

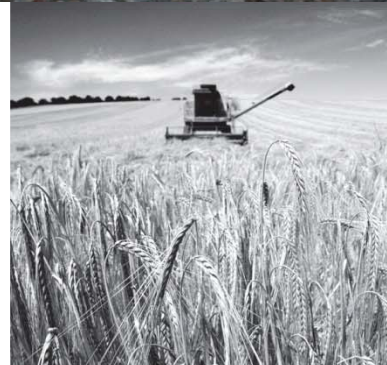


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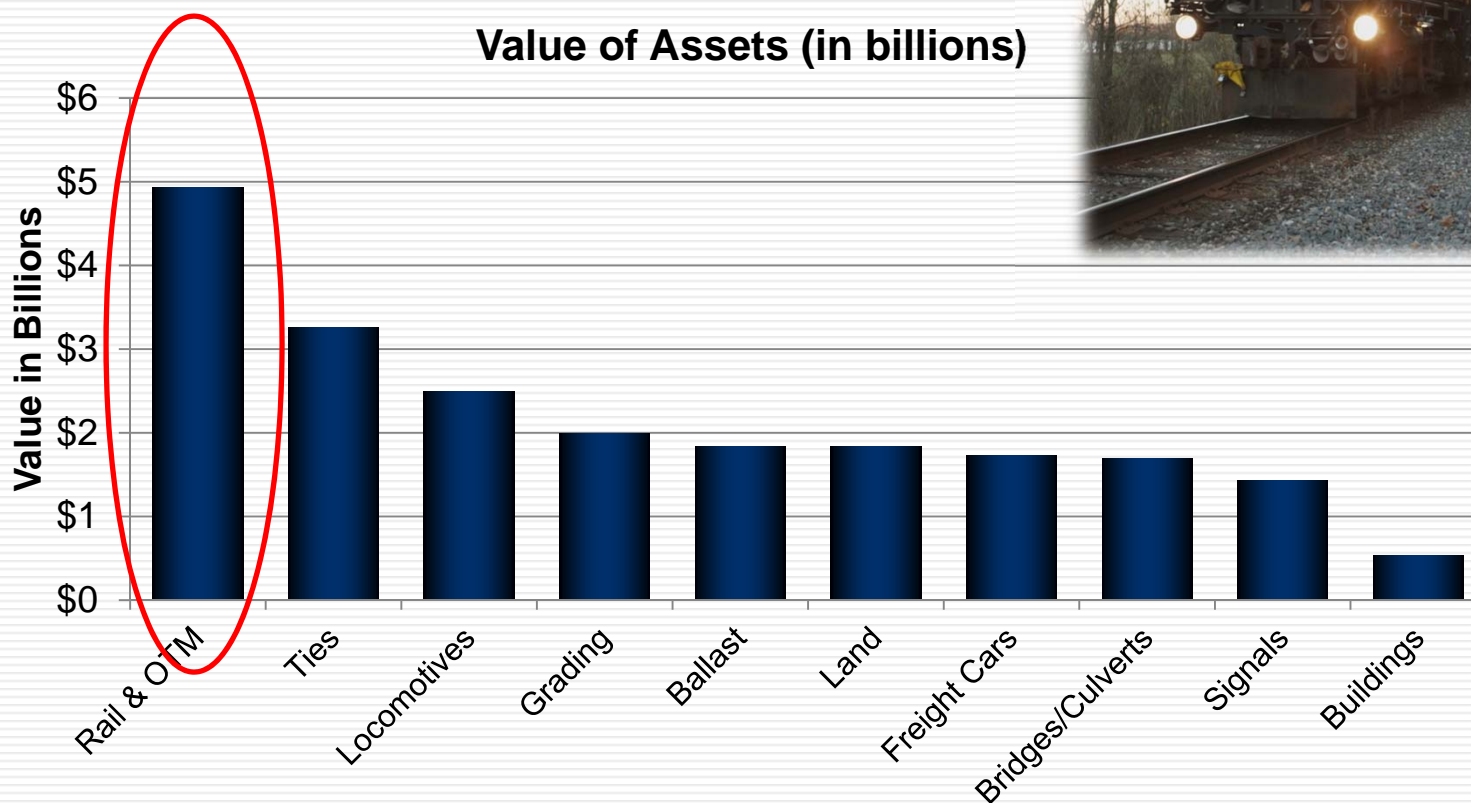


Moving CSX to a Predictive Grinding Program

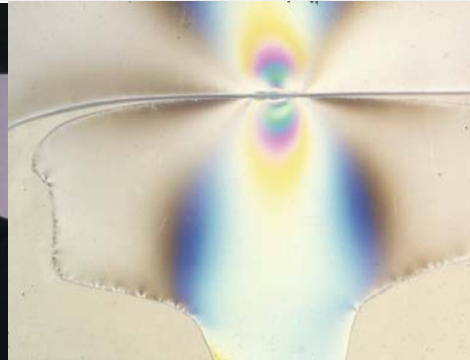
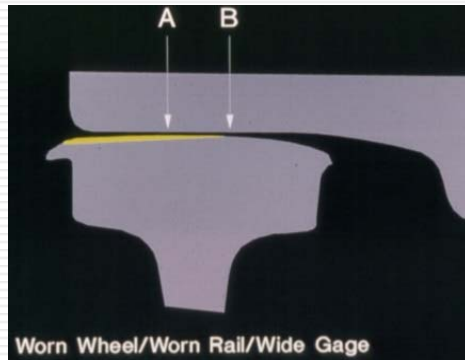


It is essential to protect our most valuable asset

“The single most effective maintenance practice to control the effects of rolling contact fatigue, restore profile and maximize value from the rail asset.”



Rail Grinding



Why Grind?	Profile Correction	Surface Conditions
Benefits:	Optimize Point of Contact <ul style="list-style-type: none"> ▪ Less rail wear ▪ Less rail fatigue ▪ Prolongs rail life ▪ Less fuel <ul style="list-style-type: none"> ▪ Reduced vertical loads ▪ Less vibration ▪ Improved curving of wheel sets 	Minimize Risk <ul style="list-style-type: none"> ▪ 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

A closer look, before and after...

Before



After



Grinding Prevents Defects

CSX – SELKIRK S/D

M.P. QG28.3 – LEFT RAIL (H)

TRACK #2

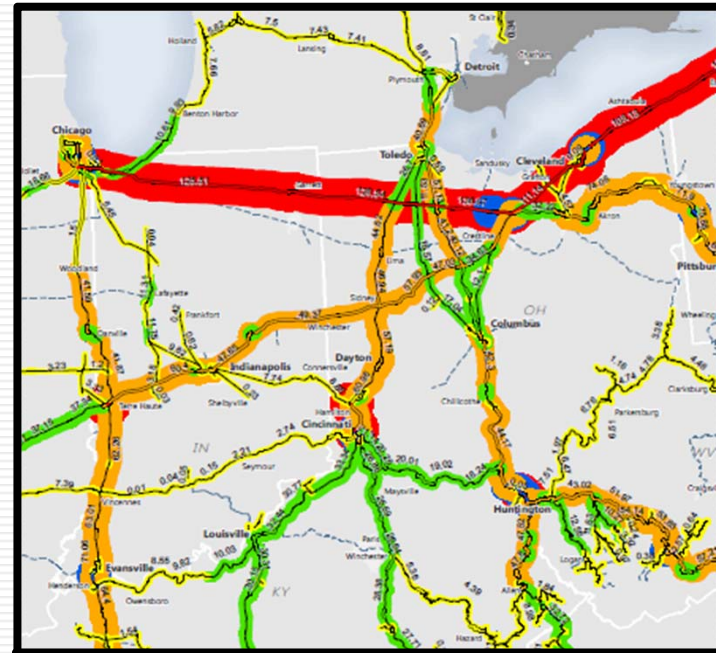
RAIL SERVICE FAILURE – 09/17/2014



Rail Grinding Frequency Determination

– Current State

- Frequency target is determined by subdivision/route
 - Tonnage and Curvature
 - 30 MGT Curves
 - 50 MGT Tangent
 - Preventative (single pass) vs. Corrective (multiple passes)
 - Route Criticality (Passenger, Hazmat)
 - Surface Defects (Rail testing data) dictate increased frequency
- Routing to obtain target frequency
 - Rail bound equipment



2 production grinders & 2 specialty grinders in 2015:

RG318 – 88 Stones

RGS9 – 24 Stones

RG403 – 116 Stones

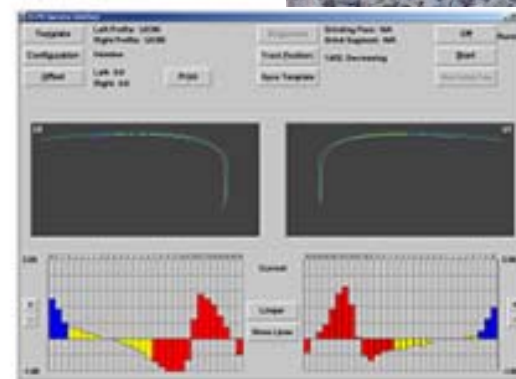
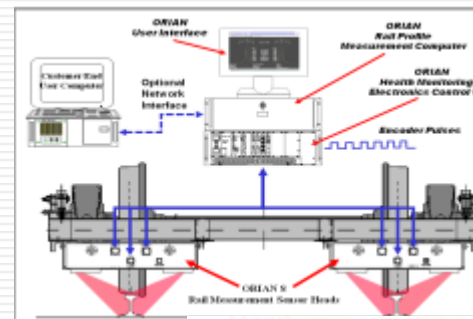
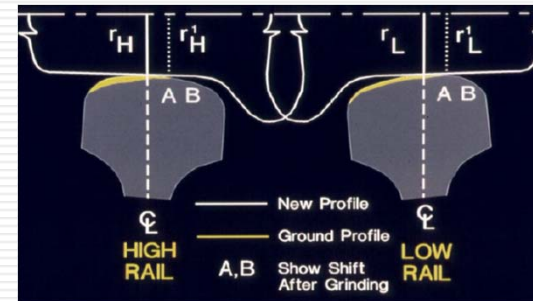
RGS6 – 24 Stones

Pass Miles: 15,990

Track Miles: 13,294

Rail Grind Plan per Cycle – Current State

- Grinding amount determined for each rail by track segment*
 - What is the DESIRED RAIL PROFILE post grind?
 - CSX Templates (match common wheel profile)
 - 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



Rail Grind Plan per Cycle – Current State

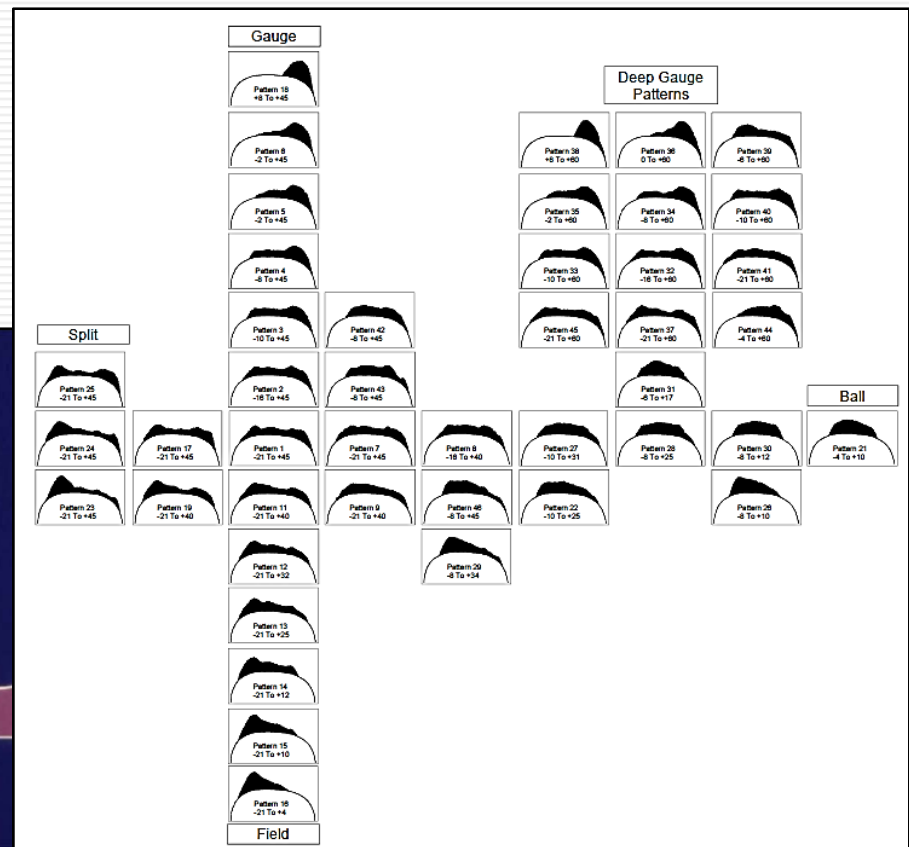
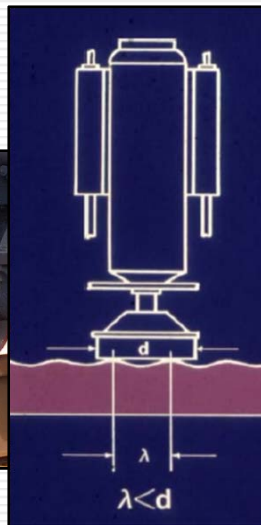
- What is the CURRENT SURFACE CONDITION?
 - RIV uses the KLD Labs Railscope
 - Operator reviews images and MANUALLY inputs defects observed per segment
 - RCF: Light, Moderate, Severe
 - Software applies depth of template application (surface crack removal or surface defect removal)

Table 2 – Standard Minimum and Conditional Depths of Cut

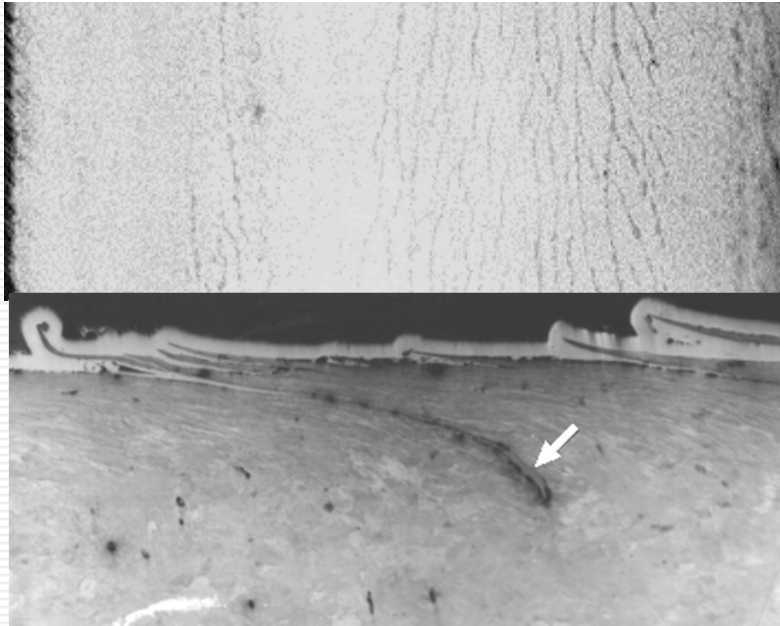
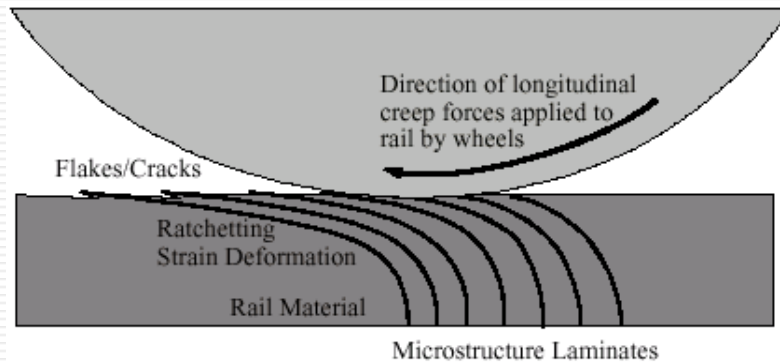
Condition	Rail	Depth of Cut
<i>Minimum Depth</i>		
	High	0.006"
	Low	0.006"
	Tangent	0.006"
<i>Conditional Depth</i>		
Spall – Very Light	All	0.002"
Spall – Light	All	0.006"
Spall – Moderate	All	0.012"
Spall – Severe	All	0.024"
Checking – Light	All	0.002"
Checking – Moderate	All	0.010"
Checking – Severe	All	0.020"
Corrugation - Moderate	All	0.012"
Corrugation - Severe	All	0.020"
Shell	All	0.000"
Wheel Burns	All	0.005"
Welds	All	0.010"
New	All	0.000"
Crushed Heads	All	0.010"

Rail Grind Plan per Cycle – Current State

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



Rolling Contact Fatigue - RCF



Incipient Cracks



Fully Grown Cracks

Example of insufficient grinding cycles



Example of insufficient grinding cycles (cont.)



Methodology for developing Predictive Grinding

Goal: Develop condition based Predictive Grinding program

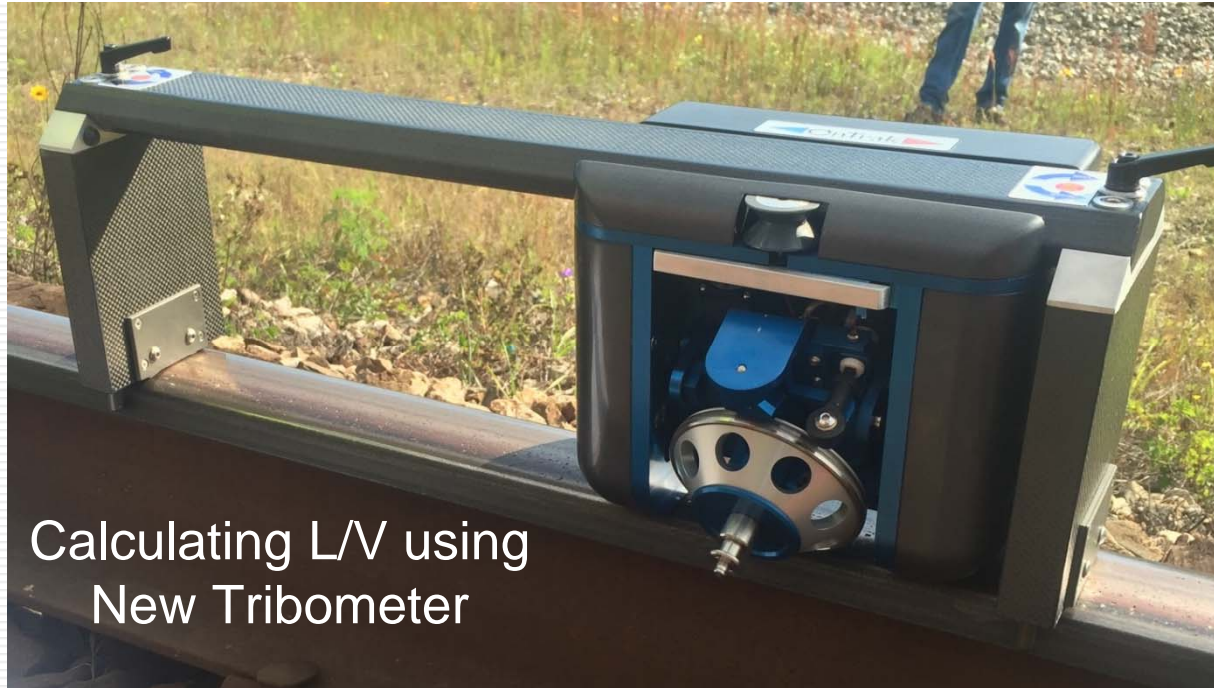
1. Enable suppliers to use a standard scoring system industry wide (0-7 in severity), or ability to convert data to same scores.
2. Determine how many MGT it takes to go from score to score.
3. Determine when action is needed based on scoring.

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, or other systems all can generate the same scoring.
- Testing various degrees of curvature and tangent

RCF Data Alignment Study – Jesup & Fitzgerald



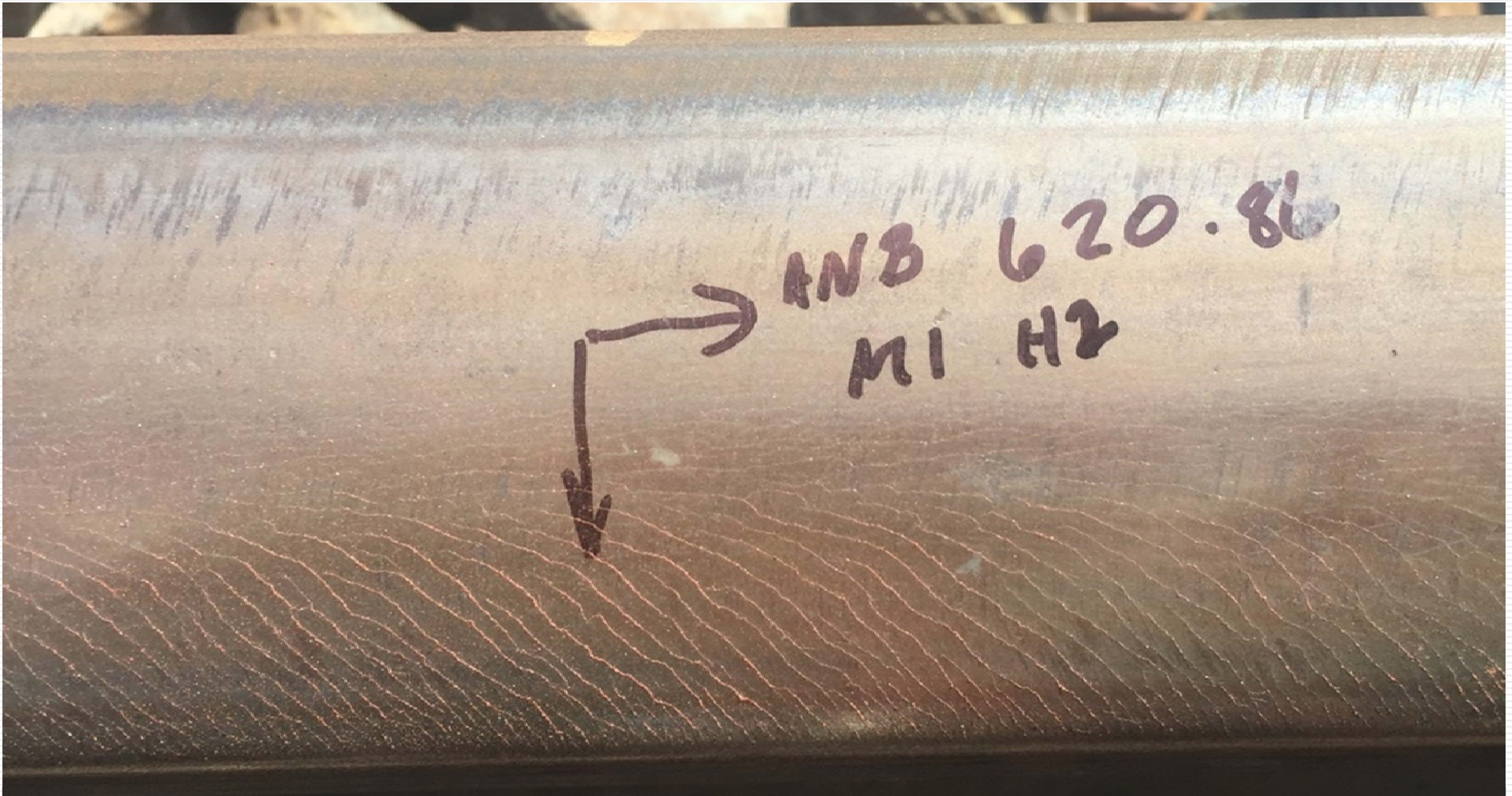
Calculating L/V using
New Tribometer

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

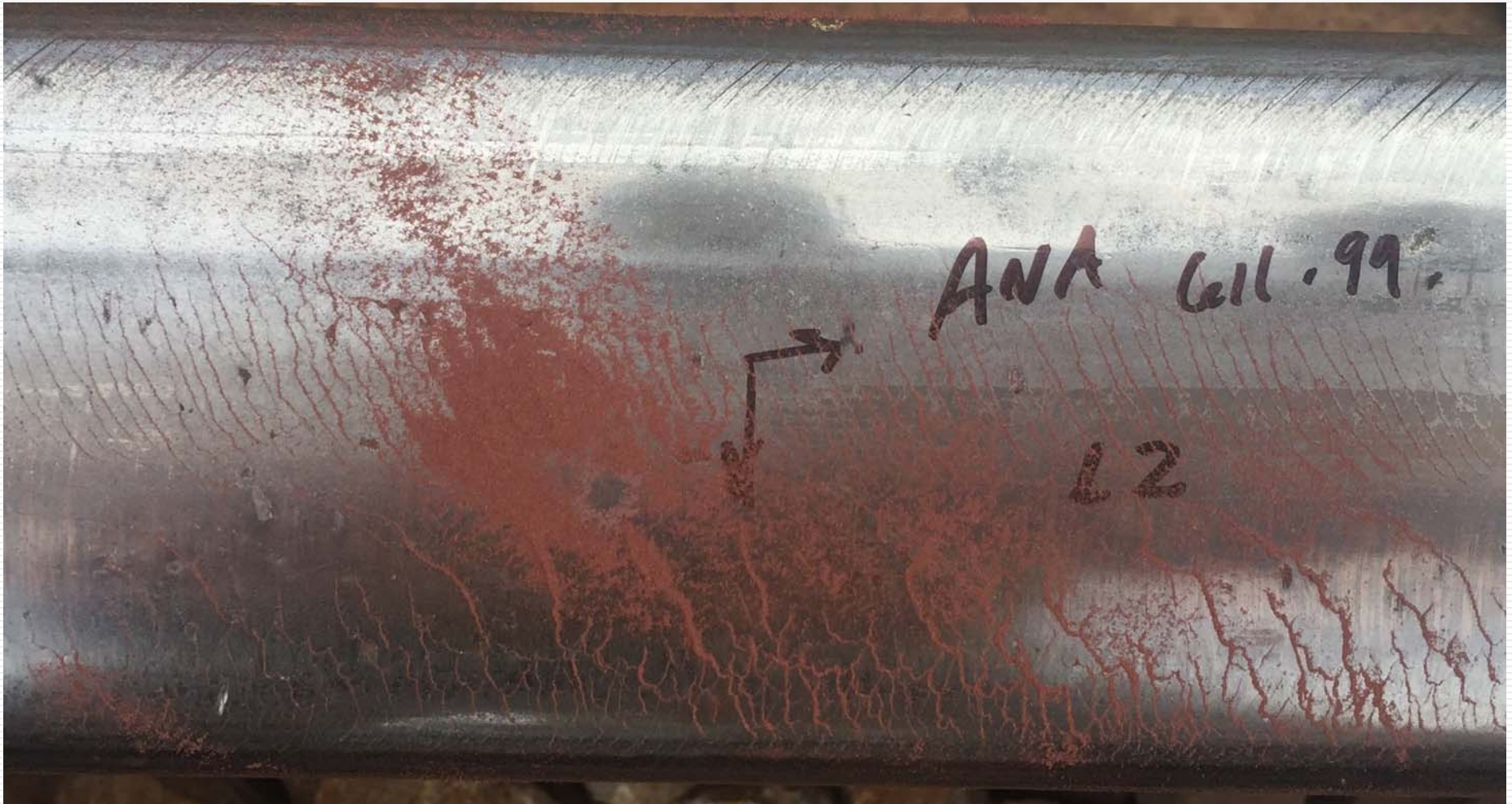
RCF Data Alignment Study – Jesup & Fitzgerald



RCF Data Alignment Study – Jesup & Fitzgerald



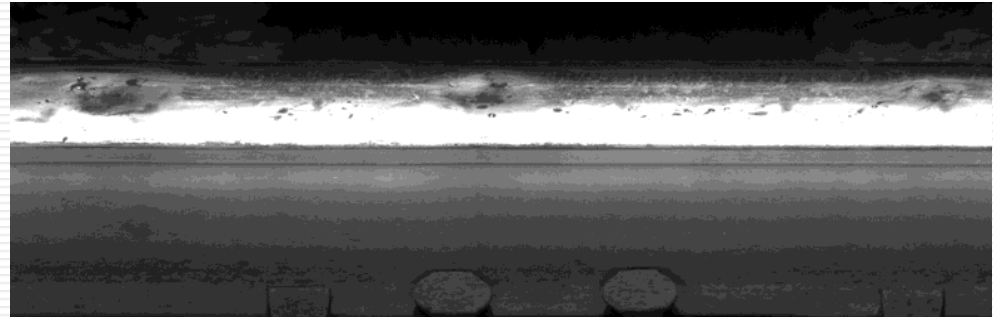
RCF Data Alignment Study – Jesup & Fitzgerald



Different collection methods may provide different aspects of the surface conditions

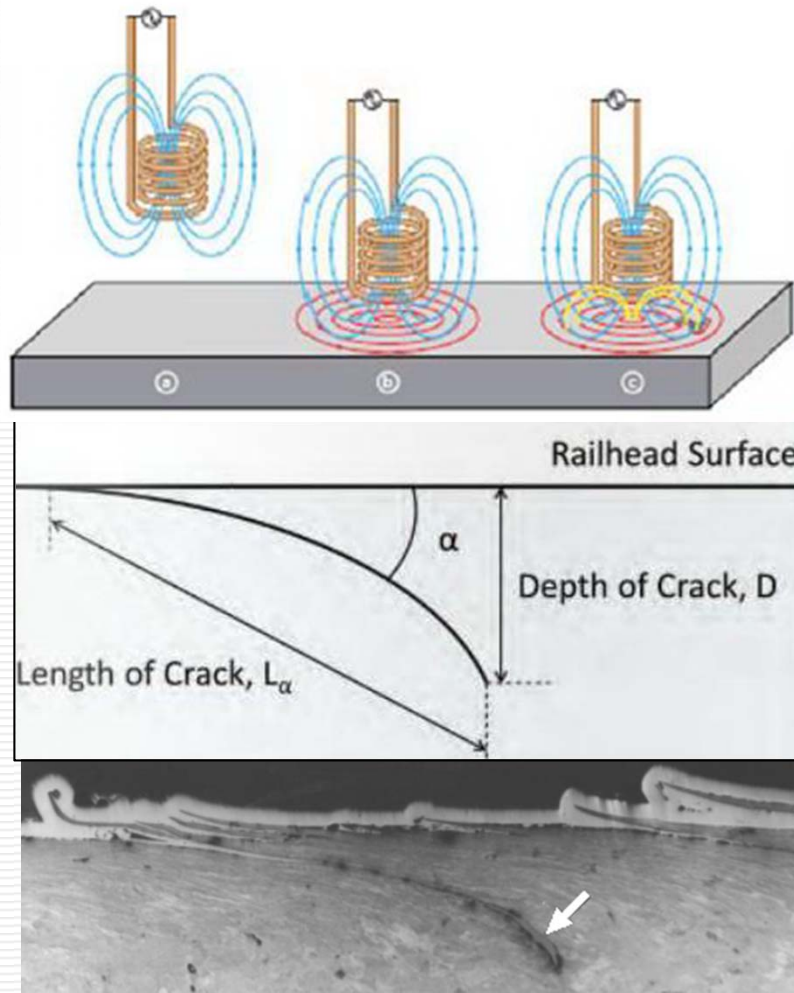


SSCs have
deep cracking
in center bands



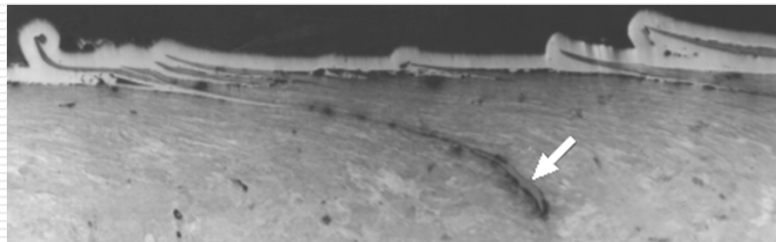
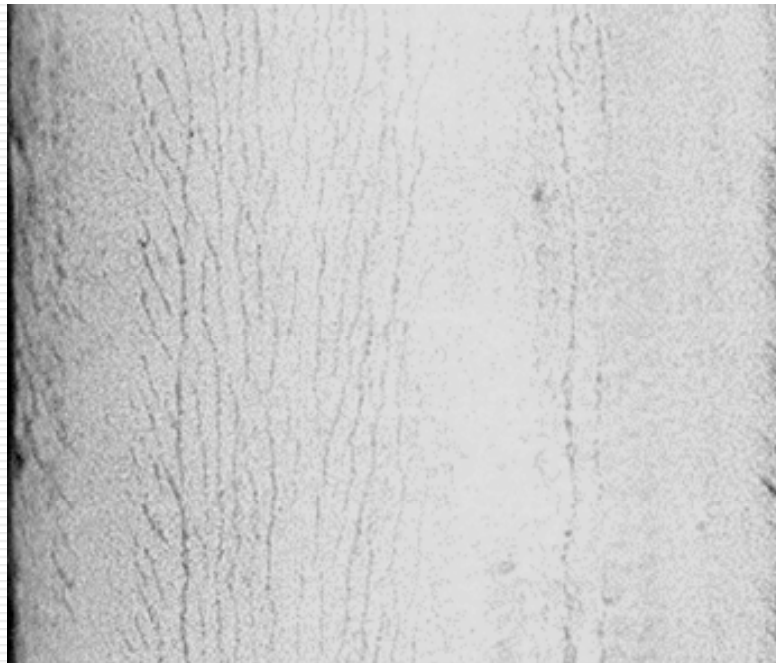
Category	Description
0	None
1	barely perceptible, but clearly regular pattern (preventive grinding < 0.5).
2	clear, distinct individual cracks - but no pitting at tip (maintenance, depth < 1.0 mm)
3	clear cracking, pits up to 4 mm diam (corrective grinding 1.0-2.5 mm deep)
4	pitting greater than 4mm < 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

Eddy Current Technology



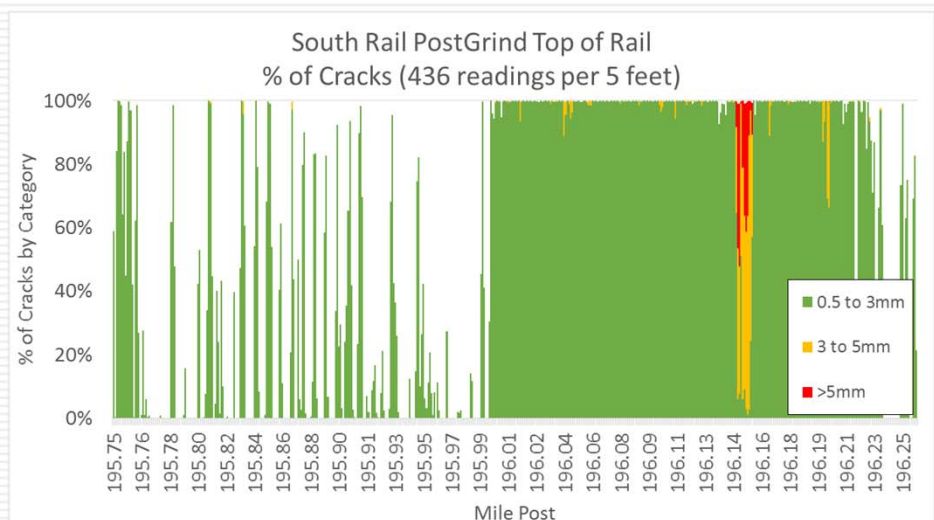
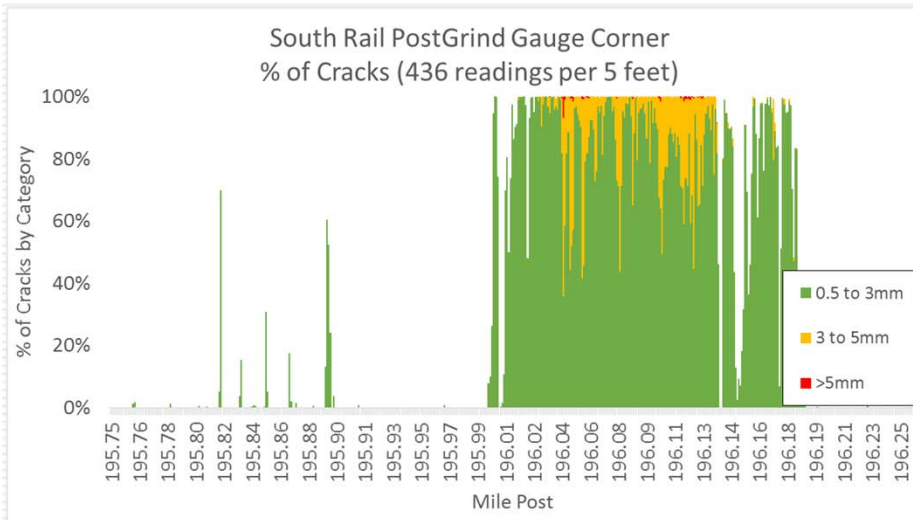
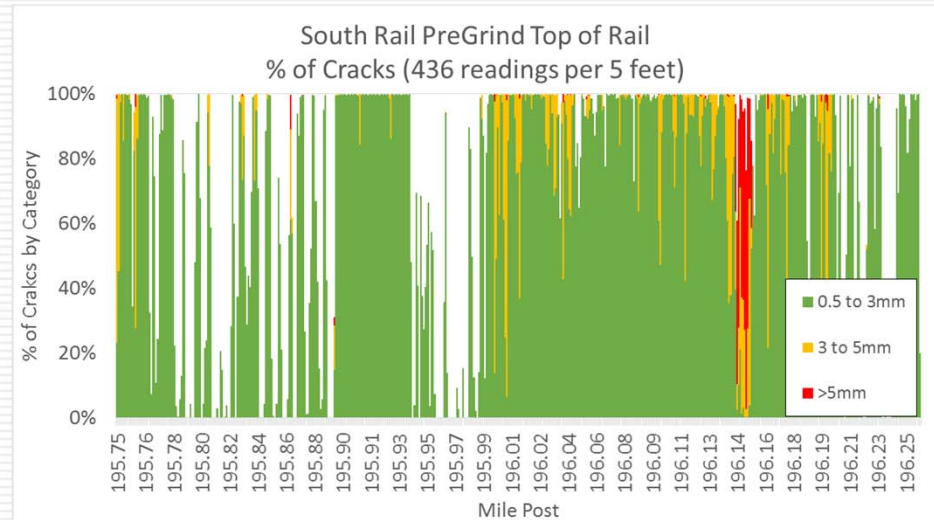
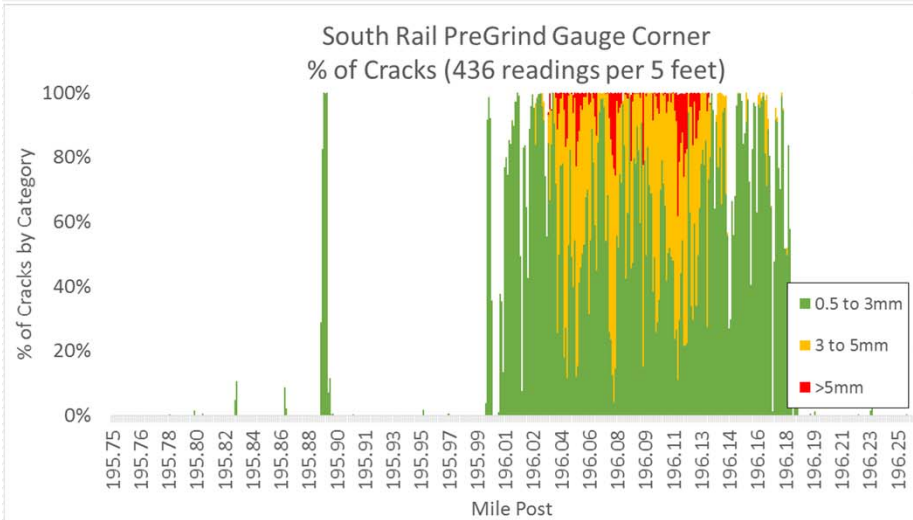
- a) Alternating current flowing through a coil generates a magnetic field around the coil
- b) Placing the coil close to conductive material, an eddy current is induced in the material
- c) A flaw will disturb the eddy current circulation, and through magnetic coupling with the probe defect length can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

Eddy Current Data – Surface Condition Scoring



Sev_MaxC rack_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

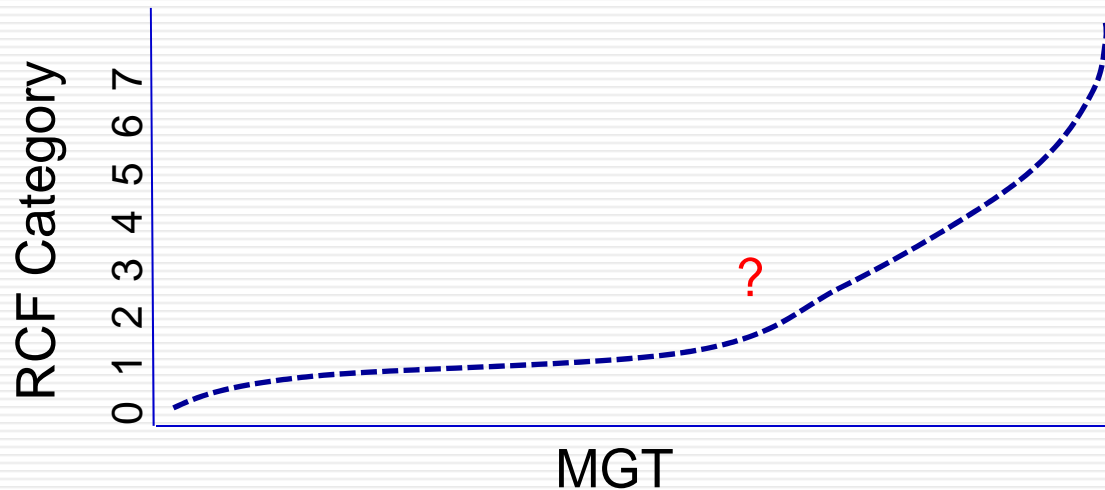
Eddy Current: Pre-Grind and Post-Grind



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 – 1,000 mile Continuous Test Loop, data every 25 days



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.

Related initiatives to address surface issues

1. Obtain foot by foot surface condition scoring, instead of whole curve or 1 mile of tangent.
2. Joint Ops 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.
3. Work with suppliers to develop road deployable small grinder for short segments that develop and interfere with ultrasonic testing
 - a. Small rail grinding drone to follow the ultrasonic testing vehicle and grind surface conditions as needed. These would be deployed on routes where we cannot reach the desired grind frequency due to routing, or when needed between grind cycles.

Current, Near, and Future States

Grind Frequency			
	Current	Near	Future
Input level	Subdivision/ Route	Track segment	Meter by meter
Inputs	Tonnage, curvature, criticality	Tonnage, curvature, rail weight, rail age, criticality	Rail Profile rate of degradation calculated at track segment level (GQI rate of change). Surface condition scoring aggregated to track segment level and a Surface Quality Index (SQI) calculated.
Output Level	Subdivision/ Route	Subdivision (curve vs. tangent)	Track segment

Current, Near, and Future States

Grind Plan				
		Current	Near	Future
Profile	Input level	Foot by Foot	"	"
	Data Collection	Automated and stored	"	"
	Output Level	Track segment	"	Track segment for RG and shorter demand driven lengths for additional work by RGS
Surface	Input level	Track segment	"	Meter by Meter
	Data Collection	Visual and manually input	"	Automated
	Output Level	Track segment	"	Track segment for RG and shorter demand driven lengths for additional work by RGS

Current SSC initiatives

- Improve location accuracy and visual marking by UT suppliers – Reduce search time, avoid missing or grinding wrong spot
- Automate sending surface defect data every 24 hrs to Loram which would then be pushed to the grinders nightly
- Ensure compliance - Loram to develop a GIS based SSC tracking system using daily grind history.



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