Moving Toward Predictive Grinding

Presentation:

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Collaborators:

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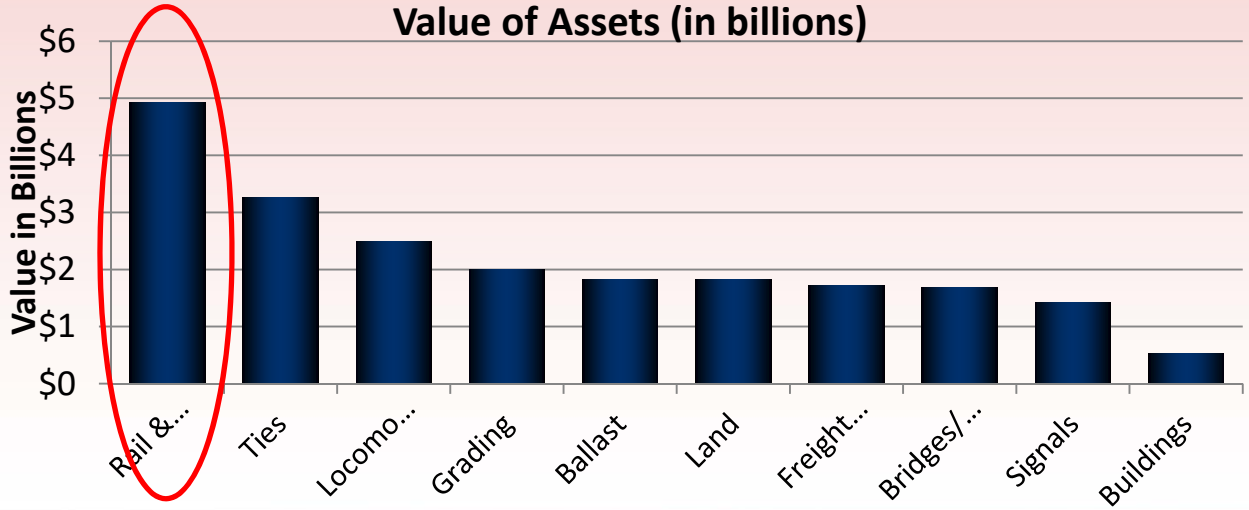
It is essential to protect our most valuable asset

- Rail Grinding is an effective maintenance practice to control the effects of rolling contact fatigue, restore profile and maximize value from the rail asset.



Why we grind

	Profile Correction	Surface Conditions

Benefits:	Optimize Point of Contact
	▪ Less rail wear
	▪ Less rail fatigue
	▪ Prolongs rail life
	▪ Less fuel
	  ▪ Reduced vertical loads
	  ▪ Less vibration
	  ▪ Improved curving of wheel sets
		Minimize Risk
		▪ Allows ultrasonic testing to see internal defects
		▪ Reduces vertical and lateral forces
		▪ Reduces track surfacing cycles (CAT)
		▪ Reduces rail fatigue defects (TD & SD Defects)
		▪ Reduces Rail Service Failures
		▪ Minimizes Derailments

Rail Grinding Planning

Current State

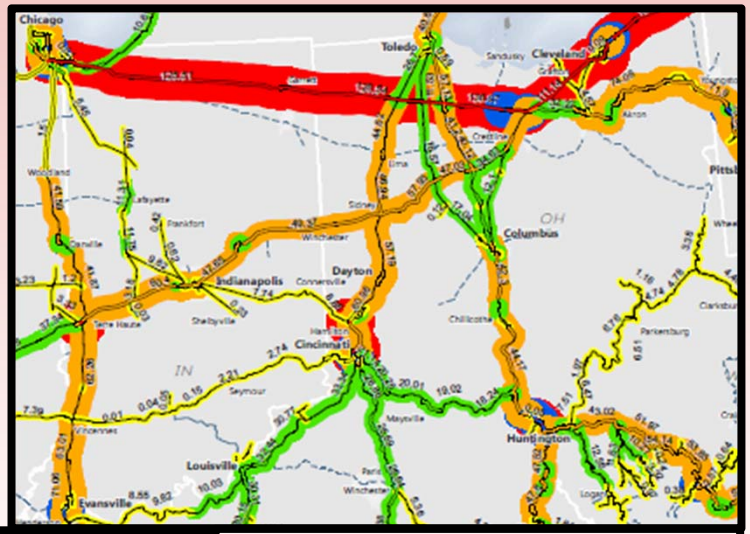
Frequency	+	Metal Removal per Cycle
Network => Scheduling Segments: Track lengths with common railcar tonnage, broken by route intersections or territory boundaries		Subdivision/Prefix => track grinding Segments: each track is divided by boundaries such as mileposts, curve points, or change in prefix
CSX: 400+ scheduling segments		CSX: 57,000 grinding track segments

Frequency Determination

- Frequency target given per scheduling segment
  - Tonnage and Curvature
    - 25-35 MGT Curves
    - 50-75 MGT Tangent
  - Preventative (single pass) vs. Corrective (multiple passes)
  - Route Criticality (Passenger, Hazmat)
  - Surface Defects (Rail testing data) dictate increased frequency

Meeting the Target Frequency

- Routing to obtain target frequency
  - Rail bound equipment
  - 2 rail grinding teams
- Routing Optimization Model
  - Obtain target freq, min travel



RG414 – 120 Stones **RGS9 – 24 Stones** **RG403 – 120 Stones** **RGS6 – 24 Stones**	**2016 RG Production:** **Pass Miles: 17,009** **Track Miles: 14,402**	**2016 RGS Production:** **Pass Miles: 3,119** **Units: 23,419**

Rail Grinding Planning

Pre-Grind Inspection - Current State:

Profile Templates

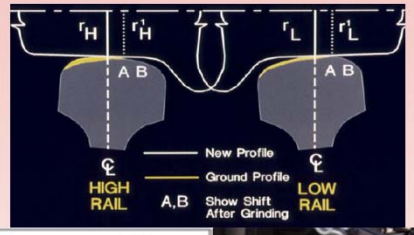
Measured Profile  Surface Condition

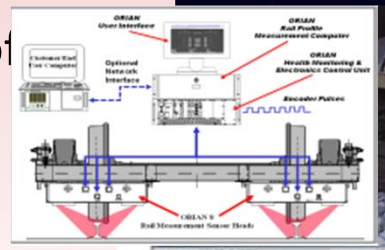
Automated: KLD ORIAN8
Profiles collection every 10’ – 25’

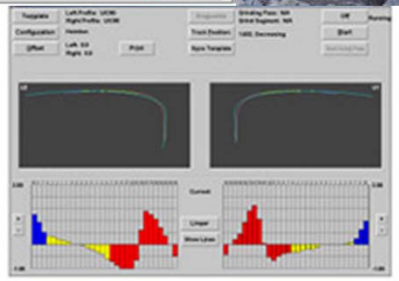
Manual Enhanced: KLD Railscope
Observation entered for
track grind segment

Pre-grind Inspection

- Grinding amount and where on the rail head is determined for each rail by track segment
  - What is the DESIRED RAIL PROFILE post grind?
    - CSX Templates (match common wheel prof
  - What is the CURRENT RAIL PROFILE?
    - Rail Inspection Vehicle equipped with KLD Labs ORIAN 8 (Optical Rail Inspection and ANalysis)
  - Software automatically applies template to current profile







Pre-Grind Inspection

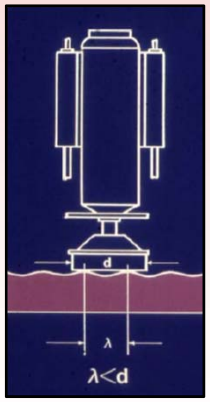
- What is the CURRENT SURFACE CONDITION?
  - RIV uses the KLD Labs Railscope
  - Operator reviews images and MANUALLY inputs defects observed per segment
  - RCF: Light, Moderate, Severe
  - Software applies depth of template application
    (surface crack removal or surface defect removal)

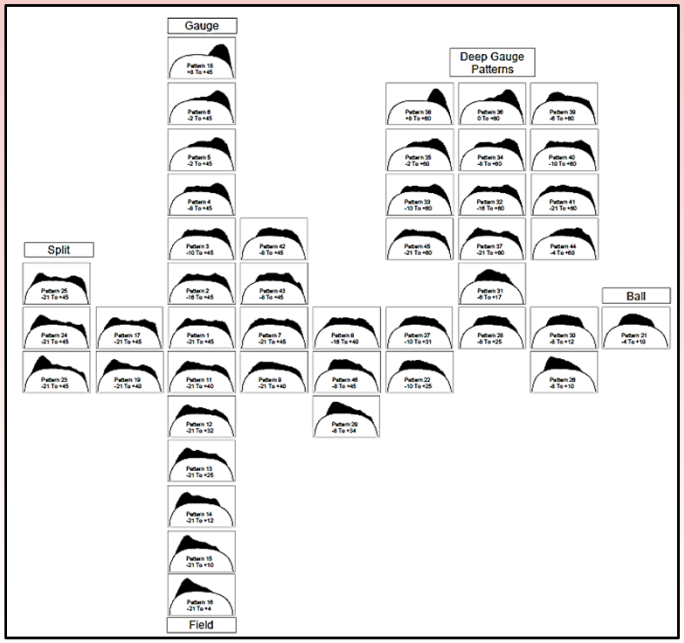
Table 2 – Standard Minimum and Conditional Depths of Cut

Condition	Rail	Depth of Cut
Minimum Depth		
	High	0.006"
	Low	0.006"
	Tangent	0.006"
Conditional Depth		
Spall – Very Light	All	0.002"
Spall –Light	All	0.006"
Spall – Moderate	All	0.012"
Spall – Severe	All	0.024"
Checking – Light	All	0.002"
Checking – Moderate	All	0.010"
Checking – Severe	All	0.020"

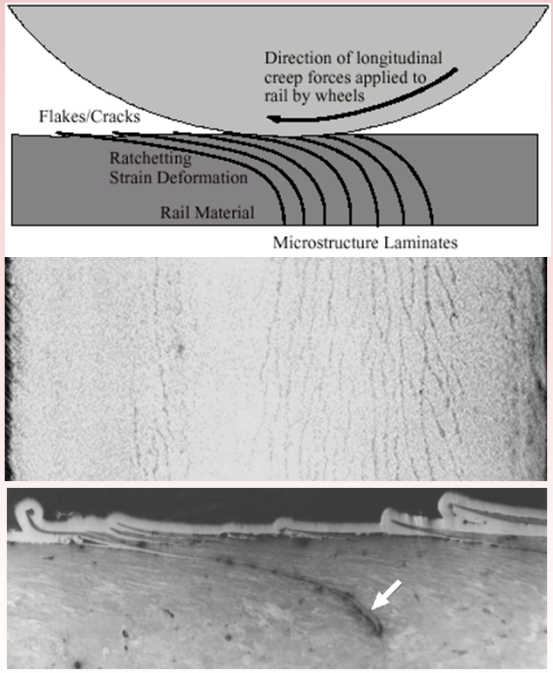
Equipment Grind Plan

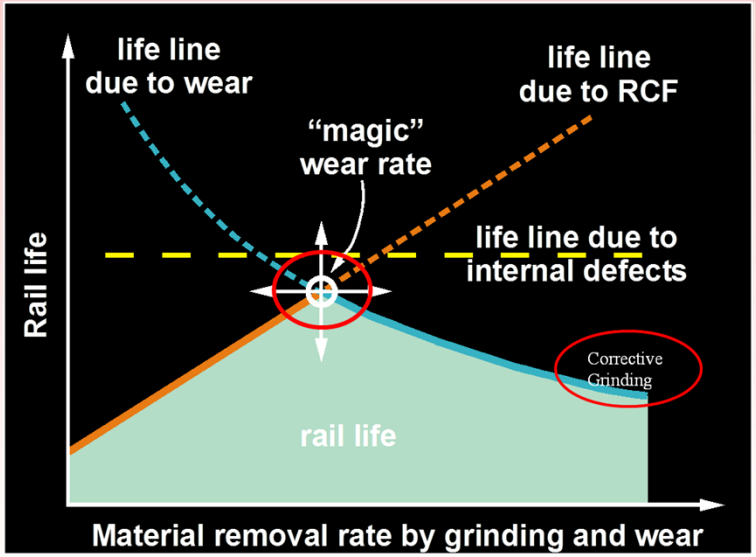
- How will we obtain the desired metal removal?
  - Grind pattern selection
  - Speed and downward pressure
  - Number of passes





Issue: Rolling Contact Fatigue - RCF



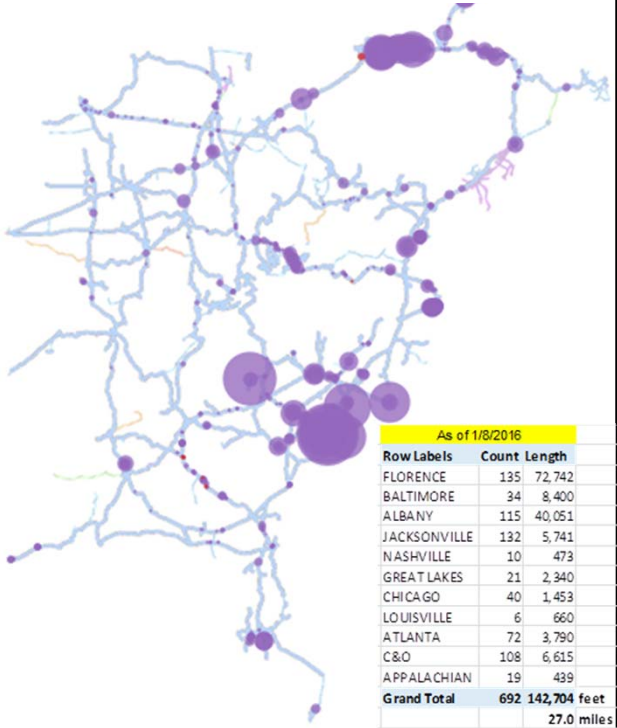


Incipient Cracks Fully Grown Cracks

Issue: Surface Condition Interference

SSC/SDZ Defects – Lagging Indicator

JANUARY 8, 2016



As of 1/8/2016

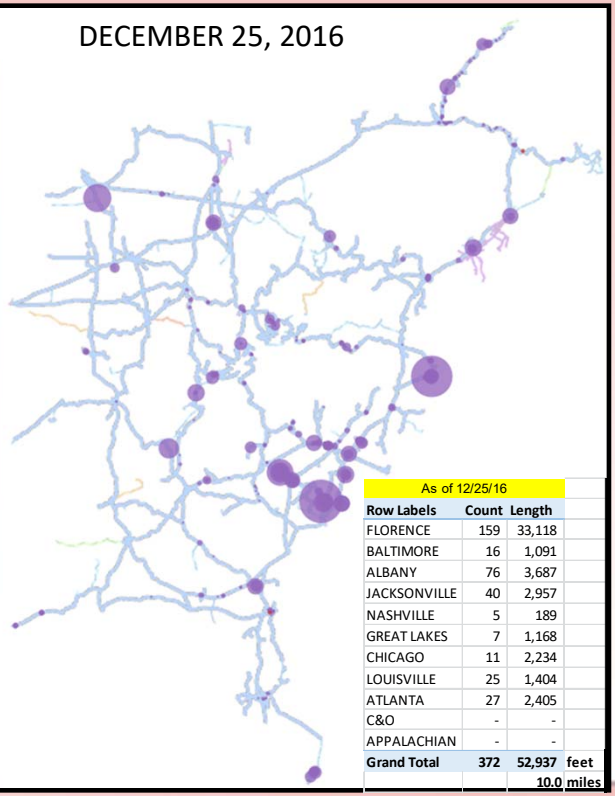
Row Labels	Count	Length	
FLORENCE	135	72,742	
BALTIMORE	34	8,400	
ALBANY	115	40,051	
JACKSONVILLE	132	5,741	
NASHVILLE	10	473	
GREAT LAKES	21	2,340	
CHICAGO	40	1,453	
LOUISVILLE	6	660	
ATLANTA	72	3,790	
C&O	108	6,615	
APPALACHIAN	19	439	
Grand Total	**692**	**142,704**	feet
		27.0	miles

*Defect **Count** reduced by **47%**

*Defect **Length** reduced by **66%** (**17 miles less**)

*Less SSC defects on core routes

DECEMBER 25, 2016



As of 12/25/16

Row Labels	Count	Length	
FLORENCE	159	33,118	
BALTIMORE	16	1,091	
ALBANY	76	3,687	
JACKSONVILLE	40	2,957	
NASHVILLE	5	189	
GREAT LAKES	7	1,168	
CHICAGO	11	2,234	
LOUISVILLE	25	1,404	
ATLANTA	27	2,405	
C&O	-	-	
APPALACHIAN	-	-	
Grand Total	**372**	**52,937**	feet
		10.0	miles

Rail Grinding Planning

Pre-Grind Inspection - Future State:

Profile Templates

Measured Profile

Automated: KLD ORIAN8
Profiles collection every 1’

PREDICTIVE

Surface Condition

Automated
Industry accepted scoring (SQI)
Collected & stored every meter
Collection rate up to 30mph

Methodology for developing Predictive Grinding for surface

Goal: Develop condition based Predictive Grinding program

1. Enable suppliers to use a standard scoring system industry wide (0-7 in severity), or ability to convert data to same scores.
2. Determine how many MGT it takes to go from score to score.
3. Determine when action is needed based on scoring.

Data Alignment

1. **Enable suppliers to use a standard scoring system industry wide**
   - Collecting and aligning data from multiple suppliers on test sites on the Jesup and Fitzgerald, so that machine vision systems, eddy current, magnetic induction, or other systems all can generate the same scoring.
   - Testing various degrees of curvature and tangent

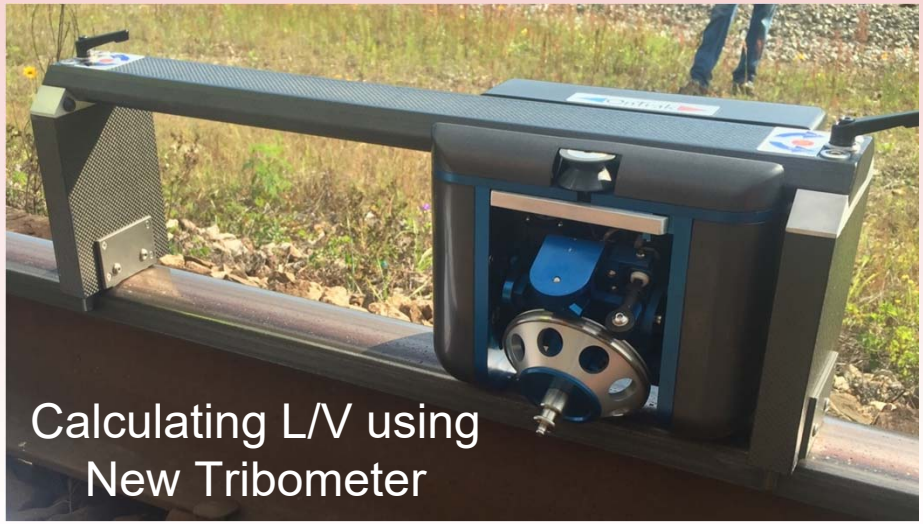
Surface Condition Scoring

Surface Quality Index (SQI) with corrective actions

Category	Description
0	None
1	barely perceptible, but clearly regular pattern (preventive grinding < 0.5).
2	clear, distinct individual cracks - but no pitting at tip (maintenance, depth < 1.0 mm)
3	clear cracking, pits up to 4 mm diam (corrective grinding 1.0-2.5 mm deep)
4	pitting greater than 4mm < 10 mm (preventive gradual, up to 3.5 mm deep)
5	isolated pitting/shelling/spalling > 10, diam (up to 5 mm deep)
6	Shelling/spalling: regular pitting, >10mm diam (busted, near impossible to catch up on)
7	Shelling/spalling: any defect > 16 mm diam, >20mm length

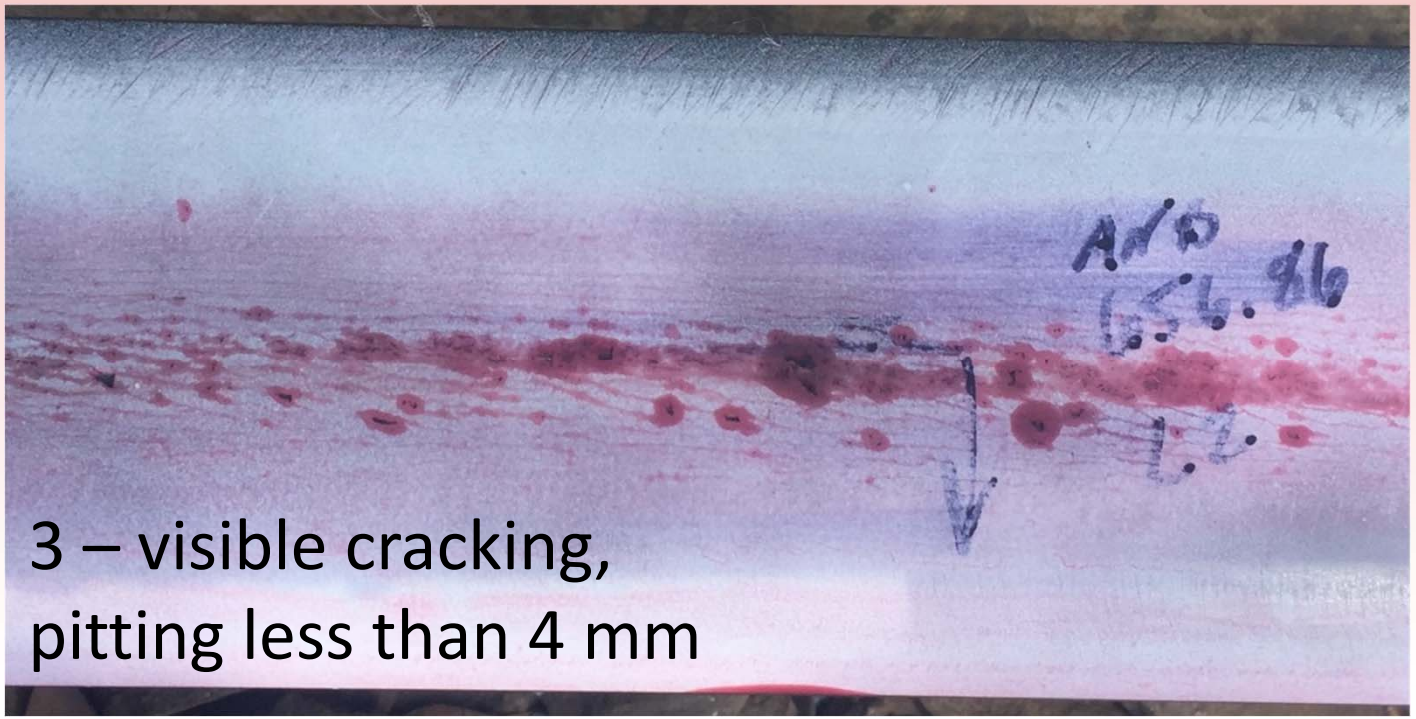
Surface Condition (RCF) Study

Jesup and Fitzgerald Subdivisons



Subdivision \ Lubricator Units	Top of Rail	Gauge Face
Fitzgerald	YES	YES
Jesup	NO	YES

RCF Data Alignment Study

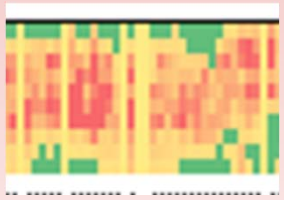


RCF Data Alignment Study

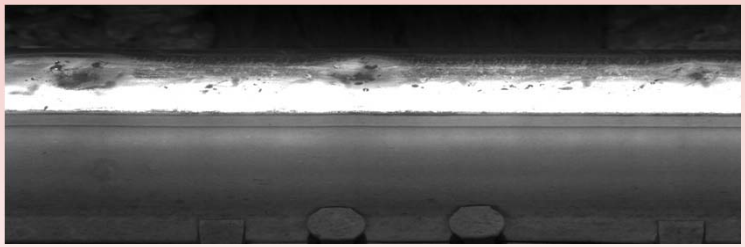
2 – clearly visible cracks, no pitting

RCF Data Alignment Study

Different technologies = different aspects of the surface condition



SSCs have deep cracking in center bands



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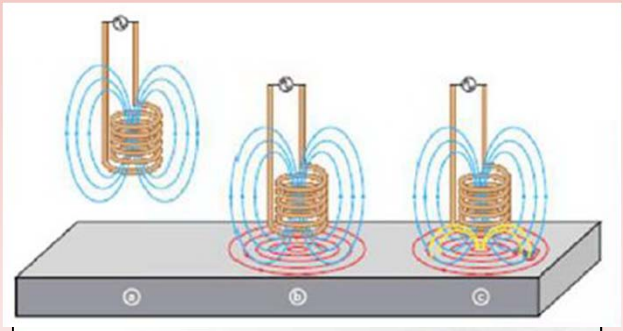
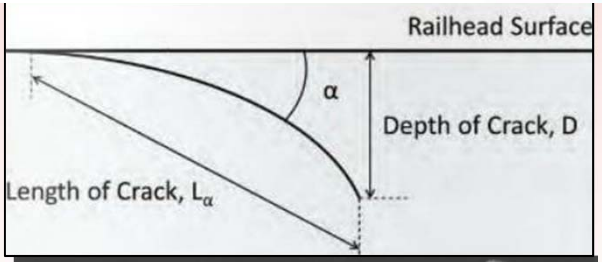
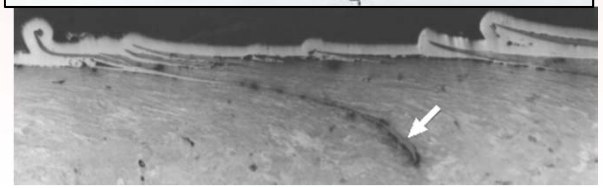
Eddy Current Technology

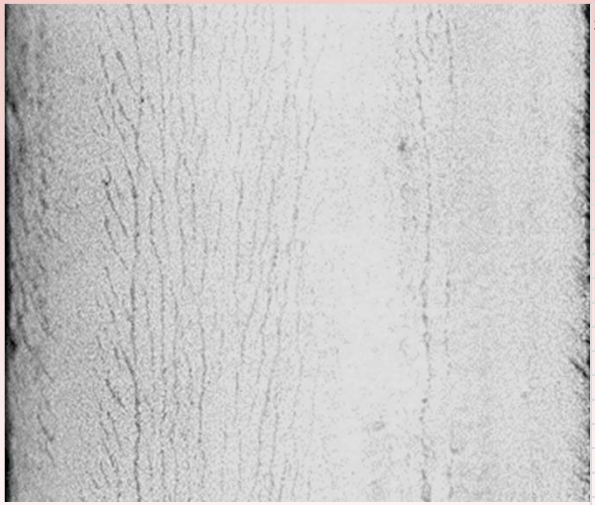


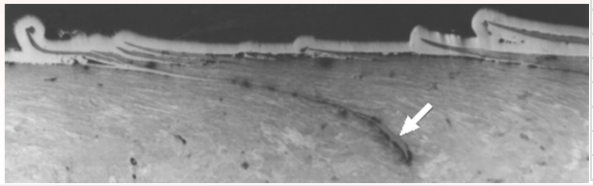




a) Alternating current flowing through a coil generates a magnetic field around the coil
b) Placing the coil close to conductive material, an eddy current is induced in the material
c) A flaw will disturb the eddy current circulation, and through magnetic coupling with the probe defect length can be determined

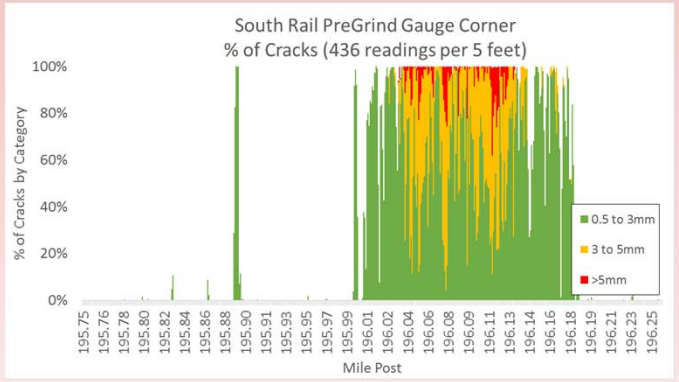
Eddy Current Data
Surface Condition Scoring

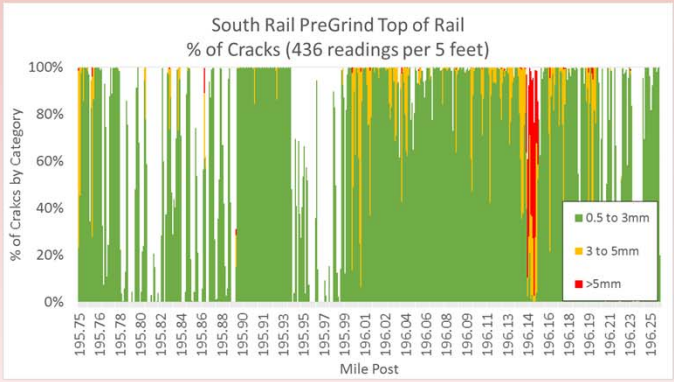


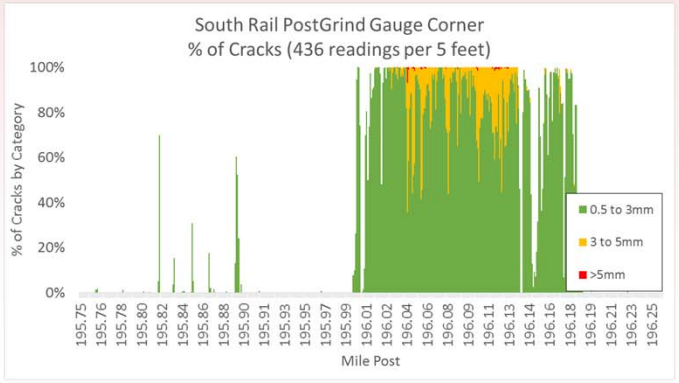


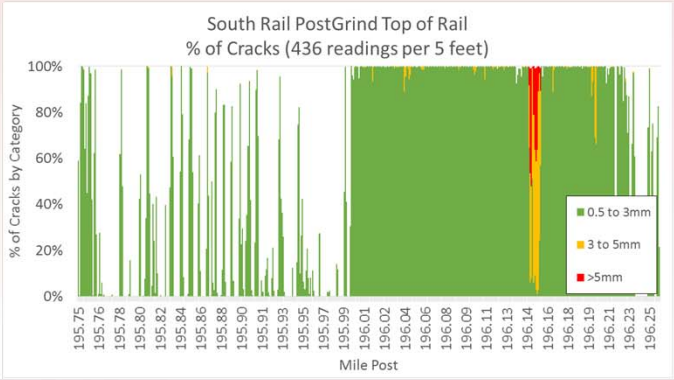
Sev_MaxCrack_Txt	Max Depth	DC_0	DC_1	DC_2	DC_3	DC_4	DC_5	DC_6	DC_7	DC_8	DC_9	Feet
Heavy	2.5	1.1	2.4	2.5	0.8	0.5	0.5	0	2.2	0.4	0.5	2.6
All	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3.2
Severe	3.6	1.4	1.4	3.6	3.5	0.7	0.8	0	0	0	0	3.7
Severe	4.2	1.3	1.7	2.1	2.7	0.8	1.1	0.6	4.2	1	0.7	4.2
Heavy	2.9	2.9	1.7	1.5	1.8	0.5	1.1	0.4	0	0	0	4.8
Moderate	1.1	0.6	0.7	0.8	0.8	0	1.1	0.4	0	0	0	5.3
Light	0.5	0	0	0	0	0	0	0	0.5	0	0	5.8
Severe	5	1.4	1.4	5	5	2.4	1.1	0.6	0	0	0	17.4
Severe	5	1.3	3.1	5	5	4.2	1.7	0.7	1	0.7	0.5	18.0
Severe	5	0.7	1.4	4.6	5	0.9	0.5	0	0	0	0	18.5
Heavy	3	1.4	1.6	3	3	0.7	0	0	0	0	0	19.0
Heavy	2	1	1.6	2	1.6	0	0.6	0	0	0	0	19.5
Severe	3.3	3.3	3.2	1.5	1.2	0	0.6	0.5	0	0.4	0.4	20.6
Heavy	1.6	1.6	1.5	0	0.6	0.5	0.7	0	0.4	0	0	21.1
Moderate	0.7	0	0	0	0	0	0.7	0	0	0	0	21.6
Heavy	2.2	2.2	1.2	1.5	0.9	0	0.4	0	0	0	0	62.3
Light	0	0	0	0	0	0	0	0	0	0	0	62.8
Heavy	3	3	2.6	2.3	1.7	0	0	0	0	0	0	70.2
Moderate	1.5	1.5	0.8	1.1	0.8	0.5	0.8	0	0.6	0.8	0.5	70.8
Moderate	1.5	0	0	0	0	0	1.5	0	0	0	0	71.3
Moderate	0.6	0	0.5	0.6	0.6	0	0.6	0	0	0	0	109.3
Moderate	0.8	0.4	0.5	0.5	0.8	0	0	0	0	0	0	109.8
Severe	5	3.7	3.3	5	5	2.5	2.8	0.6	0	0	0	169.5
Severe	5	2.6	3.7	5	5	2.2	0.9	0	0	0	0	170.0
Severe	3.3	0.4	0.6	2.6	3.3	2.8	2.1	0	0	0	0	170.5
Severe	5	2.6	1.2	4.6	5	3.9	3.2	0.6	0	0	0	171.1

Eddy Current: Pre-Grind / Post-Grind







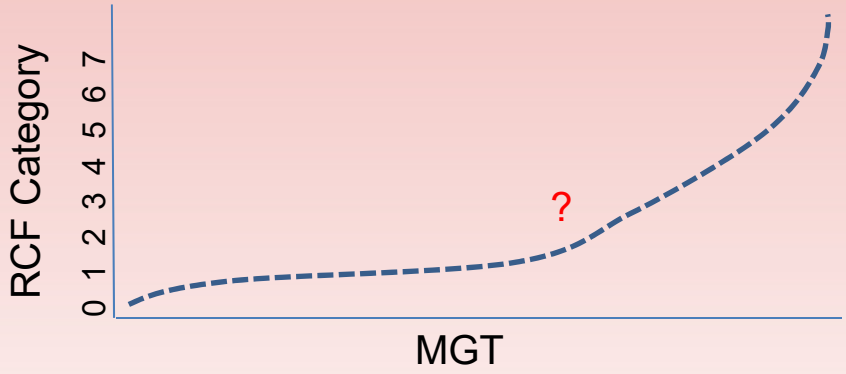


Surface Condition Lifecycle Study

2. **Determine how many MGT it takes to go from score to score.**

   – Collect eddy current data on the 119 continuous test loop to track and analyze surface condition growth on many types of curves, rails, and tonnage conditions along the 1,000 mile loop.

RCF Lifecycle Study



Category	Description	MGT
0	None	?
1	barely perceptible, but clearly regular pattern (preventive grinding < 0.5).	
2	clear, distinct individual cracks - but no pitting at tip (maintenance, depth < 1.0 mm)	
3	clear cracking, pits up to 4 mm diam (corrective grinding 1.0-2.5 mm deep)	
4	pitting greater than 4mm < 10 mm (preventive gradual, up to 3.5 mm deep)	
5	isolated pitting/shelling/spalling > 10, diam (up to 5 mm deep)	
6	Shelling/spalling: regular pitting, >10mm diam (busted, near impossible to catch up on)	
7	Shelling/spalling: any defect > 16 mm diam, >20mm length	

Big Data Analysis – Establishing Correlations

3. **Determine when and what action is needed based on the surface condition score.**
   - Analyze defect data with the eddy current data to correlate scoring and defects.
   - Set grind frequencies and amount of metal removal per visit to prevent an SSC or TDD from developing.

Addressing surface issues

1. Obtain foot by foot surface condition scoring (SQI), instead of whole curve or 1 mile of tangent.
2. Use Dynamic Track Segmentation based on demand
3. Joint Operations Complementary Grind Plans
   a. Use foot by foot scoring to develop an RGS grind plan that targets smaller segments needing additional work after the full track segment is ground by the production grinder.
4. Work with suppliers to develop road deployable small grinder/milling machine for mid-grind-cycle short segments that develop and interfere with ultrasonic testing

Rail Grinding Planning

Future State

Frequency

+

Metal Removal per Cycle

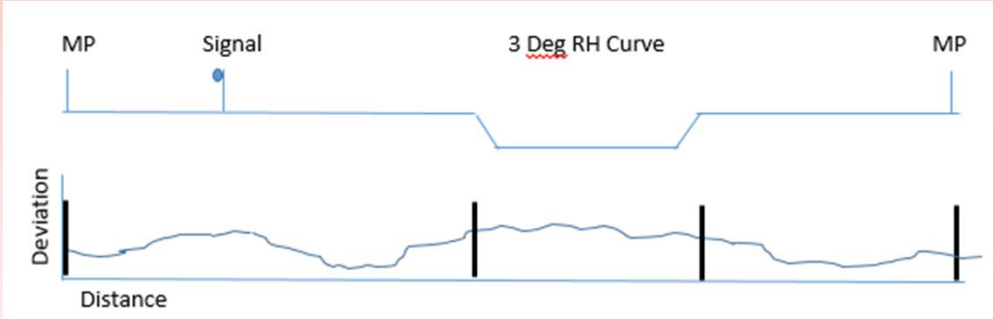
Network => Scheduling Segments: Track lengths with common railcar tonnage, broken by route intersections or territory boundaries

CSX: 400+ scheduling segments

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

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.

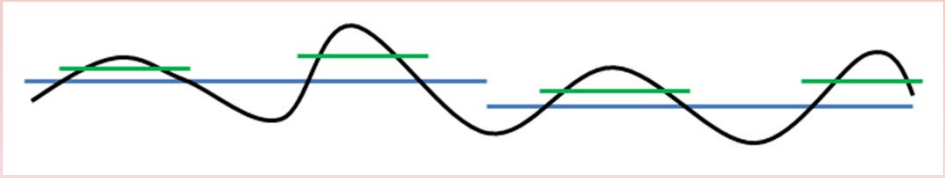
= More grinding where needed, and less where not needed

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)

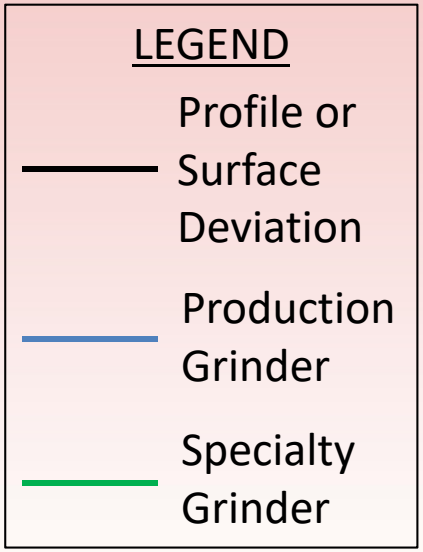
Complementary Grind Plans

- Cycle 1



- Cycle 2 when Cycle 1 *without* Specialty Grinder

- Cycle 2 when Cycle 1 *with* Specialty Grinder

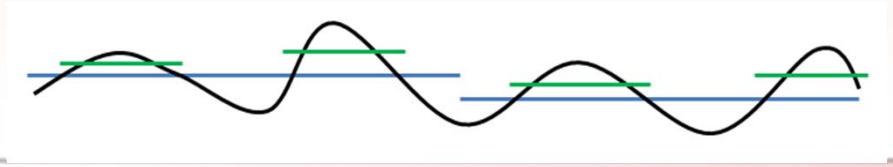


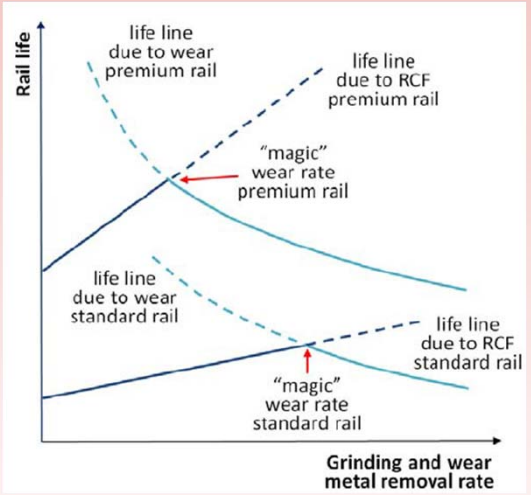
- RESULTS: More closely match demand = rail life extension by minimizing grinding wear and surface initiated defects

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)

Rail Grinding Planning

Pre-Grind Inspection - Future State:

Profile Templates

PREDICTIVE

Measured Profile

Automated
Profiles collection every 1’
Outputs PQI & wear points

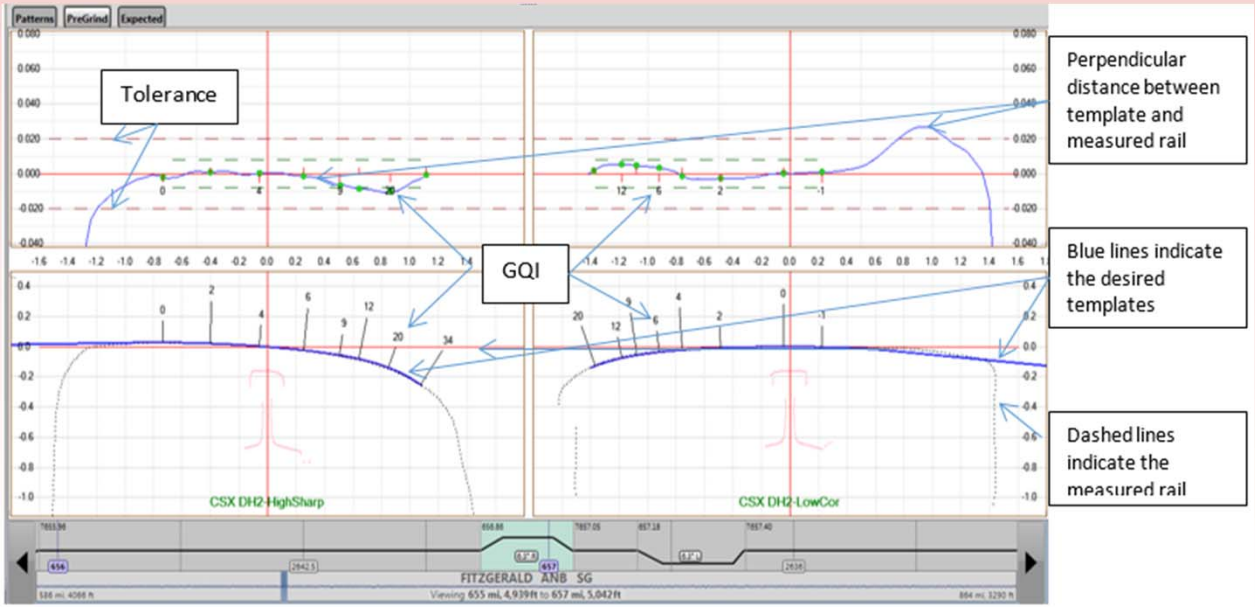
+ Surface Condition

Automated
Industry accepted scoring (SQI)
Collected & stored every meter
Collection rate up to 30mph

Grind Quality Index (GQI)

Profile Quality Index (PQI):

- Score accounts for variation outside of the tolerance.
- Good measure vs. template
- Cannot be used as a predictive measure



Grind Quality Index (GQI)

Profile Quality Index (PQI):

- Accurate profile prediction would allow grinding so the predicted wear brings 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

Summary: Capturing Demand

Pre-Grind Inspection - Future State:

Profile Templates

PREDICTIVE

Measured Profile

Automated
Profiles collection every 1’
Outputs GQI & wear points

PREDICTIVE

Surface Condition

Automated
Industry accepted scoring
Collected & stored every meter
Collection rate up to 30mph

Summary: More Precise Operations

Planning Future State

MORE CLOSELY MATCH DEMAND

Frequency

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

CSX: 400+ scheduling segments

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

Moving Toward Predictive Grinding

QUESTIONS?

Presentation:

Daniel Hampton – CSX Transportation

Collaborators:

Eric Magel – CNRC

Robert Harris – Loram (retired)