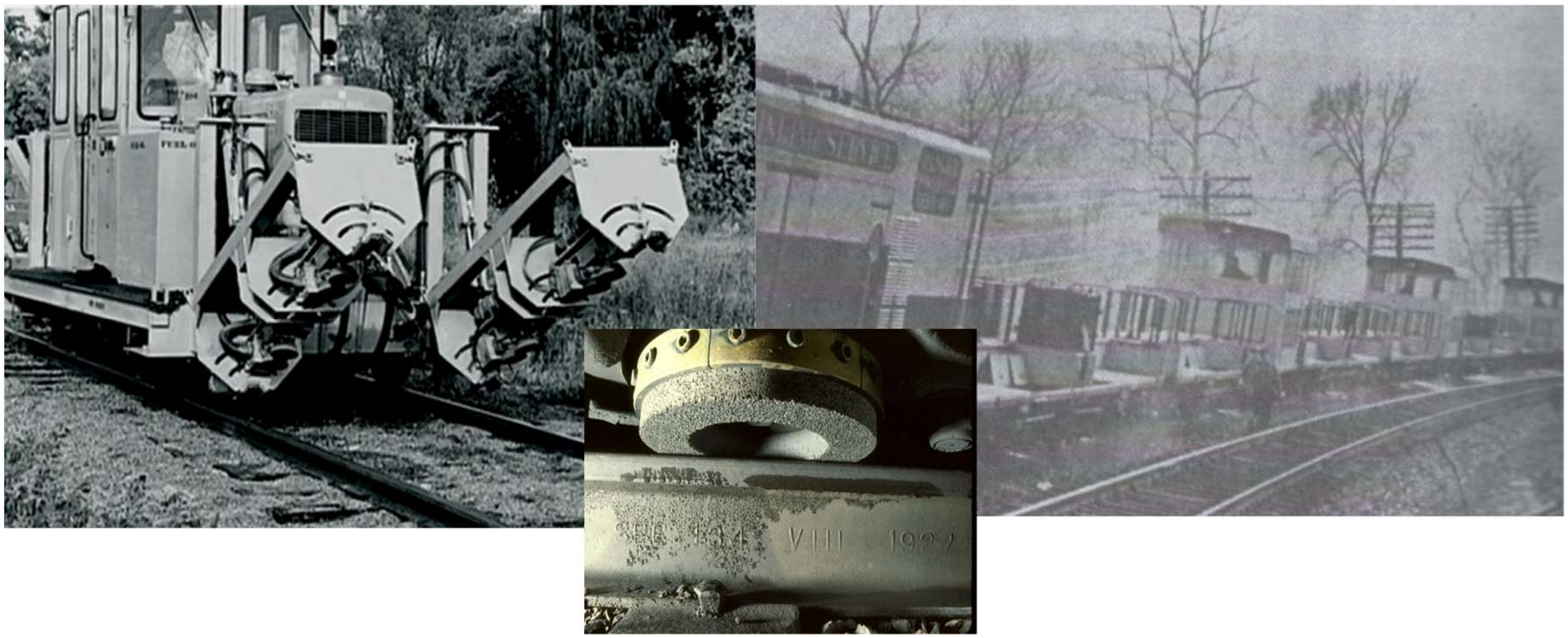
- How rail grinding saved our bacon
- From corrective grinding to profile grinding
- Preventive grinding at the Magic Wear Rate
- Rail maintenance strategies and the role of milling
- What has made us successful to date
- Gaps to tackle
- Towards proactive control of RCF
- An holistic approach to rail maintenance

How rail grinding saved our bacon

- Standard carbon rails experienced excessive plastic flow under the "jumbo" 100-ton cars of the 60's.
- Shelly rails and rail corrugations were a common occurrence
- Rail lives could be as short as 3 months – 1 year

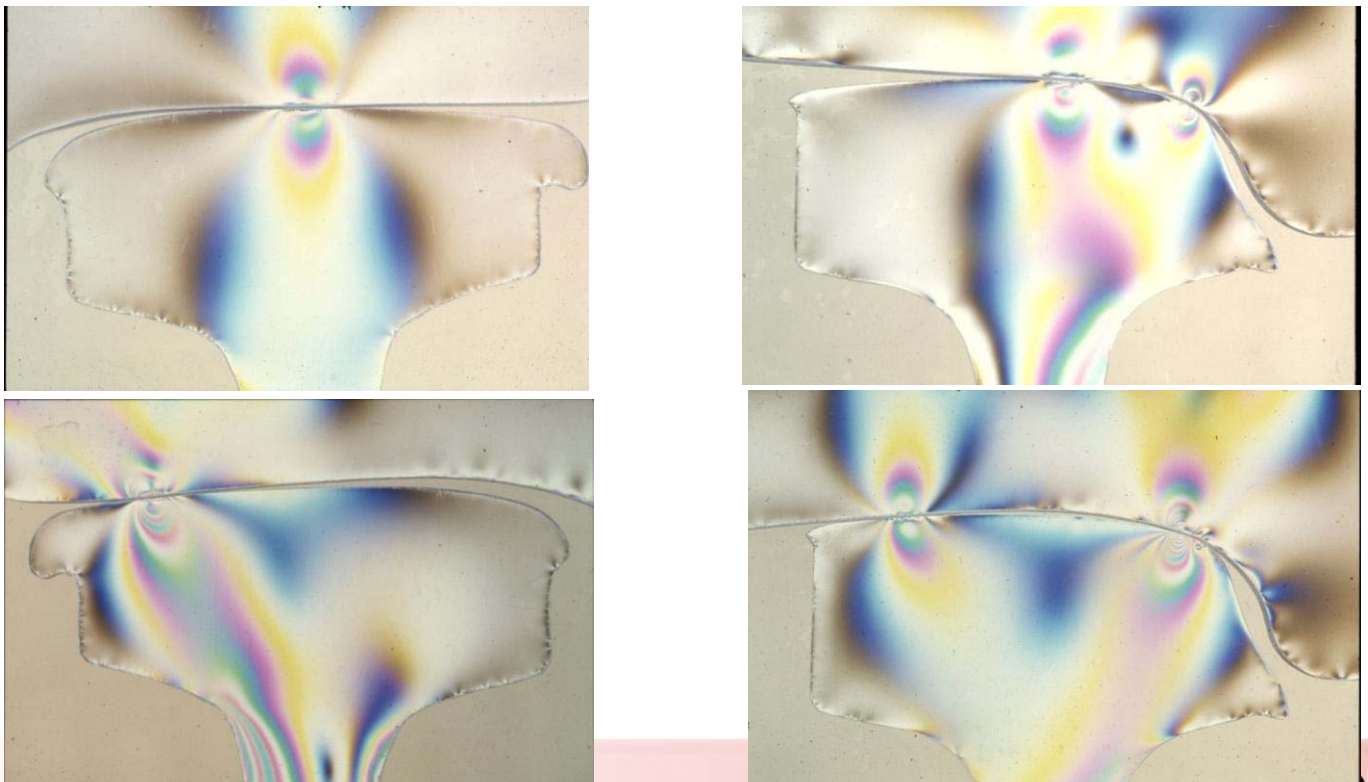


Enter rail grinders with fixed position annular stones

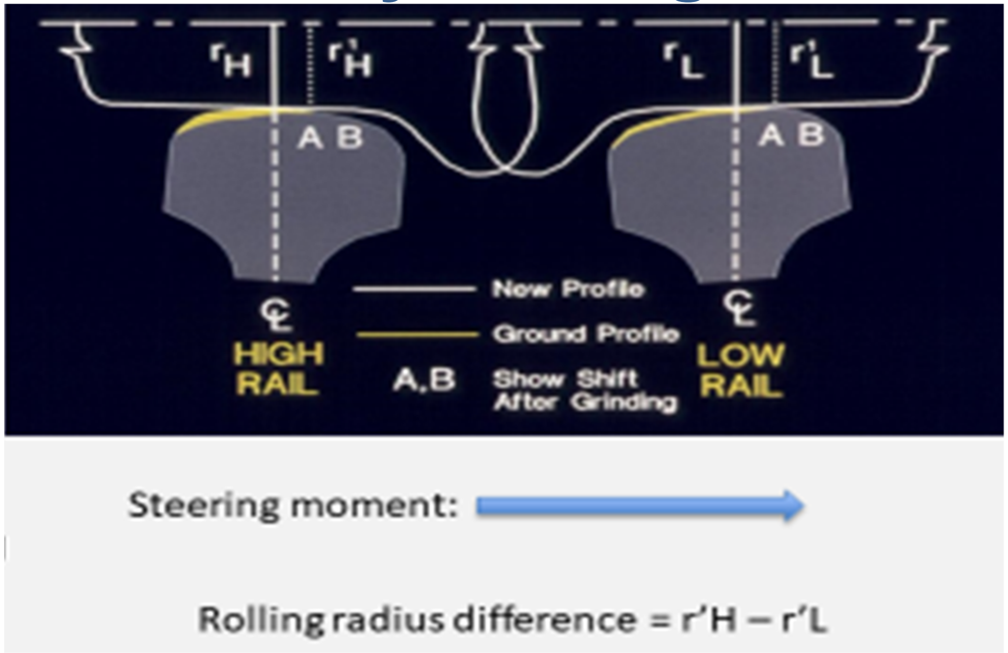


From Corrective Grinding to Rail Profile Grinding

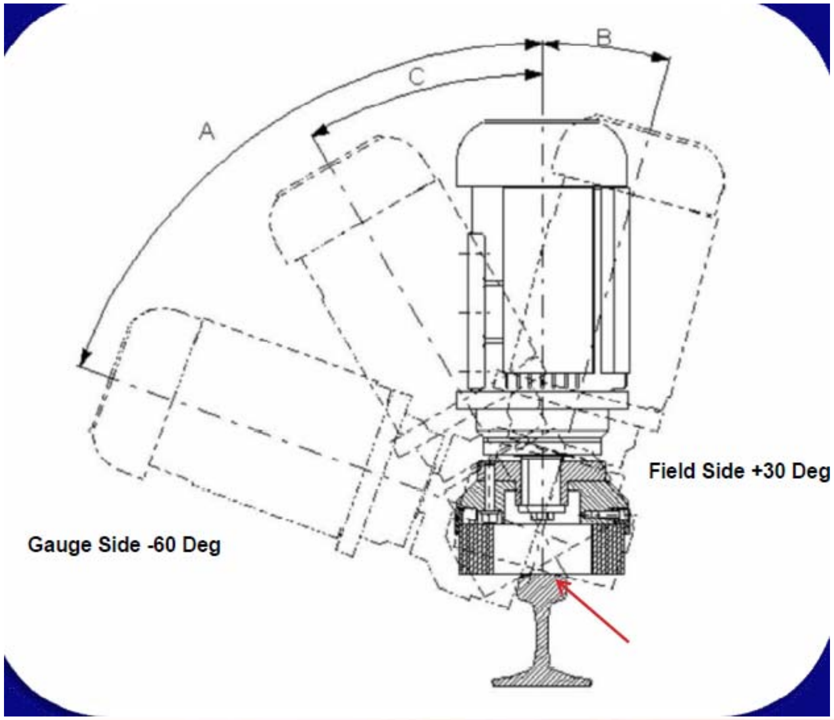
– **addressed high stress wheel/rail contact and vertical rail irregularities**



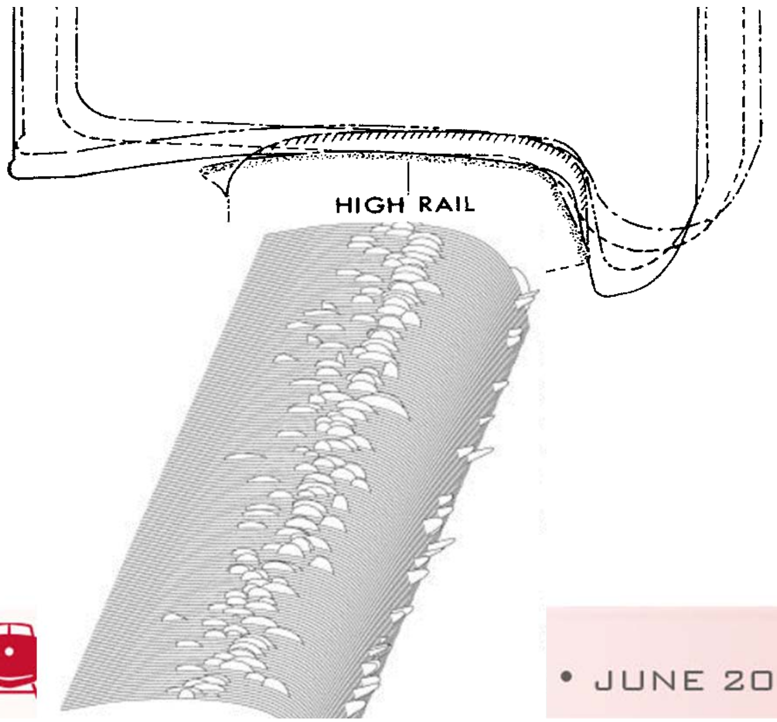
Australian ore railways were the first to use ground rail profiles to improve steering through curves by shifting contact bands

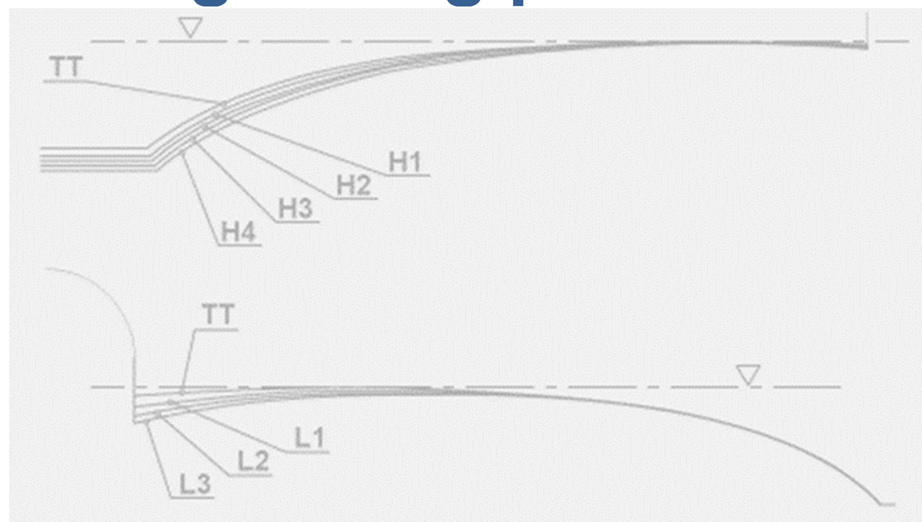


Breakthrough was programmable grinding motor positions

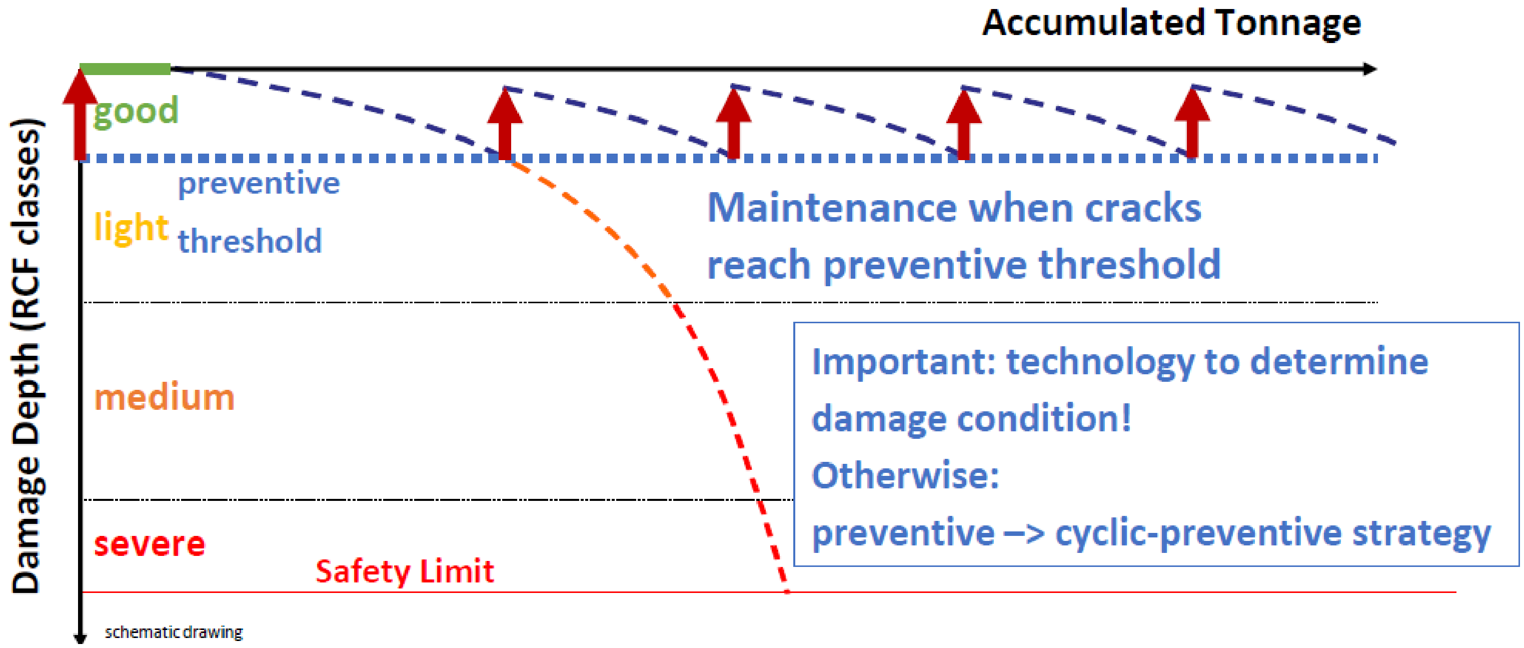


Awareness of the “pummelling” benefit of conformal contact with the population of wearing wheels led to development of a suite of engineered rail profile grinding patterns

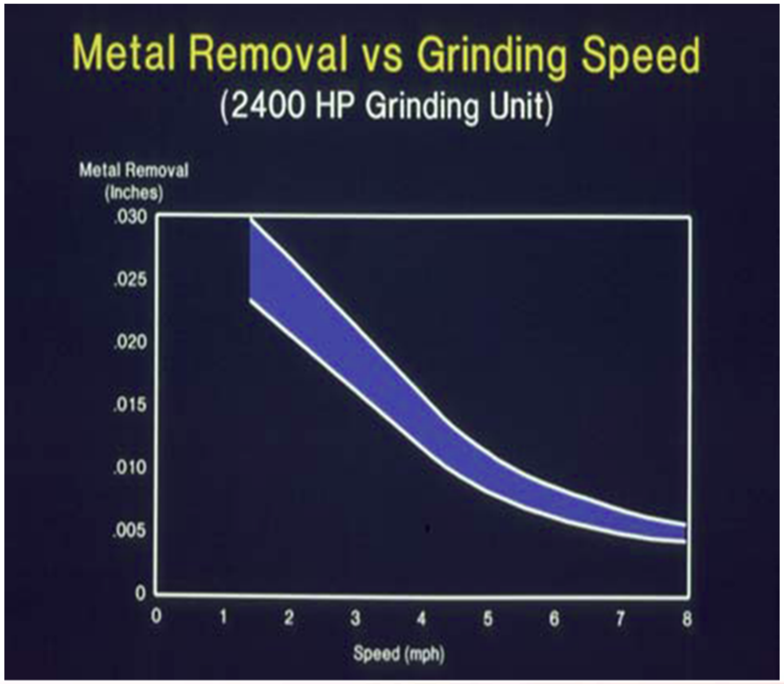




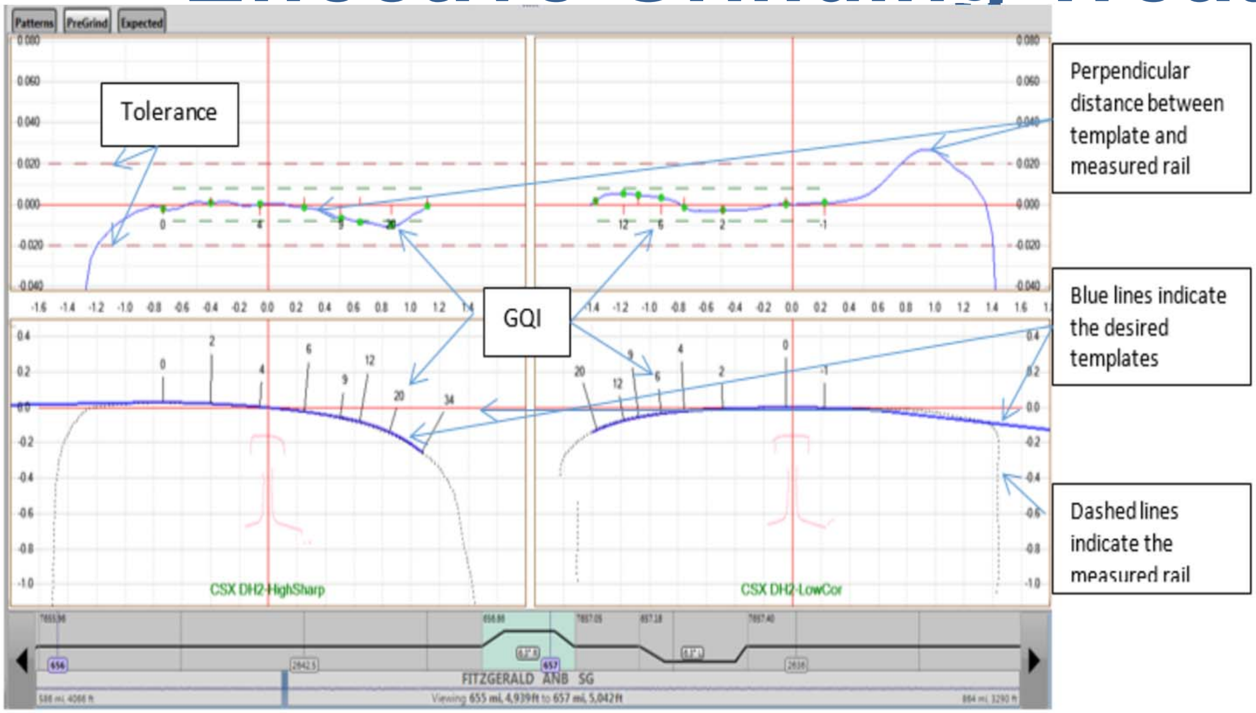
Preventive maintenance grinding has been a key to controlling RCF, often with a single pass/cycle

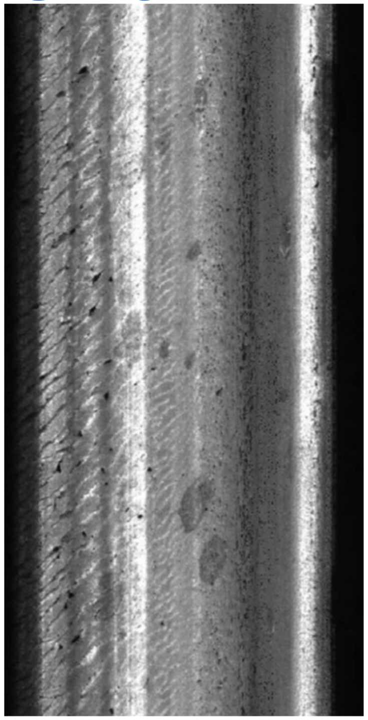


An associated breakthrough has been grinder productivity at higher speeds, facilitating increasing rail grinder speeds

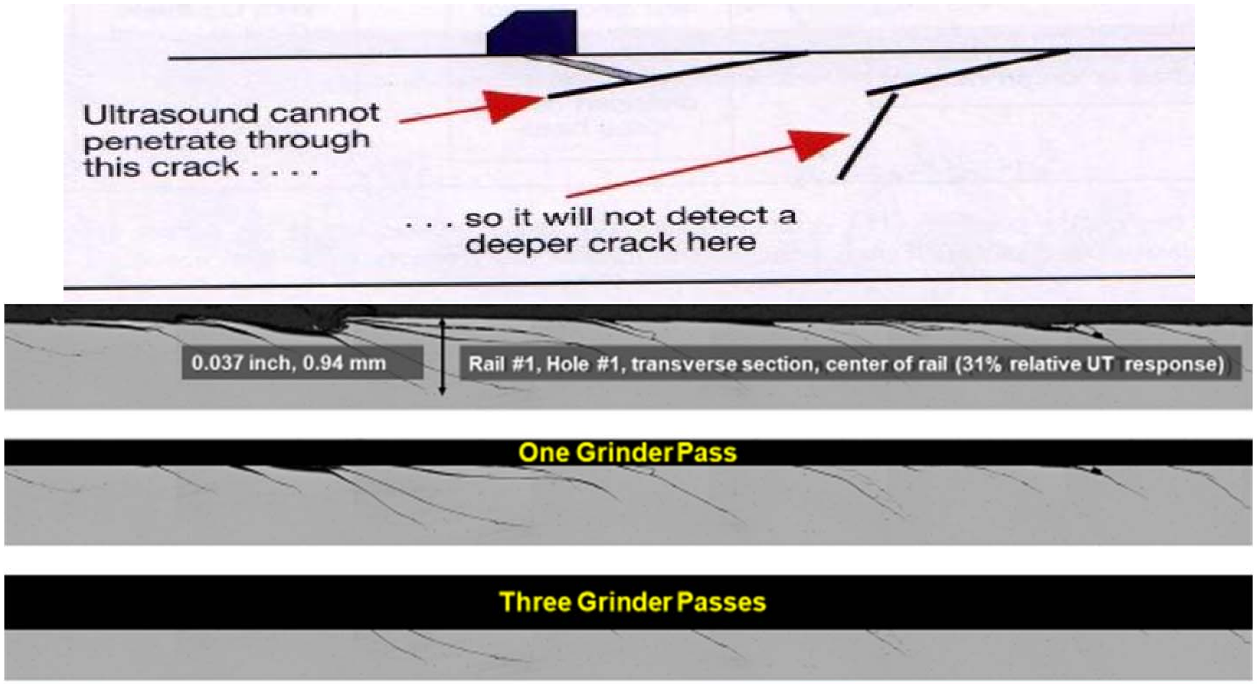


Electronic Pre-Inspections Guide Effective Grinding Treatment



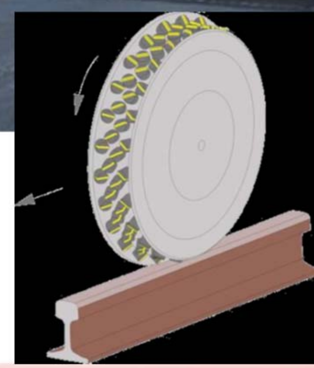


Railways have linked rail grinding with RFD Effectiveness

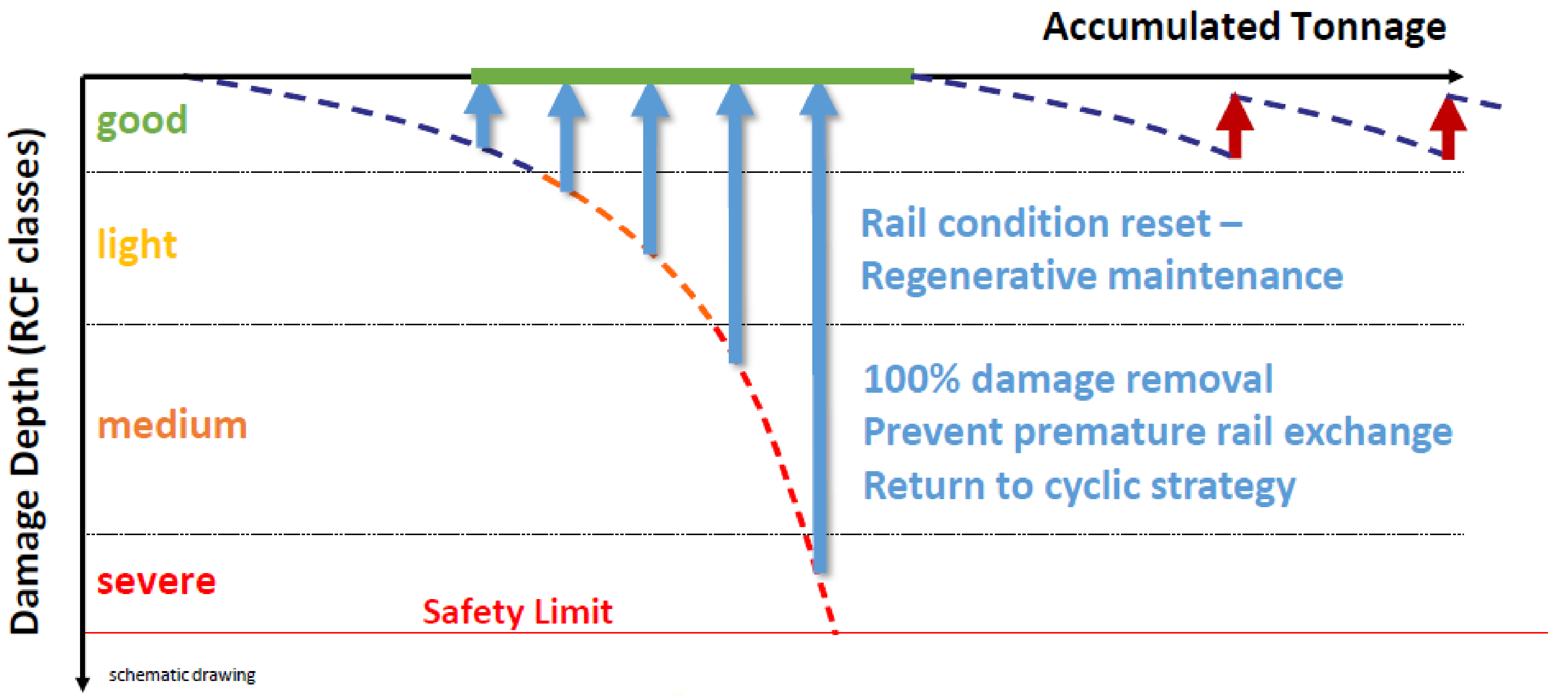


Rail milling now in North America

- Rotational cutting process
- Generation of chips collected on machine
- Heat input into cutting tools and chips, no sparks and dust
- Profile defined by shape of cutting tool
- 0.1mm –5mm per pass
- Up to 2km/h per pass
- Polishing process for noise optimized surface



Regenerative Maintenance - A Role for Milling ?



What has made rail grinding successful over the past 25 years

- Engineered “as ground” rail profiles
- Cyclic grinding at the Magic Wear Rate
- High production, higher speed rail grinders
- Pre and post grinding automated inspections
- Grinding to maintain RFD effectiveness
- Grinding linked to RFD results

What Gaps Still Exist ?

- **Accurate measurement of RCF crack depth**
- **Understanding route-specific Magic Wear rate**
- **Balancing high production, high speed rail grinding with the required result**
- **Recovering from a corrective grinding regime**
- **implementing how friction modification and grinding can work together to extend rail life**

And now …. A vision for the future

- **Starring Dan, the Rocket Man**

Future of Metal Removal

Goal: Maximize rail life -> Achieve "Magic Wear Rate"

1. **Increase level of detail to capture RCF at the meter by meter**
   - **Improve technology for subsurface RCF and crack depth evaluation**
2. **Quantify and integrate rail surface dips into grind plan**
3. **New measures correlated to required action for rail life extension**
   - **Rail Surface Quality Index (RSQI) and Profile Quality Index (PQI)**

Future of Metal Removal

Goal: Maximize rail life -> Achieve "Magic Wear Rate"

3. **Utilize algorithms to group areas of common demand to treat uniformly based on equipment capabilities.**
   - Dynamic Track Segmentation
4. **Right size equipment to workload for maximum efficiency**
   - Combined Rail Grinding Operations
   - Complementary Grind Plans

Future of Metal Removal

Goal: Maximize rail life -> Achieve “Magic Wear Rate”

5. **Economic Modeling**
   - **Holistic Systems Engineering Approach**
6. **Predictive Modeling**
   - **Segment Frequencies**
   - **Depth of Cut**
   - **Profile Shape**

Measurement Level of Detail

Pre-Grind Inspection - Current State:

Profile Templates

Measured Profile + Surface Condition

Automated: KLD ORIAN8
Profiles collection every 10' – 25'

Manual Enhanced: KLD Railscope
Observation entered for
track grind segment

Measurement Level of Detail

Pre-Grind Inspection - Future State:

Profile Templates

Monitoring Alerts for update

Measured Profile

- Automated Real Time Evaluation
- Profiles collection every 1’
- Predictive Rail Wear
- Refined PQI – contact stress

PREDICTIVE

Surface Condition

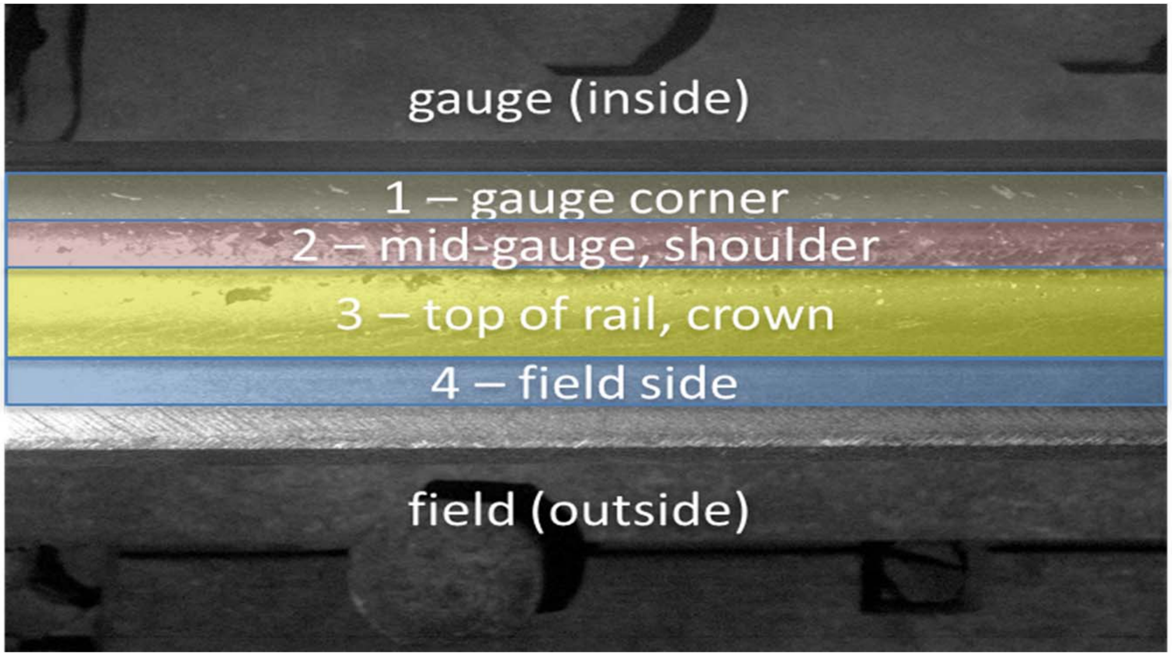
- Automated Real Time Evaluation
- Industry accepted scoring (RSQI)
- Collected & stored <= 1 meter
- Collection rate >= 30mph

PREDICTIVE

Rail Surface Quality Index (RSQI)

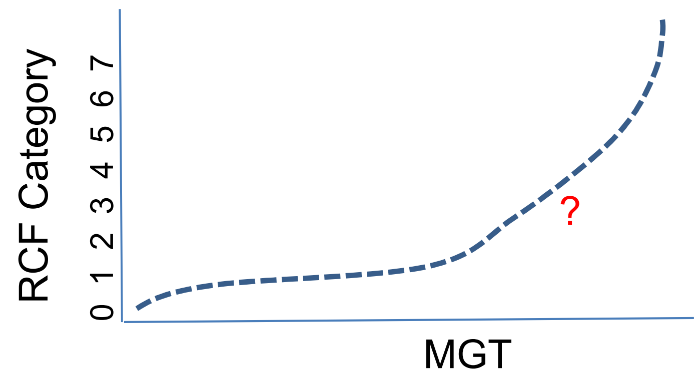
0	**None**
1	Barely perceptible, but clearly regular pattern. Unable to feel with a finger. **Suggested Depth of Cut < 0.5 mm**
2	Clear, well-defined, distinct individual cracks – but no pitting. Might detect with finger nail. **Suggested Depth of Cut < 1.0 mm**
3	Strong, regular cracks, consistent spacing. Edge or Crack Width. Easily snags skin or cloth **Suggested Depth of Cut < 2.0 mm**
4	Clear cracking, pitting maximum width 4 mm **Suggested Depth of Cut 2.0 - 2.5 mm**
5	Pitting width between 4 mm - 10 mm. "Heavy", well defined gauge corner cracks. **Suggested Depth of Cut 2.5 - 3.5 mm**
6	Shelling/spalling: regular pitting, > 10 mm diameter **Suggested Depth of Cut: 3 - 5 mm**
7	Shelling/spalling: any defect > 16 mm diameter, > 20 mm length **Suggested Depth of Cut: > 5 mm**

Rail Surface Quality Index (RSQI)



Rail Surface Quality Index (RSQI)

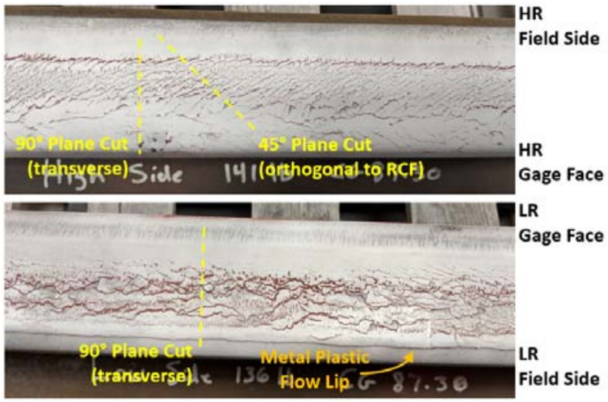
- **Industry accepted = multiple sources to accumulate data with fewer MGT between runs**
- **Scoring is progressive = enables damage/MGT prediction / track segment**



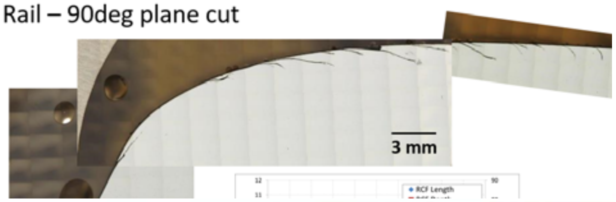
- **Known remedial action / depth of cut required**

Areas to Build Knowledge

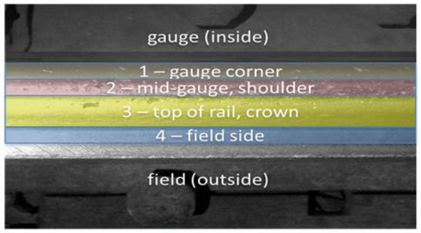
RCF Surface Damage vs. Subsurface Damage

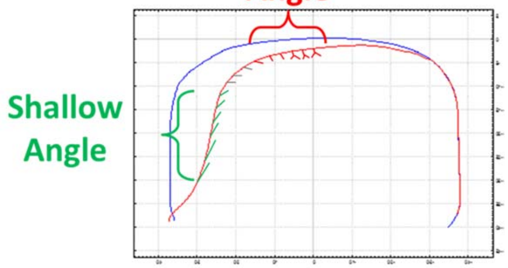


High Rail – 90deg plane cut



Improve Eddy Current inferred depth by determining a more accurate crack angle based on location on the rail head



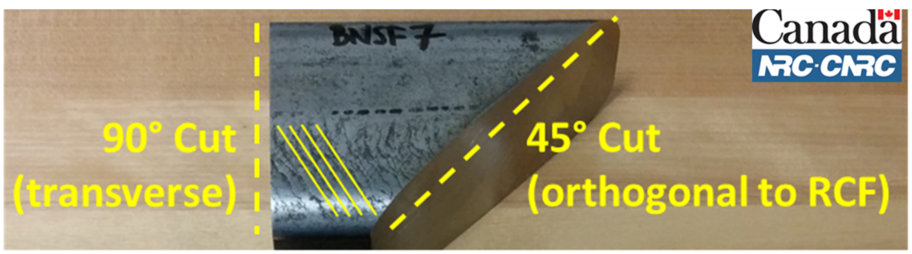


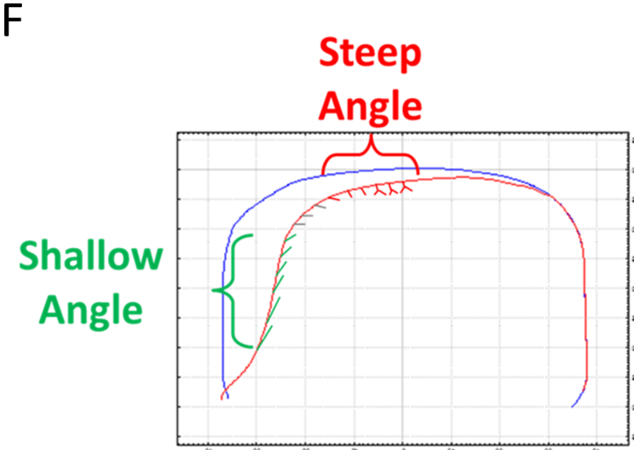
RCF Project Proposal

- Class 1s contribute rail samples for the from various tonnages, and curvatures (High and Low rails, and some tangents)
- TTCI and CNRC provide testing for uniformity
- Daniel Szablewski (CNRC) – Provide format of data needed and standards for testing, which include surface images, eddy current probe, cut sections, and hardness testing

RCF Destructive Testing

- Methodical documentation of RCF in rails
- Achieve RCF crack plane cross-sectional morphology by doing 2 cuts:
  - At 90° and 45°
- Map steep to shallow angle vs. position on railhead running surface
- Compare Surface RCF vs. Subsurface RCF

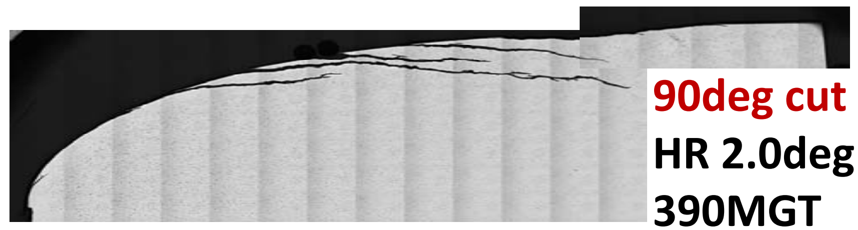




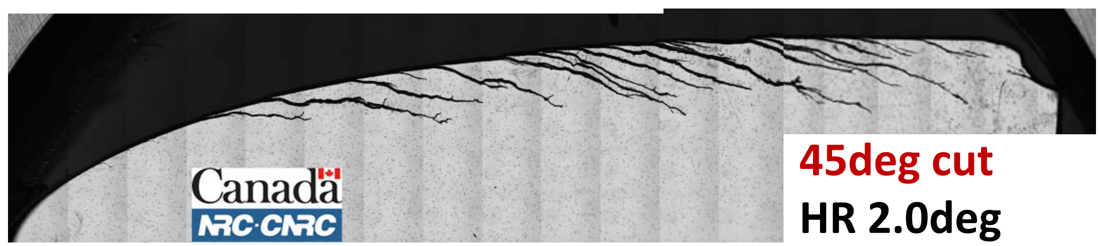
RCF Destructive Testing

- **Why the 2 cut planes?**
  - **RCF appears different on cross-sections when cut at different orientations**
  - **We need to map the accurate depth and angle of the cracks**

2 Different Cuts - Same Rail



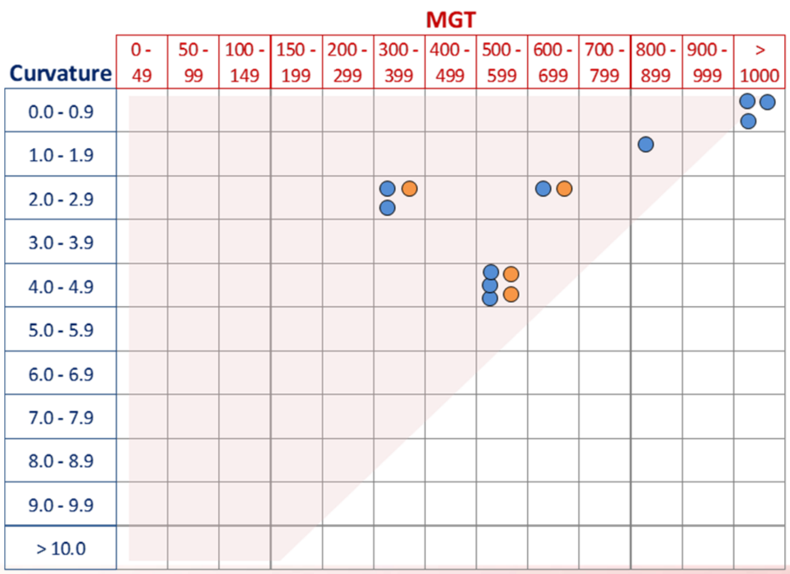
90deg cut
HR 2.0deg
390MGT



45deg cut
HR 2.0deg
390MGT

RCF Destructive Testing

- Comparing Surface vs. Subsurface RCF requires destructive testing
- 14 rails in the matrix to date, to add rails from other tests with TTCI
- Requires Class 1s participation



Rails Analyzed to Date:
90 degree cut
45 degree cut

Canada NRC·CNRC

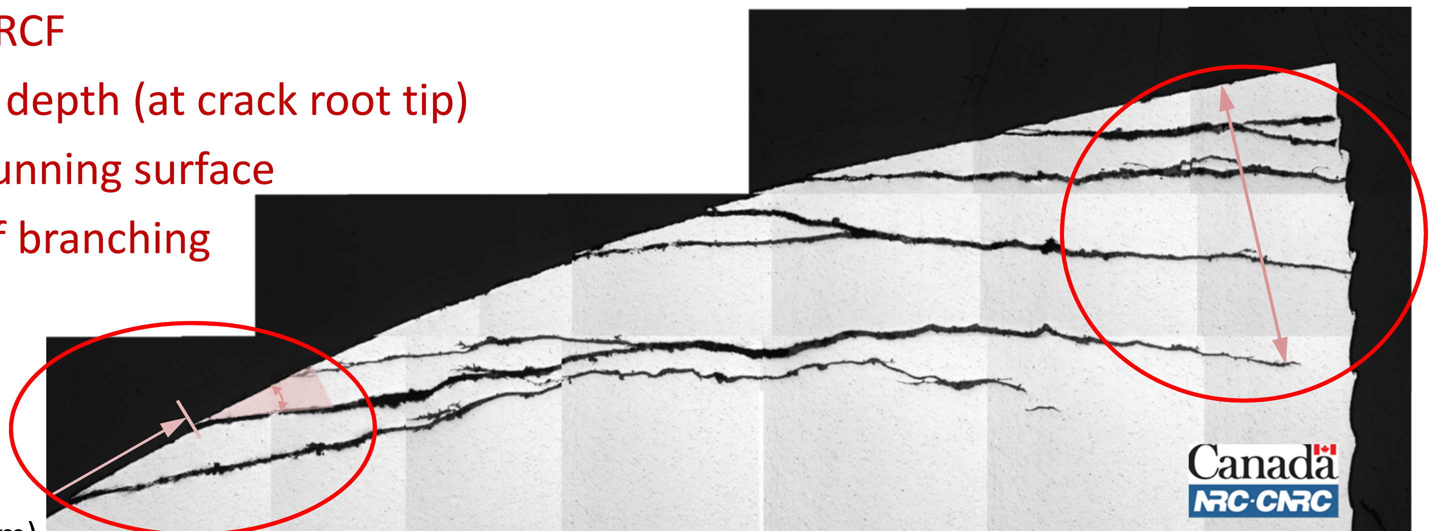
Layers to Consider:

- High & Low Rails
- Rail Grade (i.e. standard, intermediate, premium)
- Track Curvature (i.e. variable radius)
- Tonnage Accumulation (i.e. variable MGT in rail life-cycle)
- Running Surface Condition (i.e. dry, lubricated, TOR friction modified)
- Superelevation
- Average Train Speed
- Authorized Speed
- Traffic Type (i.e. axle load, train speed)
- Maintenance Grinding (frequency and amount)

RCF Destructive Testing

RCF Morphology: Document for each cut plane

- Position of initiation point on rail running surface
- Length of RCF
- Maximum depth (at crack root tip)
- Angle to running surface
- Amount of branching



BNSF-7 rail:
2-deg curve,
high rail
136 RMSM
2002 (premium)

Rail Surface Dips Integration - Grind Plan

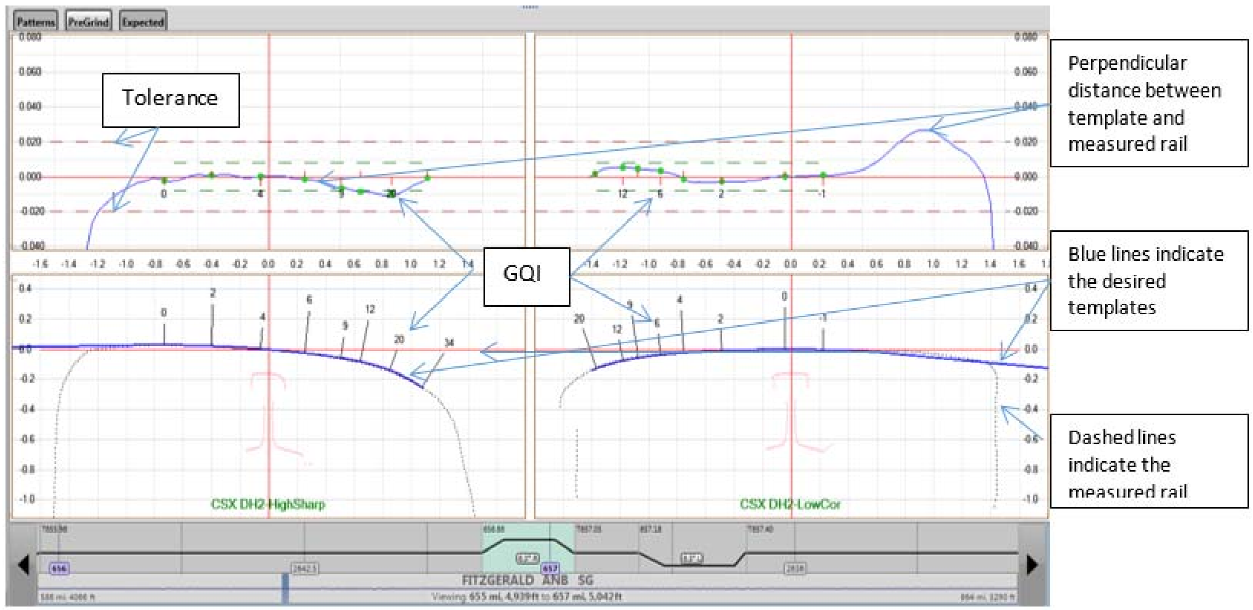
- Goal: Reduce or eliminate rail surface dips that increase vertical loading, causing premature fatigue of the rail
  - Corrugation
  - Engine burns
  - Crushed head/Flattened head (not a joint 3/8"+ depth and 8"+ long: FRA Compliance manual)
  - Dipped Welds
- Technology refinement
- Data cleanup for non rail surface dips -> grind plan
- Agree on criteria, depth of cuts, right equipment

Profile Quality Index (PQI)

- Determine correlation between current measure Grind Quality Index (GQI) and rail life extension
  - Current project with Sentient Science & Canadian National Research Council
- Establish new profile quality measure directly correlated to rail life extension
  - Determine whether corrective grinding for profile needed based on economics

Rail Wear Measurements (x,y to base)

- Measure wear values along the rail head
- Align run over run profile shapes and wear values



- Requires dynamic segmentation to group similar profiles for predicting wear and determine treatment to apply.

Predictive Wear to Higher PQI

- Account for predicted wear when grinding to bring the optimal profile mid cycle
- Results in more optimal wheel rail interaction for a longer duration.

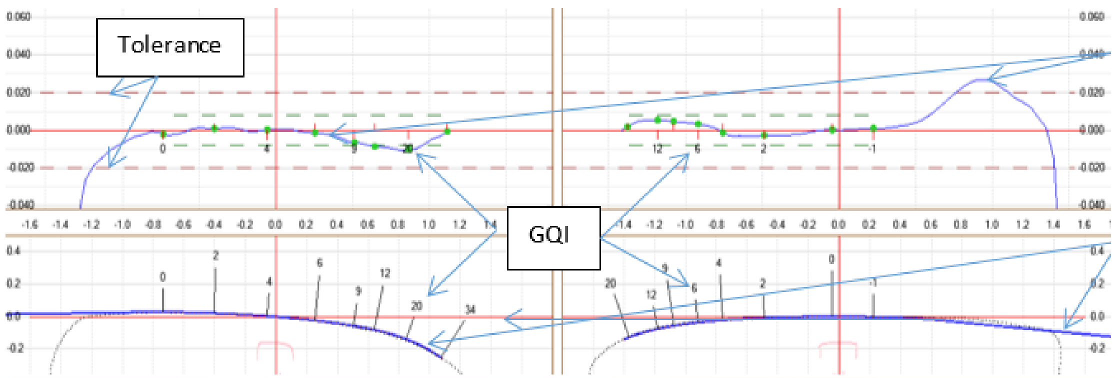
		Standard	Predictive
	MGT	PQI	PQI
Post Grind	0	100	80
	10	90	90
Mid Cycle	20	80	100
	30	70	90
New Grind	40	60	80
	AVG PQI	80	88

New/Revised PQI Measure

- Directly correlated to profile shape impact on rail life
- Real time comparison to RR average wheel profile or route average wheel profile
  - Determination of conformal, non-conformal, and closely conformal
- Compares predicted wear to determine whether can grind to a shape that will wear to optimal or can only grind to target profile shape now.

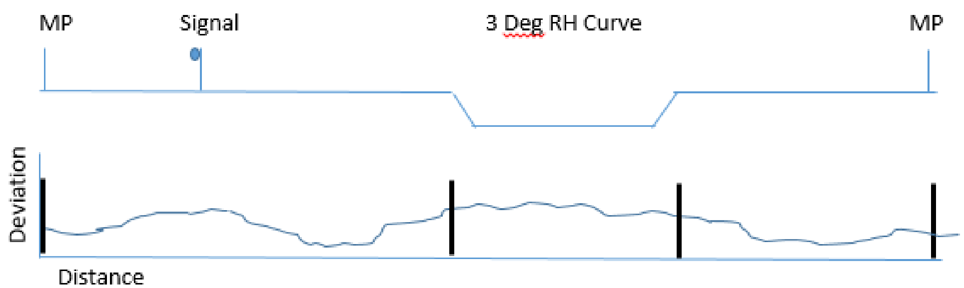
PQI – Where Deviation occurs matters

- Specific angles currently have different weights based on criticality but allowable variation in one location should change the allowable variance in another.
- Need to account for difference in overall shape and estimated contact stress.

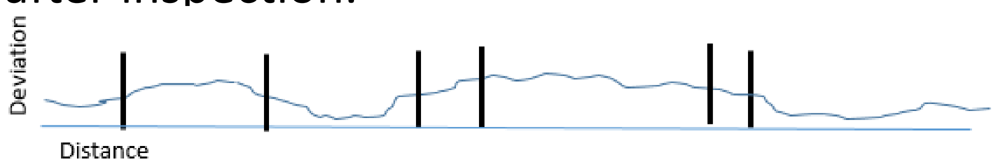


Dynamic Track Segmentation

- Traditional Segments: Length of Curve, tangents broken by mileposts, curves, or a boundary (prefix, subdivision).



- Dynamic Track Segmentation – creates segments based on similar demand after inspection.



= More grinding where needed, and less where not needed

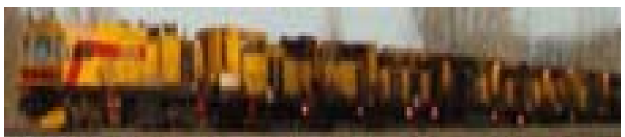
Dynamic Track Segmentation

- Traditional segments based on physical markers so operator knows where to change to next configuration: patterns, speed, downward pressure
- Executing Dynamic Segmentation requires accurate knowledge of where the pre-inspection equipment and the grinding equipment is located on the rail.
  - GPS, GIS surveys, redundant systems
  - Same technology enables performing a complementary grind using the specialty grinder (24 stone) behind the production grinder (120 stone)

Right Size Equipment to Workload

Combined Rail Grinding Operations Configuration

120 Stone Production Rail Grinder
1 Foreman



Length = 0.12 miles

Fire Suppression Truck #1:
1 Operator

800’ to 1 mile

24 Stone or 48 Stone Specialty Rail Grinder
1 Foreman

1 mile to 7 miles

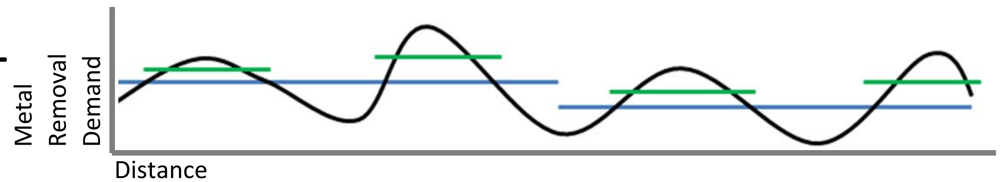
Fire Suppression Truck #2:
1 Operator

800’ to 1 mile

- Benefits – full coverage, split work load, 65% less track time, single pre-grind inspection using same templates, fewest passes to achieve target, uniform running band across all rail

Work Load Leveling – Complementary Grind Plans

- Cycle 1



- Cycle 2 when Cycle 1 *without* Specialty Grinder

- Cycle 2 when Cycle 1 *with* Specialty Grinder

LEGEND

- Profile or Surface Deviation (black line)
- Production Grinder (blue line)
- Specialty Grinder (green line)

RESULTS: More closely match demand = rail life extension

Work Load Leveling – Spiral Transitions

Problem:

- Transition between targeted profiles – tangent profile to sharp curve high rail profile
- Demand in spiral often higher/different than full body but treat for average from PTS – PST
- First 200' tangent past spiral point has damage higher than rest of tangent – closer to curve demand

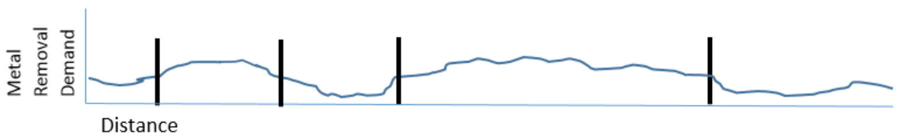
Solution:

- Create transition templates
- Create separate grind segment
- Spirals less than 300' ground by specialty grinder
- Full body profile starts prior to consistent flange contact
- Requires accurate location

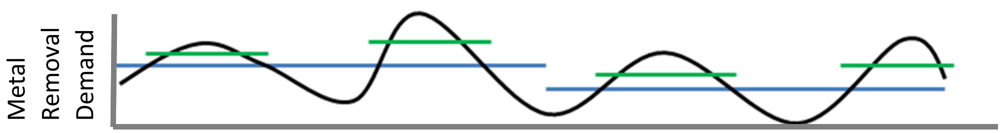
RESULTS: More closely match demand = rail life extension

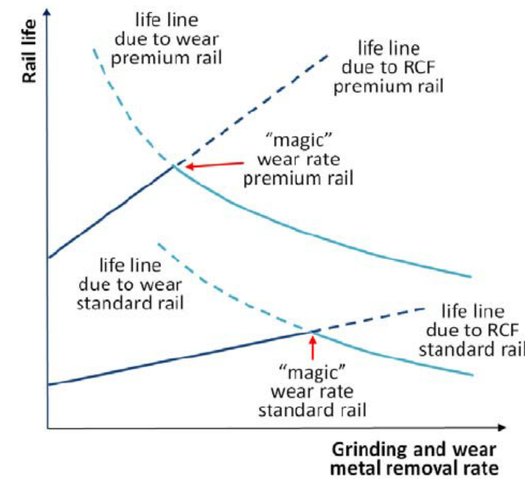
Benefits: Closer to Optimal Rail Life

- **Dynamic Track Segmentation** – creates segments based on similar demand after inspection.



- **Complementary Grind Plans** – Allows detailed work on shorter segments to meet demand variation and maximize equipment productivity.





Different locations have different demands / Magic Wear Rates (optimal balance of grind without overgrinding)

Summary: More Precise Operations

Planning Future State

Frequency

Network => Scheduling Segments: Track lengths with common railcar tonnage, broken by route intersections or territory boundaries

CSX: 400+ scheduling segments

PREDICTIVE

+

Metal Removal per Cycle

Subdivision/Prefix => **Dynamic Demand Driven Segmentation**: each track is divided by areas with similar demand (profile and surface variation)

Complementary Grind Plans

MORE CLOSELY MATCH DEMAND

Future of Metal Removal

Goal: Maximize rail life -> Achieve "Magic Wear Rate"

- **Level of detail - capture RCF & profiles meter by meter**
- **RSQI industry accepted for predictive grinding**
- **PQI correlated to rail life extension & use predicted wear**
- **Group common demand -> right-size equipment to work load -> work load leveling based on equipment capabilities**
- **Economic modeling for optimization**