Condition Monitoring & Condition Based Maintenance

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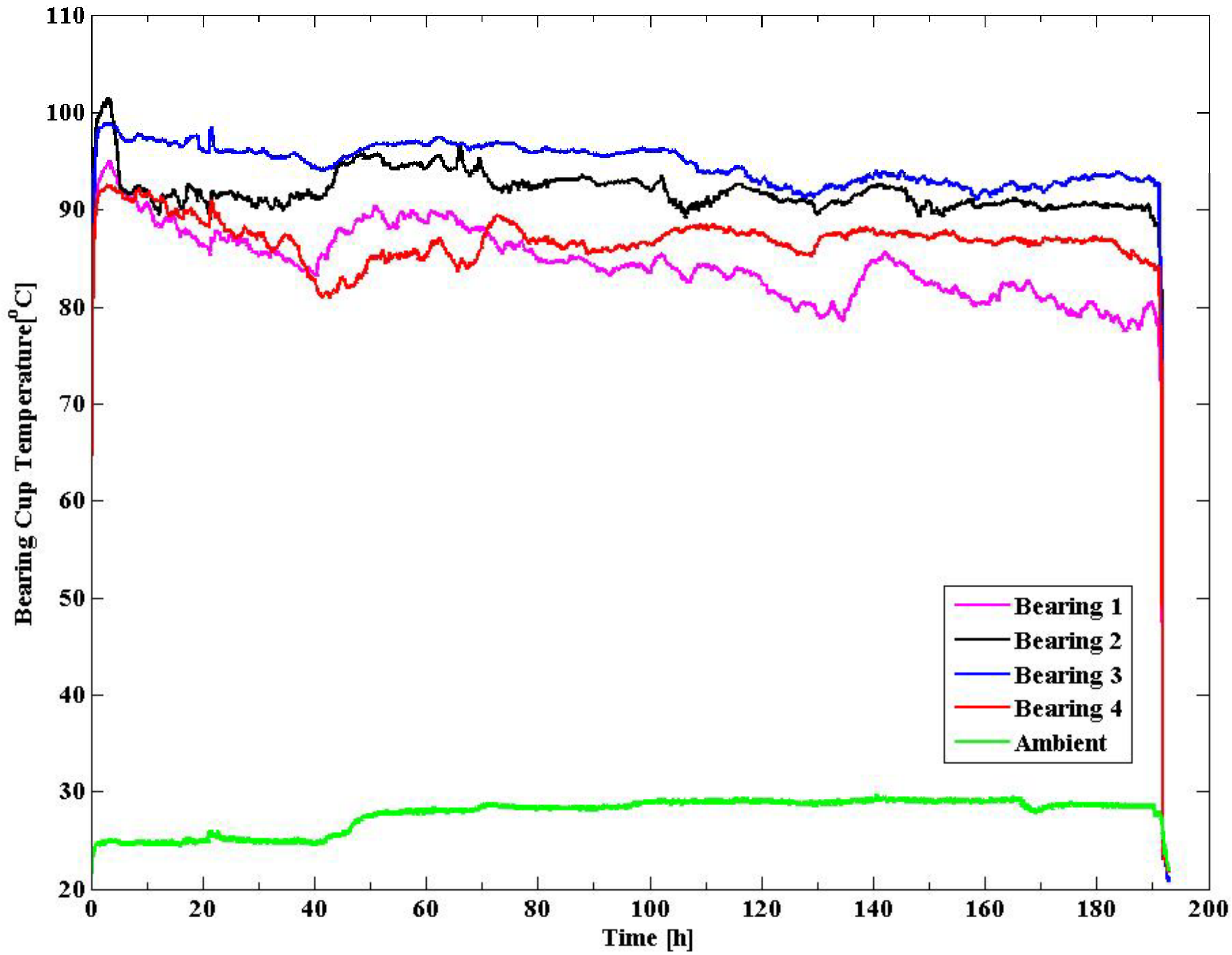
Amsted Rail

Why Condition Monitoring??

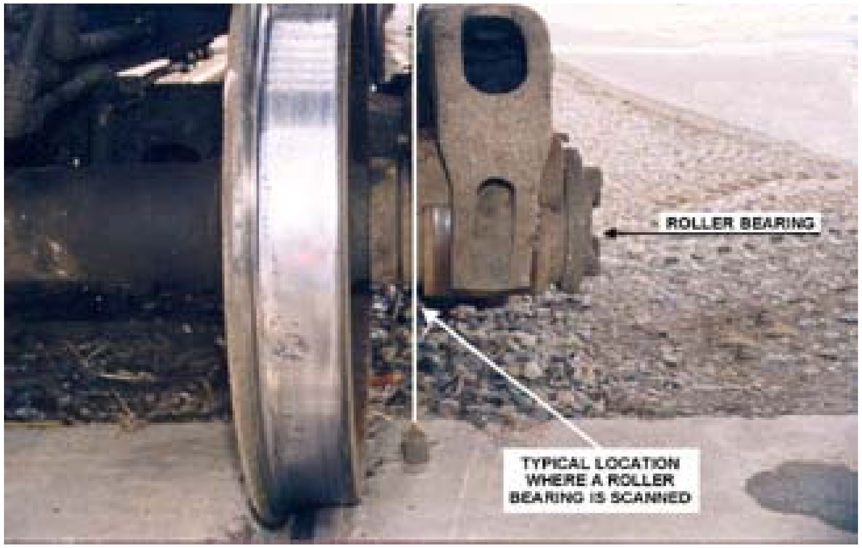


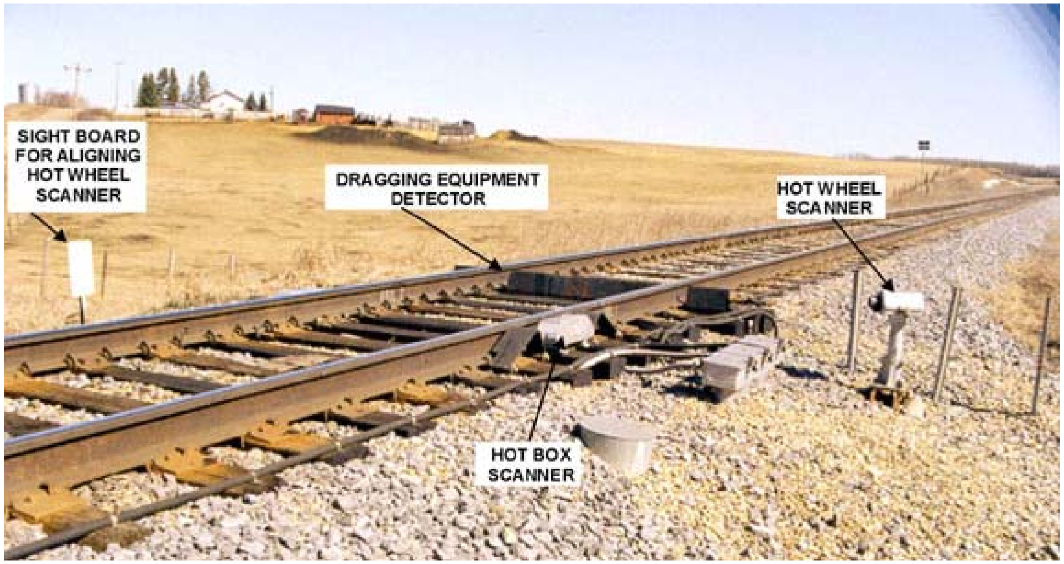
Wayside Detection

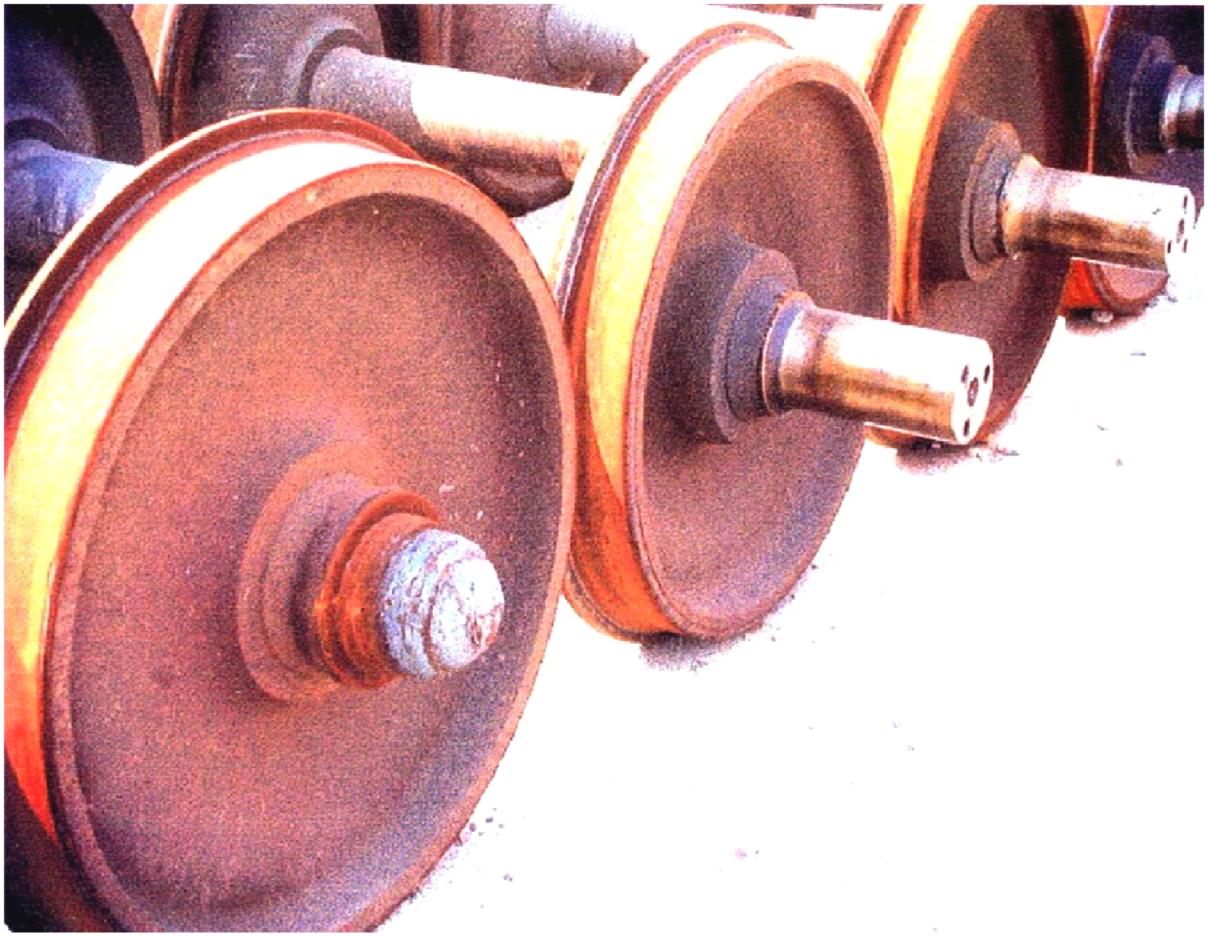
- A primary reason for bearings to be pulled is due to overheating
  - Bearing overheating is detected by a hot box scanner
  - Hot Box Trigger is @

    T > 170°F above ambient
- A primary reason for wheels to be pulled is through impacts

    Load > 90 kips



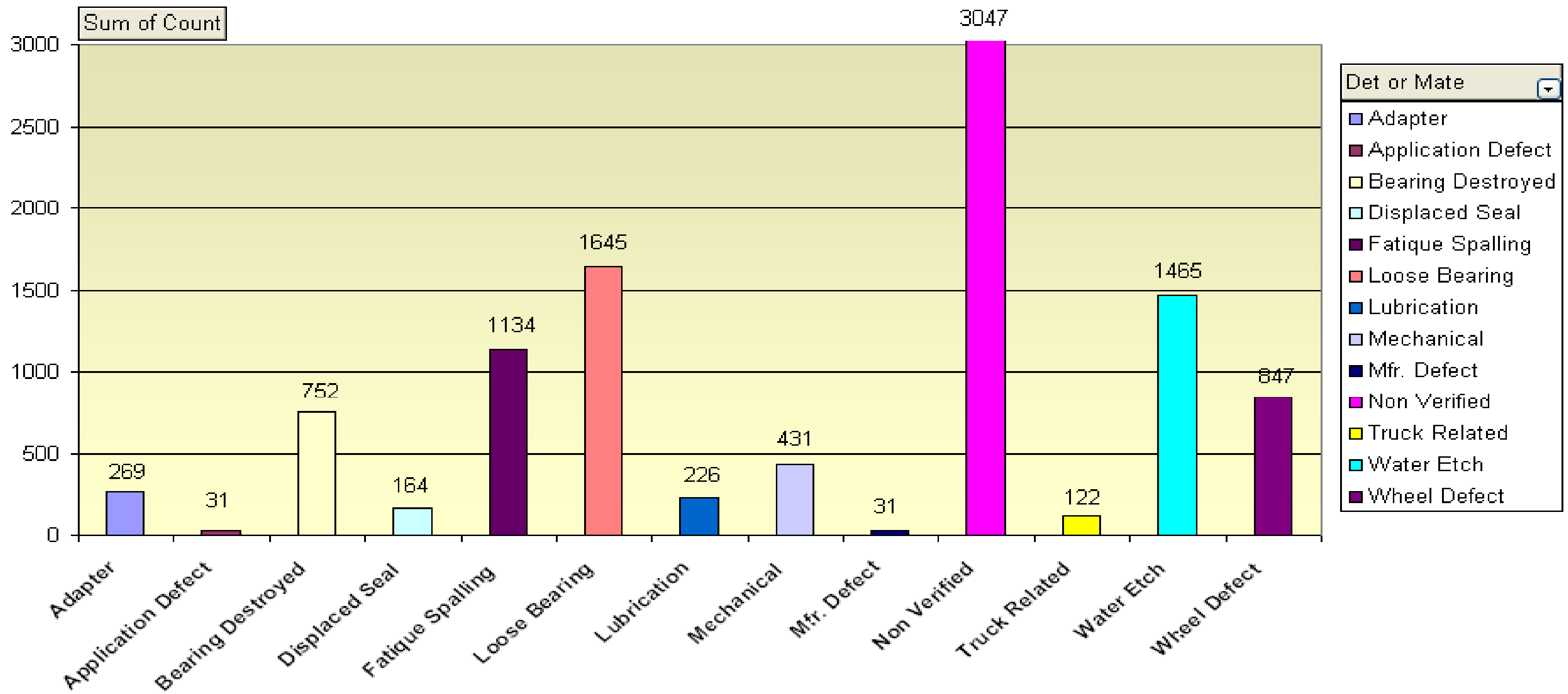


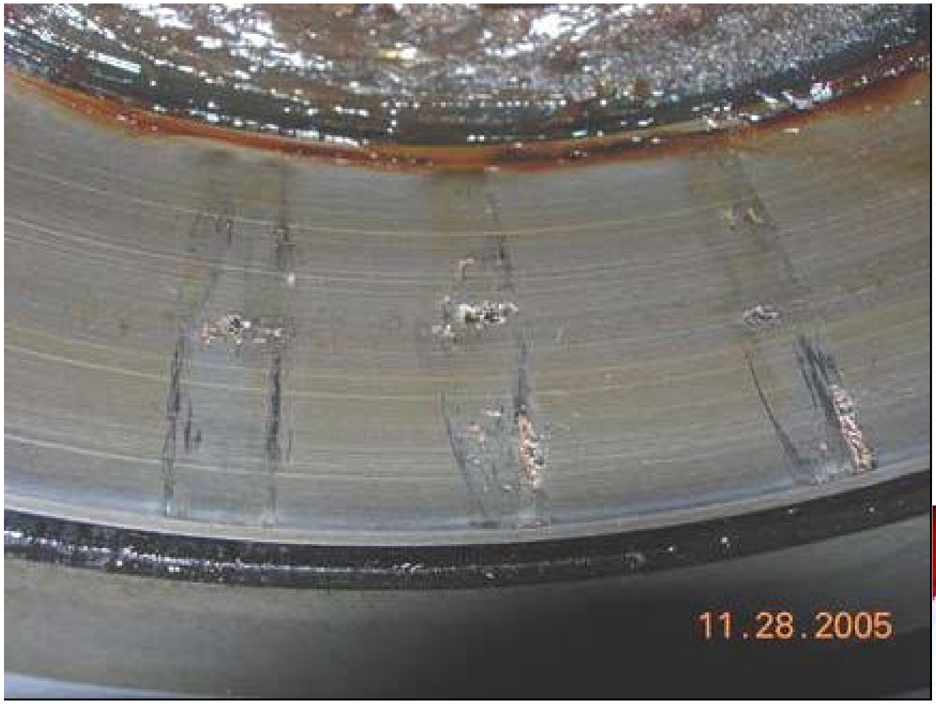


a) Wheel flat b) Shell / Spall

c) Shattered rim d) Built-up-tread

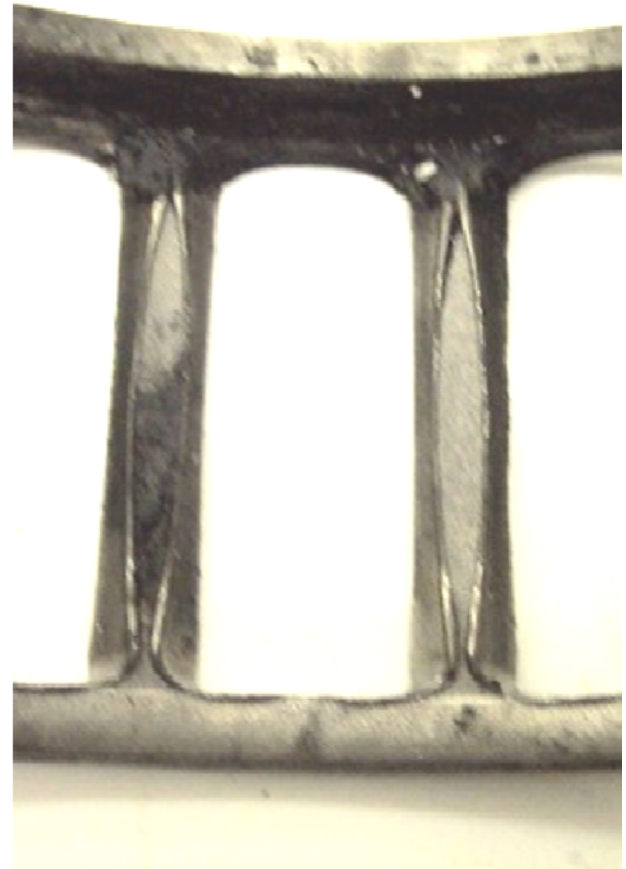
WMC 50 removals




11.28.2005


10 11 12 13 14 15 16 17 18 19 20


4 5 6 7 8 9

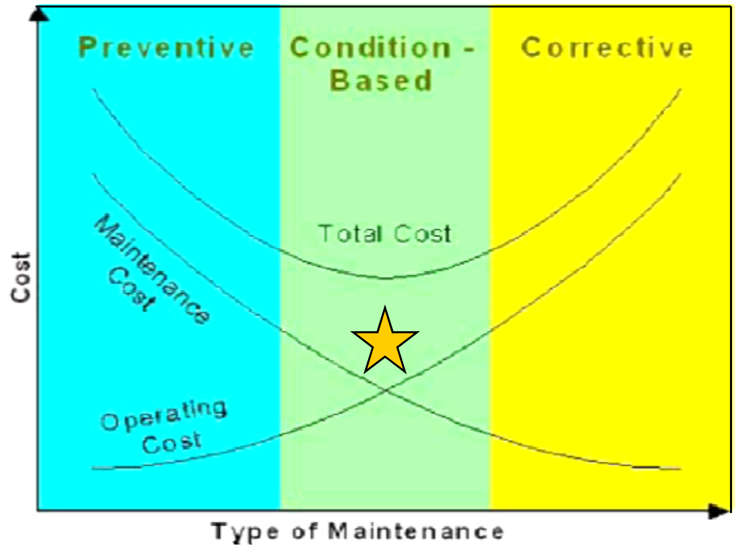


Condition Based Maintenance (CBM)

Maintenance Philosophies

Preventive Maintenance

- ***Scheduled*** maintenance - based on life statistics of similar equipment
- ***High*** maintenance costs - unnecessary maintenance
- ***Low*** operating costs – limited downtime scheduled



Corrective Maintenance

- Run equipment to ***failure***; no scheduled maintenance
- ***Low*** maintenance costs – performed only **after** failure
- ***High*** operating costs – downtime and damage

Condition Based Maintenance

* Maintenance ***when required***

* Unnecessary maintenance is avoided

* Availability of the equipment is guaranteed

* ***Overall*** cost is reduced

* Extends useful life of equipment

but…

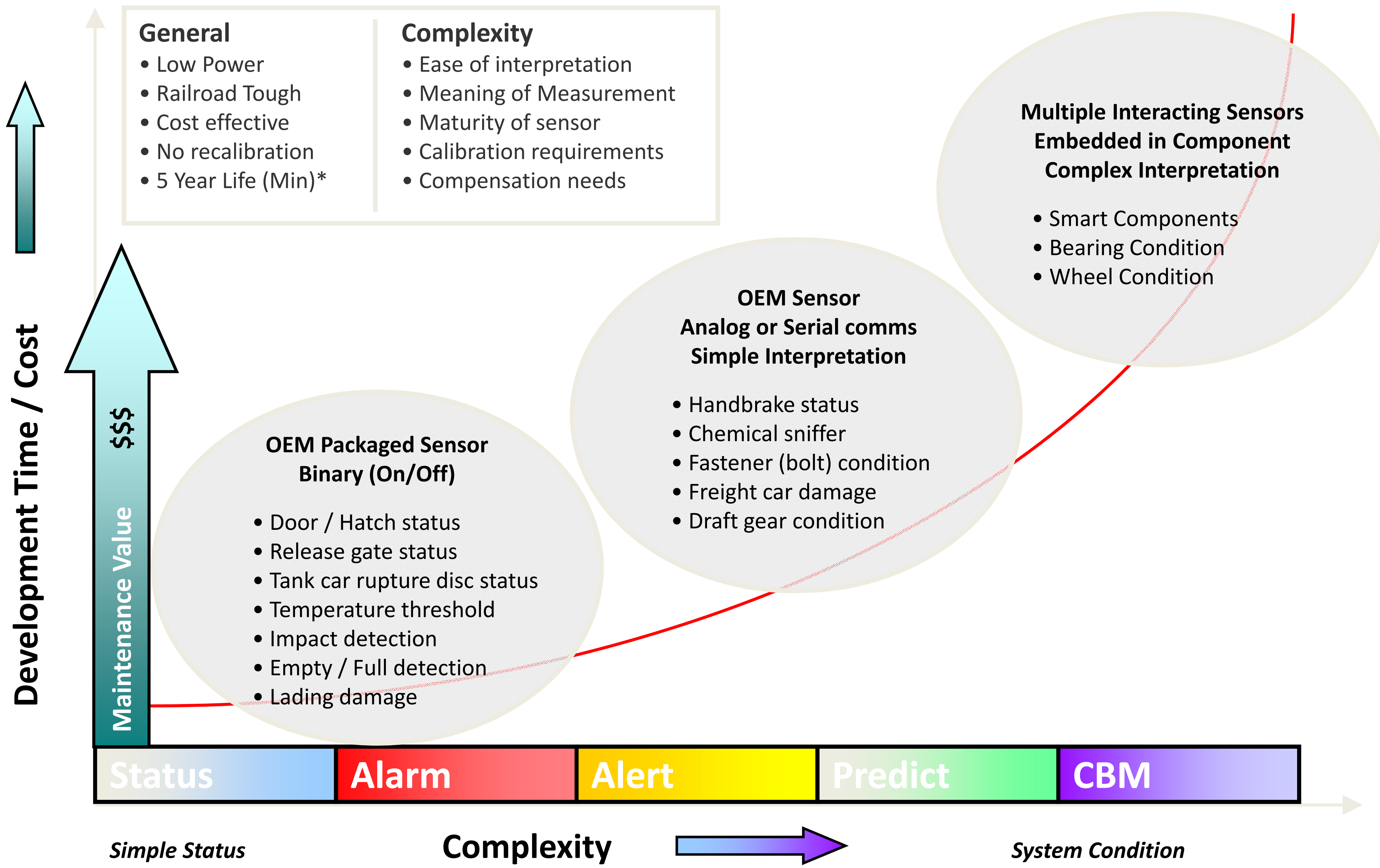
* Condition monitoring ***adds cost***

Why do we care about CBM?

- CBM opportunity: 5-12% savings on Life Cycle Cost
- Metrics support better quality and premium performance
- Condition Monitoring supports:
  - Higher reliability
    - Less downtime – asset utilization
    - Higher network velocity – efficiency and productivity
  - Reduced network congestion
    - Heavier freight cars (315 Klb GRL)
    - Higher operating speeds
  - Lower transportation costs (One Engineer locomotive operation, etc.)

Railroad	**Increased train velocity and productivity**
Car Owner	**Reduced costs and higher asset utilization**
Supplier	**Differentiation; premium price; metrics to benchmark**

Wireless Sensing - Ease of Development



Condition Monitoring

- Condition Monitoring represents the highest value to
  - Railroads
  - Shippers
  - Car owners
- Condition Monitoring enables pre-emptive maintenance

  (Fix it only when necessary - before it fails - at convenient time / location)

- Algorithm (mathematical model and logic) development
  - **Effort** intensifies along the spectrum from status to CBM

  - **Complexity** intensifies along the spectrum
  - Laboratory and field test **data** volume and analysis increases
  - Benefits everyone by getting the full useable life out of OEM products
    - Opens the door for premium/long-life components

Bearing Monitoring & Locomotive Alarm System

SCT Logistics, Australia

AmstedRail

IONX

System Commissioning

Inaugural test run from Melbourne to Perth approx. 4,000 Km

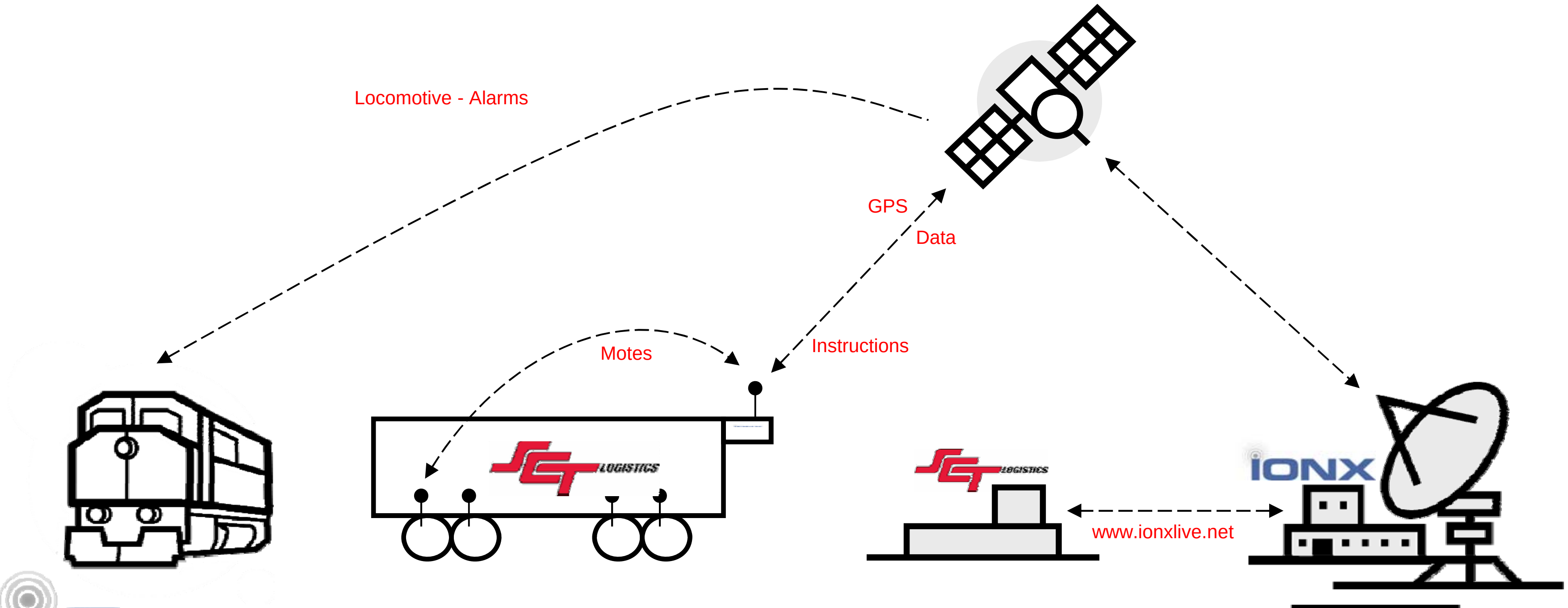
Solution Overview

Challenges:

(1) Data logging

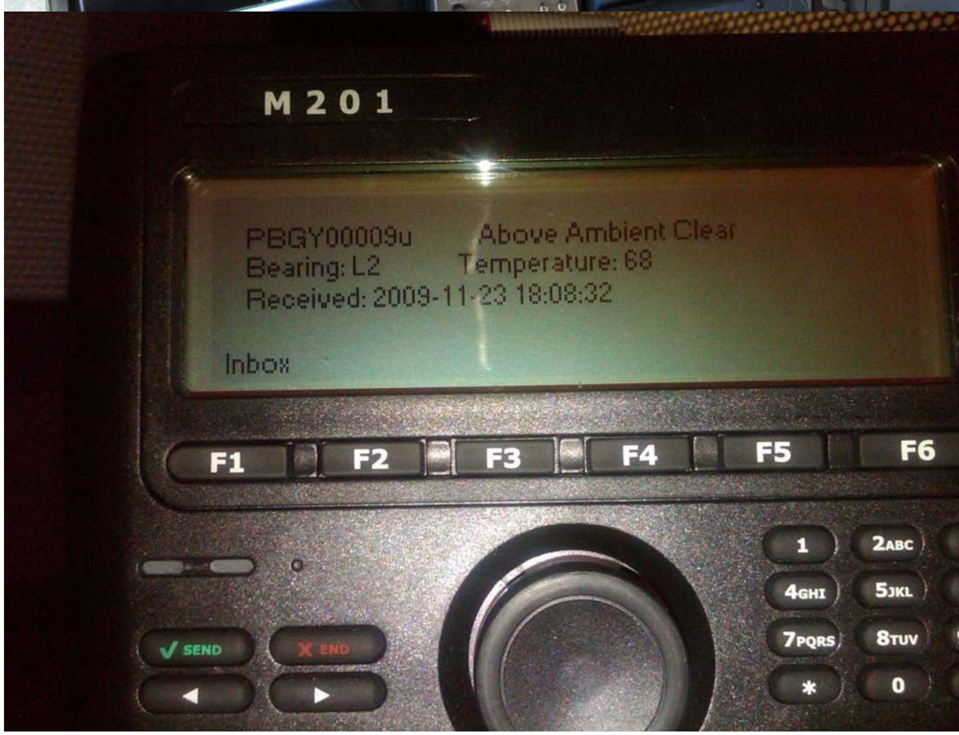
- > ½ million temperature readings/day on 10 cars
- Daily uploads from Australia to West Chester, PA

(2)Communicating alarms to locomotive engineer



IONX
information from the edge™


IONX Display Unit for alarms installed in Locomotive
FIRST AID KIT
Locomotives equipped with IONX satellite communications

Dual Satellite/Cellular Mode CMU installed on SCT Wagon
IONX

M201
PBGY00009u Above Ambient Clear
Bearing: L2 Temperature: 68
Received: 2009-11-23 18:08:32
Inbox
F1 F2 F3 F4 F5 F6
SEND
END

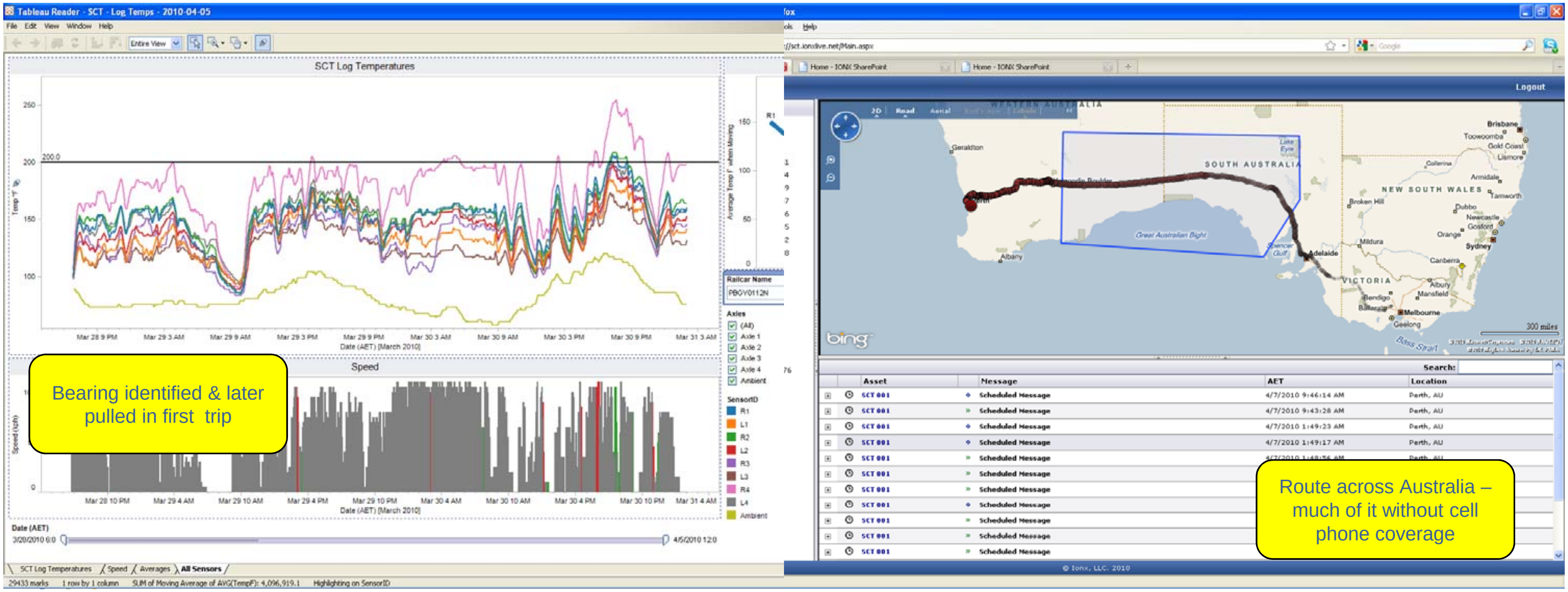
6X11
Wireless temperature sensor bolted to standard adapter

Alert Instructions

Stage	Alert	Level	Action
1	Bearing Trending Alert	>200ºF	• Alarm to IONX only. – not sent to locomotives • Used for trending recommendations & repeat offender identifications
2	Axle Differential Alarm	>105ºF axle differential	• Action: Stop train, check journal of alarmed bearing. Look for signs the bearing is "walking off" the axle or grease is being purged. • Proceed at reduced speed of 60 kph maximum until stage 2 alarm clear message is received at locomotive terminal • If stage 2 alarm clear message is received at the locomotive terminal, proceed as normal
3	Above Ambient Alarm	>190ºF above ambient	•Action: Stop train, check journal of alarming bearing. Look for signs the bearing is "walking off" the axle or grease is being purged •Proceed at reduced speed of 30 kph maximum until stage 3 alarm clear message is received at the locomotive terminal at which point speed can be increased to 60 kph. •If the alarm message does not clear, a choice can be made to remove and change the bearing at an appropriate stoppage point, otherwise reduced speeds are required to reduce the chance of a screwed journal. •If Stage 2 and Stage 3 alarm clear messages are both received at the locomotive terminal, proceed as normal
4	Bearing Temp Alarm	>320ºF	•Action: Stop train, remove bearing.

IONX

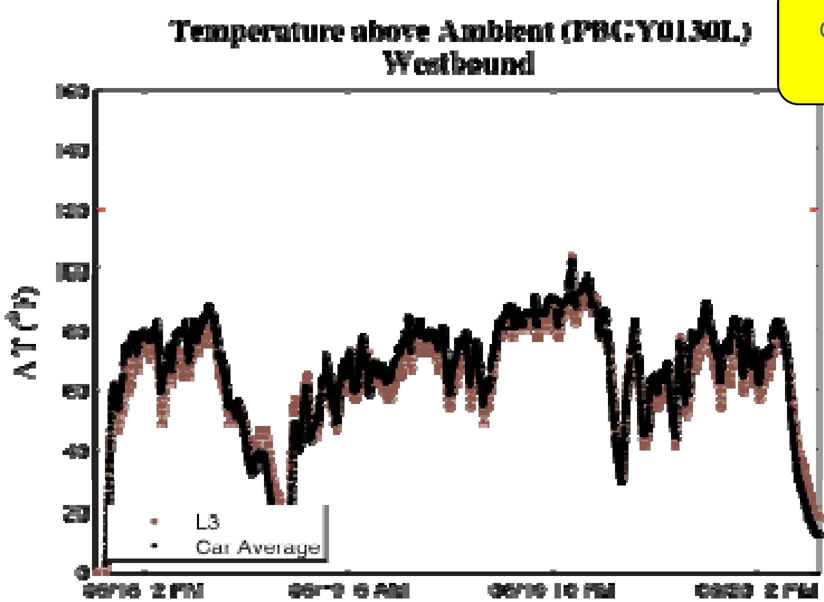
information from the edge™

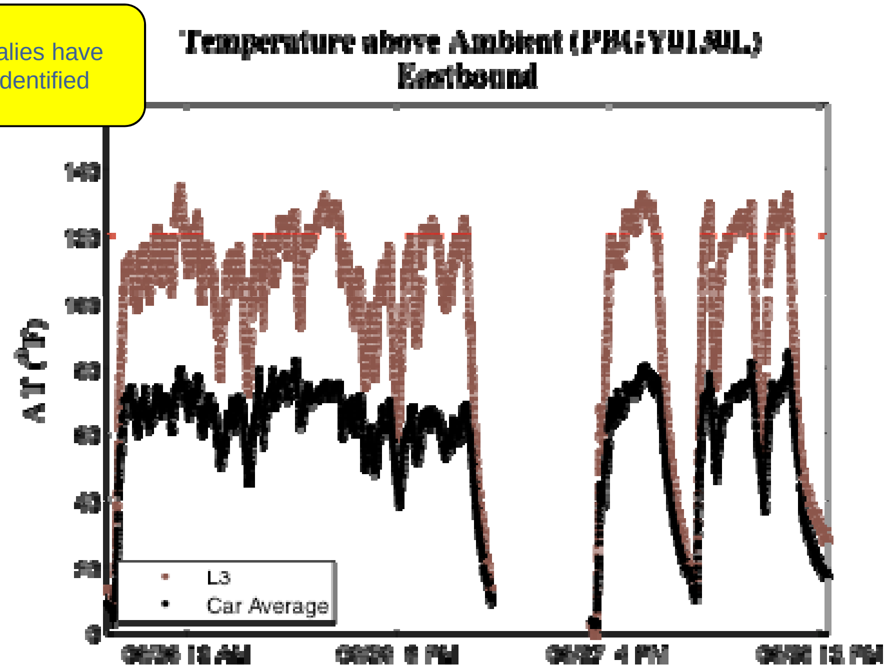


Bearing identified & later pulled in first trip

Route across Australia – much of it without cell phone coverage

Other anomalies have also been identified





Bearing Condition Monitoring

Faulty Bearing Detected During the Inaugural Run

- This bearing exhibited temperatures significantly above >200F, and trended towards higher temperatures compared to its peers
- The acoustic bearing detector reported this bearing as normal
- After the trip the bearing was removed, and a subsequent inspection discovered a short lateral as the primary cause

Bearing Condition Monitoring

- Bearing 130L-L3 (Node 6) was pulled on 7/30/2010 using logic algorithms
- Subsequent teardown and inspection revealed spalling and discoloration on the raceways (below left)
- Bearing was run to failure in the laboratory at 86,000km (11 trips)
- Replacement eliminated the fault (below right)

Algorithm results before/after bearing change

July	Level 2.1	Level 2.2	Level 2.3	Level 2.4	Level 2.5
Node	≥25% Temp≥200F	≥25% ΔT≥120F	≥1σ Above Car	≥1σ Above Fleet	≥4% Slope≥1.25
1	✖	✖	✖	✖	✖
2	✖	✖	✖	✖	✖
3	✖	✖	✖	✖	✖
4	✖	✖	✖	✖	✖
5	✖	✖	✖	✖	✖
6	✔	✔	✔	✔	✔
7	✖	✖	✖	✖	✖
8	✖	✖	✖	✖	✖

August	Level 2.1	Level 2.2	Level 2.3	Level 2.4	Level 2.5
Node	≥25% Temp≥200F	≥25% ΔT≥120F	≥1σ Above Car	≥1σ Above Fleet	≥4% Slope≥1.25
1	✖	✖	✖	✖	✖
2	✖	✖	✖	✖	✖
3	✖	✖	✖	✖	✖
4	✖	✖	✖	✖	✖
5	✖	✖	✖	✖	✖
6	✖	✖	✖	✖	✖
7	✖	✖	✖	✖	✖
8	✖	✖	✖	✖	✖

Bearing Condition Monitoring

Bearing Condition Monitoring

The system detected an issue with the A-end truck on wagon 130L which is causing all the bearings on that truck to trend warm.

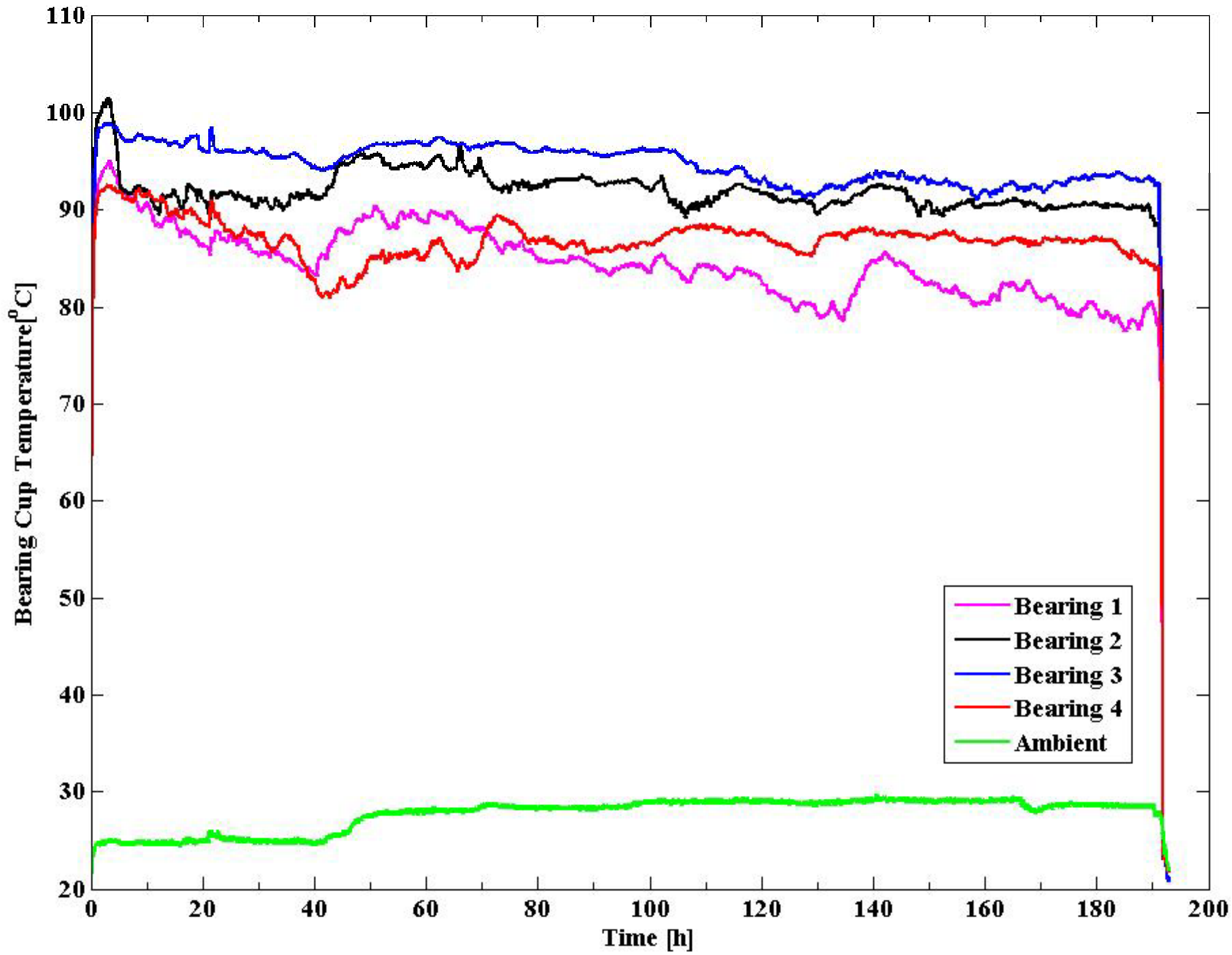
Criteria	Node	November '10	December '10	January '10
3.1 %Temp≥200F	5	**6.162**	**2.316**	**7.468**
	6	**8.669**	**6.554**	**7.297**
	7	**3.79**	0.373	**4.113**
	8	**2.212**	**2.888**	3.344
3.2 %ΔT≥120F	5	1.929	1.284	**1.816**
	6	**8.159**	**6.716**	**8.109**
	7	2.141	0	0.673
	8	0.182	**1.555**	0.385
3.3 nσ Above Car	5	0.27	0.205	0.168
	6	**0.381**	**0.351**	0.312
	7	0.239	0.021	0.051
	8	0.041	0.091	0.123
3.4 nσ Above Fleet	5	**0.809**	**0.43**	**0.76**
	6	**0.901**	**0.562**	**0.868**
	7	**0.782**	0.251	**0.668**
	8	**0.611**	0.32	**0.726**
3.5 %Slope≥1.25	5	**2.301**	**3.094**	**2.019**
	6	**3.038**	**3.56**	**2.32**
	7	**2.398**	**2.956**	**2.47**
	8	0.991	1.803	1.149

- PBGY 130L
  - From November to January, the A-end truck bearings on wagon 130L have been trending warm and tripping several Level 3 Alarm Criteria.
  - This condition has been worsening steadily throughout the trial.
  - All bearings on the truck were removed January 16, 2011 for wheel spalls. At that time, the issue receded but it is slowly worsening.
- Recommendations to GEMCO:
  - Inspect bearings which were removed from the truck
  - If bearings have been reconditioned, get inspection report for IONX
  - Continue to monitor for future degradation

Bearing Condition Monitoring

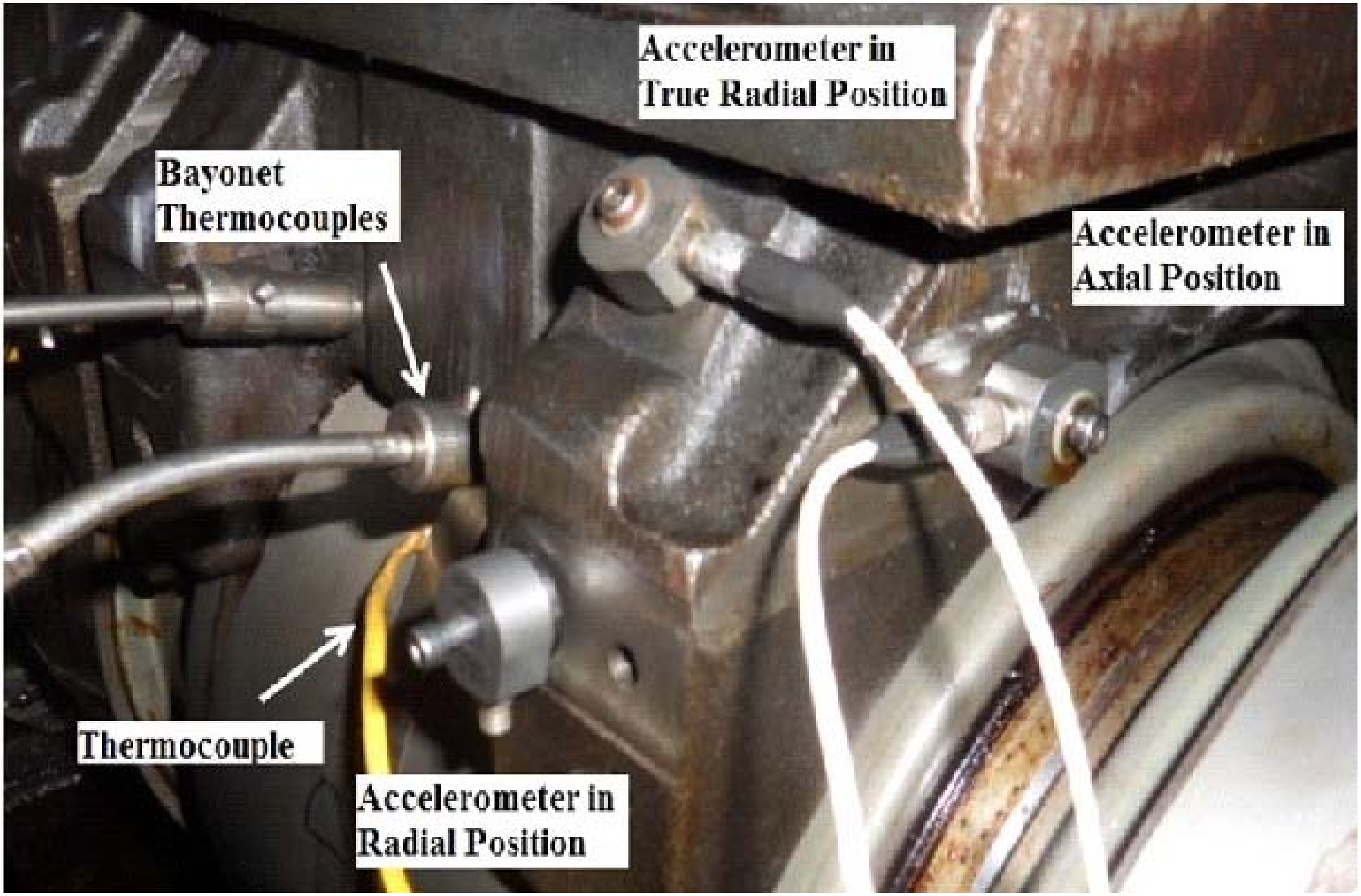
- GEMCO has changed 44 wheels on 10 wagons between 4/2010 and 7/2011
- Only 41% of bearing positions perform better after a wheel set change out
  - 29% perform the same after a wheel set change out
  - 30% perform worse after a wheel set change out
- A classic example of how component maintenance sometimes results in bearings that perform worse than the original bearings that were replaced
- SCT can leverage this information to question reconditioned bearing quality supplied by its maintenance supplier (GEMCO)

Why Condition Monitoring??

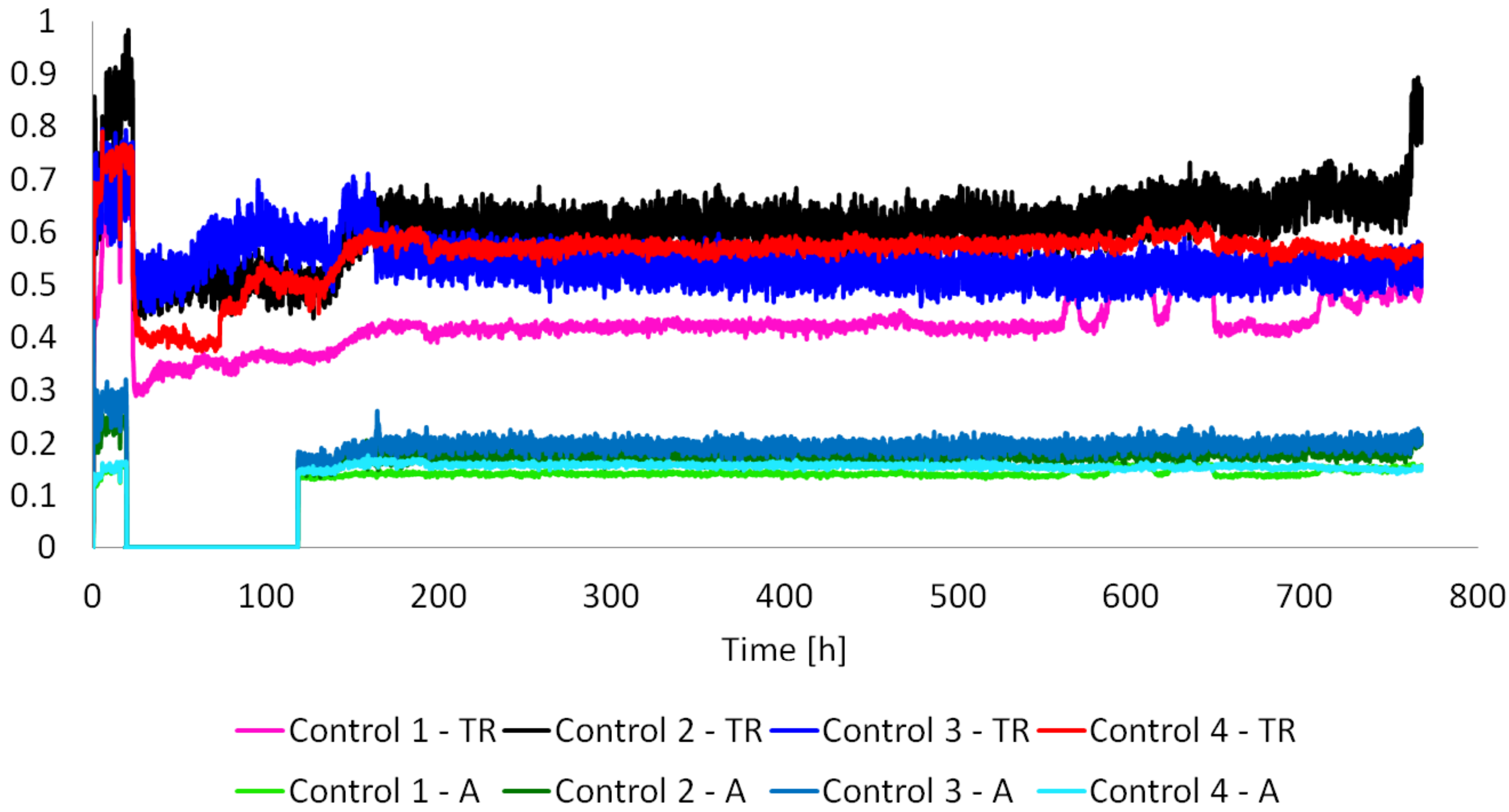


Max length: 1.047 in
Max width: 0.224 in
Area: 0.235 in^2

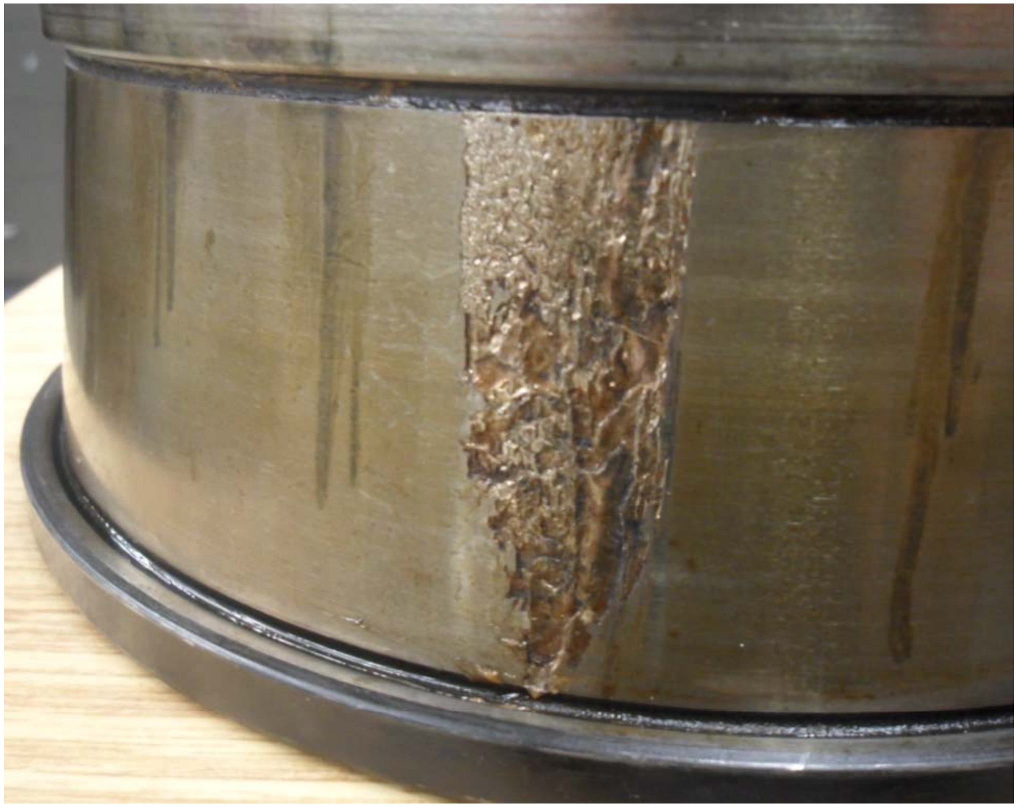
Bearing Condition Monitoring



Bearing Condition Monitoring



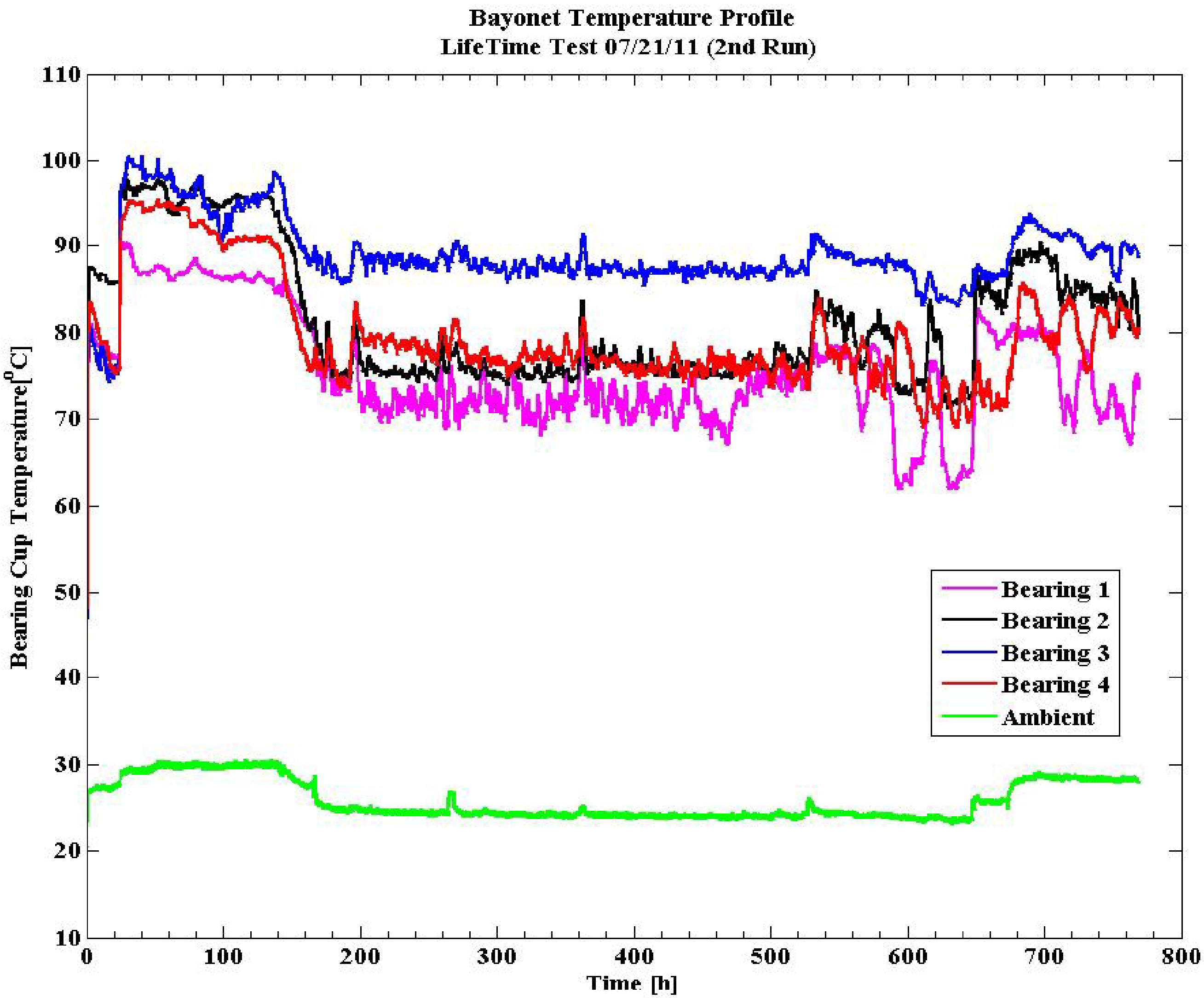
Bearing Condition Monitoring



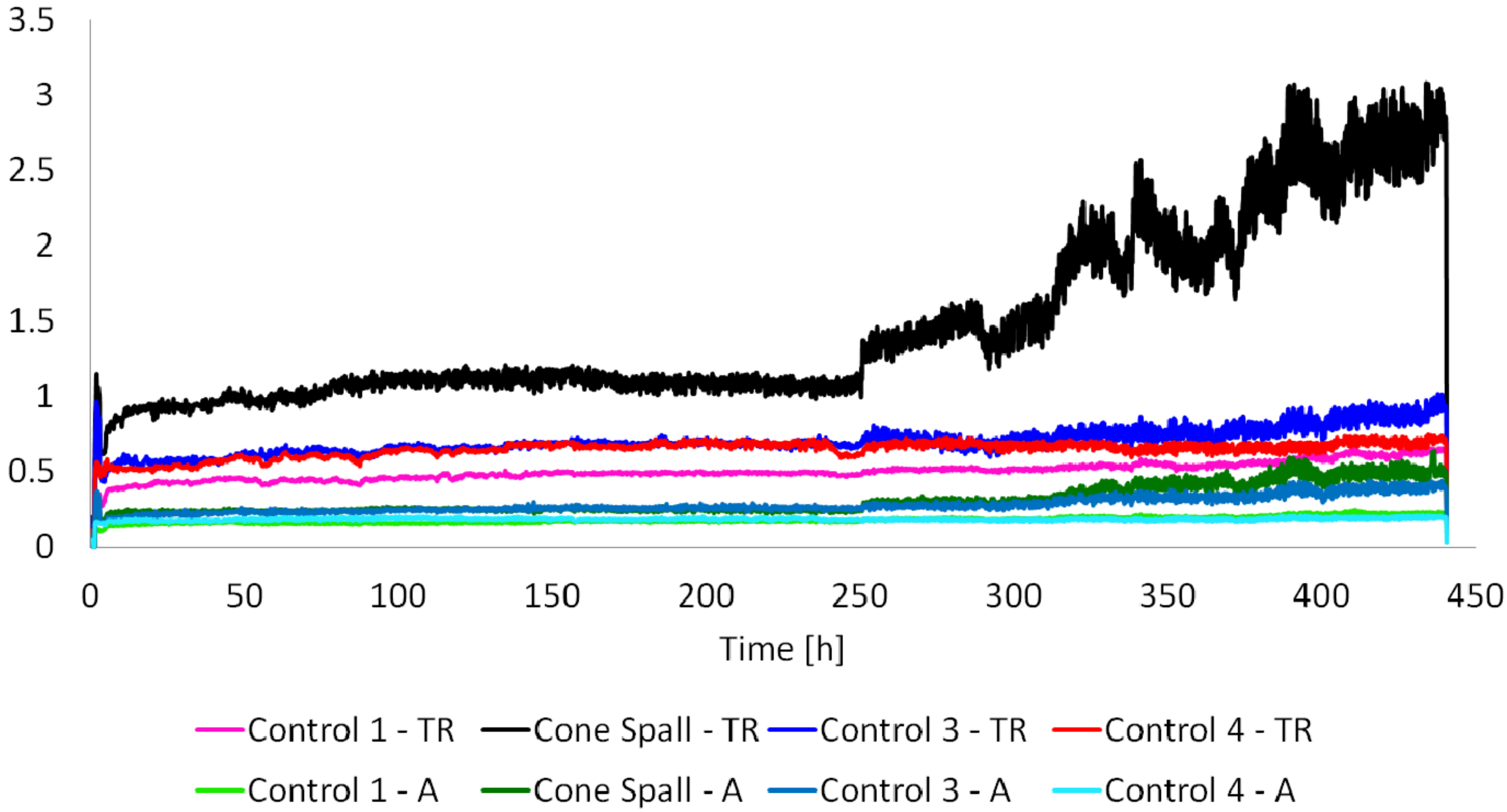
Max length: 1.850 in
Max width: 0.707 in
Area: 1.308 in^2

Deterioration after 37,400 miles!!!

Bearing Condition Monitoring



Bearing Condition Monitoring



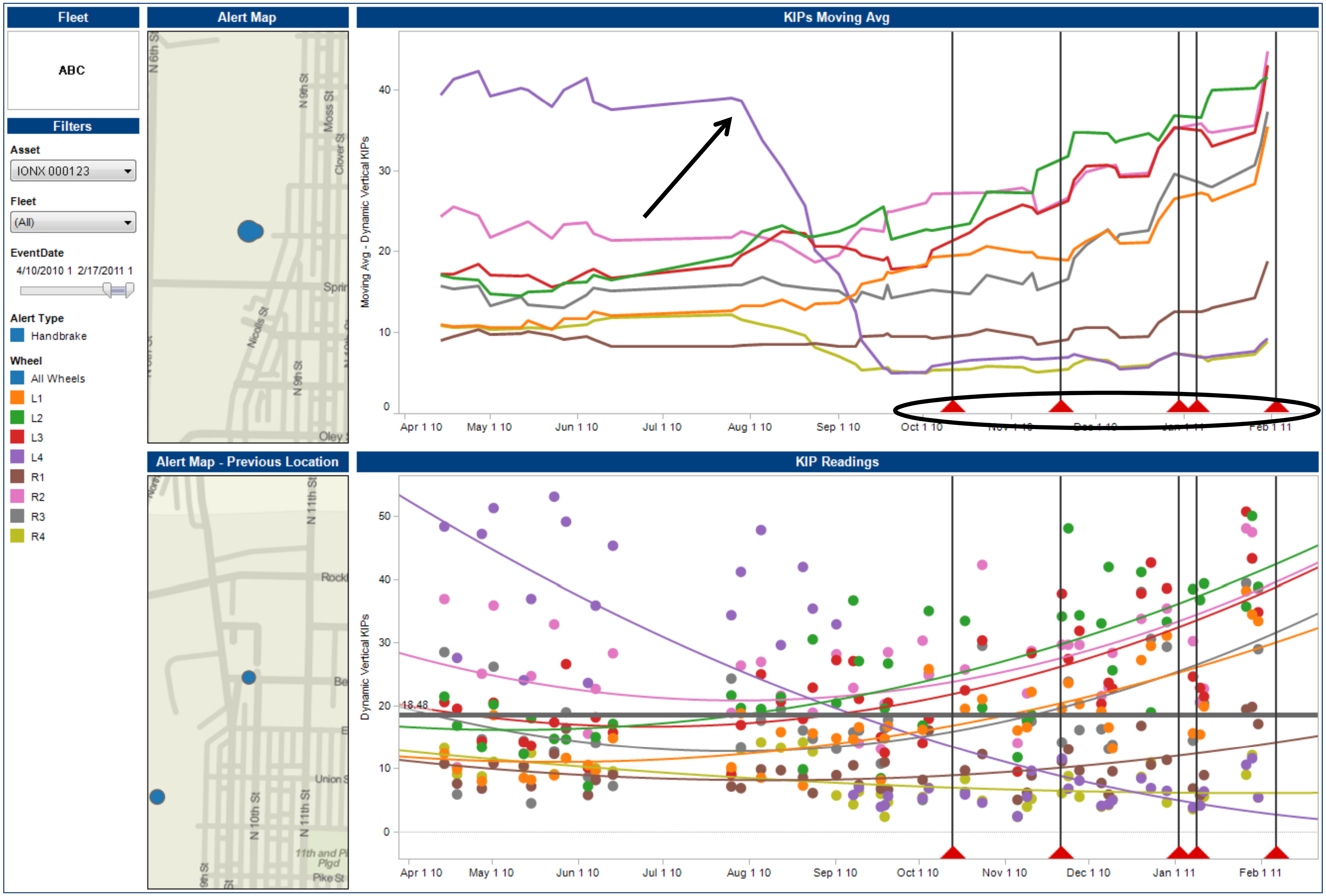
Wheel Impact Load Detectors

- “WILD” systems used by all major railroads to detect high impact wheels in service
- Dedicated detector sites - Strain gauged rails to detect wheel load
- 90,000 pounds is current condemnable wheel load
- For a 36” wheel, 562 impacts per mile
- Wheel impacts increase stress state of the railroad
- AAR Why Made Code 75 – “shelling”
- AAR Why Made Code 65 – high impact wheel, ≥ 90 kips
- Impact data for 294 tank cars, built in 2004 with truck mounted brakes: 139 wheels on B end truck has wheel impact loads consistent with a damaged wheel while only 7 wheels on the A end had had elevated load levels !
- Thus 95% of high impact wheels were on the only truck affected by the hand brake!

Wheel Condition Monitoring

Hand brake sensor

CMU mounted on a railcar


Fleet
ABC
Filters
Asset
IONX 000123
Fleet
(All)
EventDate
4/10/2010 1 2/17/2011 1
Alert Type
Handbrake
Wheel
All Wheels
L1
L2
L3
L4
R1
R2
R3
R4
Alert Map
Alert Map - Previous Location
KIPs Moving Avg
Moving Avg - Dynamic Vertical KIPs
KIP Readings
Dynamic Vertical KIPs
18.48
Apr 1 10
May 1 10
Jun 1 10
Jul 1 10
Aug 1 10
Sep 1 10
Oct 1 10
Nov 1 10
Dec 1 10
Jan 1 11
Feb 1 11

Wheel Impacts and Wheel Failures

- High impact wheels can cause bearing damage such as broken cages, leading to failure
- Other car component damage and rail fractures
- High impact, dynamic high strain rate loads can play a role in shattered rim formation and in vertical split rim formation
- Axial residual stress pattern is different for VSR and used wheels - tensile axial residual stress magnitude is greater below the tread surface of these wheels than for new wheels

Conclusions

- Railroads/car owners/suppliers can all benefit from condition based maintenance strategies
- On-board sensors can determine predictively when components are degrading through performance algorithms.
- Operational delays and damage costs can be avoided or minimized through predictive maintenance strategies
- The full life of rolling stock components can be realized, which encourages product development to increase performance.
- Modification of behaviors of railroad employees, shippers and consignees could occur through education, enforcement of rules and financial penalties