RIDEAU TRANSIT GROUP GENERAL PARTNERSHIP

**Rideau Transit Group**
805 Belfast Road
Ottawa, ON K1G 0Z4

July 21, 2021

**City of Ottawa**
110 Laurier Avenue West
Ottawa, ON K1P 1J1

| | |
|---|---|
| Our Reference: | RTG-OTT-58-0-LET-1217 |
| RTM Reference: | RTM-RTG-00-0-LET-0124 |
| Project Agreement Reference: | N/A |

**Attention:** **Michael Morgan**
Director, Rail Construction Program

**Subject:** **Final Derailment Report of LRV 1116 on March 14th, 2021**

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Dear Mr. Morgan:

Please refer to the attached correspondence from RTM which includes the final Derailment Report of LRV 1116 that occurred on March 14, 2021.

Should you have any questions, concerns, or require additional information please do not hesitate to contact us.

Regards,

**Nicolas Truchon, CFA, MBA**
*CEO*
*Rideau Transit Group General Partnership*

cc.: City: Lorne Gray, Troy Charter and Brandon Richards
RTG: Bruno Tremblay
RTM: Mario Guerra

*Attachments:*
*1) RTM-RTG-00-0-LET-0124 - Final Derailment Report of LRV 1116 on March 14th_ 2021*
*2) OTT-ENG-REP-066_revB_LRV1116 MSF Yard Derailment Report*
*3) OTT-ENG-REP-056_revB_Track14_Curve19_Geometry*

RTM

Rideau Transit Maintenance
805 Belfast Road
Ottawa, ON K1G 0Z4

July 21, 2021

**VIA EMAIL TO**
Mr. Nicolas Truchon
Chief Executive Officer
Rideau Transit Group
805 Belfast Road
Ottawa, ON K1G 0ZA

| | |
|---|---|
| RTM Letter No: | RTM-RTG-00-0-LET-0124 |
| Replying To: | |
| Reference: | Ottawa Light Rail Transit Project Amended & Restated Maintenance Contract dated September 16, 2019 between Rideau Transit Group General Partnership, a general partnership established under the laws of Ontario ("**RTG**" and/or "**Project Co**") and Rideau Transit Maintenance General Partnership, a general partnership established under the laws of Ontario ("**RTM**" and/or the "**Maintenance Contractor**"), the "**Maintenance Contract**". |
| Action Required: | |

Subject: Final Derailment Report of LRV 1116 on March 14th, 2021

Dear Mr. Truchon,

Capitalised terms not defined herein shall, save as otherwise specified, have the definitions ascribed to them in the Maintenance Contract.

Please find attached the Derailment Report of LRV 1116 that occurred on March 14th, 2021, prepared by RTM's Maintenance Subcontractor, Alstom Transportation Inc. ("**Alstom**") as well as the relevant attachment thereto, for submission to the City.

RTM is available to discuss the attached report with the City at their convenience.

RTM reserves all of its rights under contract, at law and in equity.

Sincerely,
**RIDEAU TRANSIT MAINTENANCE GENERAL PARTNERSHIP**

Mario Guerra, General Manager

RTM

Attachments: OTT-ENG-REP-066_revB_LRV1116 MSF Yard Derailment Report
OTT-ENG-REP-056_revB_Track14_Curve19_Geometry

Cc.: Meaghan Walser, Bruno Tremblay, Document Control – RTG
James Messel, Steve Nadon, Tania Seely – RTM

| ALSTOM · mobility by nature · | LRV 1116 MSF Yard Derailment Investigation Report | Document Reference: OTT-ENG-REP-66 Version B | Application date : 2021-06-28 |
|---|---|---|---|
| **Written by:** | N. Sembeyev / Bogie Warranty Engineer<br>Y. Liu / Project Engineering Manager<br>S. Hernandez / Project Qualty Manager<br>C. Khokhar / Engineering Technician | | |
| **Verified by:** | L. Goudge / Train System Engineer | Ensures that the technical/ process accuracy has been checked. | |
| **Approved by:** | R. France / Project Manager | Orders, by his signature, the implementation of the document. | |

## SECTION 1 SCOPE

On 14 March 2021, at approximately 13:19, Ottawa Confederation Line LRV 1116 derailed at low speed in the maintenance and storage facility Yard (MSF) during a routine move from the storage area to the handover platform.

The purpose of this report is to document the investigation to the flange climb derailment and present the containment actions, root causes, and recommended next steps.

## SECTION 2 INCIDENT OVERVIEW

### 2.1 Incident

On 14 March 2021 at approximately 13:19 EST, LRV 16 was coupled to LRV 17, with LRV17 as the leading car. The consist was performing a move from MSF storage shed to the handover platform. The direction of travel and train orientation is as shown in Figure 1. No passengers were on the LRV at the time. The speed of the train through the movement ranged from 0 to 10 km/h.

As the multiple unit consist moved through curve 19, the IMC and LMC1 bogie on LRV16 derailed. The detailed sequence of events as below.

○ represents position of leading cab on LRV 17

● represents position of trailing cab on LRV 16

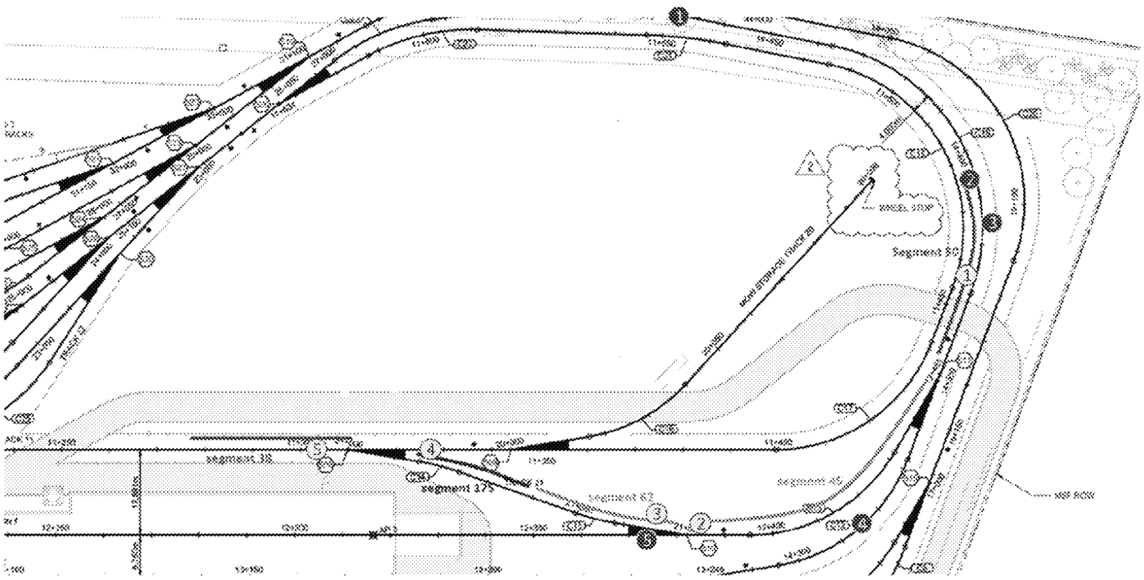


**Figure 1 Train location corresponding**

LRV17 Cabin MC2 was keyed in RM mode and the movement started at 13:14

Event Marker 1 / Time 13:19:40:

LRV17 stopped at the fouling point for Switch 511. LRV16 is not yet in curve C19.

Event Marker 1 – 2 / Time 13:19:40 to 13:20:14:

Train 17 stopped at FP SW 510, FP is 3-4 feet away from switch. LMC1 of LRV16 is stopped in curve C19.

Event Marker 2 – 3 / Time 13:20:14 – 13:20:17:

Shortly after restarting movement, LRV16 begins to detect frequent slips caused by the LMC1 bogie having climbed and derailed. LRV17 does not see any errors and continues with speed of around 10 km/h.

Event Marker 3 – 4 / Time 13:20:17 – 13:21:00:

After derailment of LRV16 MC1, the consist continued moving covering segments 62 passing over switch 510 and stopped somewhere on segment 175. LRV 16 bogie IMC derails after passing over switch 510.

Event Marker 4 – 5 / Time: 13:21:00 – 13:21:55:

Driver tried to move the train again but lost traction authorization because of fastbrake application on LRV16. Driver cycled the doors and received traction authorization. Driver moved the train and stopped on segment 38 after SW 508, where he lost traction authorization again because of fastbrake application.

Radio transcript show at 13:21:47 hostler calling yard control and reporting that 'I have a traction problem. I am not able to drive properly, and asking for warranty assistance.' At 13:21:58 YCC responds and calls WT / GT.

After the train was stopped at its final position, the driver exited the train to inspect the consist after receiving permission from yard control. The driver subsequently reported that LRV16 had derailed. Yard rail control and Alstom management were informed. After an inspection to verify the integrity of the track and the LRV, the train was rerailed around 8:46 pm.

## 2.2 Characterization of Damages on the Track

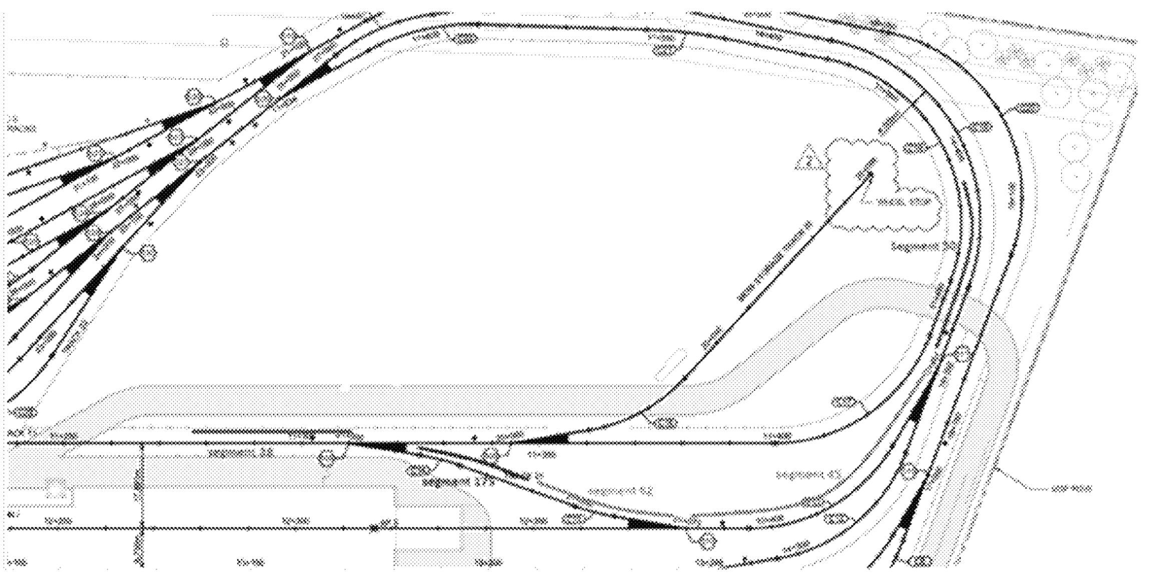


**Figure 2 MSF section map**

### 2.2.1 Segment 50:

At the derailment point, clear marks of wheel climb can be seen on the top of rail.

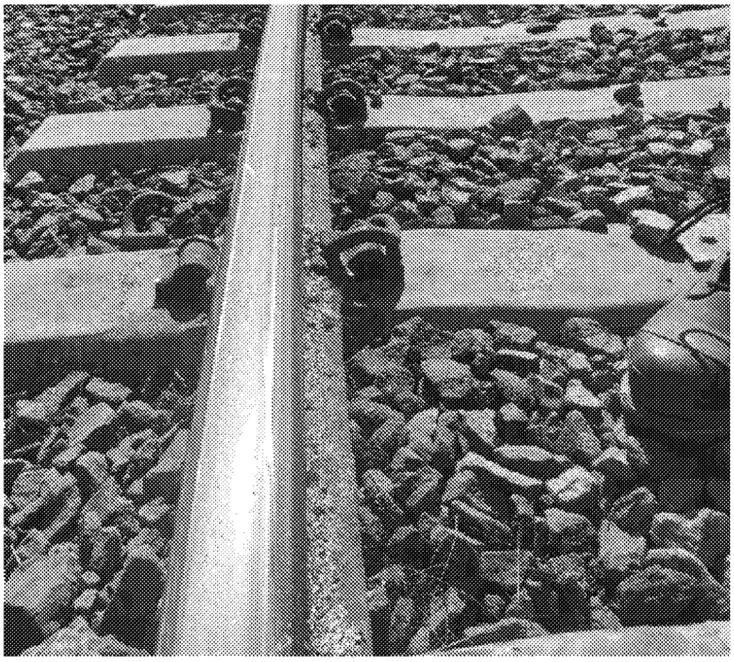


**Figure 3. Wheel flange marks on top of rail**

Outer edge of the rail showed signs of scoring from contact with the gearbox all along the rail

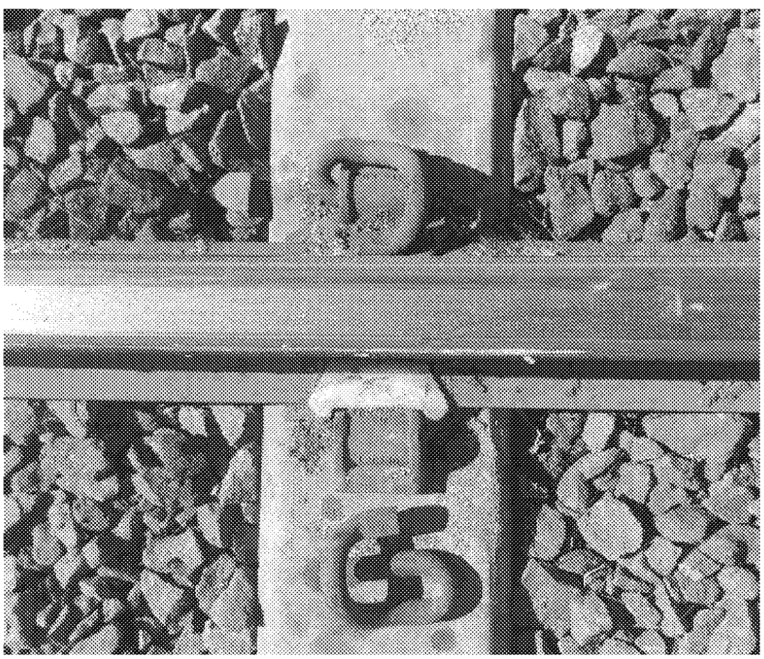


**Figure 4. Signs of scoring**

### 2.2.2 Section 45

There were noticeable damage to the pavement at the crossing due to contact from the bogie speed sensor harness bracket

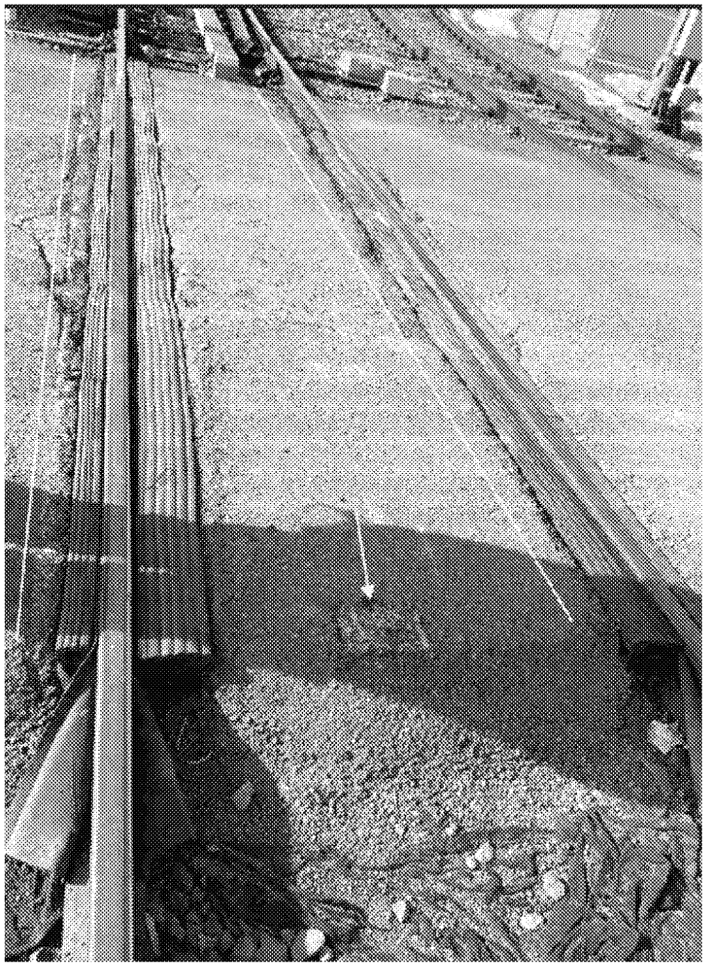


**Figure 5. Damage to pavement**

The first OCS pole showed signs of contact with LRV. The integrity of the pole was verified to be OK.

**Figure 6. Damage to OCS pole**

Switch 511 showed minor damage on the frog and duct work.

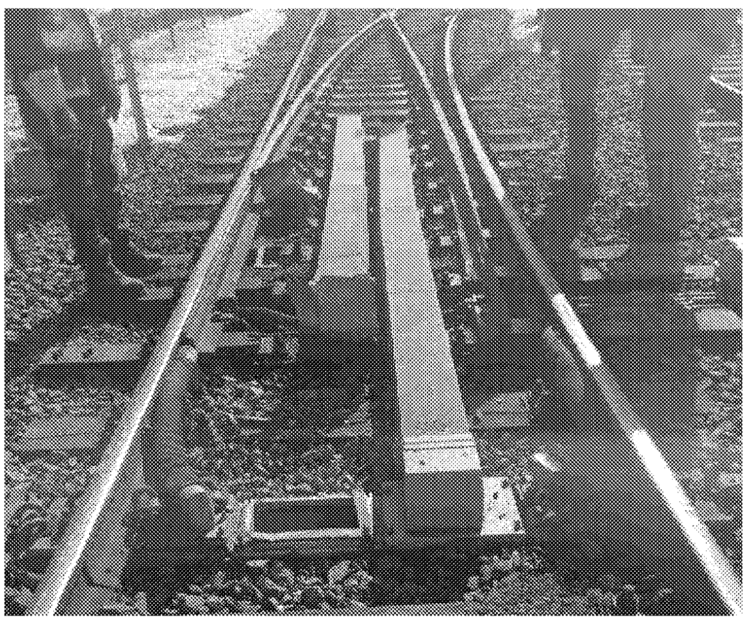


**Figure 7. Switch 511 damage**

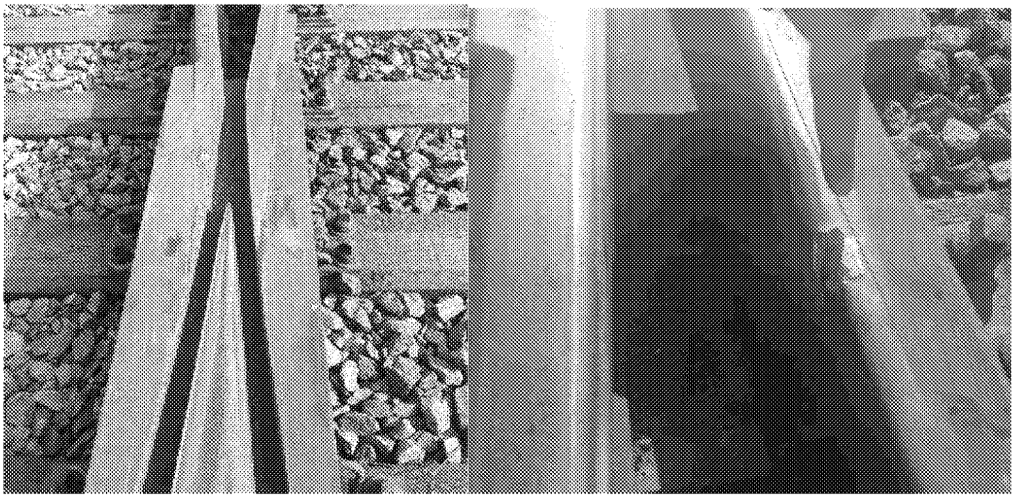


**Figure 8. Switch 511 Damage**

#### 2.2.3 Segment 62

Switch 510 showed significant damage:

- The switch heater ductwork / nozzles was damaged significantly.
- The switch point was chipped.
- One switch short throw rod was damaged
- Various brackets, hardware, and fasteners showed minor damage

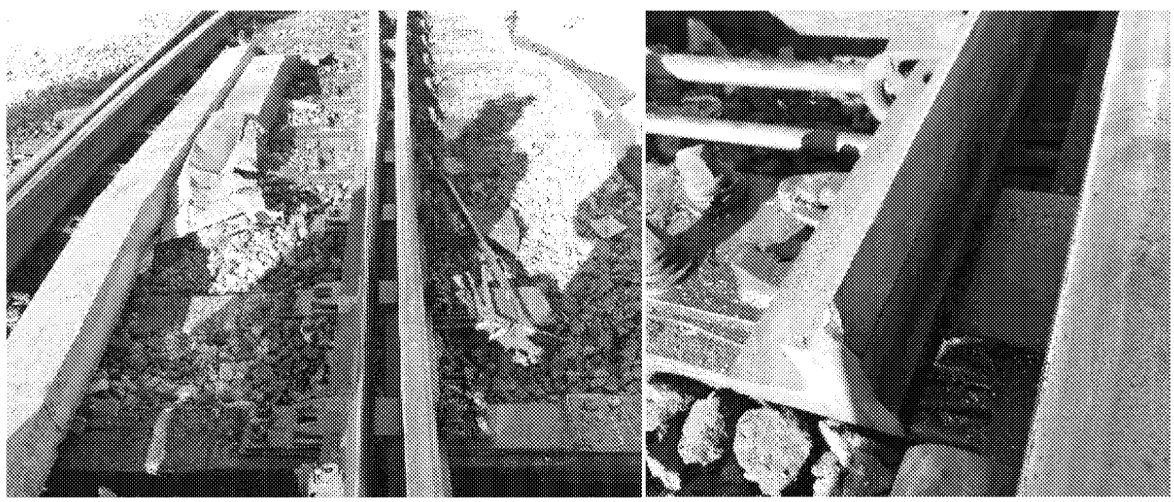
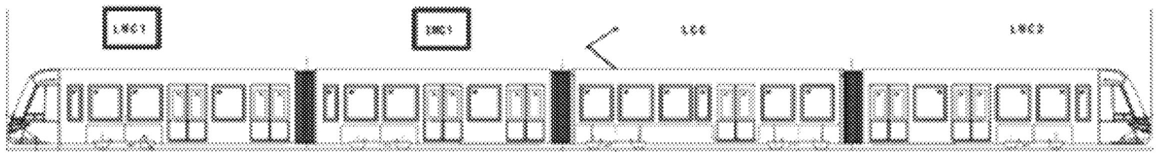


**Figure 9. Switch 510 Damage**

### 2.3 Characterization of Damages on the Train

Visual inspection of the vehicle was performed on BM1-008 and BP1-046 in the maintenance bay.



BM1-008 BP1-046

The listed components were visually damaged on LRV16 LMC1 and IMC car. No damage on LCC and LMC2 car. All damaged parts are pending replacement.

| SN | Material Description | Part Reference | Qty |
|---|---|---|---|
| 1 | OPONAM MOTOR BOGIE 1-PIVOT-NORMAL GAUGE (LMC1) | AR00000174447 | 1 |
| 2 | IPONAM OTT TRLER BOGIE 1-PIVOT-NRML GA (IMC) | AR00000172972 | 1 |
| 3 | DOUBLE GLAZED WINDOW 1384 OTTAWA FOR DIS (LMC1) | DE00000478014 | 1 |
| 4 | EQUIPPED LATERAL RIGHT SKIRT (LMC1) | AD00001129375 | 1 |
| 5 | EQUIPPED LATERAL LEFT SKIRT (LMC1) | AD00001129377 | 1 |
| 6 | BOGIE SKIRT (LMC1) | AD00001338392 | 2 |
| 7 | SYMETRIC BOGIE SKIRT (LMC1) | AD00001338474 | 2 |
| 8 | SYMETRIC LITTLE FIXED SKIRT (LMC1) | AD00001328482 | 2 |
| 9 | SLEWING RING (LMC1 and IMC) | AR00000184111 | 2 |
| 10 | EQUIPPED DOOR THRESHOLD BRACKET (LMC1) | AD00001777261 | 1 |
| 11 | EQUIPPED LATERAL LEFT SKIRT (LMC1) | AD00001129377 | 1 |
| 12 | COUPLER ISOLATION COCK (LMC1) | AD00001581057 | 1 |
| 13 | AUTOMATIC COUPLER (LMC1) | AD00001446347 | 1 |
| | Multiple underframe pipes | Various | |

### 2.3.1 LMC1 Car body inspection

- Cab front end fixed panel and bumper damaged

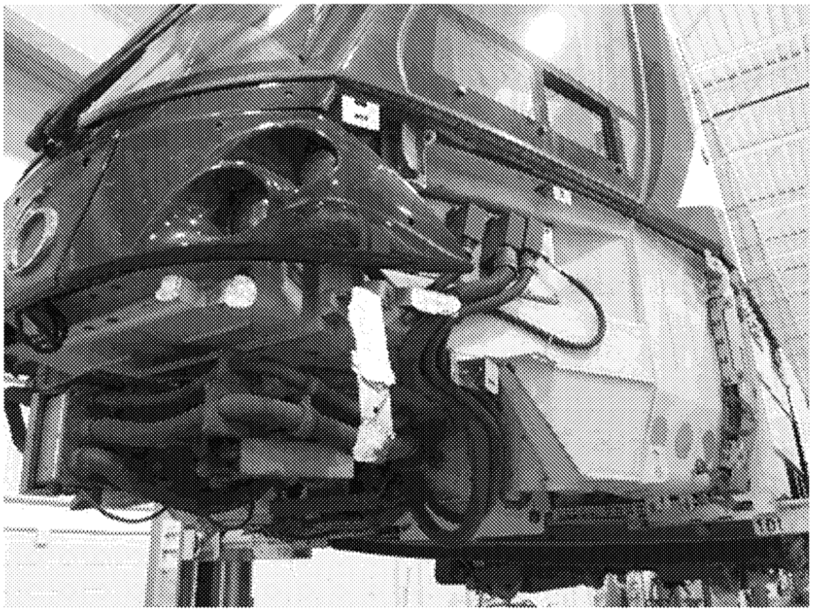


Figure 10. LMC1

- Chassis welded snow plough support bracket damaged.

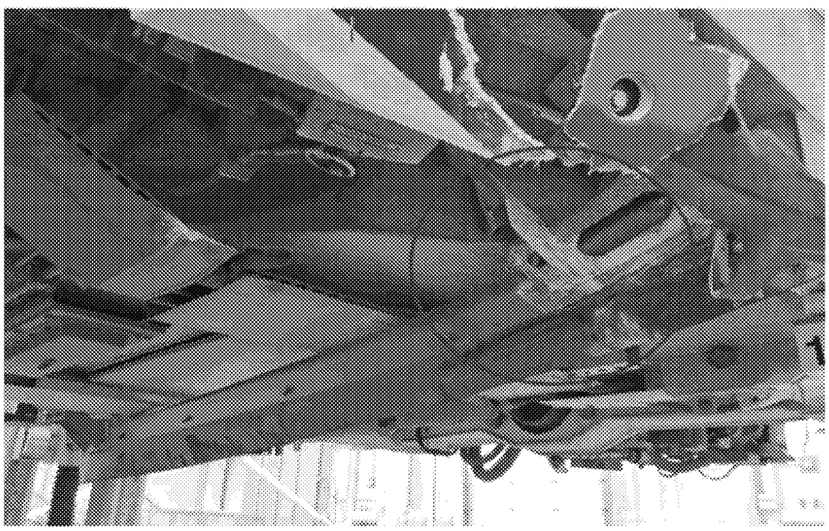


Figure 11. LMC1

- Impact on coupling isolation/coupler control panel and underframe support brackets

Figure 12. LMC1

- Impact on cab underframe and coupler pneumatic/hydraulic pipes

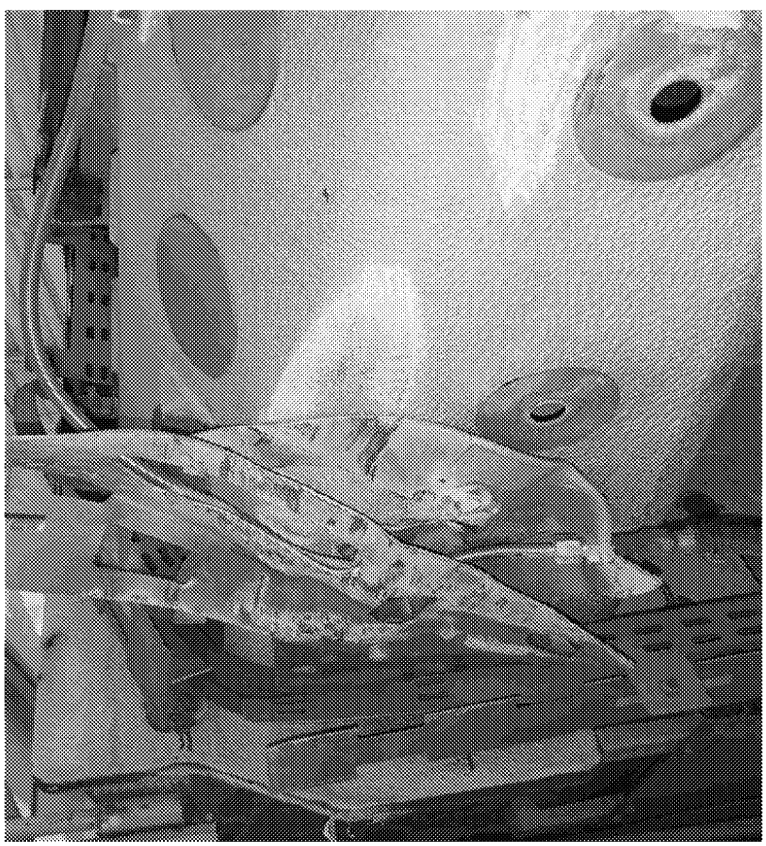


Figure 13. LMC1

- Impact on LMC1 Underframe and lifting points

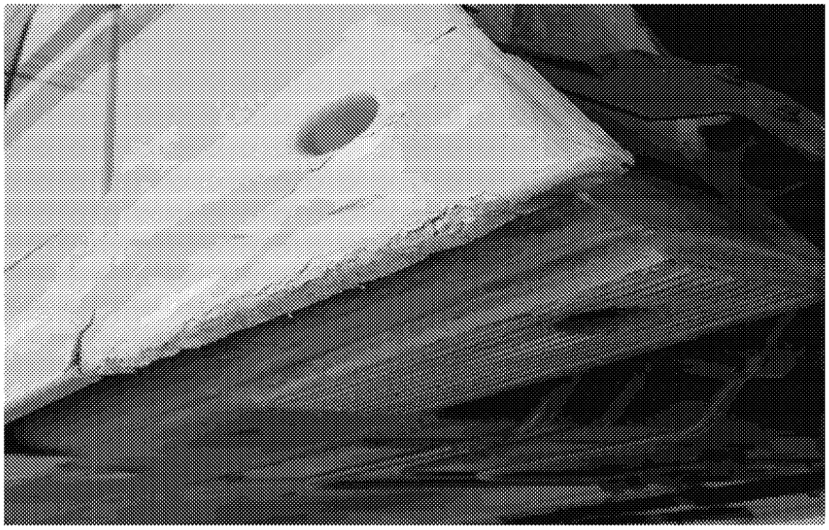


**Figure 14. LMC1**

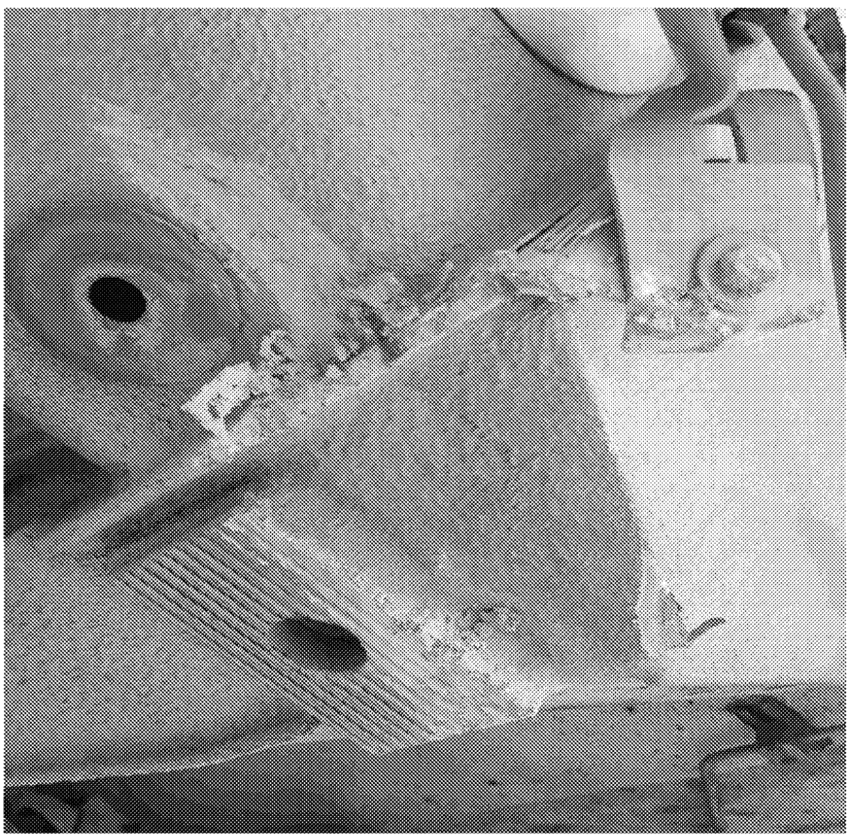


**Figure 15. LMC1**

- Impact on LMC1 underframe car body

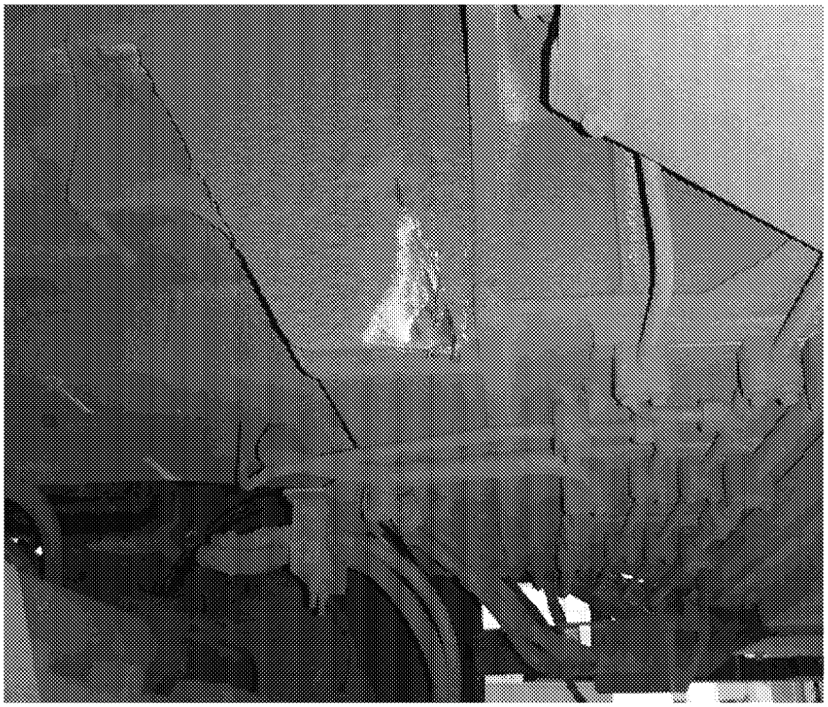


**Figure 16. LMC1**

- LMC1 right-side broken window # 2 and side panels

**Figure 17. LMC1**

- LMC1 right-side door#2 damaged door threshold cover

**Figure 18. LMC1**

### 2.3.2 LMC1 Bogie BM1-008

- LMC1 BM1 bogie overview

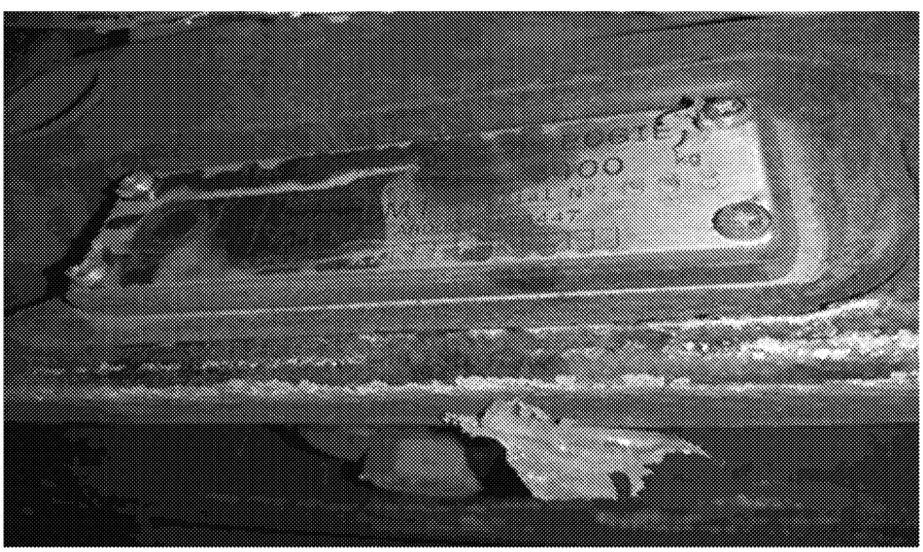


**Figure 19. Bogie BM1**

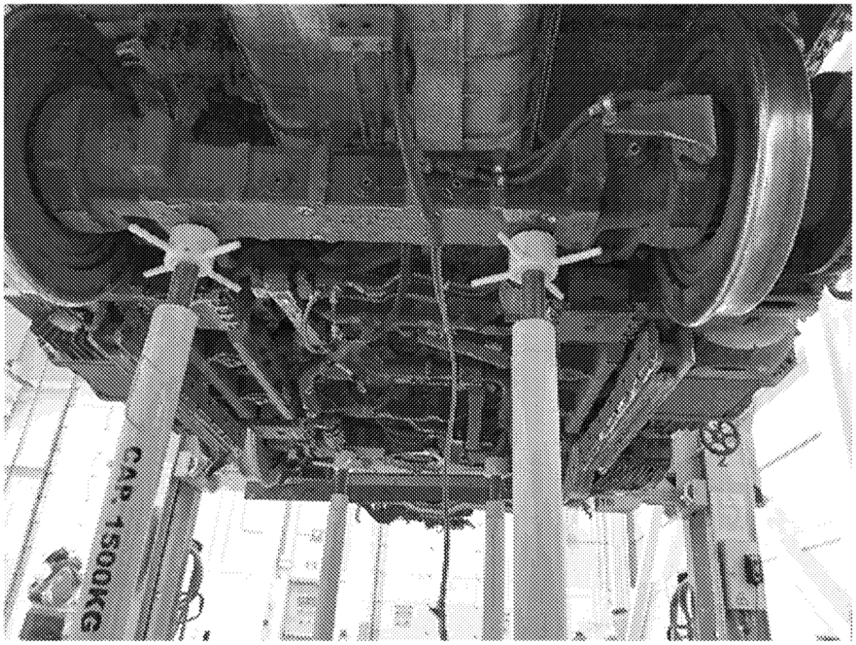



**Figure 20. Bogie BM1**

- LMC1 BM1 impact on anti-roll bar

**Figure 21. Bogie BM1**

- Damages to wheel shunts and gear box. BM1 axle 2 left side

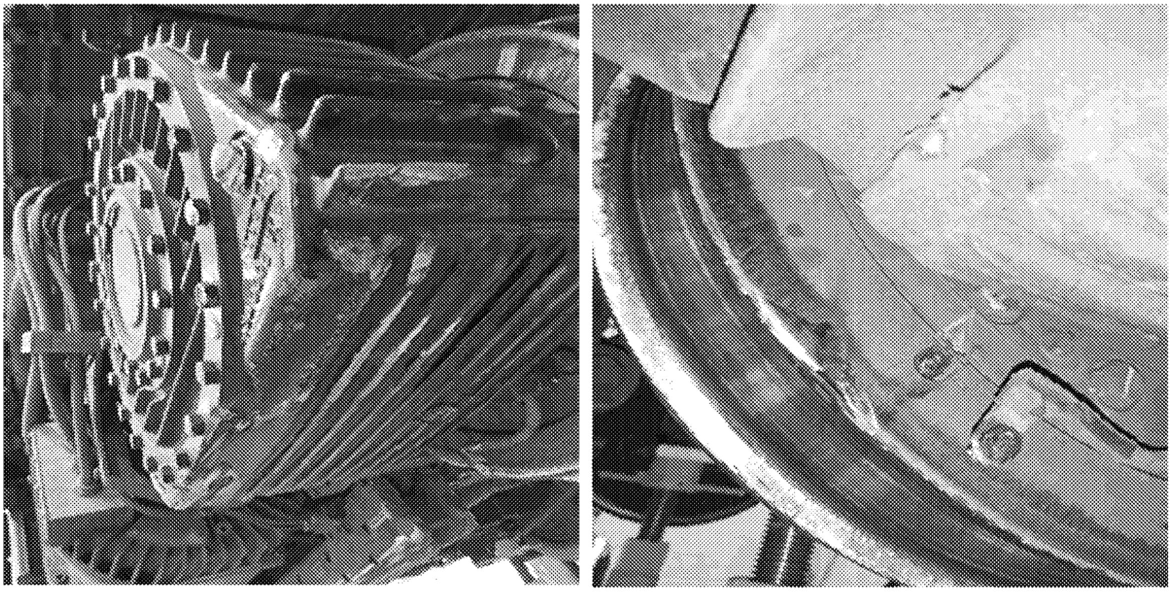


FIGURE 22. BOGIE BM1

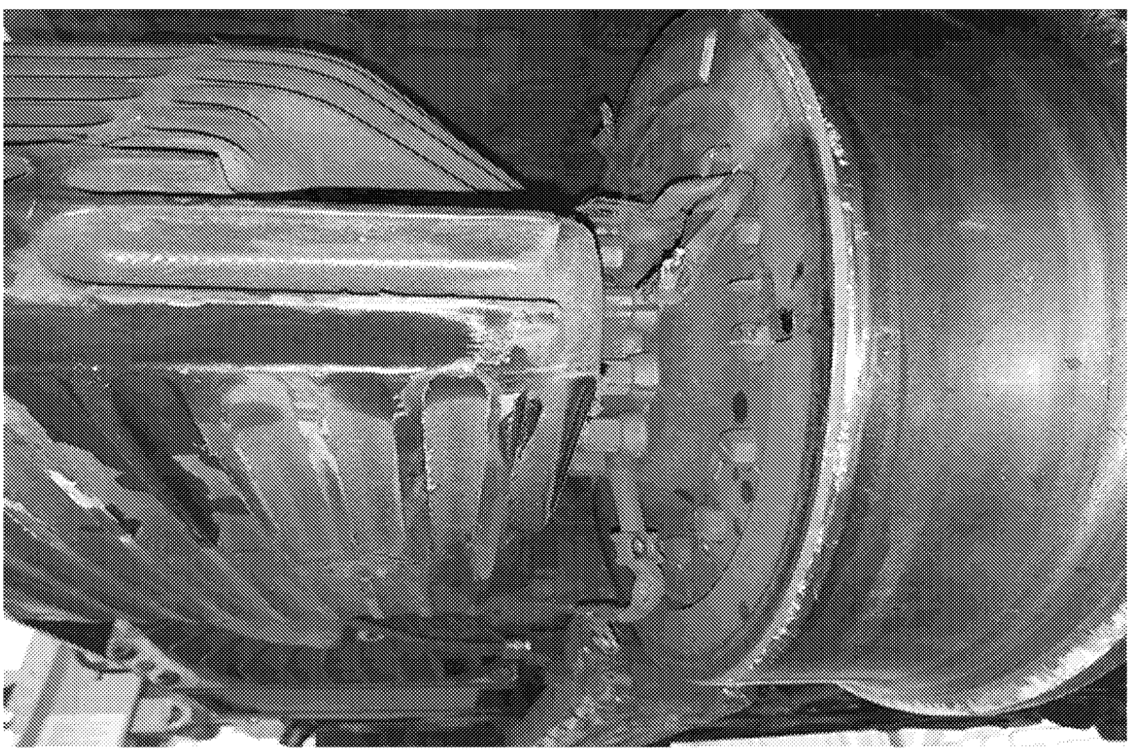


**Figure 23. Bogie BM1**

- Impact on BM1 left-side magnetic track brakes.

**Figure 24. Bogie BM1**

- Impact on BM1 primary suspension spring seat and baffle

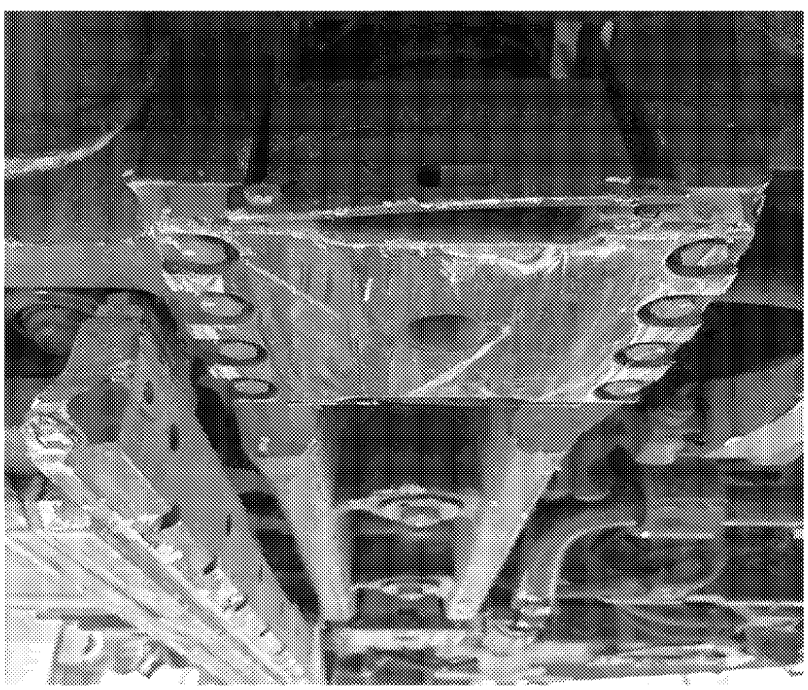


**Figure 25. Bogie BM1**

- Damage to BM1 right-side gearbox

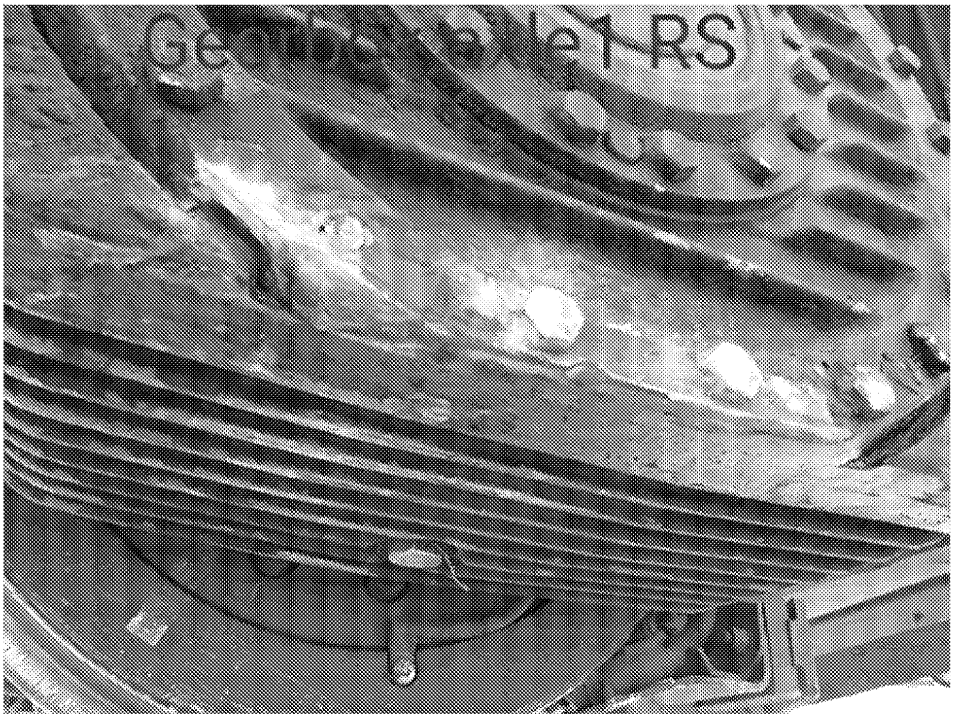


**Figure 26. Bogie BM1**

- Damages to BM1 axle 2 brake disc

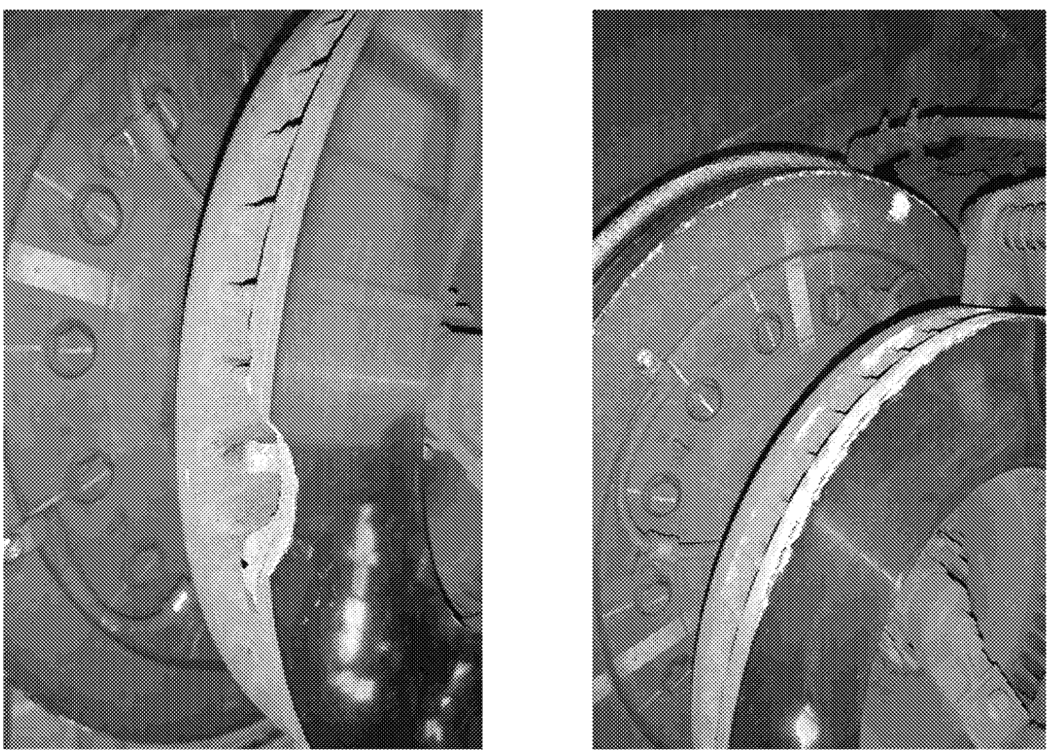


**Figure 27. Bogie BM1**

- Damages to BM1 loom brackets and hydraulic hoses

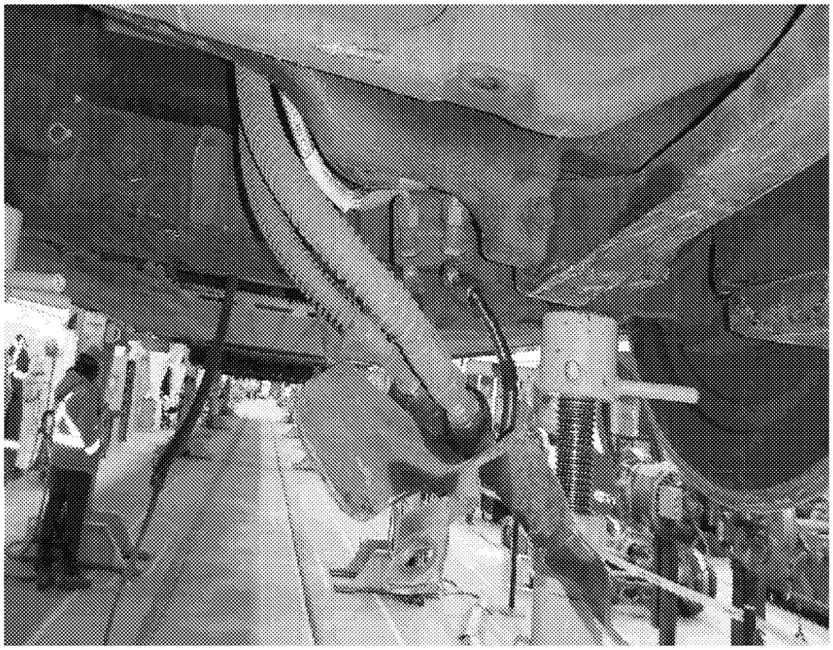


**Figure 28. Bogie BM1**

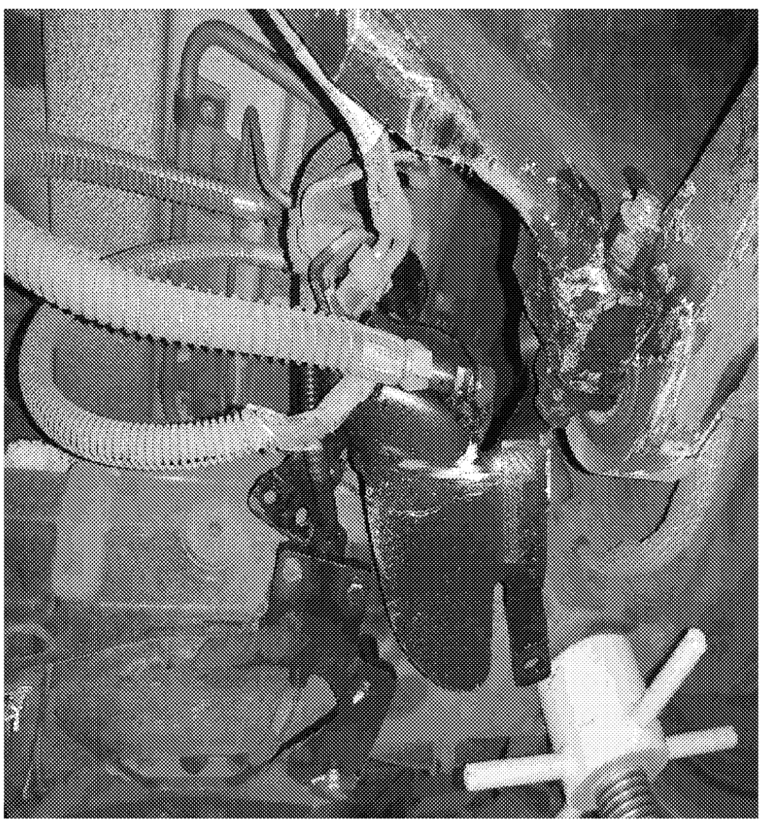


**Figure 29. Bogie BM1**

- Damages to BM1 right side Motor


**Figure 30. Bogie BM1**

Damages to BM1 low tension clamp bracket

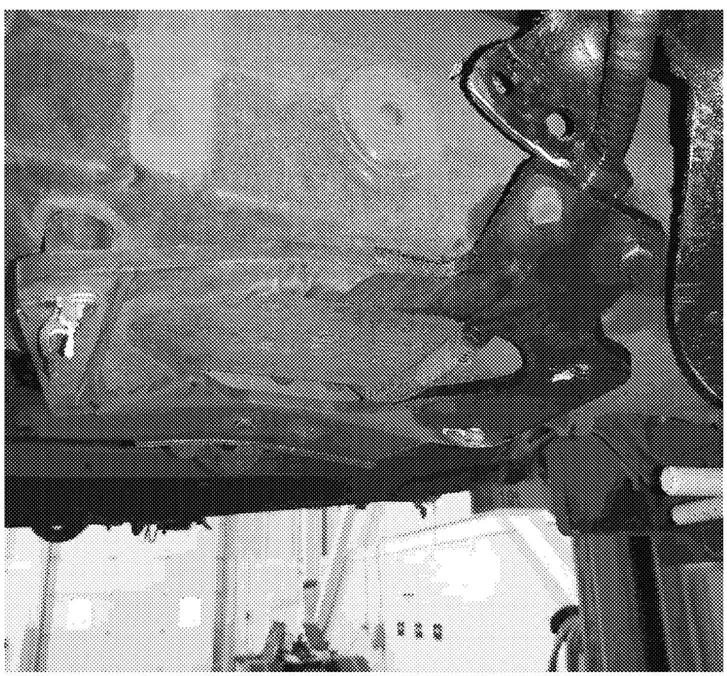


**Figure 31. Bogie BM1**

- Speed sensor harness and connector ripped off. Support bracket bent. Scrapes on the exterior axle housing.

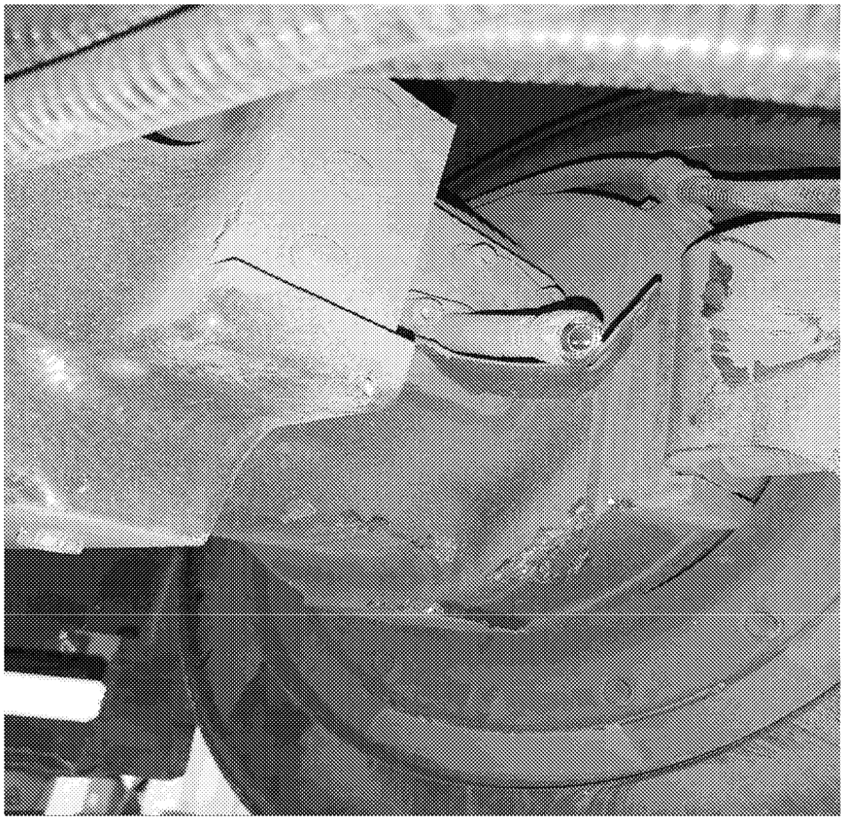


**Figure 32. Bogie BM1**

- BM1 Bolster component bent and pin displaced

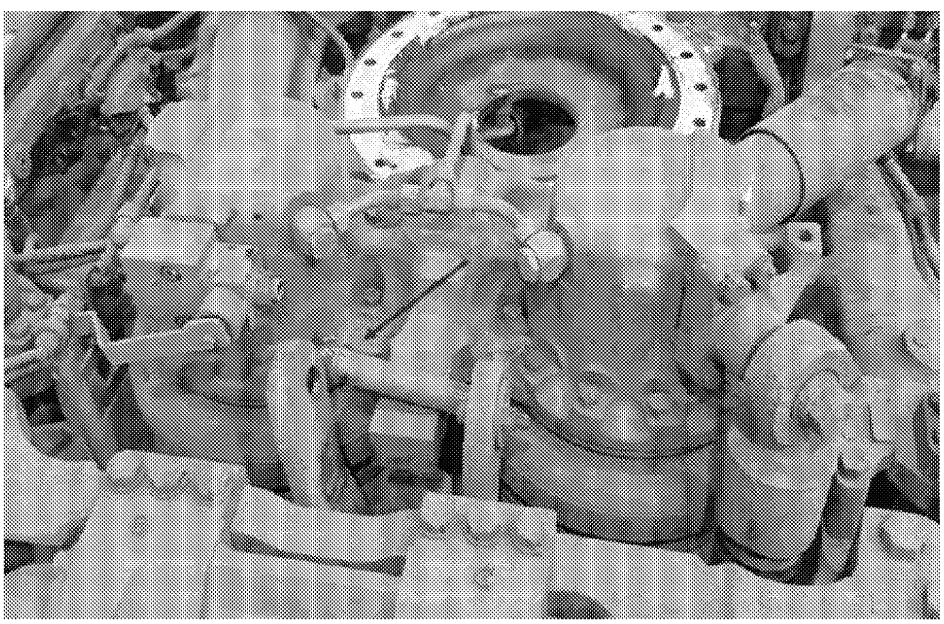


**Figure 33. Bogie BM1**

### 2.3.3 BP1-046 (DBGT) BOGIE

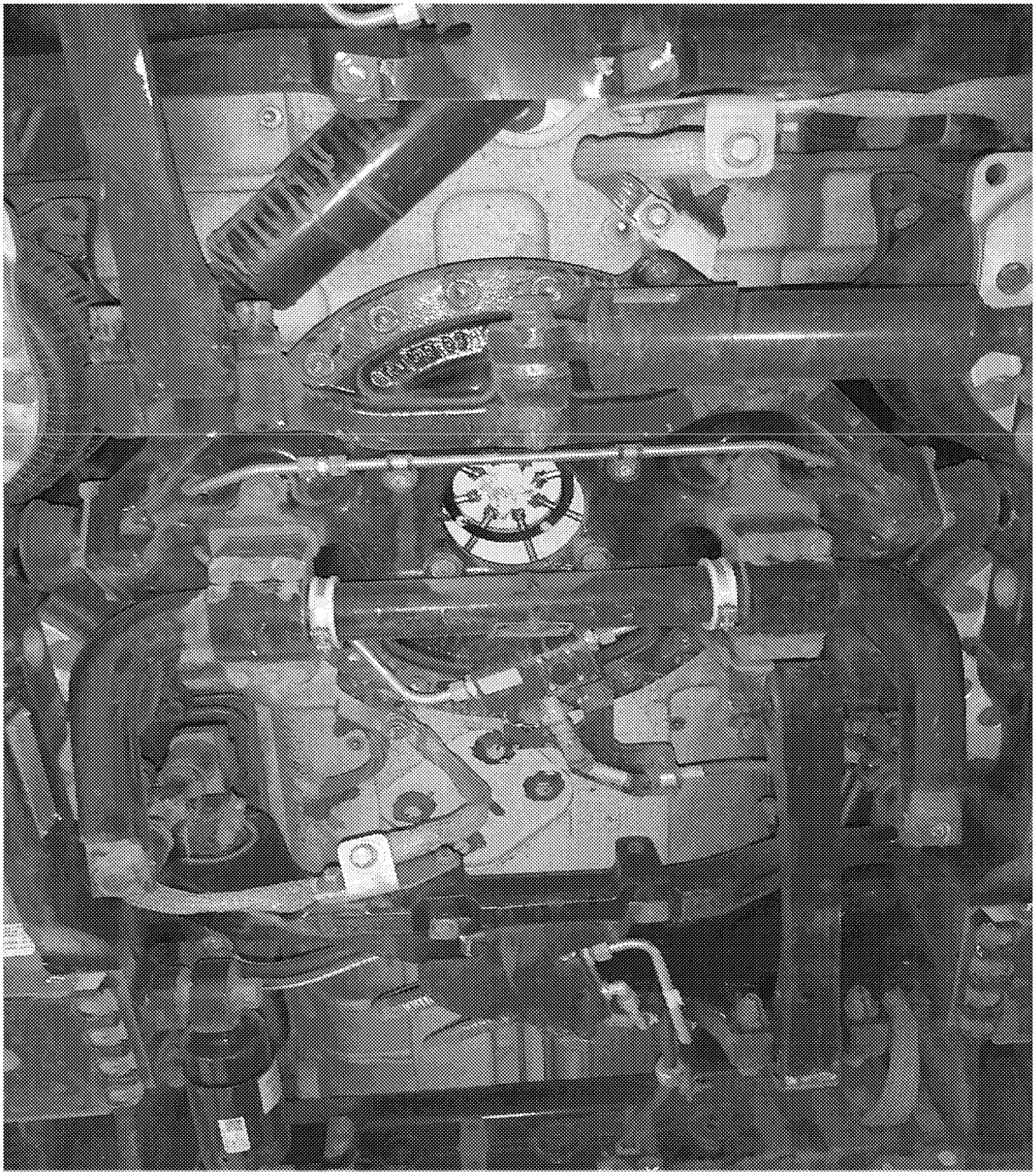


**Figure 34. Bogie BP1**

- Broken bolts on Loom brackets with the thread stubs stuck in bolster frame

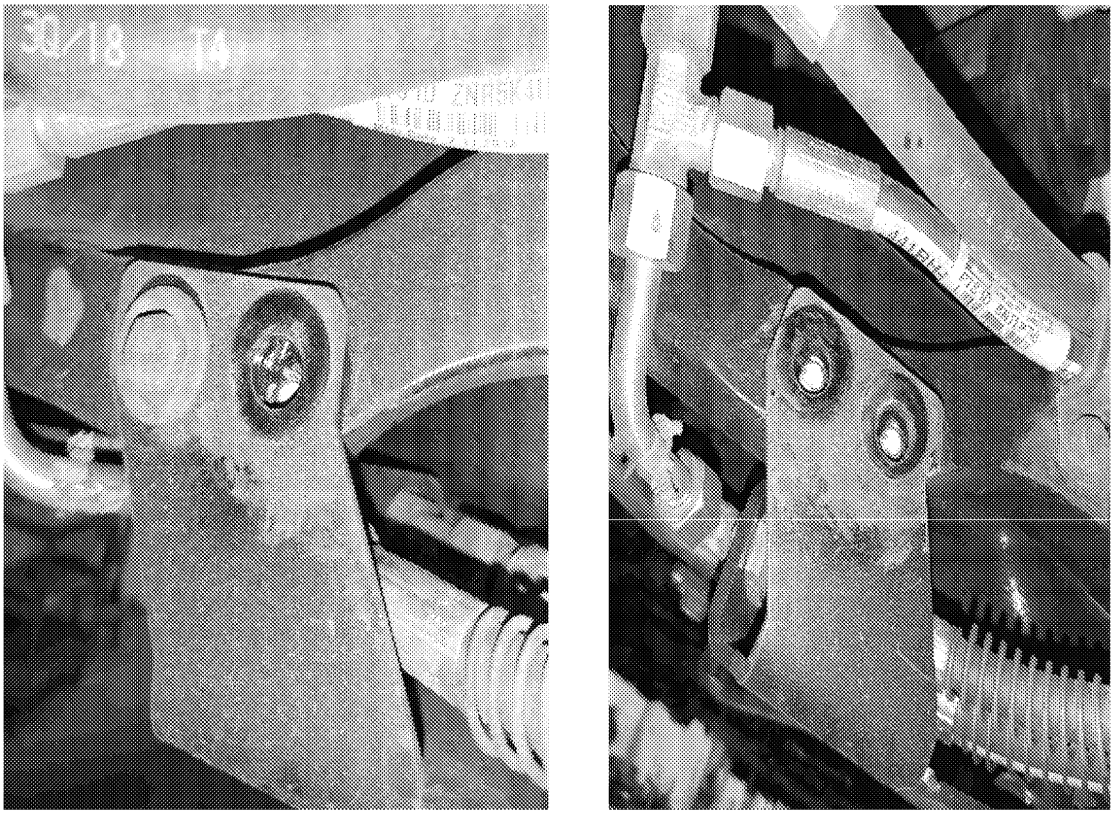


Figure 35. Bogie BP1

- BP1 impact on baffle and anti-pitch damper

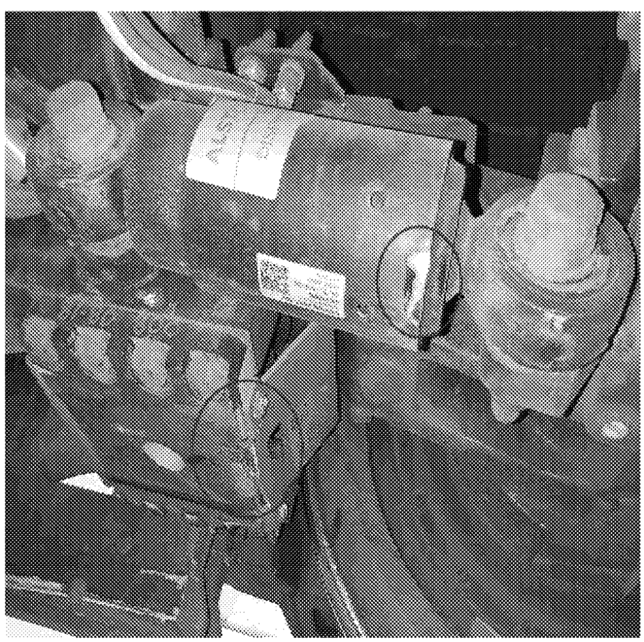


Figure 36. Bogie BP1

- BP1 Dented CPM Loom Bracket

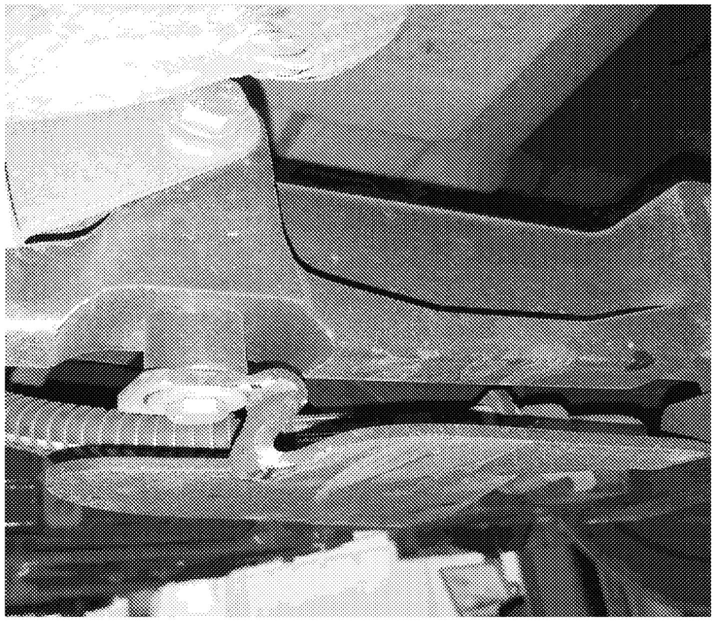


Figure 37. Bogie BP1

- Impacts on Magnetic Track Brakes and cable connection

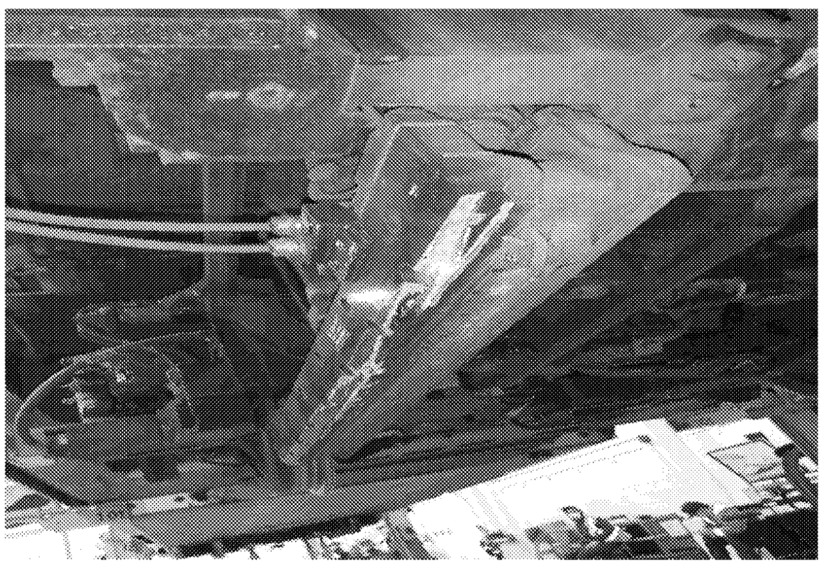


Figure 38. Bogie BP1

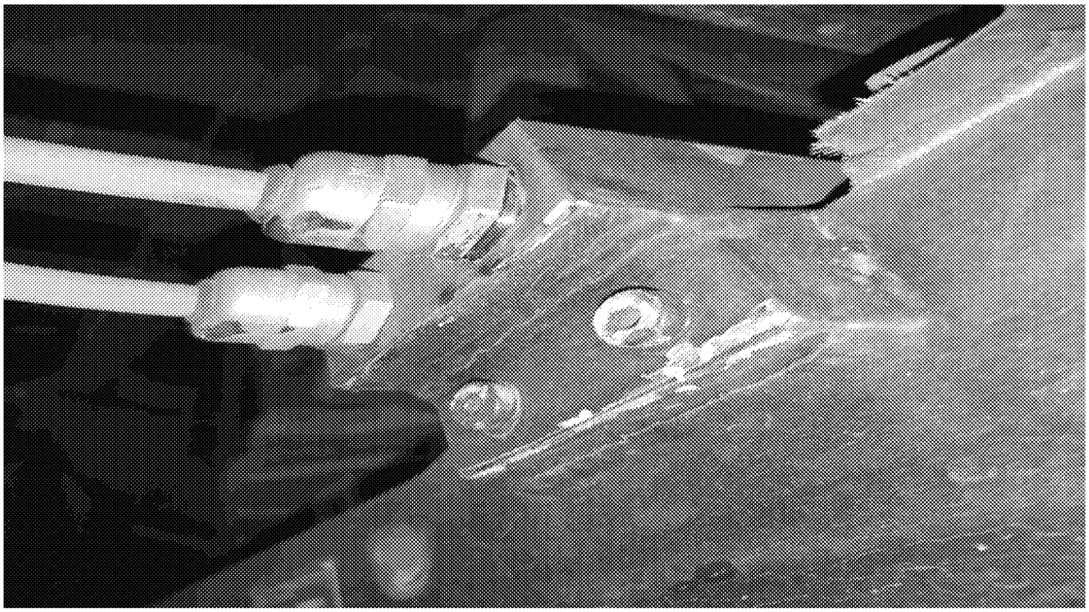


**Figure 39. Bogie BP1**

## 2.4 Train Condition

### 2.4.1 Train Condition at time of derailment

At the time of the derailment, LRV 16 was in a nominal state. The LRV daily inspection was performed and passed prior to launch. The onboard systems were healthy and no faults were indicated:

- Train mode: RM
- ATC Status
  - LRV17 VOBC active
  - LRV16 passive available,
- Brake status
  - Healthy/No fault
- TCMS
  - Healthy/No faults
- Pneumatic systems: Healthy/Not in fault
- Traction braking systems: Healthy/Not in fault, LRV speed limit of 100 kph.
- EVR
  - Healthy/No faults

### 2.4.2 Recent train maintenance history

The LRV has completed a 25K km maintenance on March 6th.

The LRV had train wide slewing ring regreasing on January 17th, 2021.

The wheel of the train were last reprofiled during 150K km maintenance on December 17th, 2020.

List of WOs for recent train preventive maintenance is as below:

| Order | Order Type | Description | Completion |
|---|---|---|---|
| 60799734 | ZS02 | RS 25K LRV1116 INSPECTION | 2021-03-06 |
| 60771622 | ZS02 | RS 10K LRV1116 INSPECTION | 2021-02-15 |
| 60594727 | ZS02 | RS LRV1116 Wheel Wear Inspection | 2021-02-04 |
| 60726654 | ZS02 | RS 10K LRV1116 INSPECTION | 2021-01-14 |
| 60686190 | ZS02 | RS 150K LRV1116 INSPECTION | 2020-12-17 |

List of WOs for recent fleet checks and retrofits as below:

| Order | Order Type | Description | Technical completion |
|---|---|---|---|
| 60809339 | ZS02 | RS1116 SPEED SENSOR BRACKET TORQUE CHECK | 2021-03-05 |
| 60788371 | ZS02 | RS 1116 BOGIE EQUIPMENT BRACKET CHECK | 2021-02-20 |
| 60611432 | ZS02 | RS 1116 Wheel flange nozzle check | 2021-02-04 |
| 60736478 | ZS02 | RS 1116 MPU1.2.6.0 & DDU1.5.5.0 INSTALL | 2021-02-02 |
| 60673390 | ZS02 | RS 1116 SENSITIVE EDGE RETROFIT | 2021-01-28 |
| 60705389 | ZS02 | RS 1116 SPEED SENSOR BRACKET CORRECTION | 2021-01-27 |
| 60742425 | ZS02 | RS 1116-B MC2 BELL RADIO UPGRADE | 2021-01-27 |
| 60742426 | ZS02 | RS 1116-A MC1 BELL RADIO UPGRADE | 2021-01-27 |
| 60563775 | ZS02 | RS 1116 Line inductor retrofit | 2021-01-20 |
| 60676506 | ZS02 | RS 1116 SLEWING RING GREASING | 2021-01-17 |
| 60687474 | ZS02 | RS 1116 SNIFFER FILE INSTALLATION | 2021-01-02 |
| 60703613 | ZS02 | RS 1116 Speed Sensor Bracket Visual Chec | 2021-01-02 |
| 60563727 | ZS02 | RS 1116 Line contactor retrofit | 2020-12-24 |
| 60705098 | ZS02 | RS 1116-A MC1 BELL RADIO UPGRADE | 2020-12-24 |
| 60705157 | ZS02 | RS 1116-B MC2 BELL RADIO UPGRADE | 2020-12-24 |

## 2.5 Track Condition

Track 14 is one of the 3 maintenance tracks in the MSF leading from the shed to the LMB. See Figure 40.

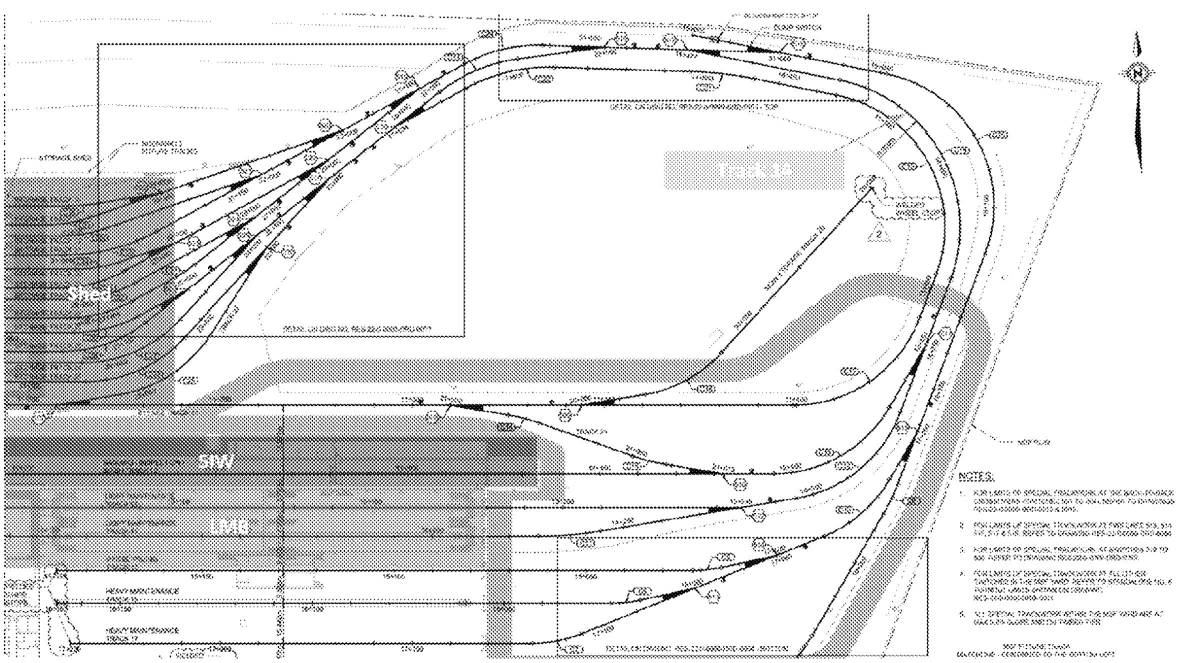



**Figure 40. MSF Layout**

The design parameters of the track 14 curve 19, where the train derailed, are specified in Table 1.

**Table 1. Track 14 Nominal Data**

| | |
|---|---|
| Class | Class 3 |
| Gauge nominal | 1435 mm |
| Speed limit [design] | 15 km/h |
| Speed limit [in effect] | 10 km/h |
| Curve 19 curve radius (design) | 39 m |
| Super-elevation (design) | No super elevation / unbalance |
| Spirals (design) | No spirals |
| Ties | Concrete ties |
| Other | Pandrolized track on ballast |

The track is used frequently each day.

### 2.5.1 Track History

LRV26 derailed at a different location on the same curve on October 18th 2020 under similar operating circumstances: the train derailment shortly after stopping and restarting movement at low speed

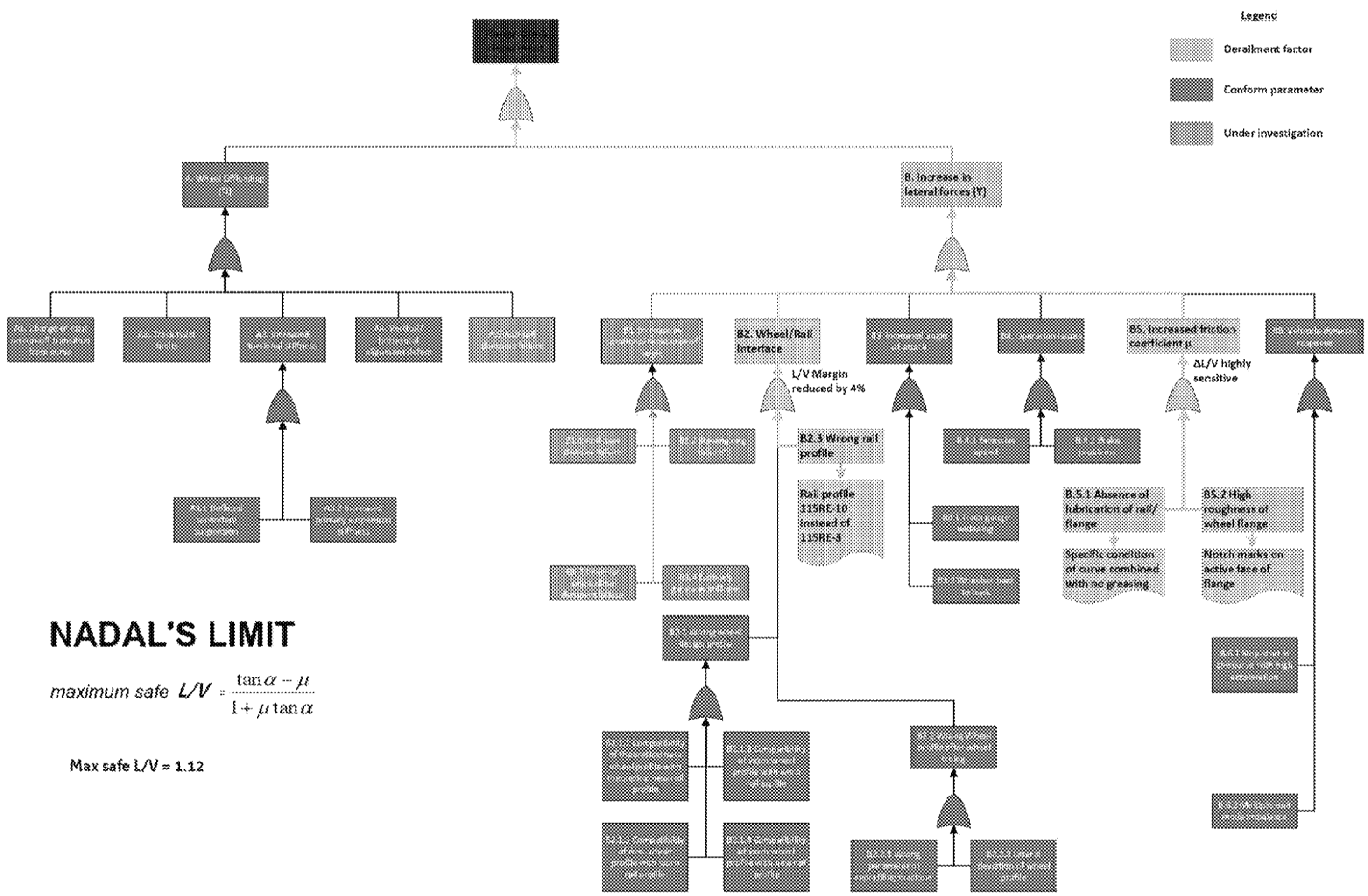
The main differences between these two derailments was that LRV26 was operating as a single unit, while LRV16 was operating in multiple unit.

The details of the LRV26 derailment is specified in report TN-018

## 2.6 Weather

There were no abnormal weather conditions at the time of derailment. The weather was dry with no precipitation. Temperature was around 0 degrees Celsius. There were also no reports of strong winds.

## SECTION 3 FAULT TREE




**NADAL'S LIMIT**

$$\text{maximum safe } L/V = \frac{\tan\alpha - \mu}{1 + \mu \tan\alpha}$$

Max safe L/V = 1.12

The fault tree is structured on two branches as defined in Nadal's limit assessing items that lead to either increases in lateral forces or reduction of vertical loads. Derailment is considered possible any time the L/V ratio exceeds Nadal's limit.

# SECTION 4 INVESTIGATION

## 4.1 Investigation into Track Factors

### 4.1.1 Track Profile (FTA Branch A1 / A2 / A4 / B3)

Characterization of the track around the location of the flange climb was completed and report in report OTT-ENG-REP-056.

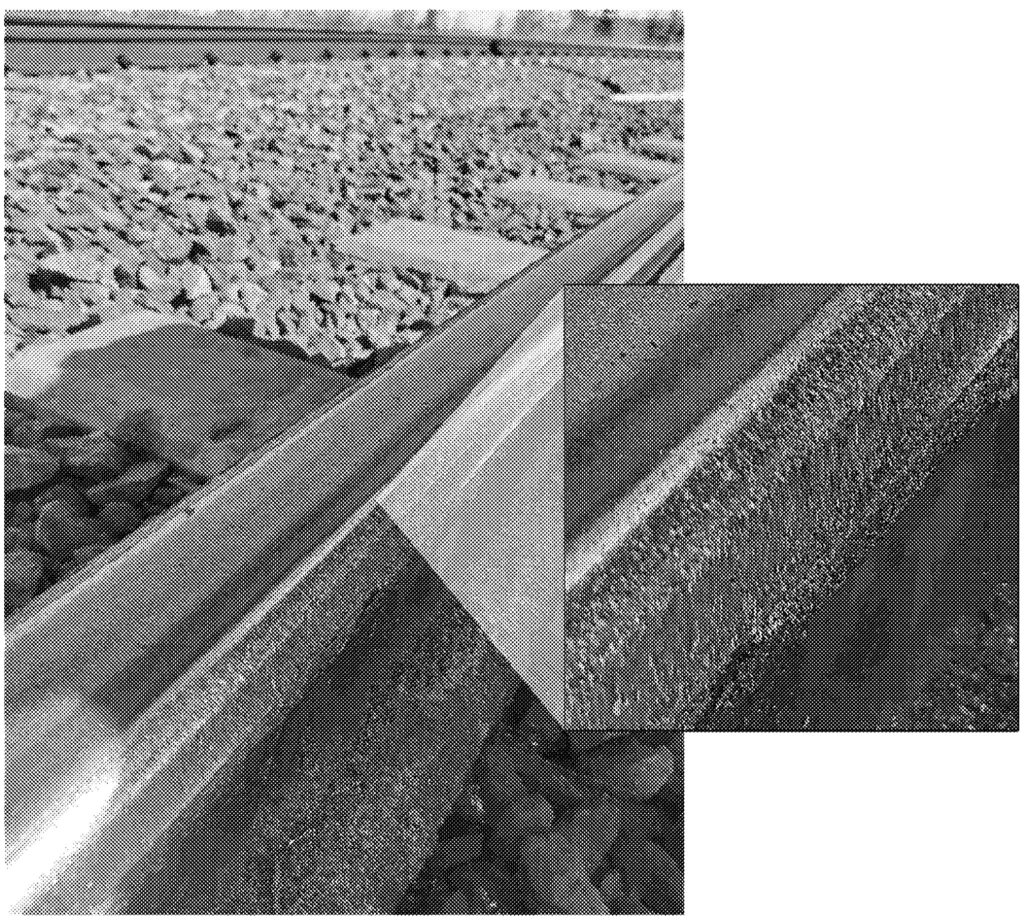
The following parameters were analyzed:

A. Track gauge
B. Track cross level
C. Rail wear
D. Rail gauge face angle
E. Horizontal deflection

The results show that all parameters were within the system operable limits, despite significant rail wear: rail wear is measured to be at 50% of the condemn limit.

### 4.1.2 Track Gauge Face Roughness / Lubrication Status (FTA Branch B5)

The gauge face of the track through curve 19 showed significant vertical scoring, as shown in the figure below:



This pattern of wheel flange showing suggests that there is still excessive friction between the wheelset and the rail, as documented in both of the previous two derailment reports (Ref: OTT-ENG-

REP-040 and TN-018). This also aligns well with reports of significant noise from the wheels as trains move through these curves, and signs of vertical scoring on the wheels.

Furthermore, no signs of the grease was present on the gauge face, but there were significant buildup of grease on the base of the rail. Maintenance records show that the previous manual lubrication were done on the following dates:

- January 7th
- February 4th
- March 4th

This is accordance to the containment actions described the previous derailment investigation reports.

Findings from LRV16 investigation suggests that monthly manual lubrication of the rails is too infrequent and insufficient.

## 4.2 LRV Event Recorder Log (FTA Branch B4)

The event recorder logs for both LRV17 and LRV16 is shown in Figure 41. The corresponding physical location of the train (nose of leading and trailing cab) is marked as shown in Figure 1

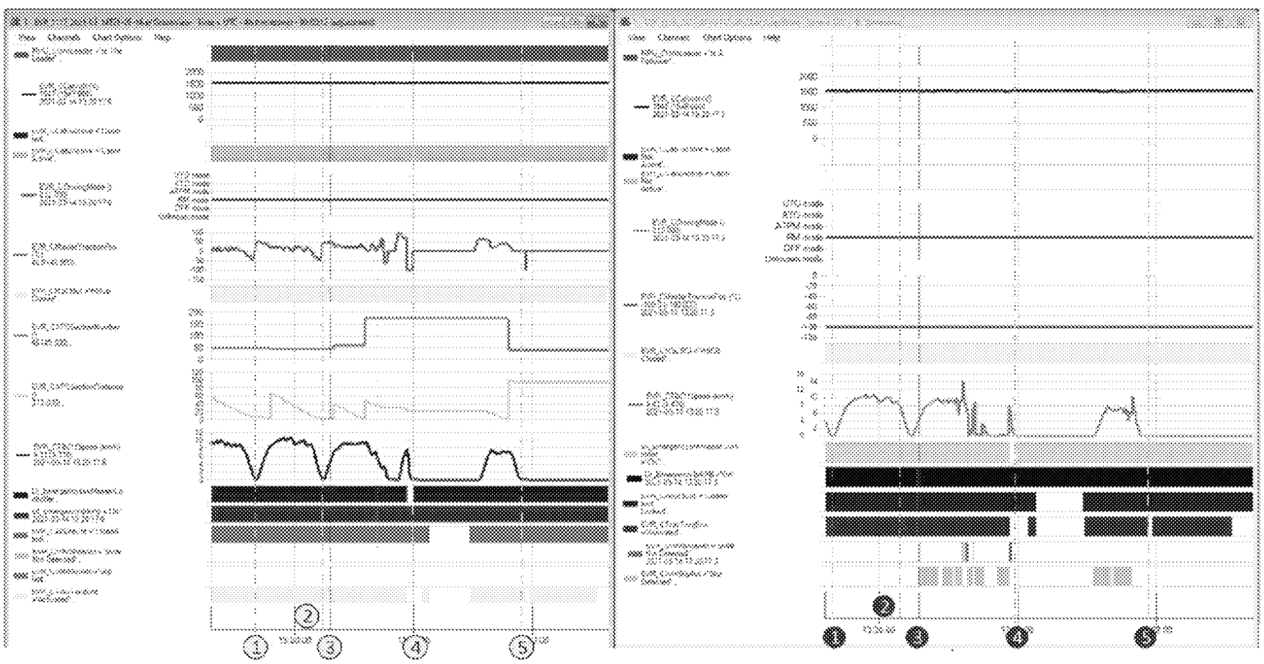



**Figure 41. LRV EVR Logs – LRV17 [Left] & LRV 16 [RIGHT]**

The logs show that at all time the train were within the speed limits of the track. As well, it is evident mechanical brake on all bogies applied and released properly (evident by the presence of the traction authorization).

## 4.3 Investigation to Vehicle Components

### 4.3.1 Primary and Secondary Suspension (FTA branch A3.1)

The secondary suspension of both derailed bogies were inspected for any failure that would lead to train imbalance.

Visual inspection of the secondary suspensions did not reveal any faults.

Inspection of the train event logs did not show any anomalies:

- incorrect weight balance
- incorrect leveling valve setting

### 4.3.2 Anti-Yaw Damper and Primary Suspension Damper (FTA branch A3.2 / B 1.1)

Visual inspection of anti-yaw dampers and primary suspension dampers for both bogies shows no signs of non-conformities.

The dampers are in process to be removed and sent to Alstom Naperville for characterization to ensure they were not contributing to an increased resistance in bogie rotation.

The results are pending.

### 4.3.3 Slewing Ring Investigation (FTA Branch B1.2)

Visual inspection of the slewing rings on LMC 1 and IMC shows signs of grease presence and no damages. Slewing rings are regreased at an interval of 100K km.

Vehicle maintenance records show both slewing rings were regreased on January 17th 2021. The mileage of the train was 160K km at that time.

Slewing rings of derailed bogies BM1 and BP1 were expertized by supplier in the presence of Alstom on 25/06/21. In summary, the signs of slewing ring blockage were not observed.

The slewing ring of BM1 bogie (s/n 507092) was cut in two parts in order to observe its state without rotation: the rolling elements are in good condition and not blocked, there is sufficient amount of grease, no presence of corrosion.

The slewing ring of BP1 bogie (s/n 507091) rotational resistance was measured: initial starting torque is 300 Nm, than 35 Nm. Rotation is smooth without jerks. We observed sufficient amount of grease, no presence of corrosion. Slight mark of false Brinelling are present on both slewing rings which is considered as normal for this application (low amplitude movement in the presence of corrosion).

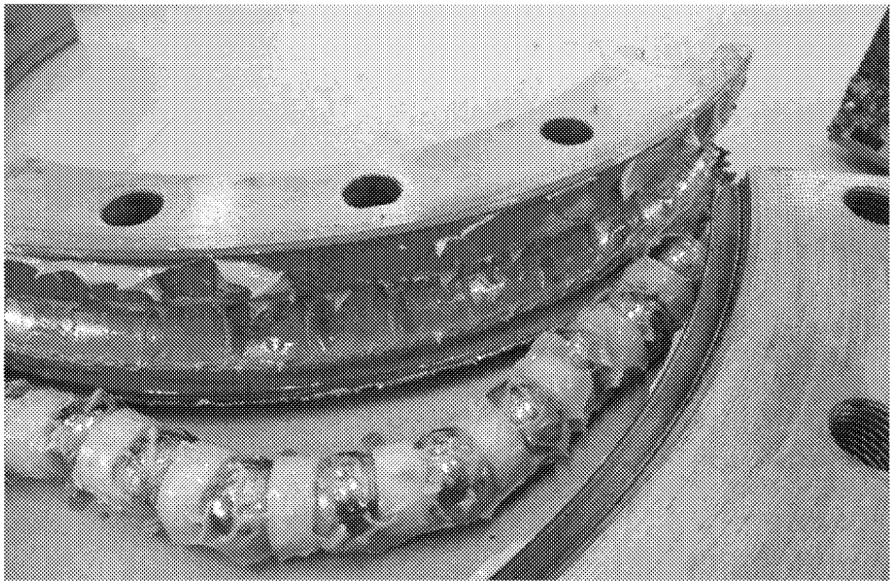


**Figure 42. Condition of slewing ring s/n 507092 (BM1 bogie) after the cut in 2 parts**

### 4.3.4 Intercar Dampers (FTA branch B1.3)

The dampers are in process to be removed and sent to Alstom Naperville for characterization to ensure they were not contributing to an increased resistance in bogie rotation.

The results are pending.

### 4.3.5 Wheel Flange Lubrication System (FTA branch B5.1)

The onboard wheel flange lubrication works on the following principle:

- grease is periodically applied to the flange of the wheel, when the train is in revenue service based upon the existence of a valid revenue mission.
- the grease is transferred from the wheel flange to the track when the flange comes in contact with the rail.
- the system relies on repetitive contact of multiple trains to lubricate the rails.

Wheel flange lubrication currently only operates on the main line when the temperature seen by the HVAC fresh air temperature sensor detects temperatures above 0C.[1]

The MSF is not lubricated by the vehicle system, and this is relatively standard across the industry, due to problems with excessive grease build up on the rails in the yard. As a result, without any fixed installations to provide location specific grease to the rails, there will be an increase in the coefficient of friction in the MSF.

Current train software revision is in development to have lubrication to be active on the trains in the MSF as well.

[1] Following the derailment of LRV26 in the connector tunnel, software patch is in development to the temperature threshold lowered to -25°C.

### 4.3.6 Wheel Flange Roughness (FTA Branch 5.2)

The wheel flange of LRV16 exhibited significant scoring, as shown in Figures below.

LMC1

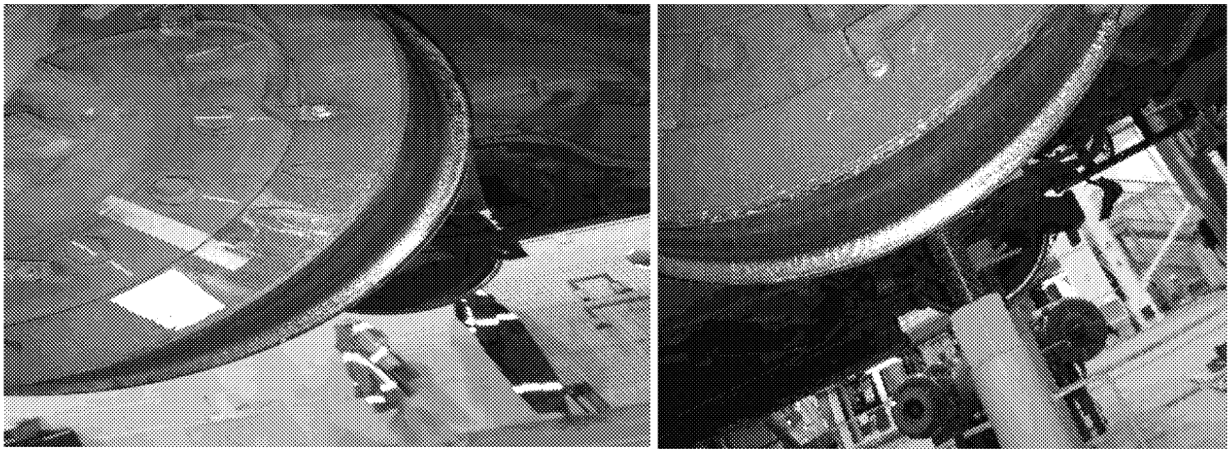


**Figure 43. Wheel Flange LMC1**

IMC

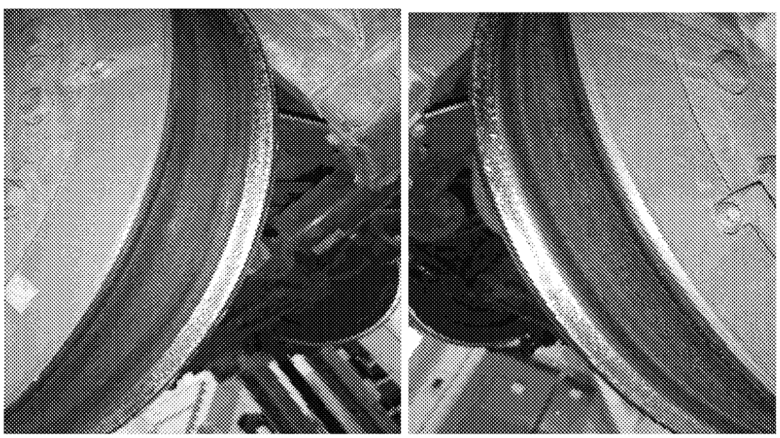


**Figure 44. Wheel Flange IMC**

LCC Motor

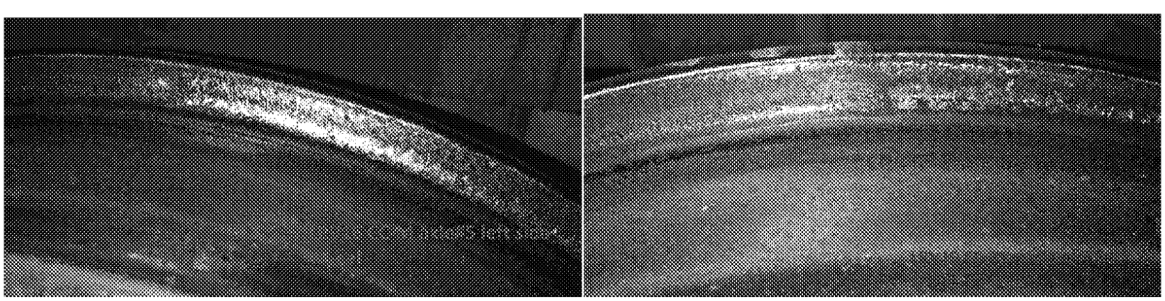


**Figure 45. Wheel Flange LCC Motor**

LCC Trailer

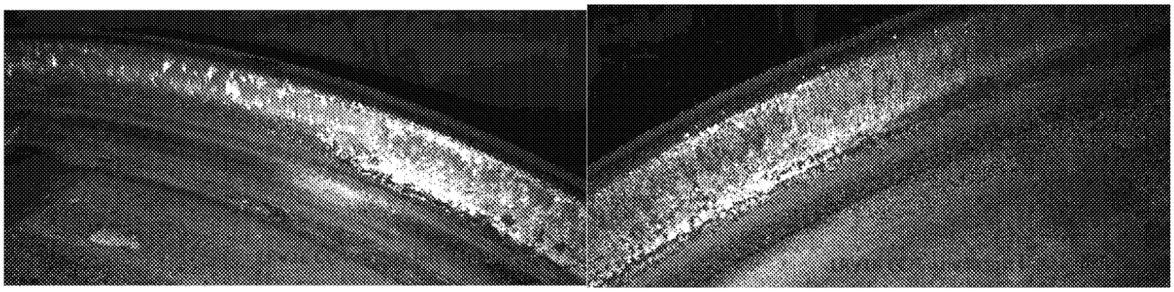


**Figure 46. Wheel Flange LCC Trailer**

<u>LMC2</u>

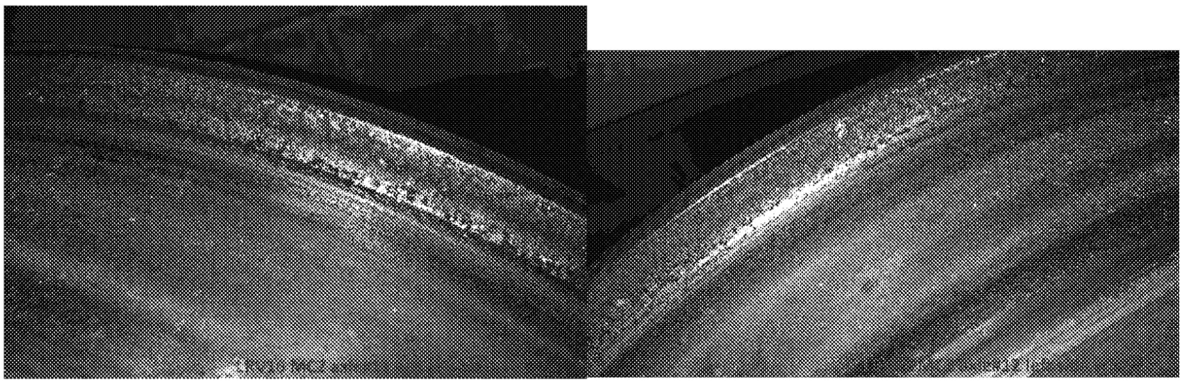


**Figure 47. Wheel Flange LMC2**

These scoring marks seems to match well with the roughness observed on the rail on the gauge face as shown in Section 4.1.5. The level of flange roughness exceeds the Ra = 12.5 µm. The flange scoring is suspected to be from the lack of lubrication / grease on the rail/wheel interface in the curves with sub-40m radius in the MSF.

## 4.4 Rail / Wheel Interface (FTA Branch B2, B6)

### 4.4.1 Rail profile

Digital profiles of the actual rail head were captured at 0.25 m intervals starting from 1 meter beyond the point of derailment. The detailed rail profiles are described in report OTT-ENG-REP-056.

### 4.4.2 Wheel profile

Digital profiles of the each of the wheels of the LRV was captured post derailment and key parameters are as shown below:

| LRV 1116 Wheel data (Calipri measurement ) after derailment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Left wheel | | | | Right wheel | | | | Back to back Wheel measurement |
| Axle no. | Diameter | Flange Height | Flange thickness | QR Cross Ref. | Diameter | Flange Height | Flange thickness | QR Cross Ref. | |
| 1 | 625.06 | 26.34 | 22.74 | 5.14 | 624.7 | 26.43 | 22.19 | 5.07 | 1378 |
| 2 | 623.2 | 26.37 | 22.71 | 5.13 | 622.86 | 26.41 | 22.49 | 5.14 | 1379 |
| 3 | 631.44 | 26.95 | 23.47 | 5.15 | 631.57 | 26.92 | 23.18 | 5.2 | 1379 |
| 4 | 622.72 | 26.04 | 23.6 | 5.42 | 623.35 | 25.95 | 23.68 | 5.34 | 1380 |
| 5 | 623.87 | 26.5 | 23.11 | 5.52 | 623.92 | 26.41 | 22.53 | 5.18 | 1379 |
| 6 | 624.82 | 26.5 | 23.02 | 5.19 | 624.35 | 26.45 | 23.11 | 5.26 | 1379 |
| 7 | 624.65 | 25.94 | 23.52 | 5.5 | 623.43 | 25.89 | 23 | 5.3 | 1380 |
| 8 | 624.97 | 25.83 | 23.26 | 5.28 | 623.11 | 25.86 | 23.48 | 5.2 | 1379 |
| 11 | 618.14 | 26.45 | 23.07 | 5.27 | 617.9 | 26.47 | 22.83 | 5.21 | 1379 |
| 12 | 621.71 | 26.46 | 22.81 | 5.15 | 621.1 | 26.6 | 22.79 | 5.35 | 1378 |

The measured wheel profiles of LRV16 correspond to worn B15 wheel profile. These profiles are not evolving in an unexpected way.

The measured actual rail and wheel profiles were used in conjunction with the measured track geometry data for rail / wheel geometry simulations to be compared with the "ideal" or "nominal" design conditions. Further details considering the rail/wheel profile are presented in Section 4.5.

## 4.5 Investigation of the derailment through dynamic simulations

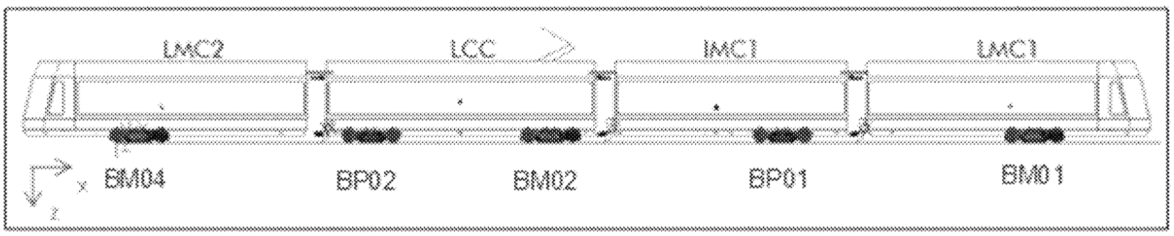
The purpose of the dynamic simulations is to make an assessment on **margins against unacceptable flange climbing**, using measured parameters of wheel profile of LRV16, measured parameters of rail and track geometry on the derailed portion of the track and other parameters that could influence the vertical and lateral forces of wheel/rail interaction such as, for example, friction coefficient between rail and wheel, and hypothetical rail defects and faults on the vehicle. Simulations are performed using SIMPACK v2020.

### 4.5.1 Vehicle model

Carbody input data:

- Weight balance DTD0000204727_F (11/12/2014). Load case AW0 (train mass 79.7 tons)
- Tram layout DTD0000099943_B

Model version: v2ind3.




The validity of the vehicle model for assessment of derailment safety has been checked based on wheel load equalization test. The diagram below (Figure 14) shows that the wheel unloading in case of single wheel elevation estimated by simulation fits with the test results, with a gap between simulation and test limited to 2-5% (simulations results being slightly conservative).

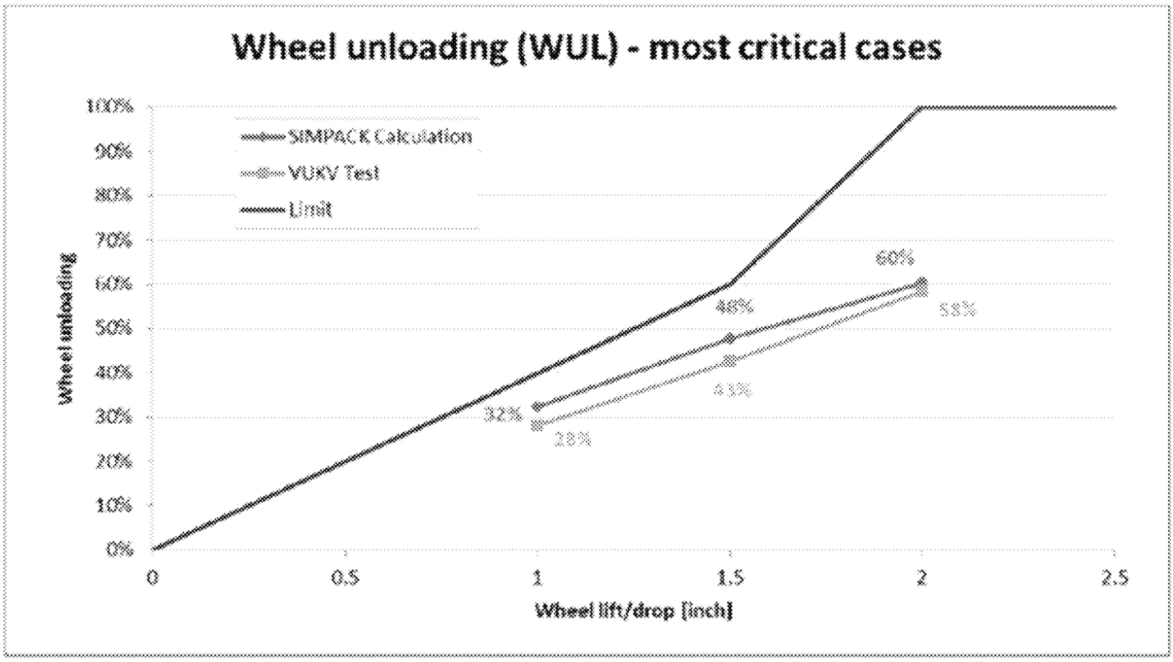
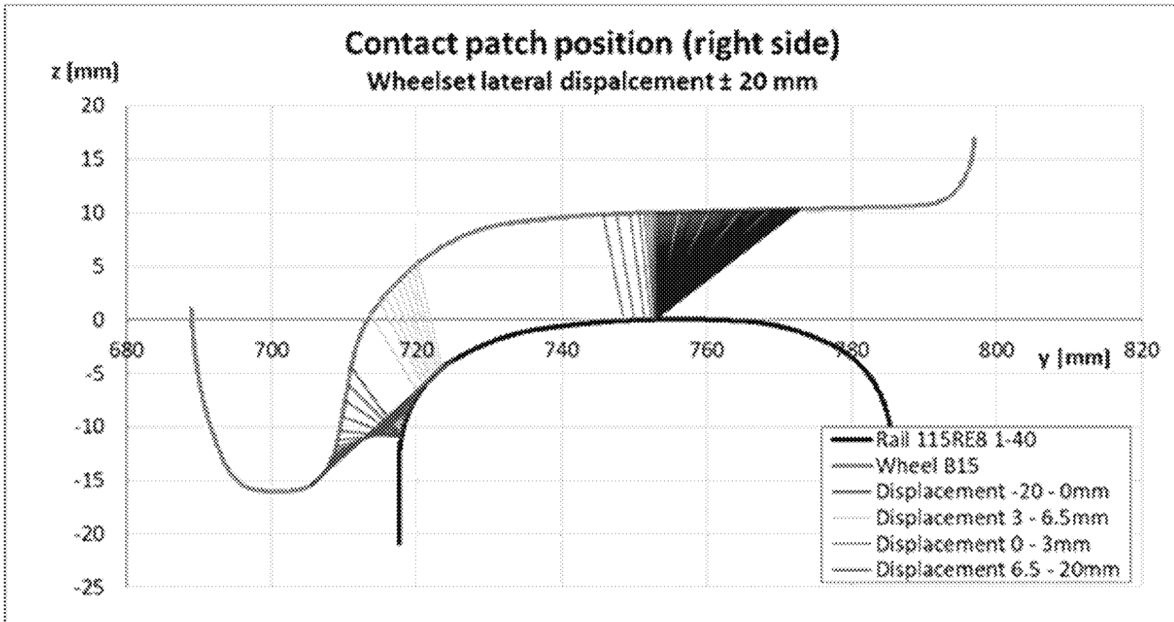



**Figure 48.** Comparison of simulation and test results of wheel load equalization test

### 4.5.2 Wheel/Rail contact hypothesis (nominal case)

- Track nominal conditions (new)
  - Track gauge 1435mm
  - Rail profile 115RE-8
  - Rail inclination 1-40
- Wheelset geometry
  - Back-to-back distance 1378mm
  - Wheel profile B15



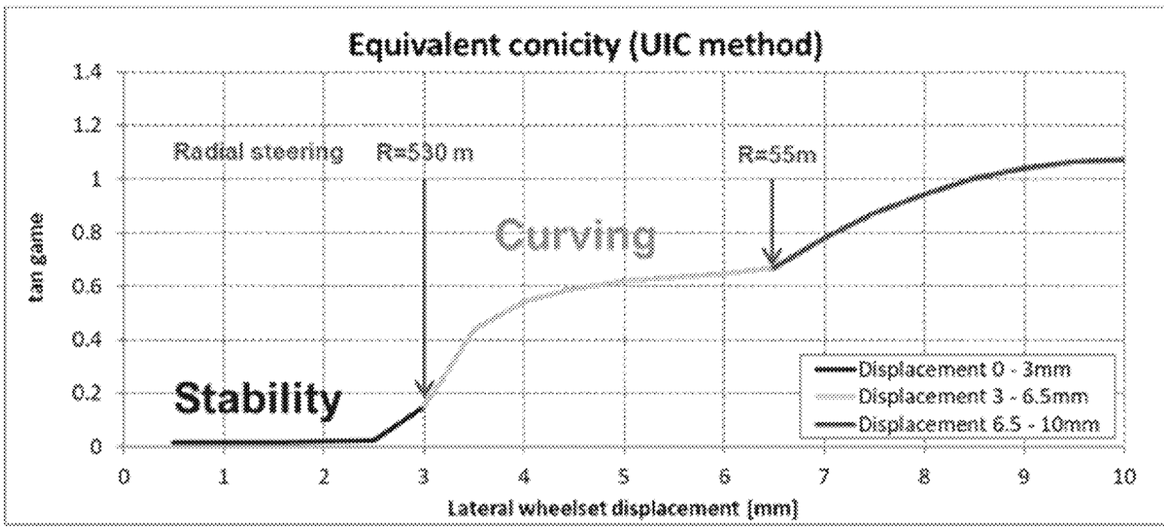




**Figure 49.** Wheel profile B15 is optimized for rail profile 115RE-8

### 4.5.3 Derailment evaluation criteria

The assessment parameter for derailment is the single wheel L/V ratio, which limit is defined with the Nadal formula:

$$\frac{L}{V} \leq \frac{\tan\delta - \mu}{1 + \mu\ \tan\delta}$$

where δ is the wheel flange angle (75° for B15 wheel profile) and μ is the friction coefficient at the wheel flange (set to 0.50).
The limit value for the considered B15 wheel profile is **1.12** for a friction coefficient of 0.50.
The wheel raise above the top of rail in case of flange contact can be provided additionally for information (indicative limit = 5 mm according to ORE B55)

### 4.5.4 Simulation in reference conditions (case A)

| Case A – Reference conditions | |
|---|---|
| Vehicle mode | Nominal |
| Wheel/Rail profile | B15/115RE-8 |
| Friction coefficient | 0.5 |
| Speed | Low (5 km/h) |
| Track geometry | R = 39 m,<br>7 mm cant,<br>twist 3.7mm |

In reference conditions the simulation shows no risk of derailment. Time signal of L/V ratio reaches its maximum at 0.81. Maximum wheel raise at leading outer wheel is 2.4 mm.

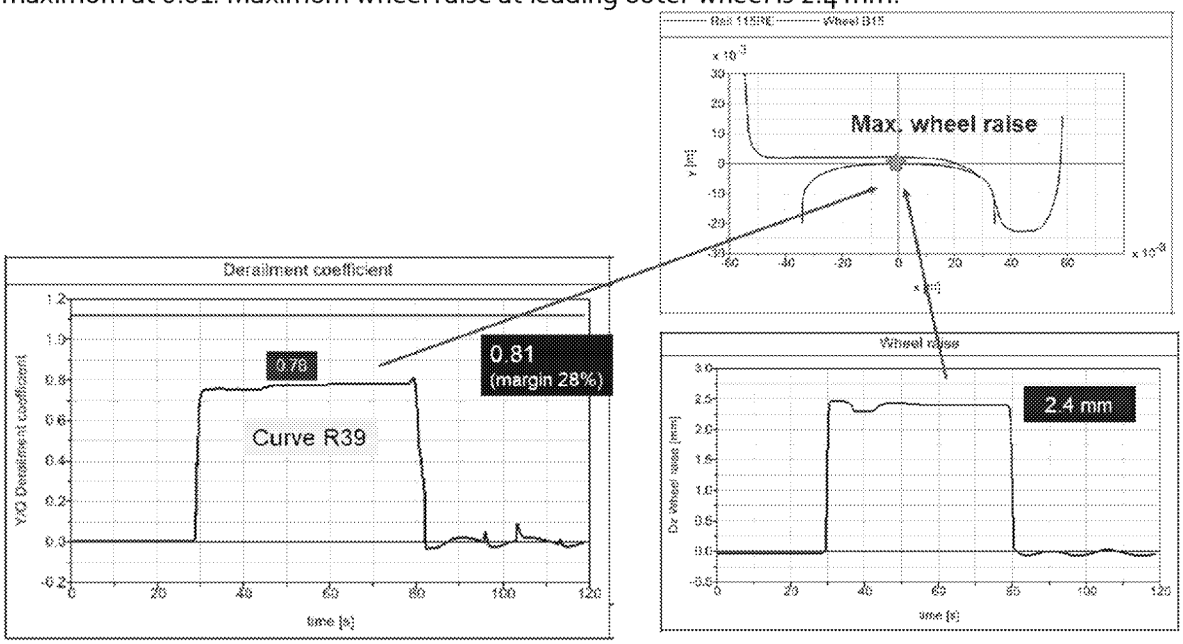



**Figure 50. Case A – Time signal of L/V ratio and wheel raise at leading outer wheel**

### 4.5.5 Investigation on influential parameters - actual wheel/rail/track geometry (case B)

| Case B – Influence of wheel/rail/track geometry | |
|---|---|
| Vehicle mode | Same as case A |
| Wheel/Rail profile | B15 measured / 115RE-8 new<br>B15 new / measured 115RE<br>B15 new / measured 115RE with transposed outer and inner rail of track 14 |
| Friction coefficient | Same as case A |
| Speed | Same as case A |

| | |
|---|---|
| Track geometry | Same as case A<br>Track gauge 1440 mm |

Measured Wheel Profiles

The measured wheel profiles of LRV16 correspond to worn B15 wheel profile. These profiles are not evolving in an unexpected way. The influence of wheel geometry on the simulation results is negligible. Nevertheless, it must be noted that increased wheel flange roughness linked to wheel wear may increase wheel/rail friction coefficient.

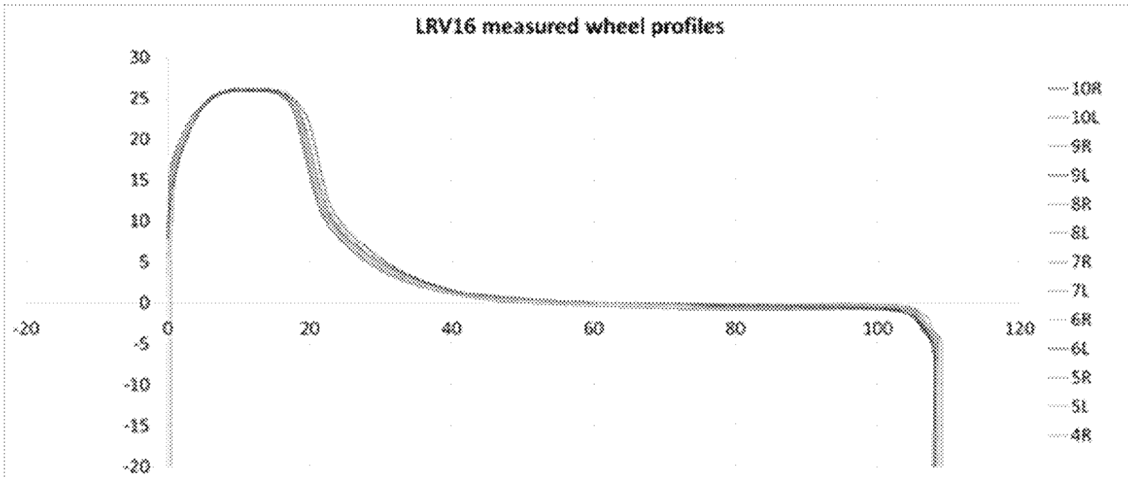
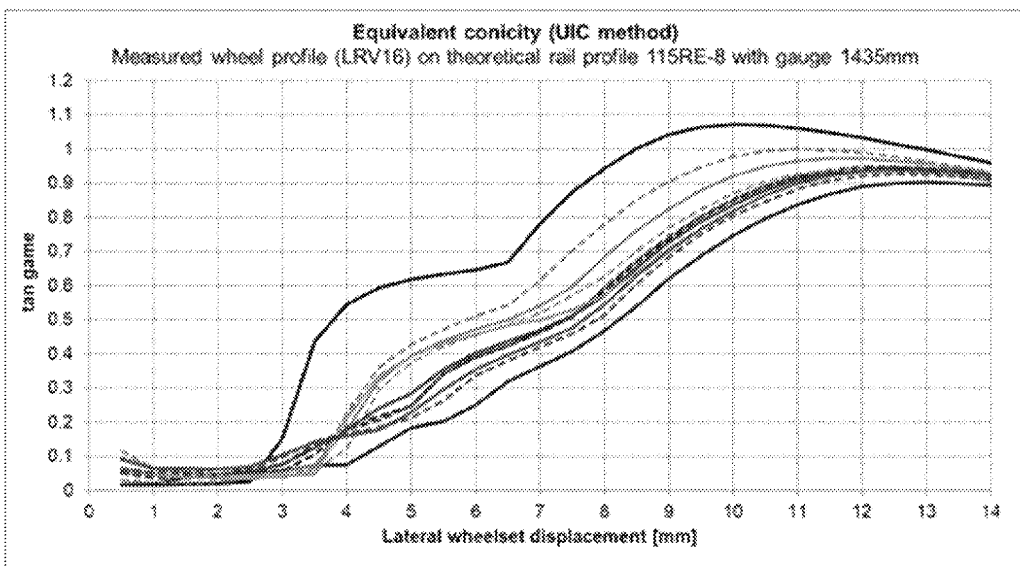



**Figure 51. Measured LRV16 wheel profiles (Calipri measurements)**

Measured Track Profile

The simulations with increased track gauge (1440 mm) showed little impact on the derailment safety margin: L/V ratio is 0.8, wheel raise is 2.7 mm.



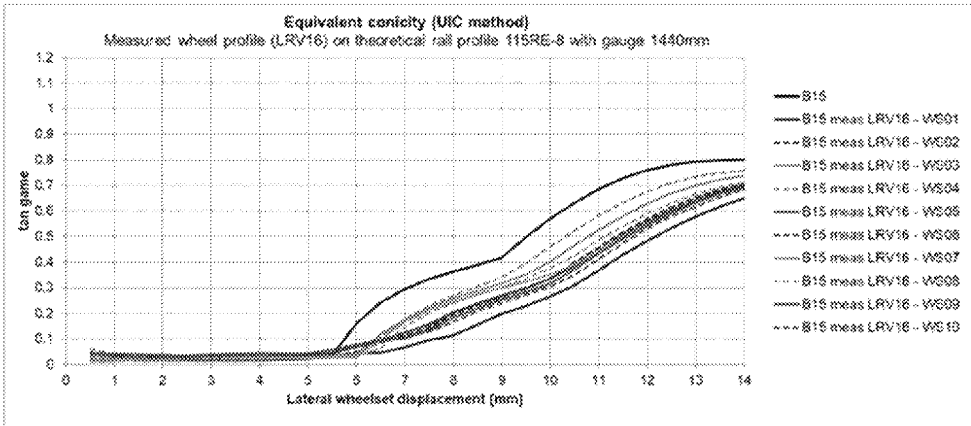



**Figure 52. Comparison of track gauge influence on the equivalent conicity (UIC method)**

<u>Rail Profile Measurements</u>

The following observations were made based on rail profile measurements on Track 14:

- The rail profile shows a rather flat head not corresponding with theoretical 8'' crown radius. This leads to direct contact of rail corner with the flange root increasing the equivalent conicity
- Worn outer rail shows a reduced slope of around 72 degrees compared to 90 degrees of new profile. Thus, angle of rail gauge face has predominant influence on wheel/rail contact angle (wheel flange angle becomes secondary).

However, the measured rail profile has low impact on the derailment: the safety margin is decreased by 4% compared to the reference conditions. L/V ratio is 0.74 at L/V limit of 0.98. Wheel raise is 3.3 mm.

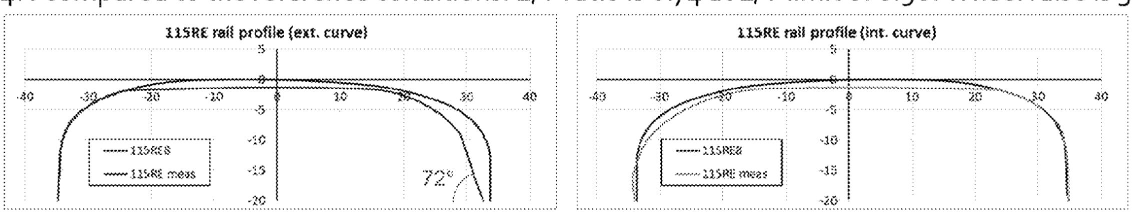



**Figure 53. Measured rail profile of track 14 compared to theoretical rail profile 115RE-8**

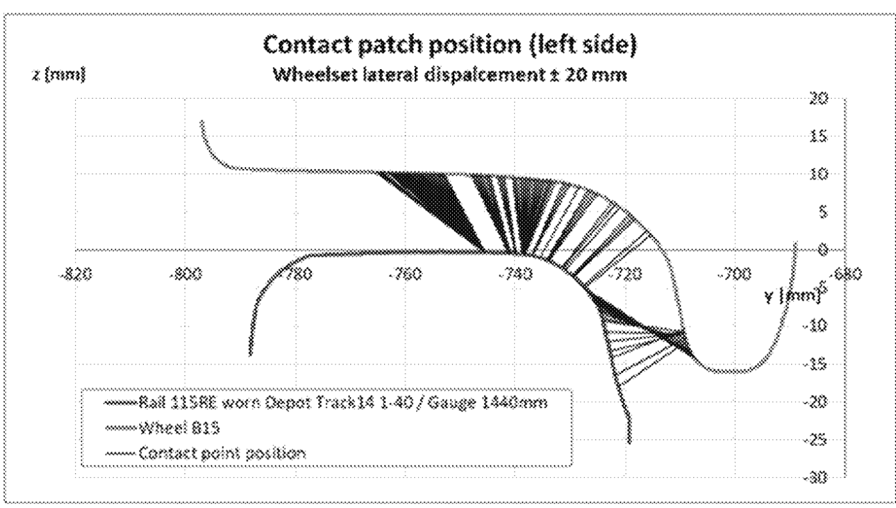



**Figure 54. Contact patch analysis of B15 wheel profile with 115RE measured worn rail profile of track 14**

Effect of Transposing Rails

The simulations with transposed measured outer and inner rails of track 14 showed the increase of safety margin by 6% compared to non-transposed rails. L/V ratio is 0.78, wheel raise is 3.2 mm. Wheel/rail contact comes back to nominal configuration.

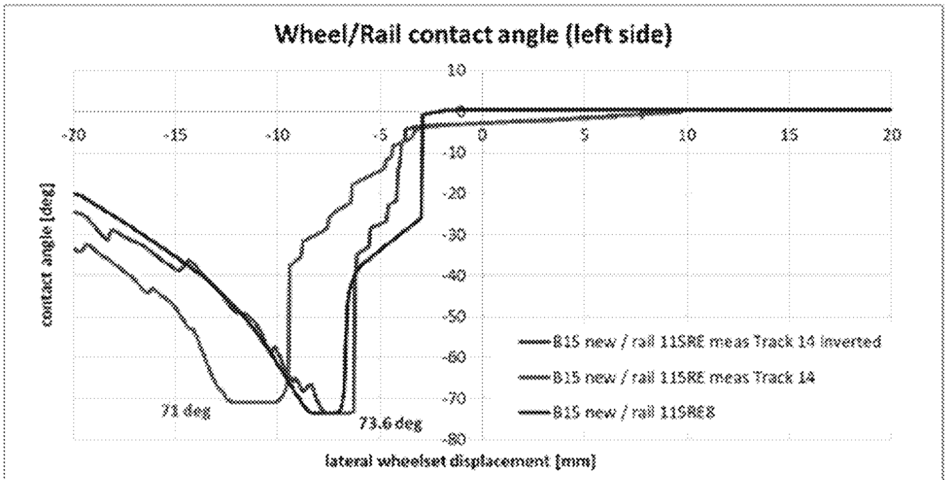



**Figure 55. Influence of track 14 rails transposing on wheel/rail contact angle**

### 4.5.6 Influence of the wheel/rail friction coefficient (case C)

| Case C – Influence of wheel/rail friction coefficient | |
|---|---|
| Vehicle mode | Same as case A |
| Wheel/Rail profile | B15 new / 115RE -8<br>B15 new / measured 115RE |
| Friction coefficient | From 0.5 to 0.65 |
| Speed | Same as case A |
| Track geometry | Same as case A |

Wheel/rail friction coefficient is found to be the 1st order influential parameter.
Friction coefficient increases lateral forces and reduces Nadal limit, so derailment risk increases.

The simulations were performed with theoretical rail profile 115RE-8 and with measured rail profile of track 14. The results of simulations are presented in the table below.

With both profiles the tendency is similar. At μ = 0.6, L/V ratio almost reaches the safety limit. And at μ = 0.65 the safety limit is exceeded – the derailment is possible.
We consider that high friction coefficient value is credible due to observed high roughness of wheel flange/rail face, poorly lubricated track.

| Wheel profile | Rail profile | W/R friction coefficient | L/V | L/V lim (Nadal) | Wheel raise, mm |
|---|---|---|---|---|---|
| B15 | 115RE-8 | **0.50** | 0.81 | 1.12 | 2.7mm |

| | | | | | |
|---|---|---|---|---|---|
| B15 | 115RE-8 | **0.55** | 0.87 | 1.04 | 2.7mm |
| B15 | 115RE-8 | **0.60** | 0.96 | 0.97 | 2.8mm |
| B15 | 115RE-8 | **0.65** | Derailment | | |
| B15 | 115RE meas | **0.50** | 0.74 | 0.98 | 3.3mm |
| B15 | 115RE meas | **0.55** | 0.78 | 0.91 | 3.3mm |
| B15 | 115RE meas | **0.60** | 0.83 | 0.84 | 3.7mm |
| B15 | 115RE meas | **0.65** | Derailment | | |

#### 4.5.7 Simulation Synthesis and conclusions

A summary of simulation results of studied cases is given in Table below. The details of the simulation results are given hereafter.

| Simulation case | L/V ratio | L/V ratio limit | Safety margin | Max wheel raise, mm |
|---|---|---|---|---|
| Case A – Reference conditions | 0.81 | 1.12 | 28% | 2.4 |
| Case B – Influence of track gauge | 0.8 | 1.12 | 29% | 2.7 |
| Case B – Influence of measured rail profile | 0.74 | 0.98 | 24% | 3.3 |
| Case C – Influence of wheel/rail friction coefficient: measured rail profile, μ = 0.60 | 0.83 | 0.84 | 1% | 3.7 |
| Case C – Influence of wheel/rail friction coefficient: measured rail profile, μ = 0.65 | **Derailment** | | | |

The simulations in theoretical reference conditions showed no risk of derailment (28% margin).

The simulations with measured geometry parameters (measured tracks geometry, wheel/rail profiles) and standard friction coefficient showed reduced safety margin but no risk of derailment.

The derailment risk was identified with high wheel/rail friction coefficient (μ = 0.6/0.65):

- high surface roughness of both wheel flange and rail gauge face
- Insufficient greasing of yard tracks

Moreover, it was observed that new rail profile does not correspond to theoretical rail profile used for bogie simulation/conception, as detailed in Section 4.5.8. While this measured profile has negligible effect on derailment safety margin it has the impact on wheel/rail contact and wheel raise. Modified wheel/rail contact (combined with insufficient lubrication) could explain the wear of wheel flange/rail face that lead to increased roughness and increased friction coefficient. And as observed above, the increased friction coefficient is the main factor of derailment safety margin decrease.

### 4.5.8 Comparison of Installed vs Designed Rail Profiles

During the investigation, rail profiles were collected of new rails to analyze the wheel/rail interface between the actual B15 wheel profile and the as installed new rail profile. Rail profiles were collected at the following locations:

A. Profile of 2 piece of uninstalled spare rail in MSF

**Figure 56. Rail Profile Captured [reference A]**

B. At BLR-Track 1 behind the rail arrestor

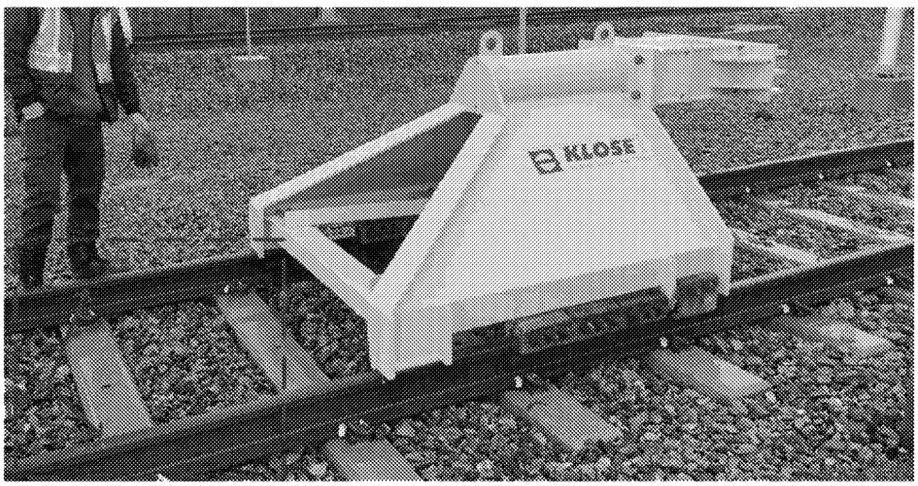
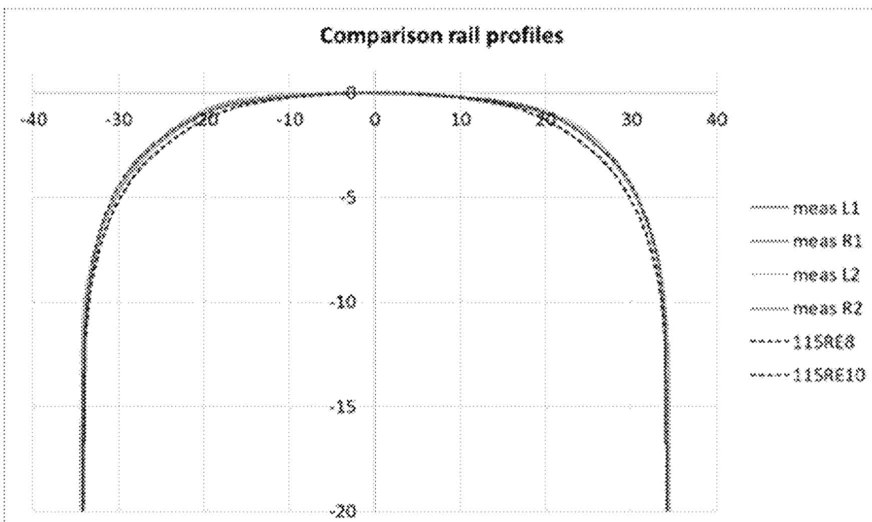



**Figure 57. Rail Profile Capture [reference B]**

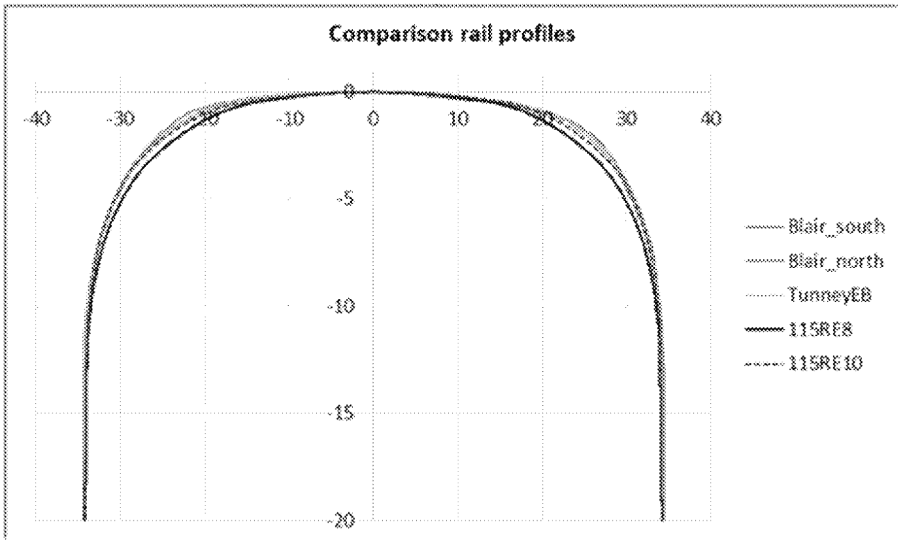
C. TUN-Track 2 behind rail arrestor

**Figure 58. Rail Profile Captured [reference C]**

It was also observed that theoretical rail profile with 10" crown radius is more representative for the measured new rail profile in Ottawa, rather than 8" crown radius as per the design. Figure overlays the measured rail profiles against the theoretical 115RE8 and 115RE10 profiles.




**Comparison of theoretical profiles 115RE-8, 115RE-10 with measured new rail profiles at MSF (reference A).**




**Comparison of theoretical profiles 115RE-8, 115RE-10 with measured new rail profiles at Blair (reference B).**

The effect of these rail profile discrepancies are as follows:

- Equivalent conicity is modified.
- Wheel/rail contact is modified – the contact with flange root starting from 1,5 mm of lateral displacement. This could lead to contact on top of flange, causing increased roughness and have a potential impact on friction coefficient. This may also negatively impact the lifespan of the wheel and/or rail.

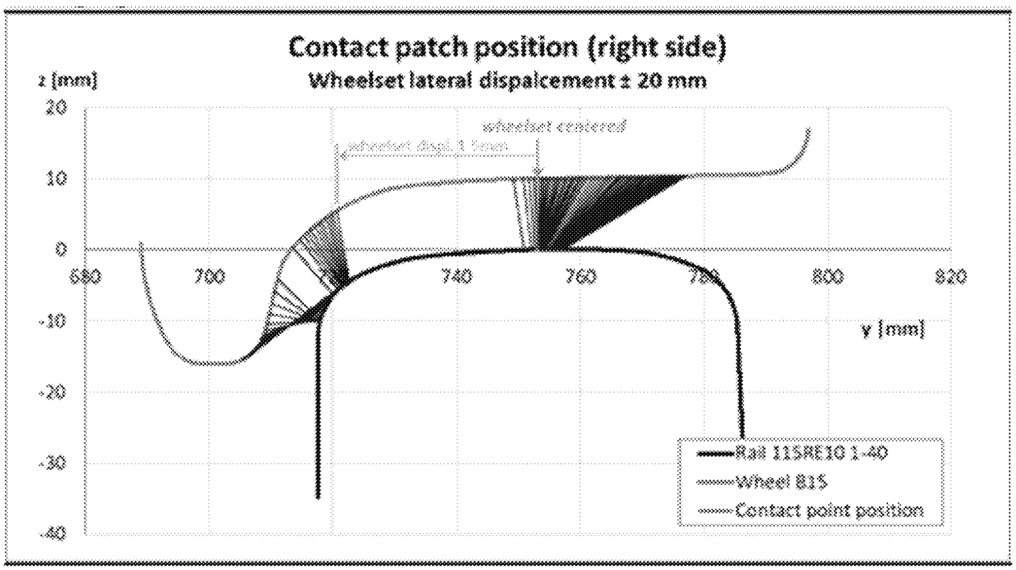



**Figure 59. Contact patch analysis of B15 wheel profile with 115RE measured new rail profile**

## SECTION 5 CONTAINMENT ACTIONS

Specifically related to the derailment containment actions were carried at the system level.

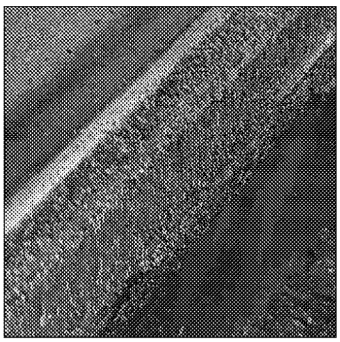
## 5.1 System Containment actions.

The following containment actions were implemented related to the overall system:

A. As the coefficient of friction represents the factor with the highest sensitivity to a derailment, the frequency of manual regreasing of entry/exit tracks into the MSF have been increased to twice per week.

Since this implementation, the gauge face on the rail has become noticeably less rough (based on visual inspection).

Before



After

B. Minimize stopping when the train is curves and certain other tracks in the MSF, as per Field Notification "35m curves LRVs/trains circulation" released March 31st, 2021.

C. Requiring the presence of a spotter to spot the rear of the train consist before restarting movement, in case the train are stopped in curves.

# SECTION 6 CONCLUSIONS & RECOMMENDATIONS

## Overall Conclusions

While the investigation did not identify a single issue that can lead directly to a derailment, it did identify that the primary factor that could lead to a derailment was those factors that can influence directly the coefficient of friction between wheel and rail, specifically the following factors:

- Minimal lubrication of the tracks in the MSF
- Roughness of the wheel flange and the corresponding gauge face on the rail
- Start stop / operation in tight radius curves
- Wear of the rail profile heads

This conclusion is similar to the conclusions made during two previous derailments:
1. LRV26 in MSF Yard on October 18th, 2020
2. LRV26 in connector tunnel on November 18th, 2020

Furthermore, the measurements of the profiles of new rails at locations in the MSF and on the mainline suggests that the actual installed rail profile has deviations from the design profile. The impact of this exceeds the scope of the LRV16 derailment and needs to be investigated further.

## Recommendations Going Forward and current status.

The following recommendations should be implemented:

1. Installation of wayside top of rail lubricators on all entry / exit tracks of the MSF.[2]
2. Maintain manual greasing of minimum twice per week while permanent wayside lubricators are not implemented.[3]
3. Transpose rails of curve 19 to restore the nominal profiles.[4]
4. Conduct full wheel/rail interface study.

[2] A trial wayside top of rail lubricator has been installed on Track 14 Curve 19 on May 11, 2021.
[3] This has been implemented since March 21st, 2021
[4] This activity has been completed on May 28th, 2021

## SECTION 7 REFERENCES

**[P1]** RES-22-0-0000-MAN-0003 Trackwork Maintenance Manual

**[P2]** EN 15313 Railway Applications – In-service wheelset operation requirements

**[P3]** TCRP-71 Track-Related Research Volume 7: Guidelines for Guard/Restraining Rail Installation

**[P4]** TCRP-155 Track Design Handbook for Light Rail Transit, Second Edition

**[P5]** APTA **Light Rail Vehicle Request for Proposals (RFP) Procurement Guideline**

**[P6]** ORE B55 Report 8, Conditions for negotiating track twists - Recommended values for the track twist and cant - Calculation and measurement of the relevant vehicle parameters - Vehicle testing, 1983

**[P7]** LCR –Ottawa Safety Note following derailment of LRV1126

**[P8]** ADD0000939541_A_DR_OTTAWA-Truck details 2nd prefinal dr

**[P9]** OTT-ENG-REP-040 LRV26 Connector Tunnel Derailment Report

**[P10]** TN-018 LRV26 MSF Yard Derailment Report

## SECTION 8 Control Sheet

| Version | Date | Content of Modification | Author(s) |
|---|---|---|---|
| A | 2021-05-13 | First issue. | L. Goudge / Train System Engineer<br>N. Sembeyev / Bogie Warranty Engineer<br>D. Song / Bogie Project Engineering Manager<br>Y. Liu / Project Engineering Manager |
| B | 2021-06-28 | Updates following RTM comments | Y. Liu / Project Engineering Manager<br>N. Sembeyev / Bogie Warranty Engineer |

| ALSTOM · mobility by nature · | Track Geometry Track 14 Curve 19 | Document Reference: OTT-ENG-REP-056 Version B | Application date : 06-04-2021 |
|---|---|---|---|
| Written by: | Mariano Garcia / Track Expert<br>Peng Jiang / Fleet Support Specialist | | |
| Reviewed by: | Mariano Garcia / Track Expert | Ensures that the technical/ process accuracy has been checked. | |
| Approved by: | Yang Liu / Project Engineering Manager | Orders, by his signature, the implementation of the document. | |

APPROVED
yliu , 2021-04-06, 4:22:03 pm

## Contents

## Section 1 SUMMARY

On 14 March 2021, at approximately 13:19, Ottawa Confederation Line LRV 1116 derailed at low speed in the maintenance and storage facility Yard (MSF) during a routine move from the storage area to the handover platform. The derailment occurred on Track 14- Curve 19 at chainage# 14+386 (+/-2 m) (Figure 1).

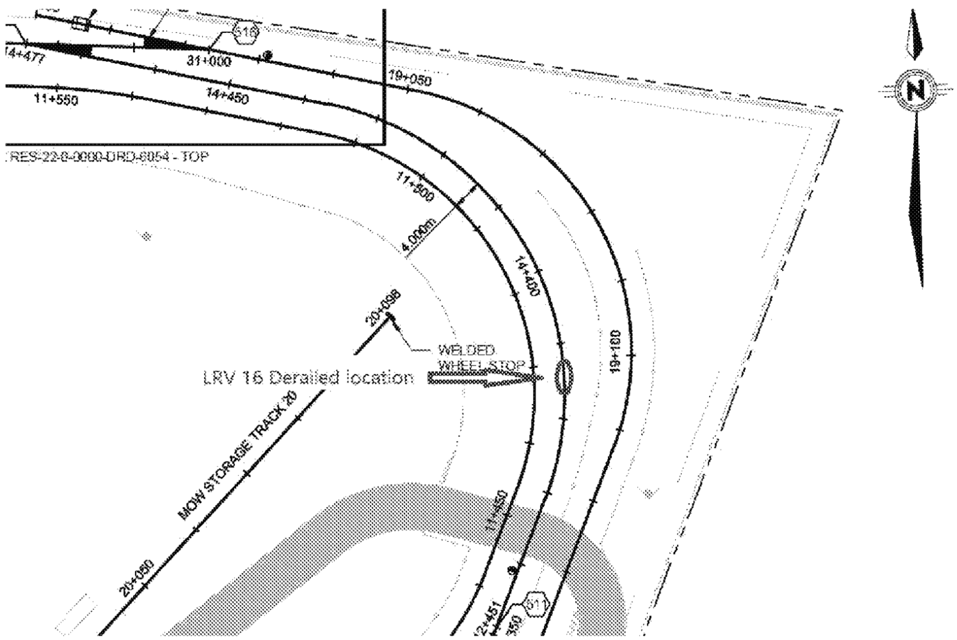



**Figure 1 – Derailment location on Track 14 Curve 19 in the MSF Yard**

The purpose of this report is to document the measurements data of Track 14 Curve 19. This report will target the following Characteristics:

- Track Geometry.
- Calipri Measurements.
- String Line

# Section 2 TRACK GEOMETRY

## 2.1 Track Geometry. -Characterization of Curve 19

Track 14 is one of the 3 principal maintenance tracks in the MSF Yard, leading from the shed to the LMB/Handover. Refer to Figure 2.

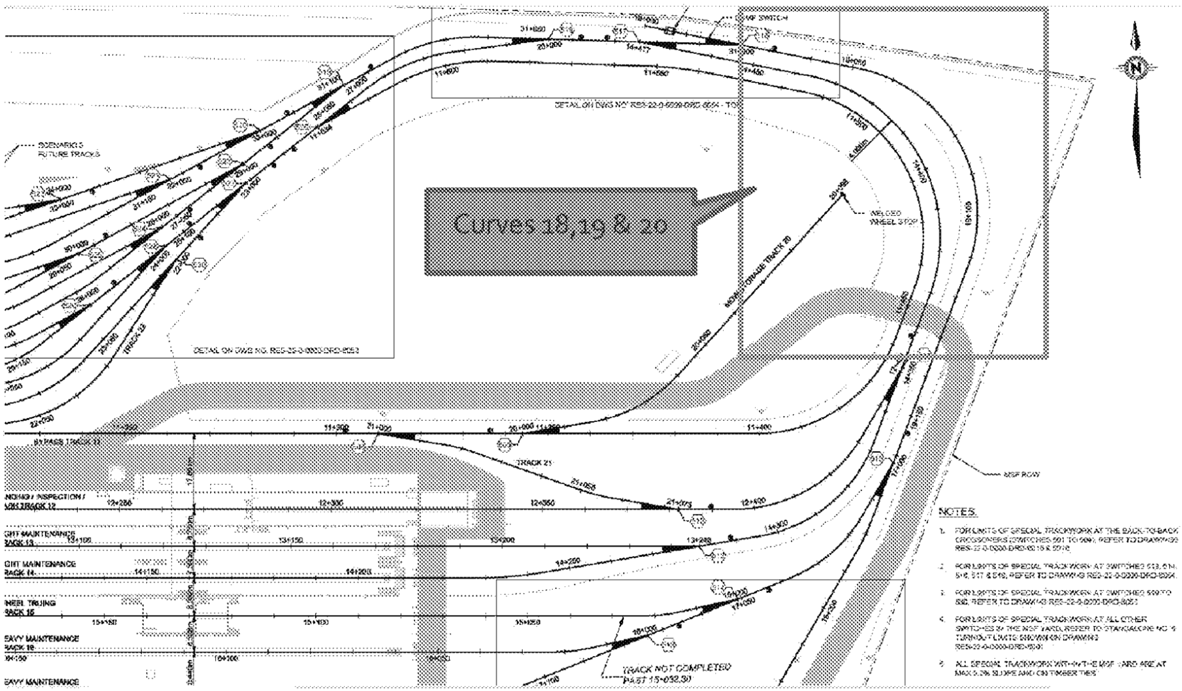



**Figure 2 - Track 14 Curve19 General View**

Track 14- Curve 19 - design parameters at the LRV derailment location. Refer to Table 1.

**Table 1 - Track 14 Nominal Data**

| Class | Class 3 |
|---|---|
| Nominal Gauge | 1435 mm |
| Speed limit | 15 km/h |
| Curve 19 curve radius (design) | 39m |
| Super-elevation | No super elevation / unbalance |
| Spirals | No spirals |
| Ties | Concrete ties |
| Other | Pandrolized track on ballast |
| Chainage # | From 14+365 to 14+440 |

## 2.2 Track Geometry - Field Measurements by Guideway Technicians for Curve 19

Refer to Table 2. - Field measurements for curve 19 on track 14. Admissible Cross is ±5mm according to track maintenance manual [A]

**Table 2 - Curve 19 Geometry Data**

| Approximate Chainage # | Gauge (mm) | Cross Level (mm) | Comments |
|---|---|---|---|
| 14 425 | 1441 | 7 | |
| 14 421.1 | 1439 | 7.8 | |
| 14 417.2 | 1439 | 5 | |
| 14 413.3 | 1440 | 7 | |
| 14 409.4 | 1439 | 7.5 | |
| 14 396.4 | 1438 | 3 | |
| 14 395.1 | 1438.5 | 4.7 | |
| 14 393.8 | 1438 | 6.5 | |
| 14 392.5 | 1440 | 9 | |
| 14 391.2 | 1440 | 7.5 | |
| 14 389.9 | 1440 | 5 | |
| 14 388.6 | 1439 | 2.5 | |
| 14 387.3 | 1439.8 | 3.5 | Point of Flange Climb (14 March 2021) |
| 14 386 | 1440 | 6.5 | |
| 14 385 | 1440 | 10 | |
| 14 384 | 1439 | 13 | |
| 14 383 | 1440 | 10 | |

# Section 3 CALIPRI DIGITAL MEASUREMENTS

## 3.1 Calipri Digital Measurements

Refer to Table 3 for Calipri Digital Measurements Data, it is showing there is average 1.8-2.1mm wear at gauge point on the outer rail for curve 19. For the inner rail of curve 19, there is 0.6-0.8mm wear at gauge point on the inner rail. Maximal Gauge Face wear according to track maintenance manual is 4.5mm [A]. Refer to Table 3.

**Table 3 - Curve 19 Calipri Digital Measurements Data**

| Approximate Chainage # | Wear at Gauge point - Inner rail (+/- 0.08) | Wear at Gauge point - Outer rail (+/- 0.08) | Comments |
|---|---|---|---|
| 14 436.7 | 0.59 | 1.25 | |
| 14 432.8 | 0.5 | 1.44 | |
| 14 428.9 | 0.55 | 1.68 | |
| 14 425 | 0.57 | 1.54 | |
| 14 421.1 | 63 | 1.68 | |
| 14 417.2 | 0.74 | 1.85 | |

| | | | |
|---|---|---|---|
| 14 413.3 | 0.52 | 2.08 | |
| 14 409.4 | 0.6 | 1.72 | |
| 14 405.5 | 0.64 | 2.01 | |
| 14 401.6 | 0.59 | 2.07 | |
| 14 397.7 | 0.65 | 1.87 | |
| 14 396.4 | - | 2.01 | |
| 14 395.1 | - | 1.89 | |
| 14 393.8 | - | 2.01 | |
| 14 392.5 | 0.7 | 1.9 | |
| 14 391.2 | - | 1.87 | |
| 14 389.9 | - | 1.85 | |
| 14 388.6 | 0.63 | 1.78 | |
| 14 387.3 | 0.71 | 2.03 | LRV16 flange climb location (14 March 2021) |
| 14 386 | 0.66 | 2.04 | |
| 14 385 | 0.68 | 1.86 | |
| 14 384 | 0.69 | 1.74 | |
| 14 383 | 0.65 | 1.9 | |
| 14 382 | 0.75 | 1.71 | |
| 14 381 | 0.65 | 1.54 | |
| 14 380 | 0.71 | 1.71 | |
| 14 379 | 0.65 | 1.65 | |
| 14 375.4 | 0.71 | 1.83 | |
| 14 371.8 | 0.4 | 1.66 | |
| 14 368.8 | 0.4 | 0.66 | |

## 3.2 Wear at gauge point on outer rail at flange climb location

From the Calipri measurement (Figure 3) on the outer rail for flange climb location (Chainage#14+386), it is showing the wear at gauge point is 2.04mm, according to the measurement on 17 March 2021.

Note: Due to the manufacturing deviation, there -0.2 to -0.3 mm different has been added to the wear calculation. The material of the head is bigger than AREMA's 115 lbs. RE Rail.

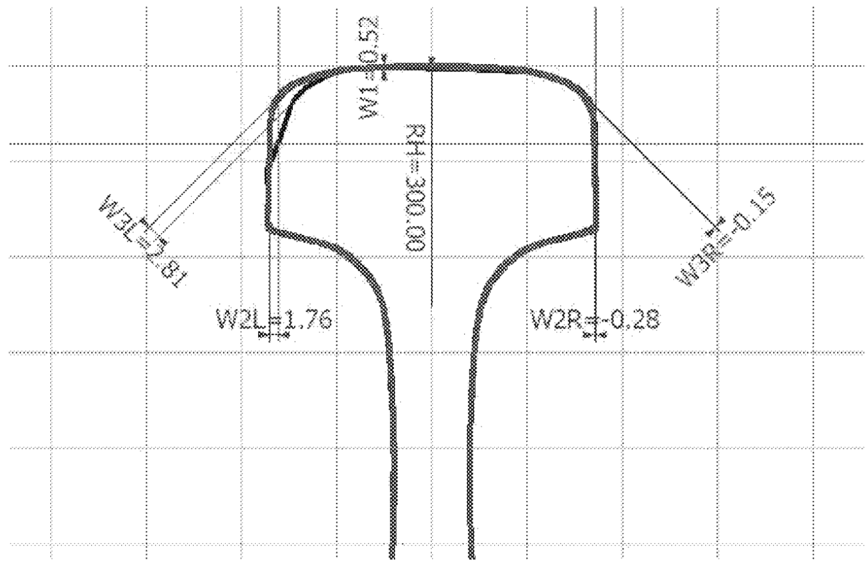



**Figure 3 - Wear at Gauge Point on Outer Rail**

The position of wear (Figure 4) is showing the big wear is at the gauge side of the head. There is also some wear from the top surface of head. The positive wear from field side is because the manufacturing deviation, which means the material is bigger than AREMA's 115 lbs. RE Rail.

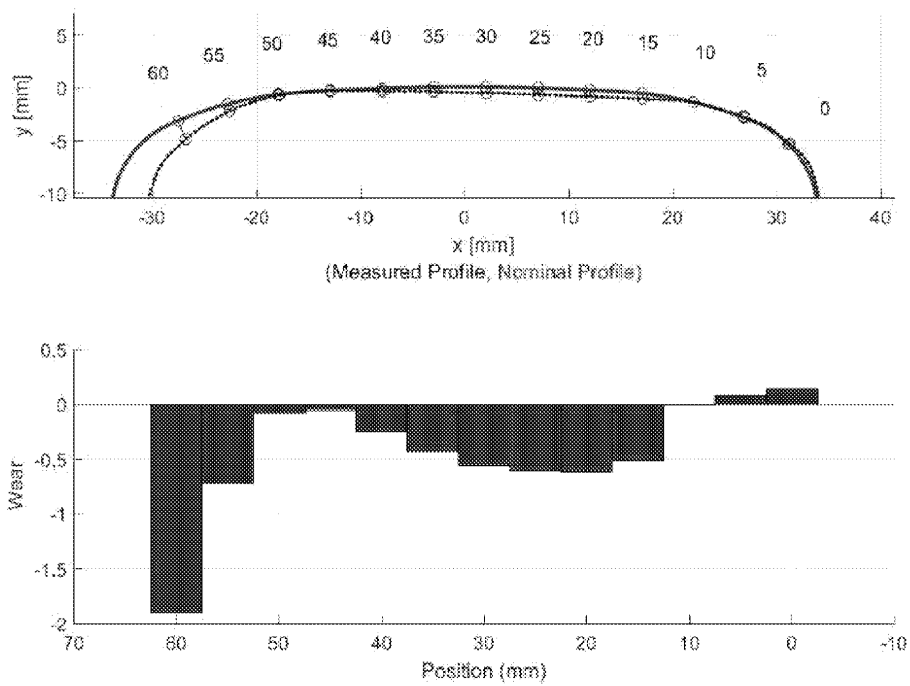



**Figure 4 - Position of Wear on Outer Rail**

### 3.3 Wear at gauge point on inner rail at flange climb location

From the Calipri digital measurement (Figure 5) on the inner rail at flange climb location (Chainage#14+386), it is showing the wear at gauge point is 0.66mm, according to the measurement on 17 March 2021.

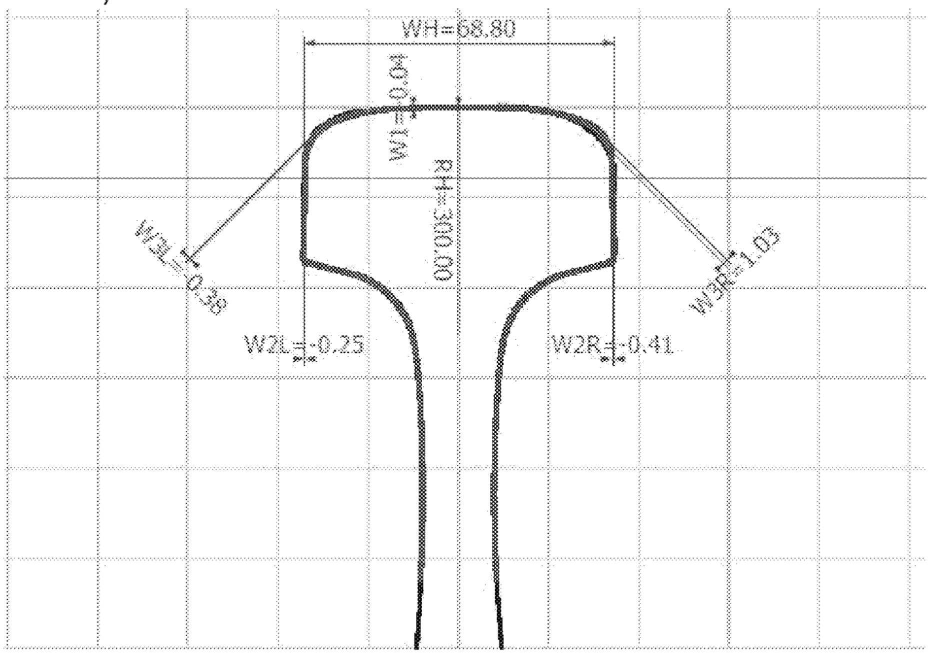



**Figure 5 - Wear at Gauge Point on Inner Rail**

The position of wear (Figure 6) is showing the bigger wear is at the gauge side of the head. The positive wear from field side is because the manufacturing deviation, which means the profile is slightly larger than AREMA's 115 lbs. RE Rail.

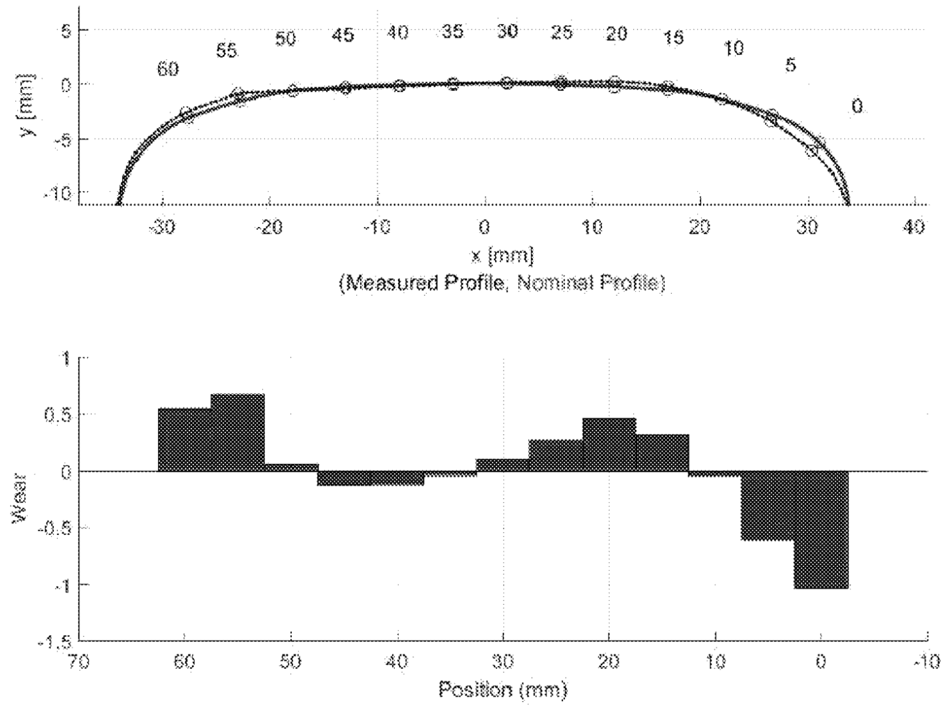



**Figure 6 - Position of Wear on Inner Rail**

## 3.4 Gauge face angle at flange climb location

By the Calipri measurement on the outer rail at the flange climb location (Chainage#14+386), the calculated Gauge Face Angle (GFA) is 18.29 degrees (Figure 7) at the flange climb location, after considering the 1/40 Cant.

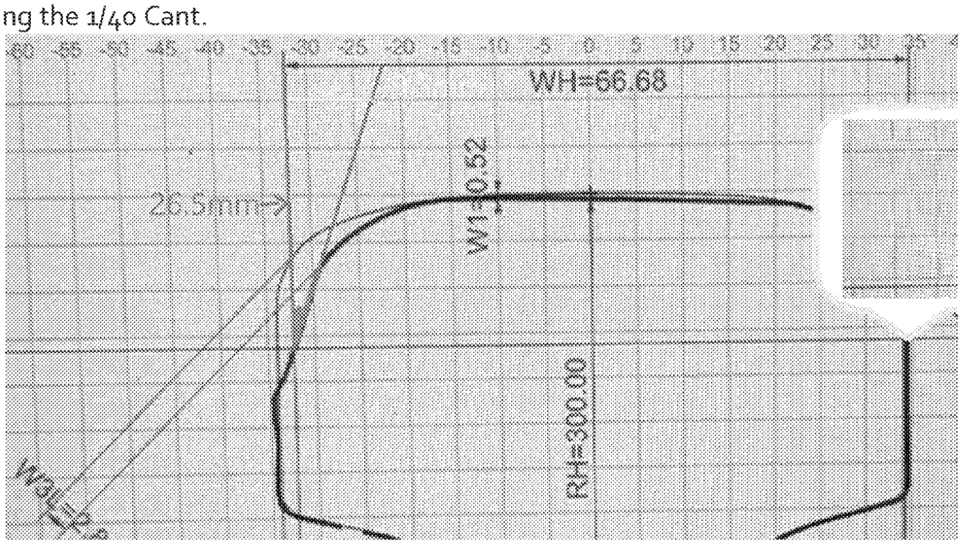



**Figure 7 Gauge face angle calculation**

## Section 4 FIELD STRING LINE MEASUREMENTS by GT's

### 4.1 Field string line measurements for Curve 19

Curve 19 in the MSF Yard has radius of 39m per design and is 67.681m in length.

Mid-Ordinate measured 53.49" (Degree of Curve) at the derailment location on Curve 19. The translates to a curve radius of 37.92m, a difference of 1.08 m from the 39m per design.

### 4.2 Field string line measurements for Curve 13

Curve 13 in the MSF Yard has a radius of 35m per design and is 36.486m in length.

Curve 13 was the second curve affected by the derailment. The Mid-Ordinate measured 60.625" (Degree of Curve) the metric conversion is 34.98m a difference of 0.02m from the 35m per design.

## Section 5 REFERENCES

A. RES-22-0-0000-MAN-0003 Trackwork Maintenance Manual
B. RTM Track Safety and Inspection Rules Rev. D
C. AREMA 2010

## Section 6 ACRONYMS

A. MSF- Maintenance Storage Facility
B. GT- Guideway Technician
C. GFA - Gauge Face Angle

## Section 7 CONTROL SHEET

| Version | Date | Content of Modification | Author(s) |
|---|---|---|---|
| A | 26-March-2021 | First issue. | Mariano Garcia / Track Expert<br>Peng Jiang / Fleet Support Specialist |
| B | 06-April-2021 | GFA at wheel climbed up location added.<br>Typo modified for chapter 4.1 . | Peng Jiang / Fleet Support Specialist |