

ICRI-Safety – an International Collaborative Research Project

Use of Premium Rail Steels An International Survey

Presentation made by:

Automotive and Surface Transportation
National Research Council (NRC) Canada

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Workflow

Background

- Premium rail steels generally provide reduction in wear and RCF occurrence at an incremental added cost (as compared to softer rail grades)
- Yet, softer rail steels are still utilized worldwide

Objectives

- Gain better understanding of premium rail steel use around the world
 - Establish conditions under which premium rail steels are most suitable, and where their use is not recommended
- Once an adequate number of responses is received from the railroads establish trends in observed results

Premium Rail Survey – Layout

Process Description

- Survey international railroads
 - Use of rail grades in field operations and selection criteria
 - General overview for each railroad

Survey

- Fill out the following survey information:
 - Name and affiliation
 - Information on railroad being reported on
 - Type of rail system: light transit, heavy transit, intercity commuter, freight, etc.
 - General types of steel employed – e.g. R260, R350HT, R370CrHT etc.
 - The curvature range or other limits under which each type of rail is installed (e.g. premium metallurgy in all curves sharper than 800 metres, standard steel at all other locations, etc.)

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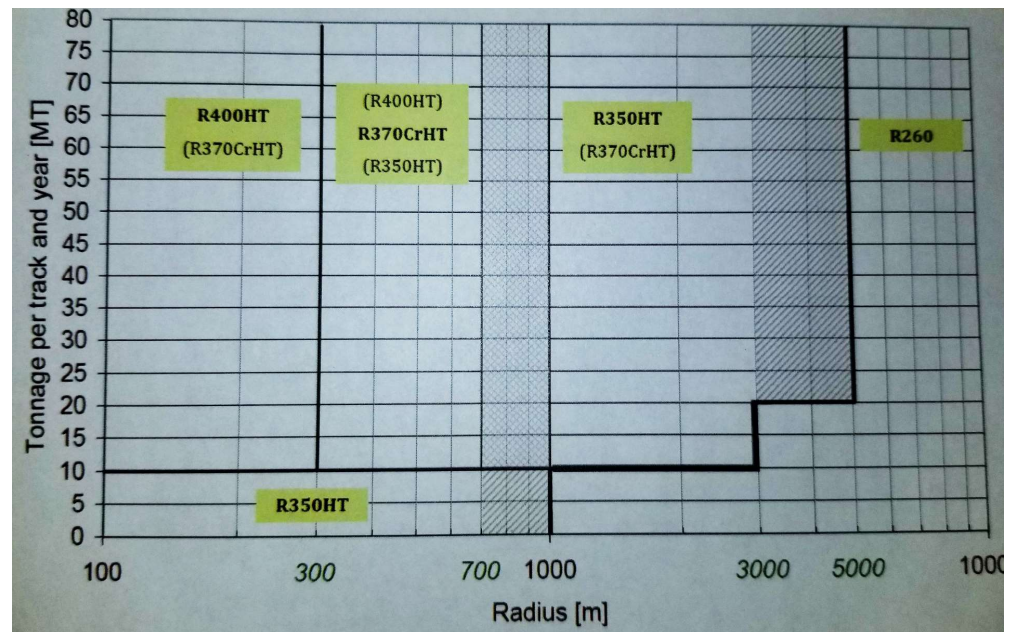
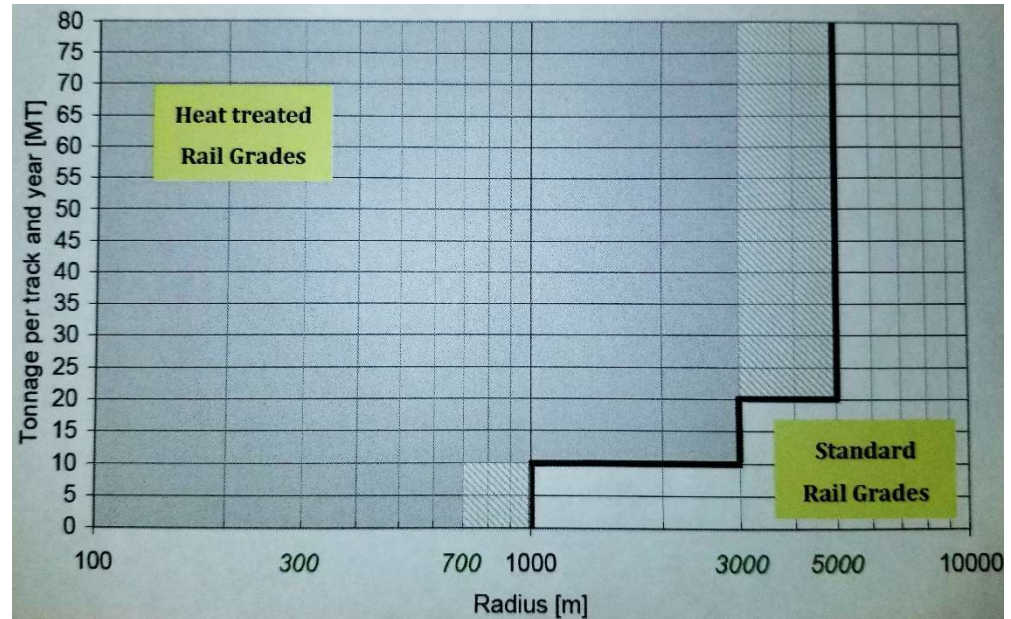
Rails R350HT, R370CrHT, and R400HT

- For tight curves ($R < 300\text{m}$) use R400HT
- For medium curves ($300\text{m} < R < 700\text{m}$) use R370CrHT (when MGT ↓) R400HT (when MGT ↑) followed by R350HT when curvature ↑
- In case of MGT ↑ use of R350HT is also recommended in shallow curves ($3000\text{m} < R < 5000\text{m}$)
- If RCF is negligible:
 - Use R350HT in $R < 700\text{m}$ - 1000m (depending on boundary conditions)
 - Standard rail grade (R260) $R > 700\text{m}$ - 1000m (depending on boundary conditions)
- Detailed mapping of rail selection for specific radii curvature was carried out 10 years ago as part of European project InnoTrack
- Part of this report details rail grade selection based on track curvature and yearly tonnage accumulation

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Rail Grade Selection Criteria

- Heat treated vs. standard grades
- Expected annual tonnage vs. curve radius
- Detailed rail grade selection map
- Expected annual tonnage vs. curve radius



Reference: InnoTrack – Innovative Track Systems, Integrated Project (IP), Project No. TIP5-CT-2006-0314115, 'Definitive guidelines on the use of different rail grades' – INNOTRACK GUIDELINE, Report D4.1.5GL

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Rail Grade Selection Criteria

- Detailed rail grade selection map as a function of track curvature

System			"reference"	"optimized"	Remarks
Description of the track elements, boundary conditions and track condition					
Track elements - Alignment					
curve	radius [m]	<300	R350HT	R400HT (R370CrHT)	Each individual rail grade (possible alternatives in brackets) and radius class of the optimised system can be interpreted as a separate alternative for LCC calculations.
		300 - 700	R260	(R400HT) R370CrHT (350HT)	
		700 - 1500	R260	R350HT	
		1500 - 5000	R260	R350HT (R260)	
		>5000 m	R260	R260	

Reference: InnoTrack – Innovative Track Systems, Integrated Project (IP), Project No. TIP5-CT-2006-0314115, 'Definitive guidelines on the use of different rail grades' – INNOTRACK GUIDELINE, Report D4.1.5GL

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Rails R350HT vs. R260

- In higher curvatures:
 - R350HT offers lower maintenance cost and longer service life due to lower wear rates and RCF (as compared to R260)
- In lower curvatures:
 - No discernable difference between the two
- R350HT has higher notch sensitivity than R260
 - Defects close to running surface increase risk of crack initiation and propagation (squats & studs)
 - Especially true when wear is low
 - Hence the use of R350HT in $R < 300\text{m}$ radius (in higher wear zones). Otherwise shortening grinding intervals would be necessary

China Railway Network

Rail Grade Use

- Standard rail grade (similar to R260) used in high speed passenger lines:
 - $R > 3500\text{m}$ for 250km/h , no RCF reported on running surface
 - $R > 7000\text{m}$ for 350km/h , no RCF reported on running surface
- Da-Qin heavy haul line (440MGT in 2011)
 - 3 curves: $R < 400\text{m}$
 - 15 curves: $400\text{m} < R < 600\text{m}$
 - 250 curves: $600\text{m} < R < 800\text{m}$
 - 36% of curves, 45% of all curve length are in this R range
 - Use of standard grades, Chinese cast PD2, PD3 both with heat treatment (target 330-340HB)
- Metro lines (max 80km/h)
 - PD3 rail without heat treatment. RCF seen on some sharp curves, but not a widespread problem.
 - **rail manufacturers are recommending use of premium rails going forward**

China Railway Network

In table format:

Track type	Rail type	Minimum radius of curvature	Performance	
High speed rails (>200 km/h, passenger dedicated)	U71MnG (very similar to R260)	7000 m for 350 km/h track 3500 m for 250 km/h track	No RCF has been reported up to now, and the wear rate is very low. In a word, very good performance.	According to China railway standard TB/T3276-2011 (Rails for high speed railway)
High speed rails (200-250 km/h, passenger and freight)	U75VG			
Da-Qin Heave haul line (440 MGT in 2011) There are 3 curves with a minimum curve radius of 400 m and 15 curves of radius between 400 m and 600 m. A large number of curves (over 250) have radii between 600 m and 800 m which account for 36% of the total number of curves and 45% of the total curve length.	For loaded-direction line: 75 kg/m (150 lb/yd) rail (mainly PD3 rails (U75V, tensile strength after heat treatment is more than 1,200 MPa, HB341.388), some PD2 rails (equivalent to U78, tensile strength after heat treatment is more than 1,175 MPa, HB 331.401), both of which are cast in China, trans-section jointless track (frozen joint applied for frogs). For empty-direction line: 60 kg/m (120 lb/yd) rail (U71Mn).			According to 09_IHHA_Best_Practice
Metros (max 80 km/h, minimum radius of curvature 300 m)	CN60 rolled rail with U75V (no heat treatment) is usually used. Rail makers are recommending the use of heat treated rail to customers. RCF can be observed at some sharp curves, but not the wide-spread problem, i.e. seems perform reasonably good.			According to our observations.

Hypoeutectoid steel chemistries

钢牌号	化学成分(质量分数) %						
	C	Si	Mn	P	S	V	Al
U71MnG	0.65 ~ 0.75	0.15 ~ 0.58	0.70 ~ 1.20	≤0.025	≤0.025	≤0.030	≤0.004
U75VG	0.71 ~ 0.80	0.50 ~ 0.70	0.75 ~ 1.05	≤0.025	≤0.025	0.04 ~ 0.08	≤0.004

表 4 残留元素上限

钢牌号	化学成分(质量分数) %									
	Cr	Mo	Ni	Cu	Sn	Sb	Ti	Nb	Cu + 10Sn	Cr + Mo + Ni + Cu
U71MnG	0.15	0.02	0.10	0.15	0.030	0.020	0.025	0.01	0.35	0.35
U75VG										

Mechanical properties similar to R260 and AREMA standard rail grades

钢牌号	抗拉强度 R_m MPa	伸长率 A %	轨头顶面中心线硬度 HBW (HBW10/3000)
U71MnG	≥880	≥10	260 ~ 300
U75VG	≥980	≥10	280 ~ 320

注:热锯取样检验时,允许断后伸长率比规定值降低1%(绝对值)。

B.C. Rapid Transit Company - Railway Network

Rail Grade Use

- BCRTC Vancouver (Translink)
- Light transit system
- AREMA standard chemistry rail steels throughout. Running surface hardness 320HB with some locations <320HB
- Some locations with intermediate strength rails (350HB)
- No requirements to install specific steel grades in sharp curves
- Requirement is for 320HB rails in system
- Rails <320HB were installed in system in Phase I of construction
- 350HB rails is being installed in system expansion line

North American Class I Railway Network

‘Standard’, and ‘Premium’ refers to AREMA rail designations:

- Standard rail: min. 320HB running surface hardness
- Premium rail: min. 370HB running surface hardness
- **Placement of rail types is tonnage and curvature dependent**

Annual MGT	Tangent	Curves 0 to 1° 30'	Curves 1° 30' to 2° 30'	Curves 2° 30' and Up
65 MGT & up	New premium 141#	New premium 141#	New premium 141#	New premium 141#
35-65 MGT	New standard 136#	New premium 141#	New premium 141#	New premium 141#
20-35 MGT	New standard 136#	New standard 136#	New premium 141#	New premium 141#
5-20 MGT	New standard 136# or 115#	New standard 136# or 115#	New standard 136# or 115#	New premium 141# or 115#
Less than 5 MGT	New standard 136# or 115#, or SH 112# & heavier	New standard 136# or 115#, or SH 112# & heavier	New standard 136# or 115#, or SH 112# & heavier	New standard 136# or 115#, or SH 112# & heavier

Rail Selection in Brazil (MRS LOGISTICA S.A.)

Rail Grade Use

- 1700km HAL railroad transporting iron ore and general freight
- 160 million net tonnes annual production
- 3 rail lines:
 - **Main Line** – iron ore, 170MGT/yr, 32.5 tonnes/axle
 - **Central Line** – typically empty trains on port-mine route
 - **Sao Paulo Line** – only freight trains with 25 tonnes/axle
- Strategies for rail use are different for each line
- **Main Line:**
 - Only 136RE premium and super-premium, both curves and tangent track, 400HB min hardness
 - Currently testing rails with 450HB head hardness
 - General philosophy: 'harder is better'
 - Line has preventive profile grinding:
 - One subdivision in flat region: 2deg typical curvature, 1% grade, no GF lube or TOR FM
 - Two subdivisions in mountains: sharp curves, 7deg radius, 2,3% grades, GF lube + TOR FM in all curves

Rail Selection in Brazil (MRS LOGISTICA S.A.)

- **Central Line:**

- 136RE intermediate strength rails, 340HB min
- Main drivers for rail planning/purchasing is cash flow and delivery logistics. Many rails come from Europe and Asia
- Line has corrective grinding on typical 2 year cycle:
 - Sharp curves, 7deg radius, 2,3% grades, GF lube but no TOR FM
 - Empty trains = light axle loads

- **Sao Paulo Line:**

- 115RE intermediate strength rails, 340HB min, flat terrain
- Similar rail implementation strategies as for Central Line
- Line has no grinding:
 - Typically 3-4deg radius curves, 0.5% grades
 - 25 tonnes/axle loads
 - No GF lube or TOR FM

Rail Selection in Brazil (MRS LOGISTICA S.A.)

- **Rail Wear:**
 - W/R interface management program started in 2008
 - Introduction of industry best-practices
 - Elimination of lateral wear on both rails and wheels, even in sharp curves
 - As a result, wear is no longer an important driver for rail grade selection
 - Rails with hardness in 350-430HB range have similar wear performance in sharp curves (in high rail position)

Rail Selection in Mauritania (National Industrial and Mining Company)

Rail Grade Use

- 30tonne/axle loads
- Dominant reason for rail replacement is wear
- Presence of sand on track accelerates abrasive head wear,
 - Shifting sand dunes and constant wind along most of track
- Wear replacement threshold is $UV + UL/2 = 24\text{mm}$
 - UV – vertical wear [mm]
 - UL – lateral wear [mm]
- Wear rate (natural + grinding)
 - 0.104mm/MGT (metric) in curves (life cycle ~230-460MGT)
 - 0.030mm/MGT (metric) in tangents (life cycle ~400-800MGT)
- Tangent rails undergo both vertical and lateral wear
- Max lateral wear is often in 16-18mm range

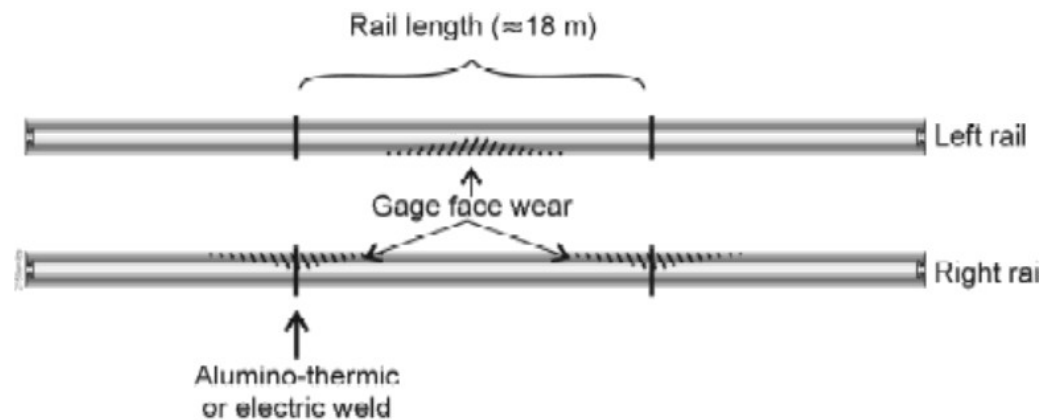
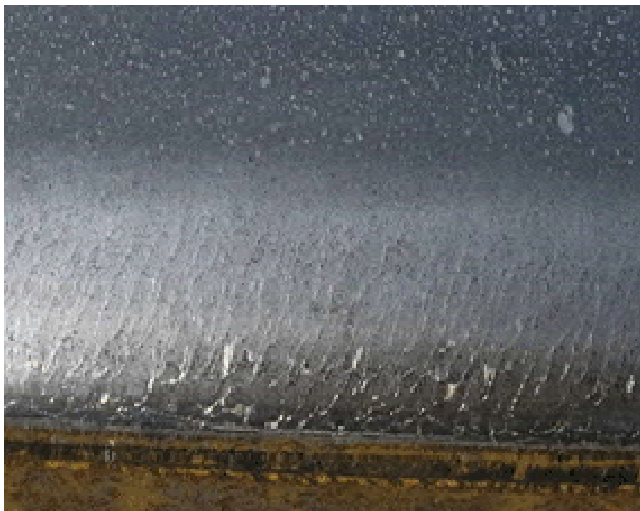
Rail Selection in Mauritania (National Industrial and Mining Company)

Rail Grade Use

- Track is mostly tangent + shallow curves
- Sharp curves only at turnouts (port & mine entry points)
- Since 2001 mainly premium 136RE rail is used
- Typical 136RE rail specs:
 - UTS = 1300 MPa
 - YS (0.2% offset) = 850 MPa
 - El. = 12 %
 - Head Hardness = 380-410HB
 - When hardness > 410HB rail manufacturer is asked to prove the rail is fully pearlitic

Rail Selection in Mauritania (National Industrial and Mining Company)

Abrasive pitting
and hunting wear,
as well as head
checking



Conclusions

- **Premium rails** (min 370HB) used when:
 - Curvature \uparrow (ex. $R < 300\text{m}$)
 - MGT \uparrow (ex. shallow curvature but higher MGT)
 - Axle load \uparrow (freight traffic)
 - Excessive wear \uparrow
 - Excessive RCF \uparrow
- **Intermediate strength** (350-370HB) rails used when:
 - Curvature is intermediate (ex. $300\text{m} < R < 700\text{m}$)
 - Lower MGT accumulation (even when curve is sharp)
 - Lower axle loads (transit traffic, but some freight as well)
 - Wear is not excessive (lower wear rates than standard rail)
 - RCF is not excessive (no visible cracking on surface between grind cycles)
- **Standard rails** (ex. R260) used when:
 - Shallow curves and tangent track when wear & RCF are low (ex. high speed network, but recommended switch to premium going forward)
 - Low MGT, low axle load (empty freight traffic, light transit)
 - *In general, when neither wear or RCF are excessive*

ICRI-Safety – an International Collaborative Research Project

Surface Fatigue Initiated Transverse Defects and Broken Rails – Untestable Rails An International Review

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Workflow

Background

- Survey looking at examples of untestable rails

Objectives

- Gain better understanding of rail conditions that prevent adequate UT on-track inspection
 - Compare light vs heavy axle load
 - Underground vs surface lines
- Determine if these can be quantified (either visually or eventually with NDT)

Survey - example

Name and organization	Ex. Tom Thompson, Rail Company
Do you grant permission to publish this information? (If not then it will only be grouped with other data to generate statistical results). (Y/N)	Y or N
Rail section, year and grade (or rail stamping)	Ex. 136RE, 2011, Grade 220
Service environment (transit, commuter, freight, mixed), some general idea of axle load	Ex. Transit (8,000 kg axle load)
Rail position (high/low/tangent)	Ex. High
Accumulated tonnage	Ex. 130 MGT
Head wear	Ex. 6 mm vertical, 3 mm horizontal
Curve Radius	Ex. 325 metres
Track type	Ex. Underground/subway, at-grade, aerial structure
Environmental conditions	Ex. rainy season, leaf fall problems, high humidity, well lubricated track, top of rail recently applied
Type of ballast, ties and fasteners?	Ex. wooden ties with elastic fasteners on ballast
Geographical location	Ex. SomeCity, Track A, MP 23.45
Date of photograph	Ex. March, 2017
Photograph of surface condition of untestable rail (please paste picture into this box, or else list the file name and include it in the email) Picture goes here	
Other comments: Ex. <ul style="list-style-type: none"> • This rail was recovered by grinding 24 passes with an 8 stone grinder • Rail was removed from service. 	

North American HAL – Survey Summary

Date	Permission to Publish	Service Environment	Rail Grade, year	Rail Position	Curvature	Accumulated Tonnage [MGT]	Head Wear [in]	Track type	Lubrication	Ballast, ties, fasteners
4/17/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE PR, 2012	Low	4' 13"	54.54	unknown	at grade	Dry, rail lubricator approx. 1.5miles away	concrete ties, elastic fasteners on ballast
4/17/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE SR, 2007	Low	3' 3"	54.54	unknown	at grade	Dry, rail lubricator just east of curve	concrete ties, elastic fasteners on ballast
4/24/2018	Yes	mixed	JFE 141RE, 2006	Low	4deg 28min	8.8	0.5"	at grade	Heavy grease on rail	concrete ties
4/18/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE, 2013	High	2deg 30min	153	unknown	at grade	-	wood ties
4/5/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE, 2012	Low	4deg 9min	50.6	unknown	at grade	dry southwest climate	concrete ties
4/6/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE, 2010	Low	4deg 5min	52.9	unknown	at grade	dry southwest climate	concrete ties
4/3/2018	Yes	Southern coal route with mixed freight	EVRAZ 141RE SP, 2010	Low	6deg 15min	12.7	unknown	at grade	rail lubricators about 2miles away in both directions	concrete ties
4/4/2018	Yes	Southern coal route with mixed freight	EVRAZ 141RE, 2012	Low	3deg 3min	13.6	unknown	at grade	rail lubricator at north end of curve and 3 miles south	concrete ties
4/4/2018	Yes	Southern coal route with mixed freight	EVRAZ 141RE, 2009	Low	5deg 19min	13.6	unknown	at grade	rail lubricator 1 mile north and 2 miles south	concrete ties
4/3/2018	Yes	Transcontinental service, primarily intermodal	Bethlehem 136RE, 1997	Low	4deg 56min	50	unknown	at grade	rail lubricators 1.5miles east and west ends of curve	concrete ties
4/13/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE, 2015	Low	3deg 0min	51.5	unknown	at grade	rail lubricators 6 miles east and 8 miles west	concrete ties
4/16/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE, 2007	Low	3deg 3min	51.5	unknown	at grade	rail lubricators at east end of curve and 5 miles west	concrete ties
4/17/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE, 2012	Low	4deg 13min	51.7	unknown	at grade	unsure of lubricator location in relation to this curve	concrete ties
4/11/2018	Yes	Transcontinental service, primarily intermodal	EVRAZ 141RE, 2012	Low	3deg 1min	11.7	unknown	at grade	rail lubricators 2 miles west at 6 miles east	concrete ties
4/23/2018	Yes	sand and ore	CF&I 136RE, 1971	Low	1deg 0min	19.6	unknown	at grade	dry environment	wood ties

North American HAL – Survey Summary

Results:

- Problems persist primarily on intermodal service lines
- Rail mostly affected is premium 141RE, 2006-2015 production years
- Damage mostly on low rail
- Curvature <6 deg. (>281 m-radius curve)
- Rail is mostly dry (i.e. lubricator positions mostly far away from trouble spots)
- Rail is mostly on concrete ties (i.e. stiff track condition)

North American HAL – Survey Summary





South American HAL – Survey Summary

Date	Permission to Publish	Service Environment	Rail Grade, year	Rail Position	Curvature	Accumulated Tonnage [MGT]	Head Wear [in]	Track type	Lubrication	Ballast, ties, fasteners
March, 2017	Yes	freight 32.5 tonnes axle load	DO UHC 136RE, 2006	Low	0.56 deg (982m radius)	900	7.5mm vertical	at grade	-	wood ties with elastic fasteners on ballast
April, 2017	Yes	freight 32.5 tonnes axle load	DHH 370, 136RE, 2011	-	tangent	840	8.4mm vertical	at grade	-	wood ties with elastic fasteners on ballast
March, 2017	Yes	freight 32.5 tonnes axle load	HE 400, 136RE, 2008	left	tangent	350	2mm vertical	at grade	excessive GF lubrication	wood ties with elastic fasteners on ballast

Results:

- Problems persist on freight service lines
- Rail affected is 136RE head hardened premium rail (2006, 2008, 2011)
- Substantial vertical wear (10-17 MGT/mm)
- Damage on tangent rail (or low rail in shallow curves)
- Rail is mostly on wood ties with elastic fasteners
- Periodic spalling and fatigue defects originating at surface witness marks

South American HAL – Survey Summary



European – Survey Summary

Date	Permission to Publish	Service Environment	Rail Grade, year	Rail Position	Curvature	Accumulated Tonnage [MGT]	Head Wear [in]	Track type	Lubrication	Ballast, ties, fasteners	Additional Comments
March, 2017	Yes	transit, 8000kg axle load	Grade 220, 115RE, 2011	high	325m-radius (5.2deg)	130	6mm ver. 3mm hor.	underground/ subway (at grade), aerial structure	rainy season, leaf fall problems, high humidity, well lubricated, TOR recently applied	wood ties with elastic fasteners on ballast	grinding 24 passes with 8 stone grinder, rail removed from service

Results:

- Problems on transit lines
- Standard grade rail: 115RE, 2011, grade 220
- Curvature approx. 5deg (325 m-radius curve)
- 130MGT accumulated tonnage
- Wear: 6mm vertical (22 MGT/mm), 3mm horizontal (43 MGT/mm)
- Fall leaf problems, high humidity, well lubricated, TOR FM applied
- Wood ties with elastic fasteners
- Periodic high rail corrugation damage

European – Survey Summary

Pre-Grind

Post-Grind



Additional North American HAL Line Defects



Results:

- Freight line traffic
- No visual evidence of recent grinding
- Severe batter on rail ends leading to spalling



Additional North American HAL Line Defects



Conclusions

- Fatigue crack defects block UT signal
 - Defects close to running surface prevent inspection of entire rail for other defects
 - Defects in questions: heavy RCF with spalling, corrugation, shelling, severe surface batter where chipping took place
- Defect inspection:
 - If only subsurface they can be inspected with UT
 - If broken through to running surface they can be inspected with eddy current
- In most cases rail replacement is imminent
 - Grinding to remove entire defect is too costly
 - Other option would be rail milling