National Transportation Safety Board
Office of Railroad, Pipeline and Hazardous Materials
Washington, DC 20594

RRD23LR008 – ANNISTON, ALABAMA

MECHANICAL

Group Chair's Factual Report

April 21, 2023

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A. ACCIDENT

Location: Anniston, Alabama
Date: March 9, 2023
Time: 0619 (Local)

Train: 245A109

B. MECHANICAL GROUP

Group Chair	John Manutes National Transportation Safety Board Denver, Colorado
Group Member	Lamont Hay Federal Railroad Administration Birmingham, Alabama
Group Member	Kevin Krull Norfolk Southern Railway Atlanta, Georgia
Group Member	Eric Shapach Norfolk Southern Railway Atlanta, Georgia
Group Member	Eddie Nix Alabama Public Service Commission Gardendale, Alabama

C. SUMMARY

For a summary of this accident, please see the Investigator-In-Charge (IIC) Synopsis in the docket for this investigation.

D. FACTUAL INFORMATION

1.0 Train Consist

Norfolk Southern Train No. 245A019 departed Atlanta, Georgia bound for Birmingham, Alabama with six locomotives and 108 railcars. No pickups or setouts were conducted while enroute prior to the accident. The train was 9,795 feet long and weighed 10,262 tons.

1.1 Locomotive Consist

All 6 locomotives were located at the front of the train. There were no mid-train or rear-end distributed power units (DPU). The first locomotive, UP 5574, was on-line and occupied by the two-person operating crew, located in their normal positions at the time of the accident. Prior to departure from Atlanta, the operating crew determined the second locomotive, UP 9039, had inoperative dynamic brakes. Therefore, this locomotive was placed in isolated status. While isolated, it could not produce tractive effort and dynamic braking. The pneumatic brakes operated normally and responded to control inputs from the front locomotive. The third locomotive, NS 4408, was in the process of undergoing periodic maintenance for the first time in calendar year 2023. The majority of the work was completed in Atlanta but was being moved to Birmingham for wheel truing.[1] The wheels did not have Federal defective conditions, they were scheduled to be trued as regular maintenance. Because the locomotive maintenance was not yet fully complete, the NS mechanical department did not place a current FRA Form F6180.49A (Blue Card) in the cab. There was a daily inspection card in the cab, but it contained no entries. The mechanical department did not place an out-of-service tag in the locomotive cab.

Prior to departure, the crew of the train noted inoperative dynamic brakes on the second locomotive. They placed the third locomotive on-line for tractive effort and dynamic braking and did not notice any concerns. The fourth locomotive was undergoing similar maintenance to the third locomotive and was therefore isolated. The fifth and sixth locomotives, RMEX 08 and RMEX 06, were "dead-in-tow" as revenue "waybilled" locomotives. Similar to the isolated status, the tractive effort was not available. Pneumatic braking functioned similar to a boxcar, the engineer could activate the automatic brake, but the independent brake was cut out. . The cabs were locked to prevent access. The NS was moving these locomotives for a customer, Reliance Rail, from Bluffton, Indiana to Mobile, Alabama where they were to be placed on an ocean vessel for shipment to an overseas customer. The NS had moved RMEX 08 and RMEX 06 on four previous trains prior to placement in the accident train.

[1] Wheel truing consists of cutting the wheel on a lathe to obtain the proper wheel profile.

Road Number	Type	Status	Coupler Type
UP 5574	C44ACCTE	Online	Front: F8513AE Rear: BF10AE
UP 9039	SD70AH	Isolated	Front: BF10AE Rear: F8513AE
NS 4408	AC44C6M	Online	Front: E8311E Rear:E8311E
NS 9485	D9-40CW	Isolated	Front: 8311E Rear: E8311E
RMEX 08	GP11	Dead-in-tow	Front: E4881E Rear: E7304
RMEX 06	GP10	Dead-in-tow	Front: E8305E Rear: E8305E

1.2 Car Consist

The train was comprised of 108 mixed-freight cars included four cars placarded "Class 8 (Corrosive Material) Dangerous", one general hazardous, and one "Class 3 (Flammable Liquid) Dangerous". Some of the cars in the train were articulated intermodal cars. NS identifies these cars as a single car. For the purposes of factually identifying the weight distribution of the train, the NS created a chart (marked "draft" below for investigation purposes) which breaks out each "well" or unit of these articulated cars. The ends of freight cars are designed to transfer the longitudinal loads of in-train forces, switching, and coupling through the ends of the cars where the couplers themselves connect to the car body through a draft pocket assembly. To manage these large forces without damaging equipment or lading, North American freight cars generally have either a standard draft gear, made up of resilient blocks or cast wedges, or a hydraulic end of car cushioning unit (EOCC). Draft gear systems have approximately 6.5-inches of travel over which the forces are absorbed in each device. EOCC systems absorb forces through hydraulic pistons in various ranges, generally about 15-inches per device. In the chart below, cars equipped with standard draft gear are indicated with blue bars, and cars with EOCC are indicated with yellow bars.

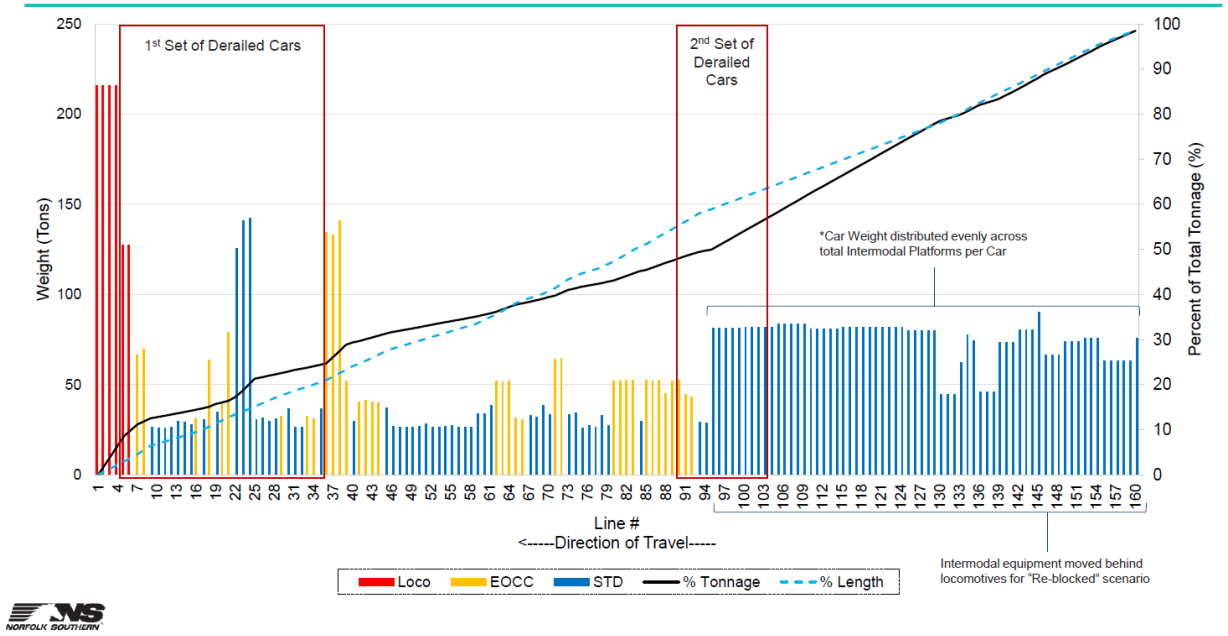
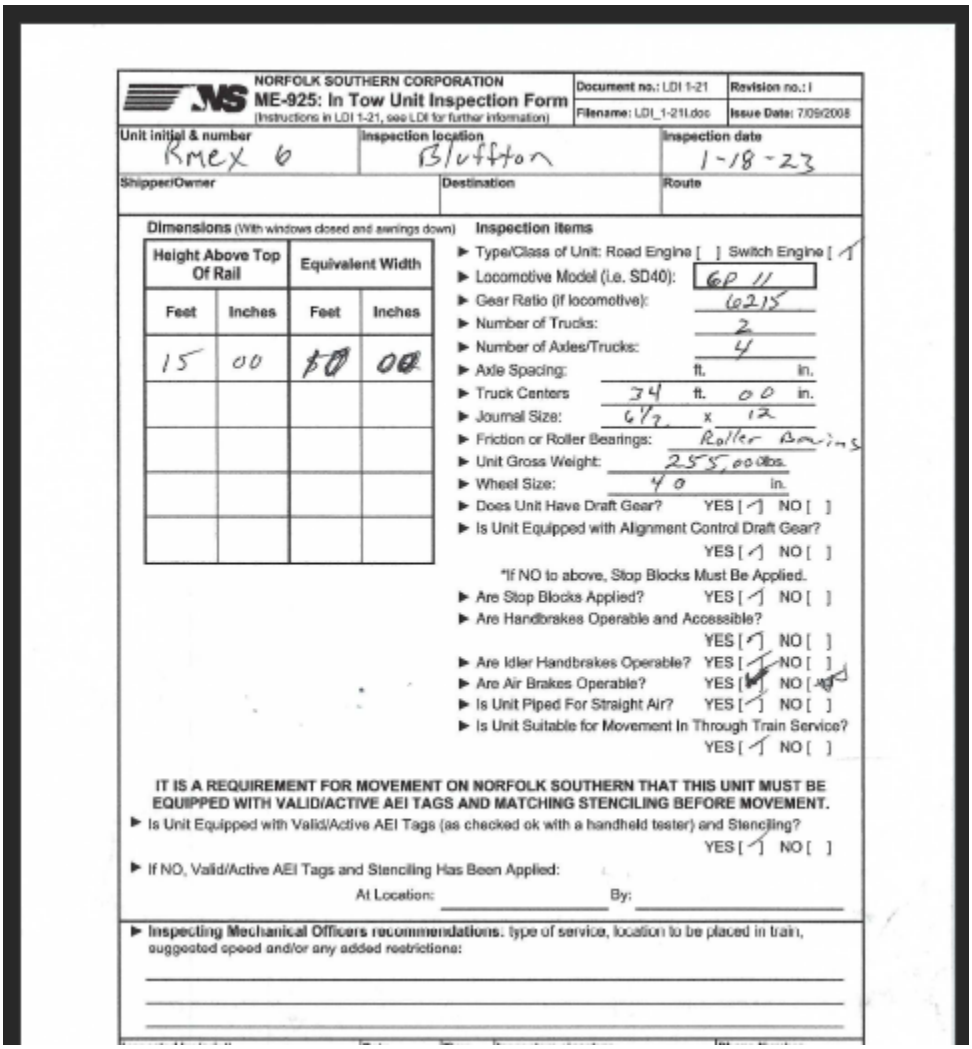


Figure 1. Tonnage profile for the accident train.

2.0 Pre-departure Inspections and Tests

2.1 In-Tow Locomotive Inspection

An NS mechanical employee conducted an inspection of RMEX 08 and 06 in Bluffton, IN. The employee filled out form "ME-925: In Tow Unit Inspection Form" which states, "Instructions in LDI 1-21, see LDI for further Instructions". On these forms, there are a number of inspection items. The line for "Is unit equipped with alignment control draft gear?" was checked "yes". The next line for "*if NO to above, stop blocks must be applied. Are stop blocks applied?" was also checked "Yes". The area for "Inspecting Mechanical Officers recommendations: type of service, location to be placed in train, suggested speed, and/or any added restrictions:" was left blank.



NORFOLK SOUTHERN CORPORATION
ME-925: In Tow Unit Inspection Form
(Instructions in LDI 1-21, see LDI for further information)

Document no.: LDI 1-21 | Revision no.: 1
Filename: LDI_1-21I.doc | Issue Date: 7/09/2008

Unit initial & number: RMEX 6
Inspection location: Bluffton
Inspection date: 1-18-23
Shipper/Owner:
Destination:
Route:

Dimensions (With windows closed and awnings down)

Height Above Top Of Rail		Equivalent Width	
Feet	Inches	Feet	Inches
15	00	10	00

Inspection items

- Type/Class of Unit: Road Engine [ ] Switch Engine [ ]
- Locomotive Model (i.e. SD40): GP 11
- Gear Ratio (if locomotive): 62.15
- Number of Trucks: 2
- Number of Axles/Trucks: 4
- Axle Spacing: ft. in.
- Truck Centers: 34 ft. 00 in.
- Journal Size: 6 7/8 x 12
- Friction or Roller Bearings: Roller Bearings
- Unit Gross Weight: 255,000 lbs.
- Wheel Size: 40 in.
- Does Unit Have Draft Gear? YES [ ] NO [ ]
- Is Unit Equipped with Alignment Control Draft Gear? YES [ ] NO [ ]

*If NO to above, Stop Blocks Must Be Applied.

- Are Stop Blocks Applied? YES [ ] NO [ ]
- Are Handbrakes Operable and Accessible? YES [ ] NO [ ]
- Are Idler Handbrakes Operable? YES [ ] NO [ ]
- Are Air Brakes Operable? YES [ ] NO [ ]
- Is Unit Piped For Straight Air? YES [ ] NO [ ]
- Is Unit Suitable for Movement In Through Train Service? YES [ ] NO [ ]

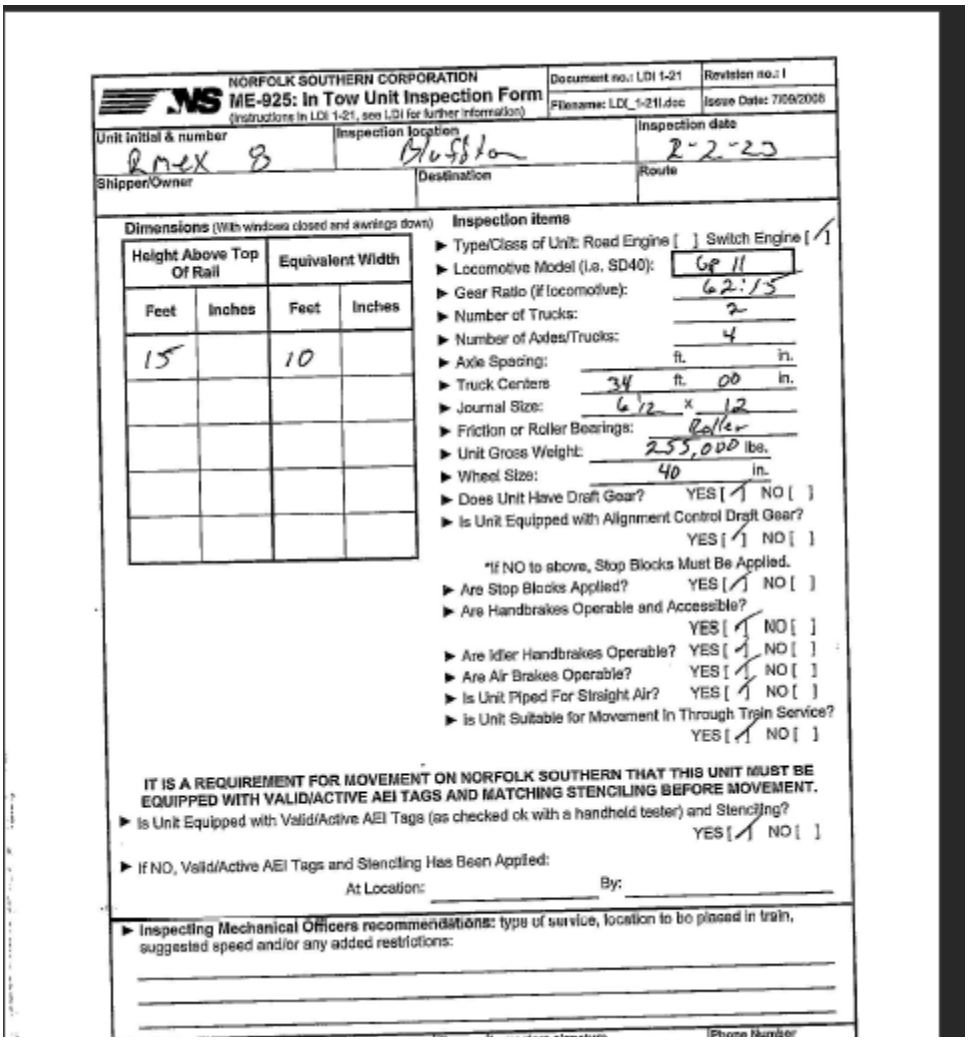
IT IS A REQUIREMENT FOR MOVEMENT ON NORFOLK SOUTHERN THAT THIS UNIT MUST BE EQUIPPED WITH VALID/ACTIVE AEI TAGS AND MATCHING STENCILING BEFORE MOVEMENT.

- Is Unit Equipped with Valid/Active AEI Tags (as checked ok with a handheld tester) and Stenciling? YES [ ] NO [ ]
- If NO, Valid/Active AEI Tags and Stenciling Has Been Applied:

At Location: _____ By: _____

- **Inspecting Mechanical Officers recommendations.** type of service, location to be placed in train, suggested speed and/or any added restrictions:

Figure 2. ME-925 for RMEX 06



NORFOLK SOUTHERN CORPORATION
ME-925: In Tow Unit Inspection Form
(Instructions in LDI 1-21, see LDI for further information)

Document no.: LDI 1-21 | Revision no.: 1
Filename: LDI_1-21.doc | Issue Date: 7/09/2008

Unit initial & number: RMEX 8
Inspection location: Bluffton
Inspection date: 2-2-23
Shipper/Owner:
Destination:
Route:

Dimensions (With windows closed and awnings down)

Height Above Top Of Rail		Equivalent Width	
Feet	Inches	Feet	Inches
15		10	

Inspection items

- ▶ Type/Class of Unit: Road Engine [ ] Switch Engine [✓]
- ▶ Locomotive Model (i.e. SD40): GP 11
- ▶ Gear Ratio (if locomotive): 62:15
- ▶ Number of Trucks: 2
- ▶ Number of Axles/Trucks: 4
- ▶ Axle Spacing: ft. in.
- ▶ Truck Centers: 34 ft. 00 in.
- ▶ Journal Size: 6 1/2 x 12
- ▶ Friction or Roller Bearings: Roller
- ▶ Unit Gross Weight: 255,000 lbs.
- ▶ Wheel Size: 40 in.
- ▶ Does Unit Have Draft Gear? YES [✓] NO [ ]
- ▶ Is Unit Equipped with Alignment Control Draft Gear? YES [✓] NO [ ]

*If NO to above, Stop Blocks Must Be Applied.

- ▶ Are Stop Blocks Applied? YES [✓] NO [ ]
- ▶ Are Handbrakes Operable and Accessible? YES [✓] NO [ ]
- ▶ Are Idler Handbrakes Operable? YES [✓] NO [ ]
- ▶ Are Air Brakes Operable? YES [✓] NO [ ]
- ▶ Is Unit Piped For Straight Air? YES [✓] NO [ ]
- ▶ Is Unit Suitable for Movement In Through Train Service? YES [✓] NO [ ]

IT IS A REQUIREMENT FOR MOVEMENT ON NORFOLK SOUTHERN THAT THIS UNIT MUST BE EQUIPPED WITH VALID/ACTIVE AEI TAGS AND MATCHING STENCILING BEFORE MOVEMENT.

- ▶ Is Unit Equipped with Valid/Active AEI Tags (as checked ok with a handheld tester) and Stenciling? YES [✓] NO [ ]
- ▶ If NO, Valid/Active AEI Tags and Stenciling Has Been Applied: At Location: _____ By: _____

▶ **Inspecting Mechanical Officers recommendations:** type of service, location to be placed in train, suggested speed and/or any added restrictions:

_____

_____

_____

Phone Number

Figure 3. Form ME-925 for locomotive RMEX 08

On April 4, 2023, FRA inspectors from the Mechanical Working Group interviewed the NS Electrician who performed the ME-925 inspections on RMEX 06 and RMEX 08. The Electrician stated he had worked at NS for 11-years and had performed one previous ME-925 inspection in late 2022. In an interview with FRA inspectors, he stated he performed the inspection alone and did not receive prior training. He stated that at the time of the inspection he did not know what an alignment control coupler was. He was allowed as much time as needed to conduct the inspections, and due to weather and operational issues, took two days to complete them over several hours each day.

2.2 NS Communications Regarding ME-925

Between January 11, 2023, and February 23, 2023, NS arranged the inspection, waybilling, and movement of locomotives RMEX 06 and RMEX 08 through email communications. On January 18, mechanical department employees

submitted the inspection form to the NS Clearance desk, who approved the movement of the locomotive via email shortly thereafter.

On February 2, 2023, NS mechanical employees submitted the inspection form for RMEX 08 to the NS Clearance desk. In subsequent emails that same day, there was a discussion related to the boxes marked "yes" for alignment control couplers and stop blocks.

Waybills for both locomotives were distributed on February 23, 2023. In the body of the email containing the waybills, the following three statements were included:

*Unit(s) is/are reported to have **4** axles, roller bearings, and are equipped with alignment control draft gear.*

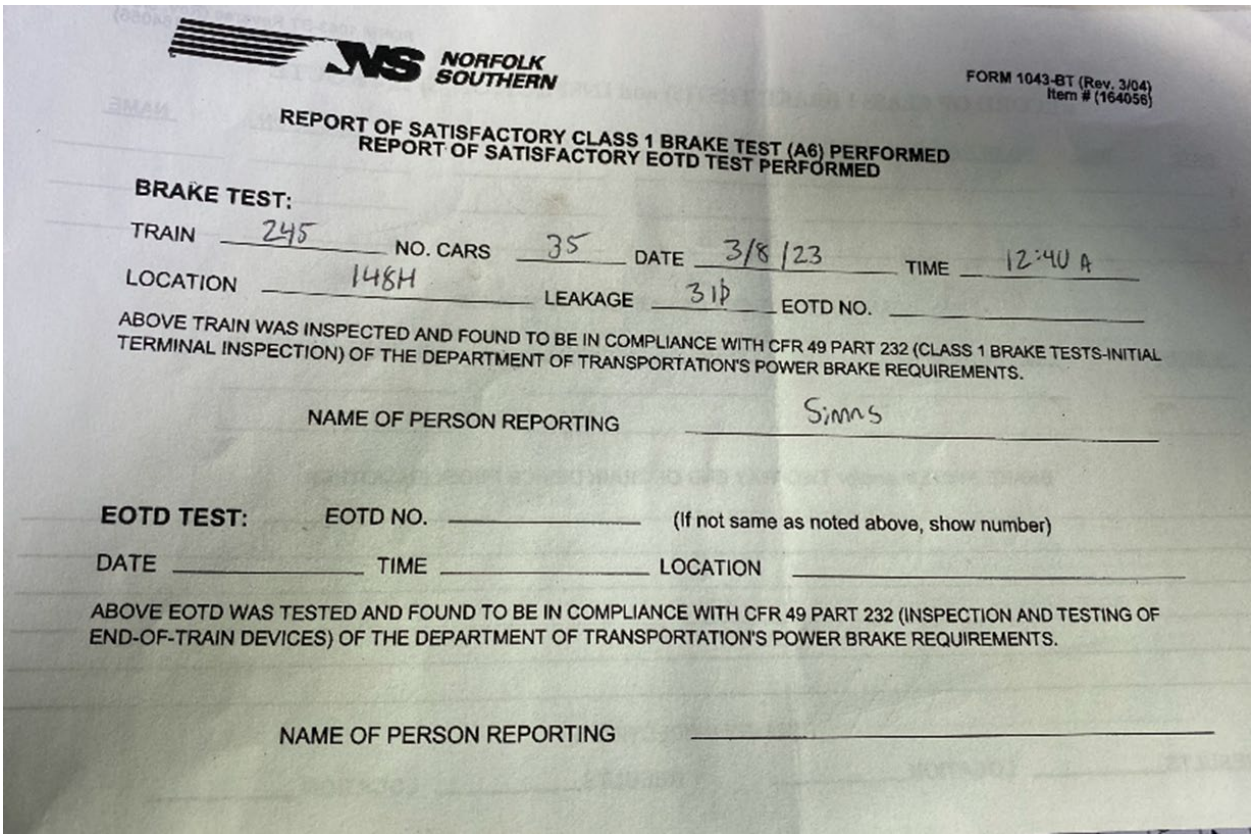
**** non alignment draft control gear in place - move per NS1 L214 & L231*

Per Tariff NS 8002-A Item 6275, Dead in Tow units not equipped with alignment control draft gear will move in Special Train Only.

Later that day, NS officials asked if the electrician who conducted the inspection had verified the presence of alignment control couplers. It was stated that "The electrician said the unit has stop blocks", and the movement was approved.

2.3 Train pre-departure Tests

Prior to the train's departure a Class I air brake test and pre-departure inspection was performed in two portions on March 8th and 9th in Atlanta by qualified mechanical inspectors.



NORFOLK SOUTHERN

FORM 1043-BT (Rev. 3/04)
Item # (164056)

REPORT OF SATISFACTORY CLASS 1 BRAKE TEST (A6) PERFORMED
REPORT OF SATISFACTORY EOTD TEST PERFORMED

BRAKE TEST:

TRAIN 245 NO. CARS 35 DATE 3/8/23 TIME 12:40 A

LOCATION 148H LEAKAGE 31# EOTD NO. _____

ABOVE TRAIN WAS INSPECTED AND FOUND TO BE IN COMPLIANCE WITH CFR 49 PART 232 (CLASS 1 BRAKE TESTS-INITIAL TERMINAL INSPECTION) OF THE DEPARTMENT OF TRANSPORTATION'S POWER BRAKE REQUIREMENTS.

NAME OF PERSON REPORTING Simms

EOTD TEST: EOTD NO. _____ (If not same as noted above, show number)

DATE _____ TIME _____ LOCATION _____

ABOVE EOTD WAS TESTED AND FOUND TO BE IN COMPLIANCE WITH CFR 49 PART 232 (INSPECTION AND TESTING OF END-OF-TRAIN DEVICES) OF THE DEPARTMENT OF TRANSPORTATION'S POWER BRAKE REQUIREMENTS.

NAME OF PERSON REPORTING _____

Figure 4. Class I air brake record for a portion of the accident train

NORFOLK SOUTHERN

FORM 1043-BT (Rev. 3/04)
Item # (164056)

REPORT OF SATISFACTORY CLASS 1 BRAKE TEST (A6) PERFORMED
REPORT OF SATISFACTORY EOTD TEST PERFORMED

BRAKE TEST:

TRAIN 245 NO. CARS 74 DATE 3/9 TIME 1:24

LOCATION 148H LEAKAGE 216 EOTD NO. 75714

ABOVE TRAIN WAS INSPECTED AND FOUND TO BE IN COMPLIANCE WITH CFR 49 PART 232 (CLASS 1 BRAKE TESTS-INITIAL TERMINAL INSPECTION) OF THE DEPARTMENT OF TRANSPORTATION'S POWER BRAKE REQUIREMENTS.

NAME OF PERSON REPORTING Simms

EOTD TEST: EOTD NO. 75714 (If not same as noted above, show number)

DATE 3/9 TIME 1:55A LOCATION 148H

ABOVE EOTD WAS TESTED AND FOUND TO BE IN COMPLIANCE WITH CFR 49 PART 232 (INSPECTION AND TESTING OF END-OF-TRAIN DEVICES) OF THE DEPARTMENT OF TRANSPORTATION'S POWER BRAKE REQUIREMENTS.

NAME OF PERSON REPORTING

Figure 5. Class I air brake record for a portion of the accident train

In addition to the FRA required inspections and tests, NS uses a Gold Card inspection process. The Gold Card process is outlined in NS Standard Work Instruction ME-114 with the most current revision dated June 3, 2022. NS Rule Number L-202, Taking Charge of Locomotives states, "When a locomotive consist is received from a mechanical facility, the presence of a current and properly completed form ME-114 (Gold Card) will indicate that the required tests and inspections have been successfully completed.

FORM ME-114 (REV 04/08/2020)

ME-114 CONSIST INSPECTION (Gold Card)
ME-114 is valid until next calendar day inspection or a consist change per L-203

Train Symbol: 245 Location: 148H Date: 3/8/23

Loco Consist: [illegible]

Fuel Readings:

The following have been checked on this consist per applicable NS-1 rules *(reference graphic for work path)*:

- ☐ 1. Confirmed calendar day inspection is completed and signed
- ☐ 2. Locomotives properly equipped with tools, supplies, ice, and water
- ☐ 3. Verified the following LCDI items: Toilet, Sand, MU Hoses/Cables, Head/Ditch Lights, Bell, Horn, Air Brake, and Alerter
- ☐ 4. Radio & HOTD tested - If prelinked, EOTD ID#: Test with TRUX Time Tested: 8:33 am/pm
- ☐ 5. Completed: ☐ PTC Departure Test *(as required)* ☐ Cab Signal Departure Test *(where required)* ☐ Bidirectional Loading ☐ Dynamic Brake Test
- 6. DP consist: ☐ Yes ☐ No Units pre-linked per SW-L-0300: ☐ Yes Linked DP units:
- ☐ 7. Checked ATC equipment for seals
- ☐ 8. Completed Form ME-615 for defective locomotives being towed *(if applicable)*
- ☐ 9. Locomotives set up properly per NS-1 L-213
- ☐ 10. Cleaned and sanitized per department instructions
- ☐ 11. Left a copy of Gold Card and DP Quick Reference *(if applicable)* in the cab of the lead locomotive

Name of person(s) inspecting: McGhee Young

NORFOLK SOUTHERN

Figure 6. Form ME-114 (Gold Card) From accident train.

3.0 Accident Sequence

Between East End District Milepost 719 and 720, Train No. 245A109 was traveling on a track that undulated between ascending and descending grade, then began a downhill grade of 1.29-percent. The train was in the process of traversing multiple curves simultaneously. Maximum authorized speed in this area is 35 MPH.

At MP 721.05 the track profile is briefly tangent between a left-hand and right-hand curve. Witness marks indicate that at this point, the south rail experienced a catestrophic lateral force to the south and subsequent rail rollover/gage rupture event. The head of the rail had witness marks consistent with the suspension hanger from a locomotive riding on the rail for approximately 29 feet. Following this mark, wheel flange impact marks from north-rail wheels were found inside the gage on the ties.

The witness marks found on the track structure matched witness marks found on locomotive RMEX 06. Specifically, the R3 wheel had outside wheel plate/rim scoring and damage. The right-rear (south in the direction of travel) suspension hanger had witness marks from the rail. The witness marks are consistent with the R3 wheel of RMEX 06 being the first wheel to derail in a gage widening/ rail roll over event.

Figure 7. East End Derailment Overview

Figure 8. East End Derailment Overview

Figure 9. West End Derailment Overview

Figure 10. Wheel and wheel tread departure mark near MP 721.05.

Figure 11. RMEX 06 R3 Wheel with rail burn witness marks.

Figure 12. RMEX 06 rear right hanger with rail burn witness marks.

Figure 13. Cars at rest (post-derailment) near MP 721.05 with jackknifed couplers

4.0 Post-accident Inspections and Tests

4.1 Locomotive Couplers

Modern locomotives, like the first four in this consist, are equipped with alignment control couplers.[2] Alignment control couplers are cast with 'shoulders' at the rear of the drawbar portion of the coupler and plungers designed to engage with the wings and draft gear when the train experiences compressive, or buff, forces (See Figure 14). Through the activation of the draft gear, the plungers provide a centering torque to the coupler.

[2] Alignment control couplers, installed on most locomotives, will allow only limited lateral movement when longitudinal in-train forces are compressed or in buff. This reduces lateral forces on the track, transformed from longitudinal forces, and therefore reduces the possibility of derailment. Manufacturers' specifications indicate that alignment control couplers, under buff conditions, can limit the draw bar angle to eight degrees, while the non-alignment control couplers permit a draw bar angle as large as 19 degrees, creating increased coupler offsets between locomotives and cars.

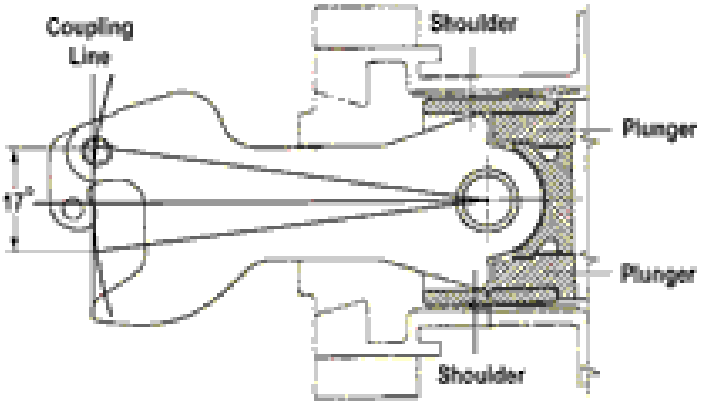


Figure 14. Alignment control coupler with plungers

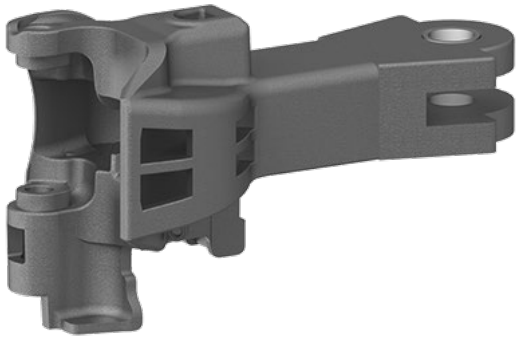


Figure 15. A Wabtec SBE8301E Coupler with alignment control.

Locomotives used extensively in switching service in areas with tight track curvature, similar to RMEX 08 and RMEX 06, may be equipped with non-alignment control couplers. These couplers lack the wings and are not equipped with the draft gear engaging plungers. The coupler head is free to rotate to larger degrees of freedom without resistance, even when the train is in buff. Norfolk Southern representatives on scene noted that NS maintains approximately 2,600 locomotives and only three of those locomotives are equipped with non-alignment control couplers. These shop switchers are used in a select few locomotive maintenance shop areas where track curvature necessitates their use to move other locomotives

around the facility. NS locomotives not equipped with alignment control couplers have a large white stripe painted under the locomotive reporting marks (numbers) for rapid identification. The RMEX 06 and 08 were not owned by NS, therefore they did not have the white stripe identification marking.

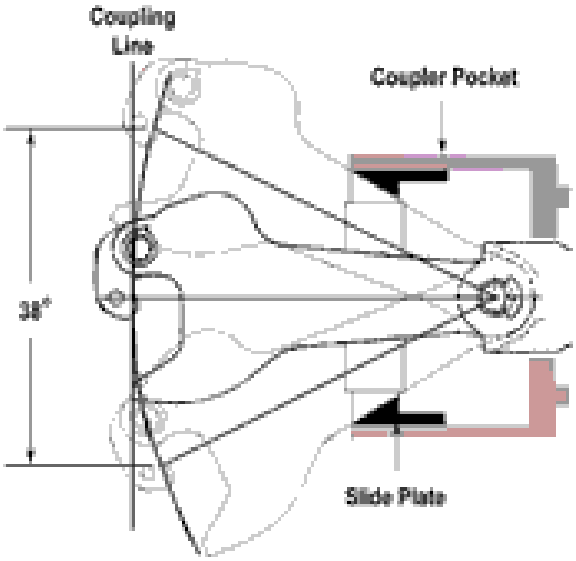


Figure 16. Coupler without alignment control.

Figure 17. NS 2103 with non-alignment control coupler identification stripe

Railroads sometimes place a removable alignment block between the front of the coupler pocket and the coupler to limit the full rotation of the coupler. RMEX 08 and 06 were equipped with these alignment blocks prior to departure from Bluffton. The application of stop blocks does not serve the same effect as an alignment control

coupler. The blocks resist rotation of the coupler, but they do not apply rotational pressure from the draft gear and provide positive rotational torque in the same way modern alignment control couplers do.

Figure 18. RMEX 08 non-alignment control coupler alignment block

Locomotives RMEX 06 and RMEX 08 were equipped with non-alignment control couplers. The draft pocket of RMEX 08 was bulged out on the left rear side. The rust, wear, and moss found inside the broken weld are consistent with 'old' break. The coupler stop block of RMEX 06 was missing at the right rear location. The bracket that held the rubber stop in place had fracture features consistent with fracture in overstress from outward bending. The facture surface was relatively flat with the exception of an upward facing shear lip toward the right, outer corner, and a depression with sharp corners on the left. The fracture was rough, with a uniform surface luster. The surface oxide was a light maroon or rust color, consistent with post-fracture oxidation from exposure to humidity or water. (Post-accident, there was significant rainfall in the area) There were no indications of localized areas of discoloration or geometries that would indicate a pre-existing crack. Investigators contacted the Pennsy company via email to ask about the proper installation of coupler stop blocks. In the email, the Pennsy company stated that they have never

seen the blocks welded to the coupler carrier in this manner. That was an incorrect application. The coupler alignment blocks are shipped assembled with the securement chain bolted to the ends of the vertical tabs, which indicates the correct method of application.

Figure 19. Draft gear pocket of RMEX 08, left rear location

Figure 20. RMEX 06 Pennsy coupler alignment block, improperly secured with weld.

Figure 21. Pennsy stop block. The bolts and chain are for securement purposes. (Pennsy marketing image)[3]

[3] https://pennsy.com/product/locomotive-coupler-alignment-block/

Figure 22. Draft gear pocket of RMEX 06 left rear location, showing broken coupler stop bracket.

4.2 Locomotive Wheel Profiles

Locomotive RMEX 08 had flanges over 1.5-inches at the following locations. Wheel R2, flange height 1.553 inches. Wheel R4, flange height 1.539 inches. Wheel L4, 1.588 inches. High flanges over 1.5-inches are FRA non-compliant conditions.[4]

[4] 49 CFR Section 229.75(h) – Wheels and tire defects

Wheel numbers R3 and R2 had a distinctive, non-standard, flange root shape.[5] The shape of the flange root is consistent with non-standard wheel lathe procedures, and not normal wear from wheel/rail contact.

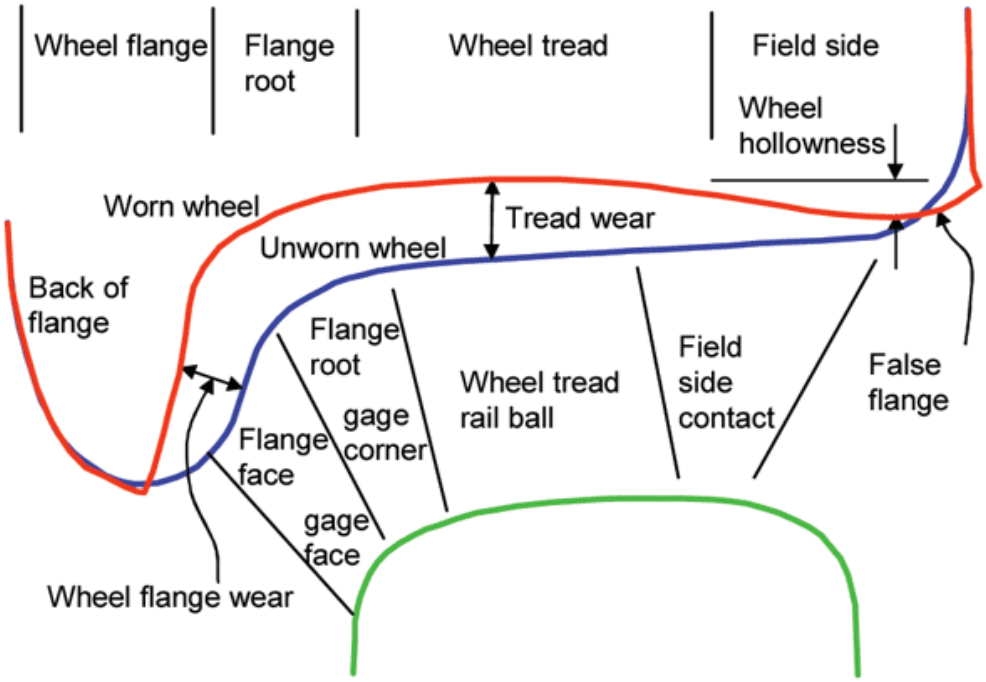


Figure 23. Exemplar Worn (red) and unworn (blue) wheel profiles with an exemplar rail profile (green).[6]

[5] The flange root is the radius between the tread of the wheel and the flange of the wheel.
[6] https://www.globalrailwayreview.com/article/2222/shape-optimisation-of-a-railway-wheel-profile/

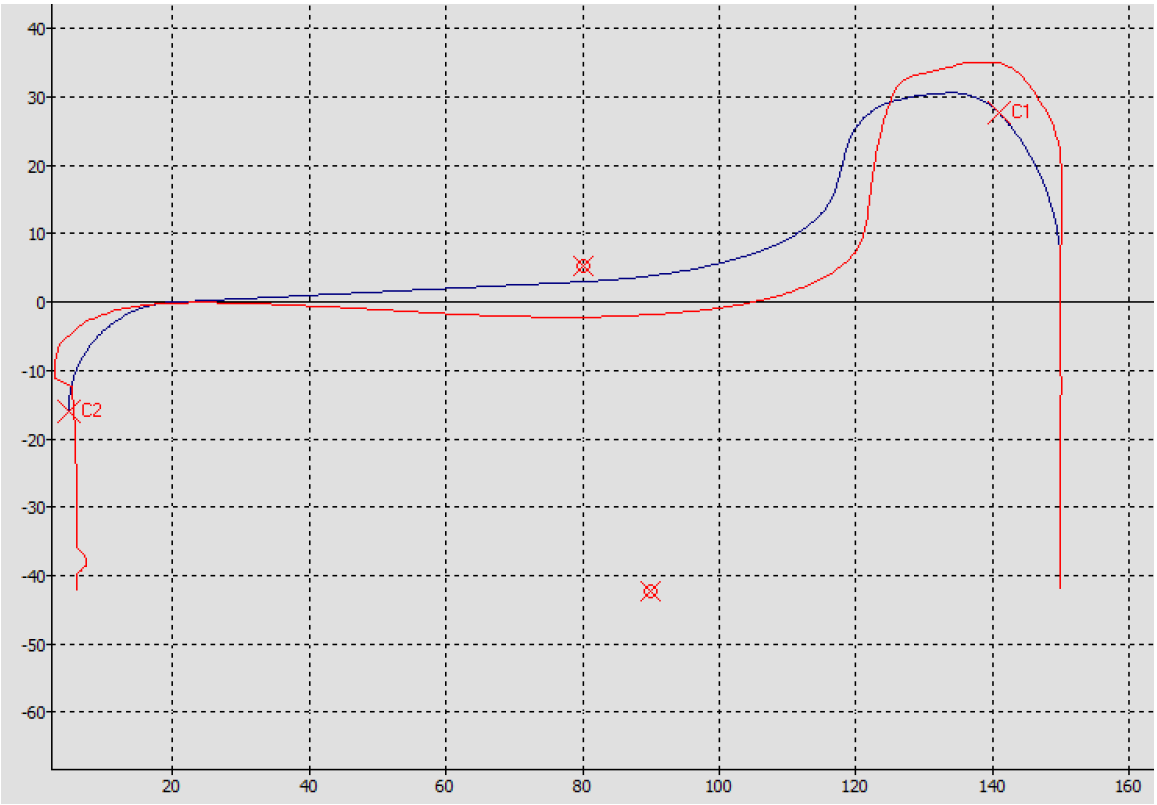


Figure 24. RMEX 08 L1 Wheel profile (Red) and new wheel profile (Blue)

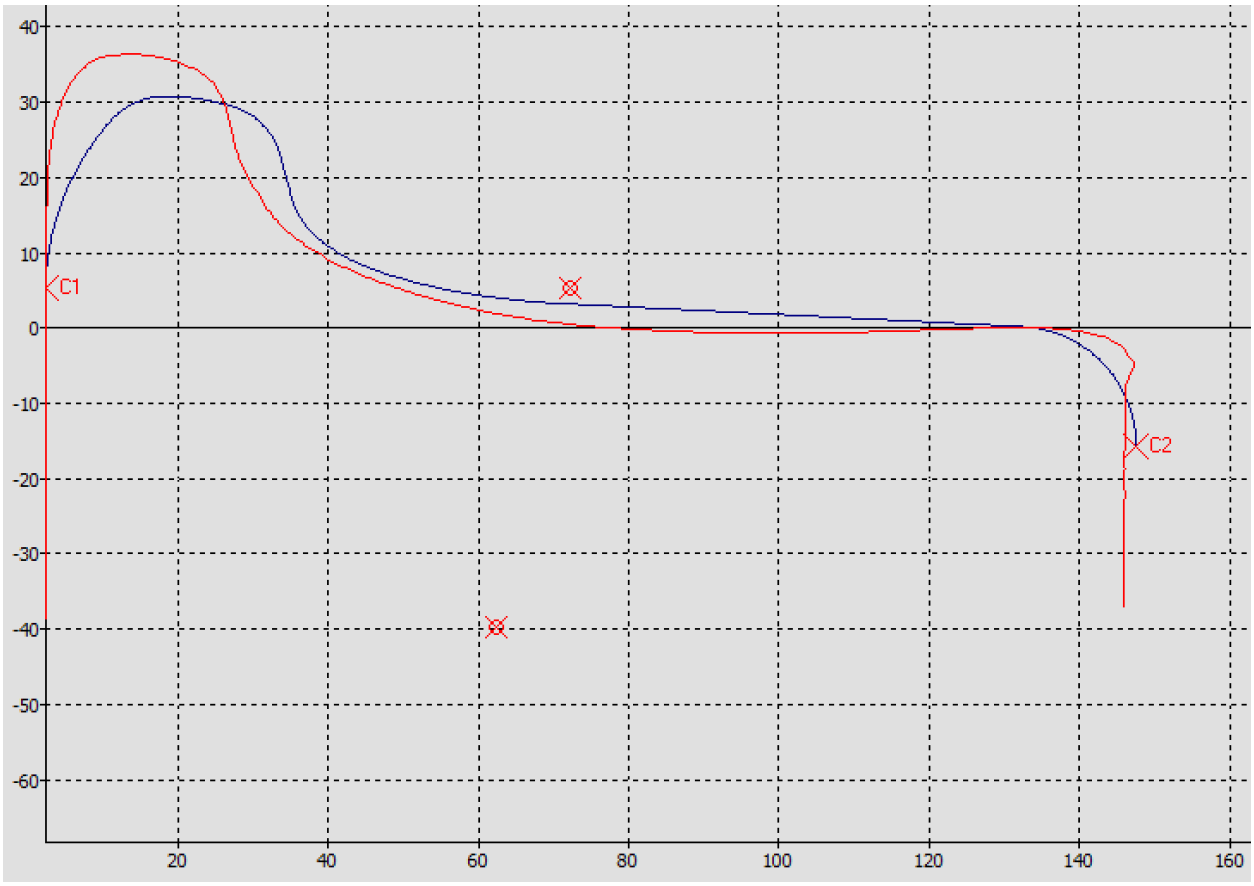


Figure 25. RMEX 08 R1 Wheel profile(Red) and new wheel profile (Blue)

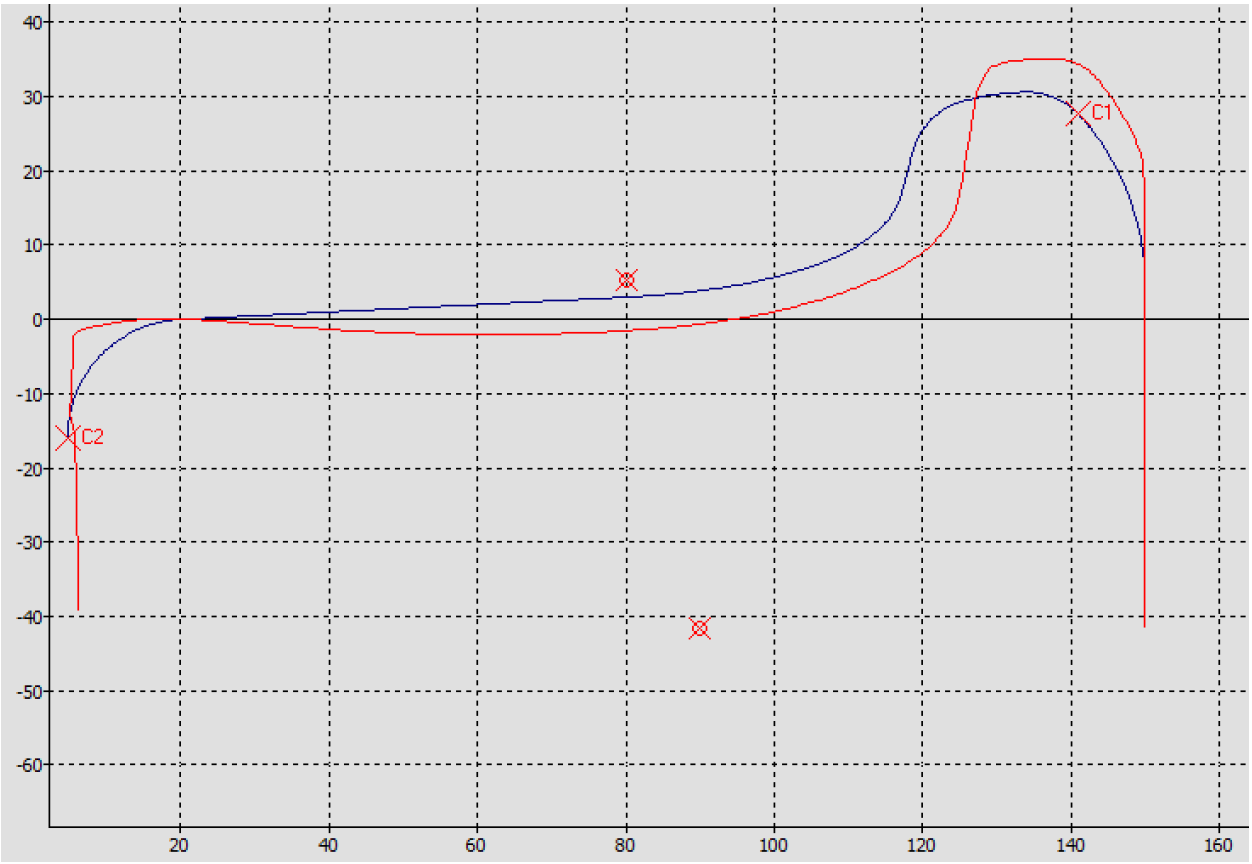


Figure 26. RMEX 08 L2 Wheel profile(Red) and new wheel profile (Blue)

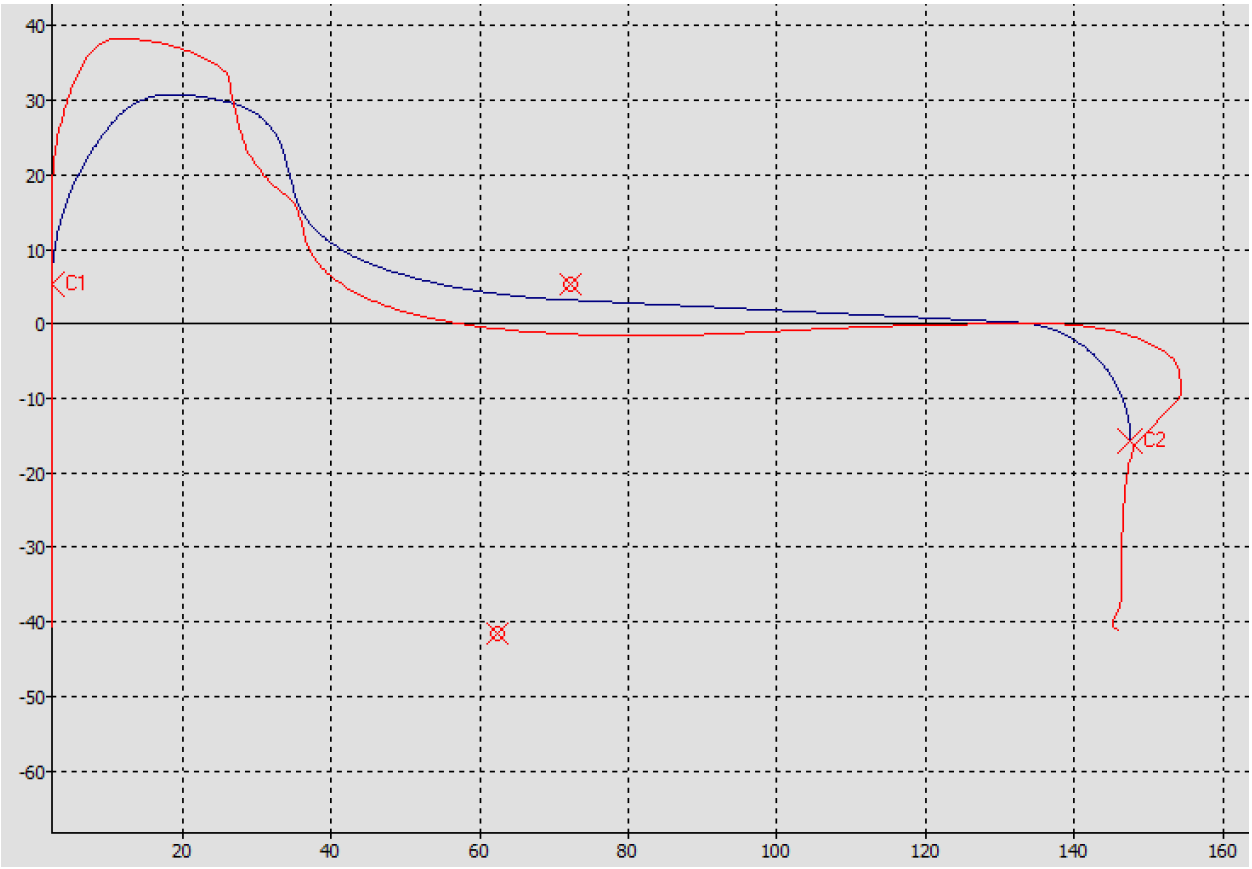


Figure 27. RMEX 08 R2 Wheel profile(Red) and new wheel profile (Blue)

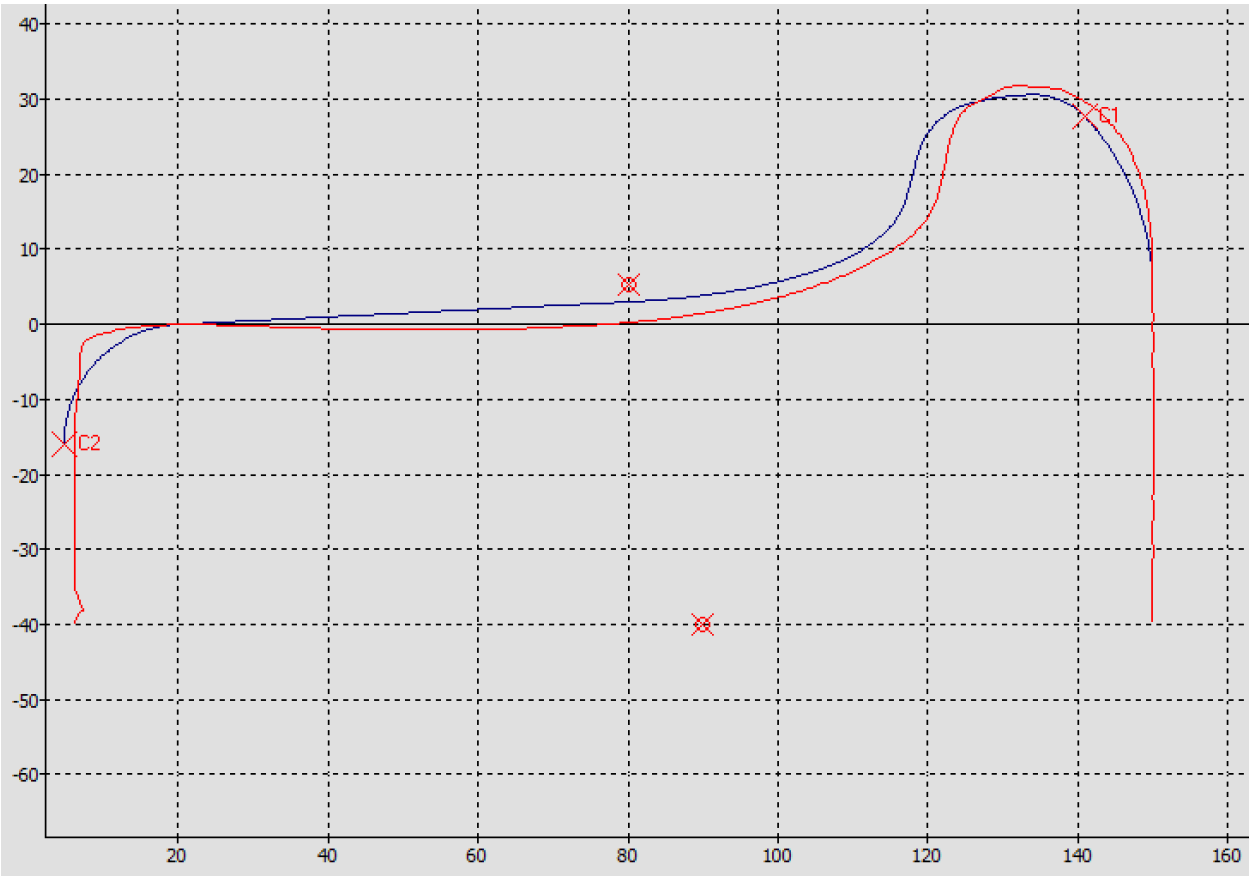


Figure 28. RMEX 08 L3 Wheel profile(Red) and new wheel profile (Blue)

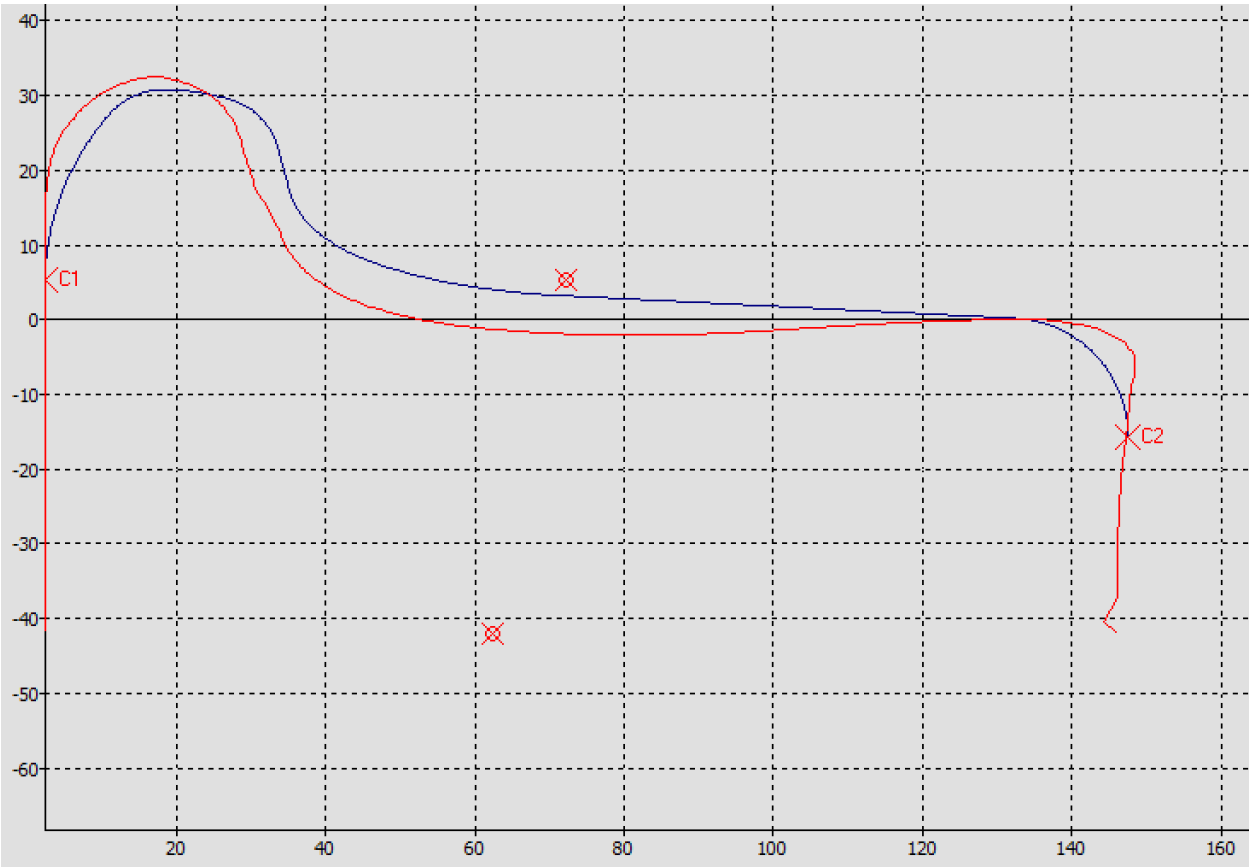


Figure 29. RMEX 08 R3 Wheel profile(Red) and new wheel profile (Blue)

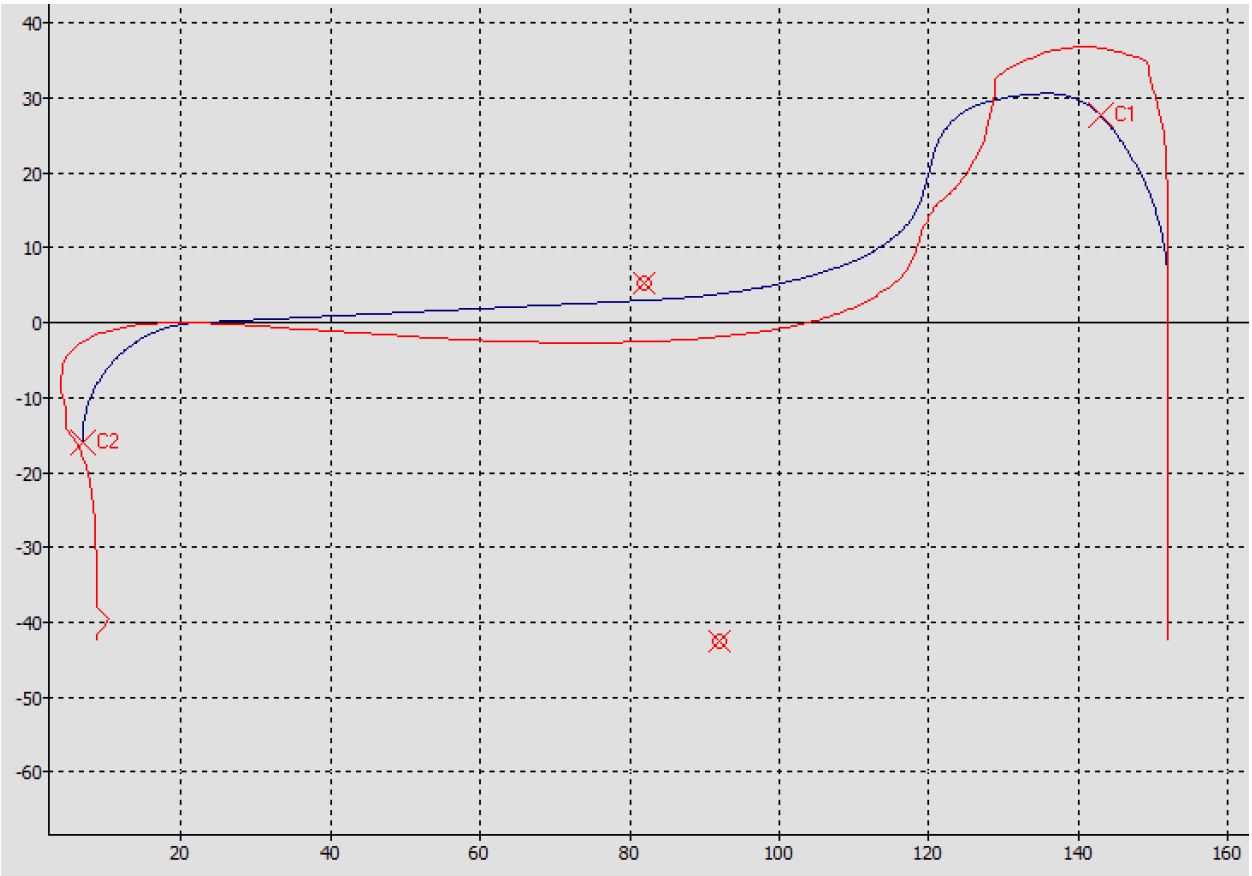


Figure 30. RMEX 08 L4 Wheel profile(Red) and new wheel profile (Blue)

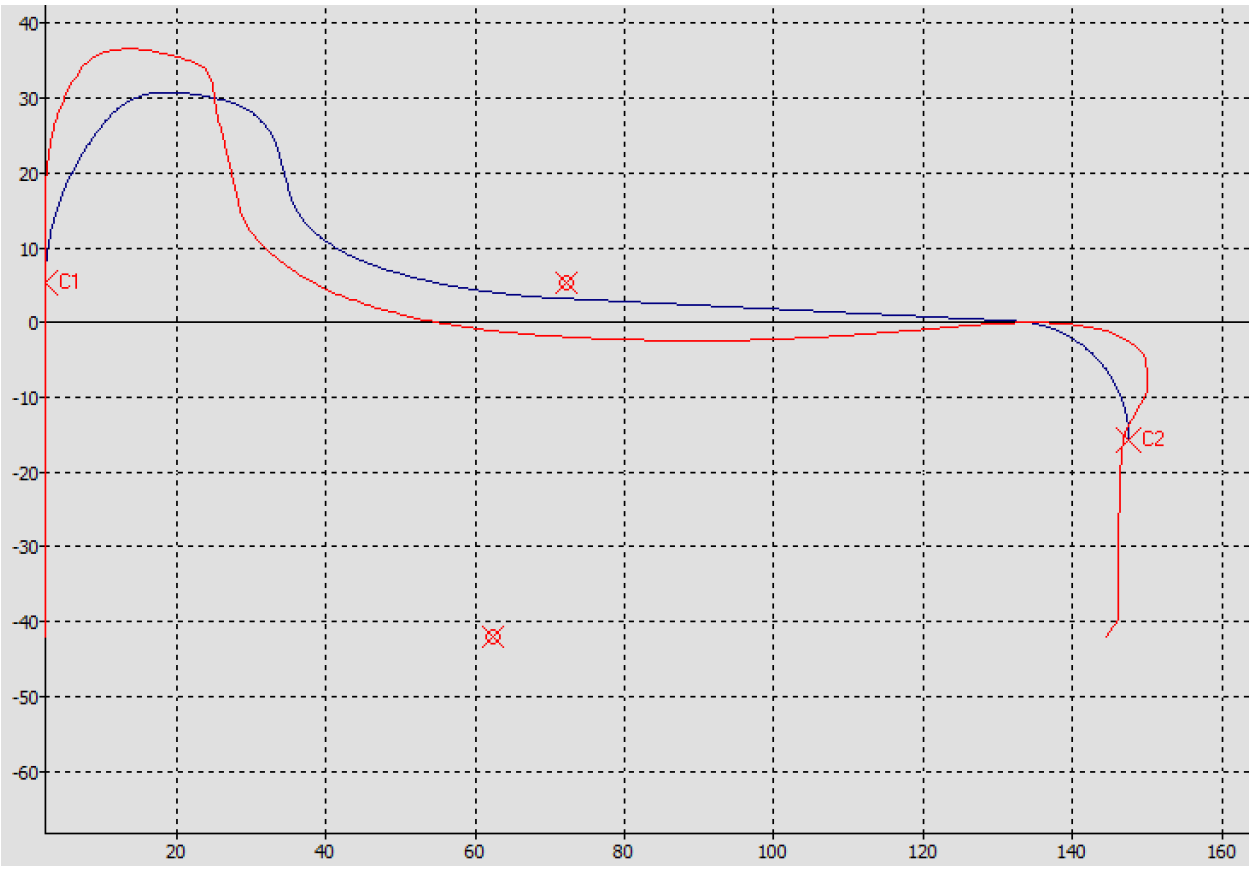
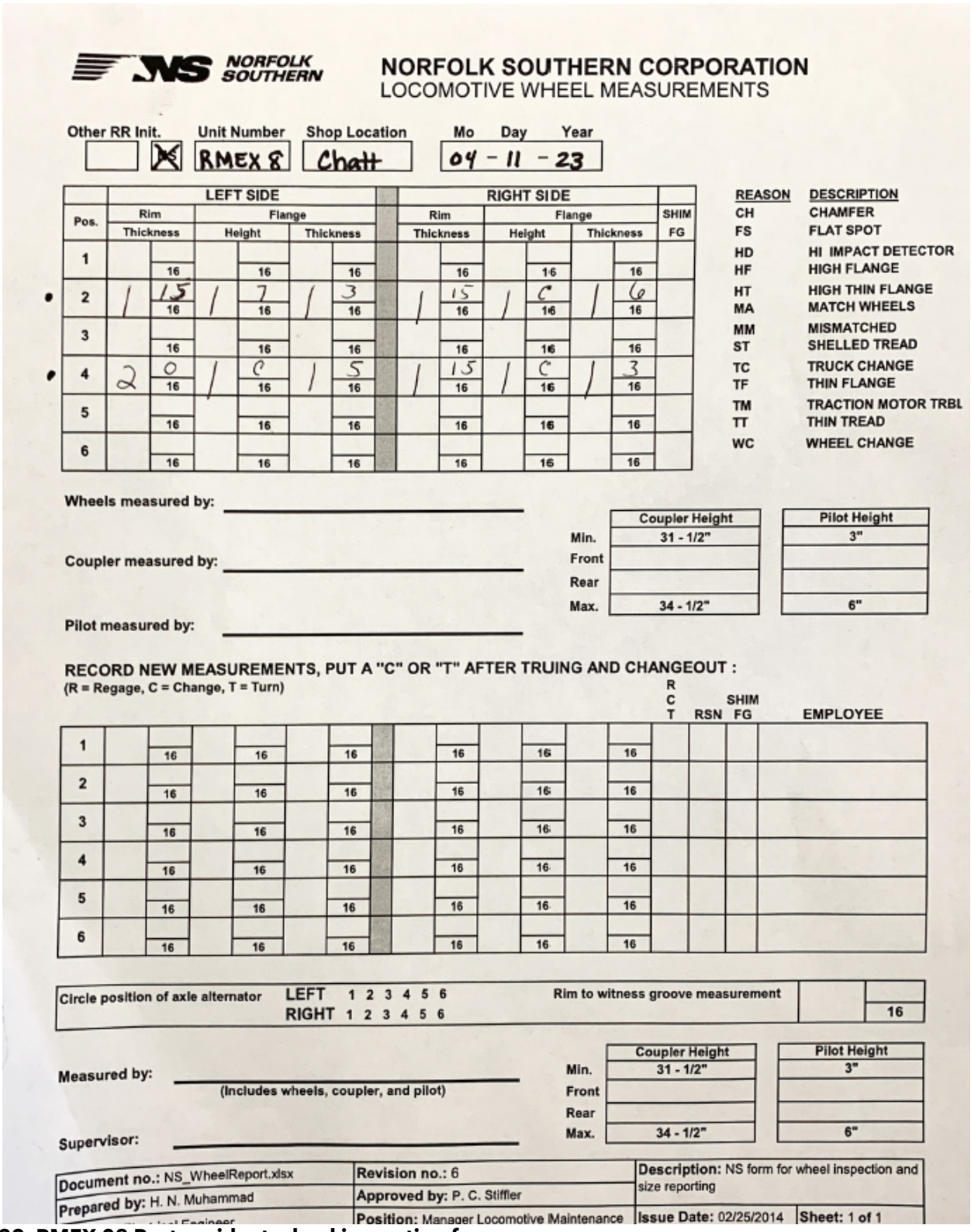


Figure 31. RMEX 08 R4 Wheel profile(Red) and new wheel profile (Blue)



NORFOLK SOUTHERN CORPORATION
LOCOMOTIVE WHEEL MEASUREMENTS

Other RR Init. | Unit Number: RMEX 8 | Shop Location: Chatt | Mo Day Year: 04 - 11 - 23

Pos.	LEFT SIDE Rim Thickness	LEFT SIDE Flange Height	LEFT SIDE Flange Thickness	RIGHT SIDE Rim Thickness	RIGHT SIDE Flange Height	RIGHT SIDE Flange Thickness	SHIM FG
1							
2	1 15/16	1 7/16	1 3/16	1 15/16	1 C/16	1 6/16	
3							
4	2 0/16	1 C/16	1 5/16	1 15/16	1 C/16	1 3/16	
5							
6							

REASON	DESCRIPTION
CH	CHAMFER
FS	FLAT SPOT
HD	HI IMPACT DETECTOR
HF	HIGH FLANGE
HT	HIGH THIN FLANGE
MA	MATCH WHEELS
MM	MISMATCHED
ST	SHELLED TREAD
TC	TRUCK CHANGE
TF	THIN FLANGE
TM	TRACTION MOTOR TRBL
TT	THIN TREAD
WC	WHEEL CHANGE

Wheels measured by: _____

Coupler measured by: _____

Pilot measured by: _____

	Coupler Height	Pilot Height
Min.	31 - 1/2"	3"
Front		
Rear		
Max.	34 - 1/2"	6"

RECORD NEW MEASUREMENTS, PUT A "C" OR "T" AFTER TRUING AND CHANGEOUT :
(R = Regage, C = Change, T = Turn)

													R C T	RSN	SHIM FG	EMPLOYEE
1																
2																
3																
4																
5																
6																

Circle position of axle alternator: LEFT 1 2 3 4 5 6 / RIGHT 1 2 3 4 5 6 — Rim to witness groove measurement: 16

Measured by: _____
(Includes wheels, coupler, and pilot)

Supervisor: _____

	Coupler Height	Pilot Height
Min.	31 - 1/2"	3"
Front		
Rear		
Max.	34 - 1/2"	6"

Document no.: NS_WheelReport.xlsx	Revision no.: 6	Description: NS form for wheel inspection and size reporting
Prepared by: H. N. Muhammad	Approved by: P. C. Stiffler	
	Position: Manager Locomotive Maintenance	Issue Date: 02/25/2014 — Sheet: 1 of 1

Figure 32. RMEX 08 Post-accident wheel inspection form.

The Mechanical Working Group toured the NS wheel truing shop in Chattanooga, Tennessee. Wheel truing operators use in-track machines equipped

with wheel profile cutting tools to re-shape worn wheels into standard profiles. Wheel truing restores flange shape, flange root, and wheel tread profiles. The truing process will therefore eliminate high flanges and hollow worn tread, returning a worn wheel profile to a standard profile by removing material from the wheel. Because this is a cutting process, the wheel must have enough metal in the rim to allow the new shape to be cut without creating a thin-rim wheel. A wheel without enough metal remaining is scrapped instead of trued.

Figure 33. NS Wheel True Machine

Investigators noted that the wheel profiles of RMEX 08 R2 and L4 had non-standard 'grooves' in the wheel flange profile. These grooves are consistent with the effects of wheel truing and not normal wheel-rail wear.

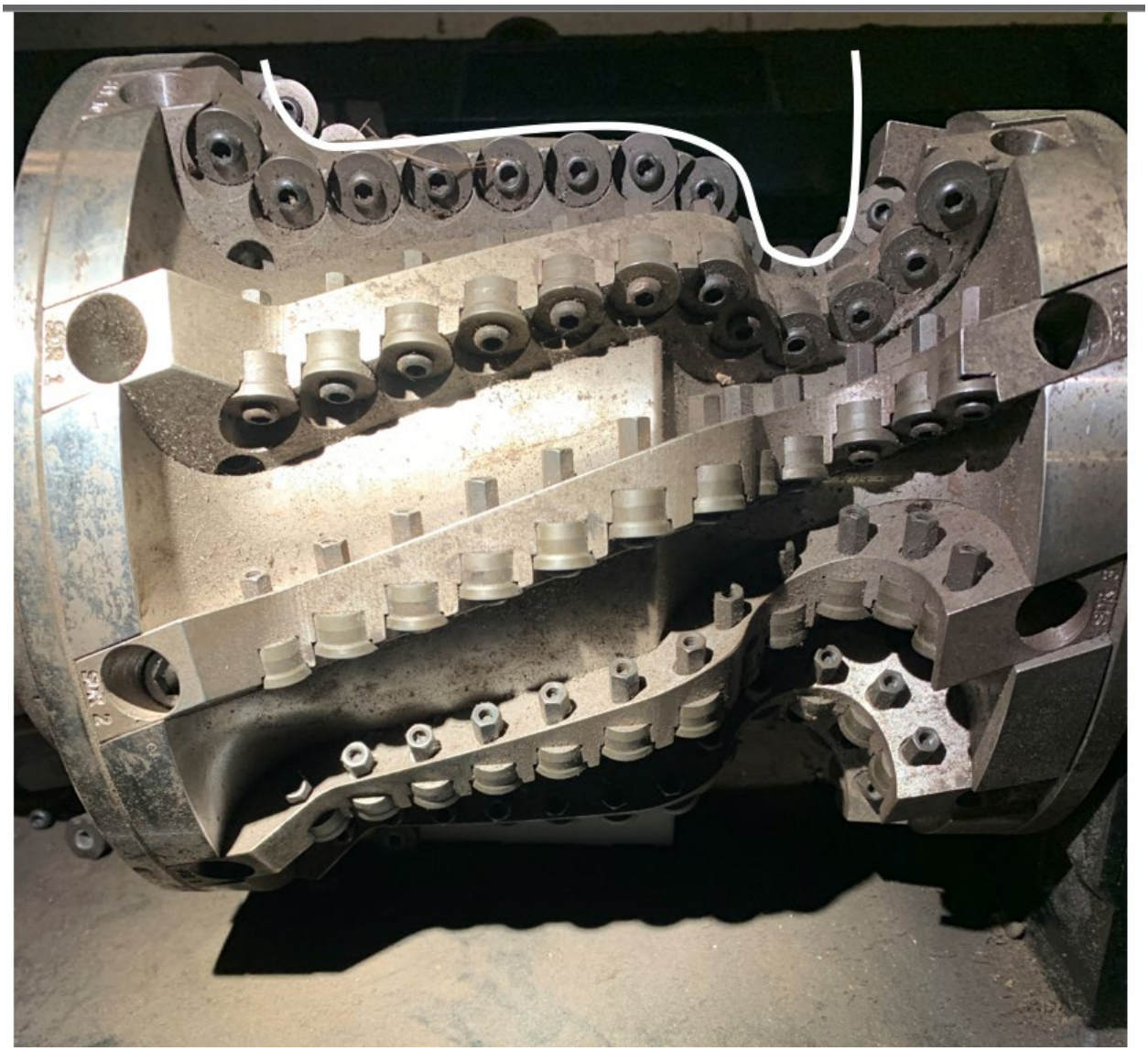


Figure 34. NS Wheel Profile cutting tool with a wheel profile sketched for reference. (NTSB photo and annotation)

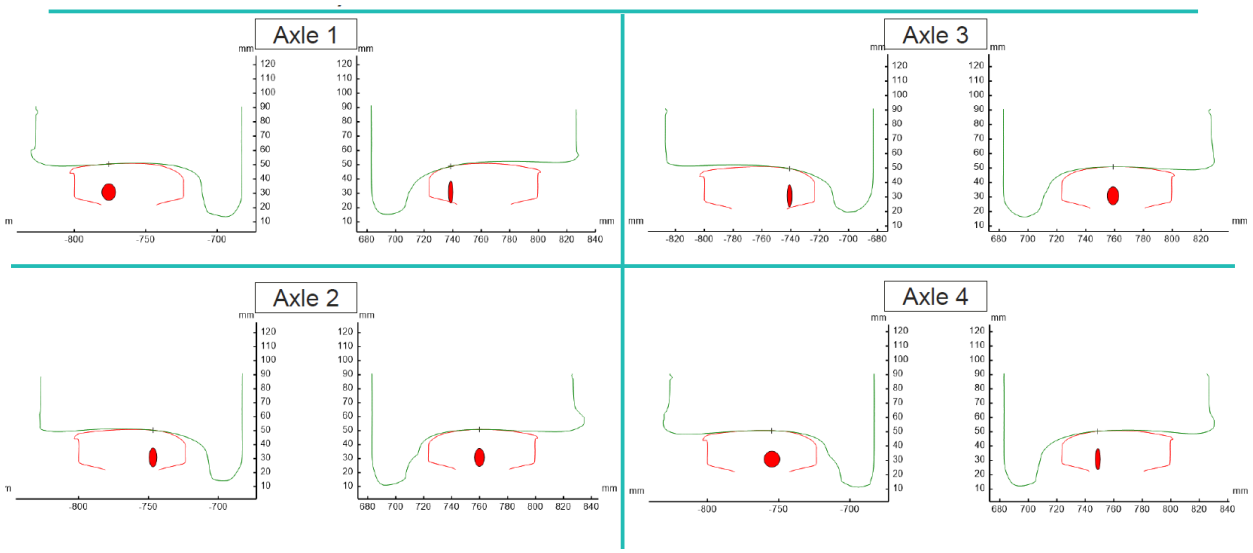


Figure 35. RMEX 08 Wheel Profiles and POD Track Profiles

4.3 TBOGI Data

Locomotives RMEX 08 and RMEX 06 passed an NS Truck Bogie Optical Geometry Inspection and Hunting Detection (TBOGI) system on March 13, 2023, in Flat Rock, Kentucky. The TBOGI wayside system is manufactured by Wayside Inspection Devices. It uses laser-based systems on trains passing at normal operating speeds. It is capable of detecting axle angle of attack, axle tracking position, misalignments between axles, differentials between the tracking of two axles, truck rotation, truck lateral shift, and truck hunting/ lateral instability. According to manufacturer documents, these systems are designed to allow customers to increase wheel life, stop premature wear, improve fuel efficiency, reduce the risk of unscheduled maintenance and derailments, and reveal hidden root causes of wear through rolling stock condition monitoring. These detectors do not send alerts to the train crews. Rather, the information is collected by maintenance personnel for diagnosis and scheduled maintenance. According to NS officials, the information can also be used post-accident to help determine root causes of accidents when applicable.

Figure 36. A field installation of TBOGI (WDI stock image)

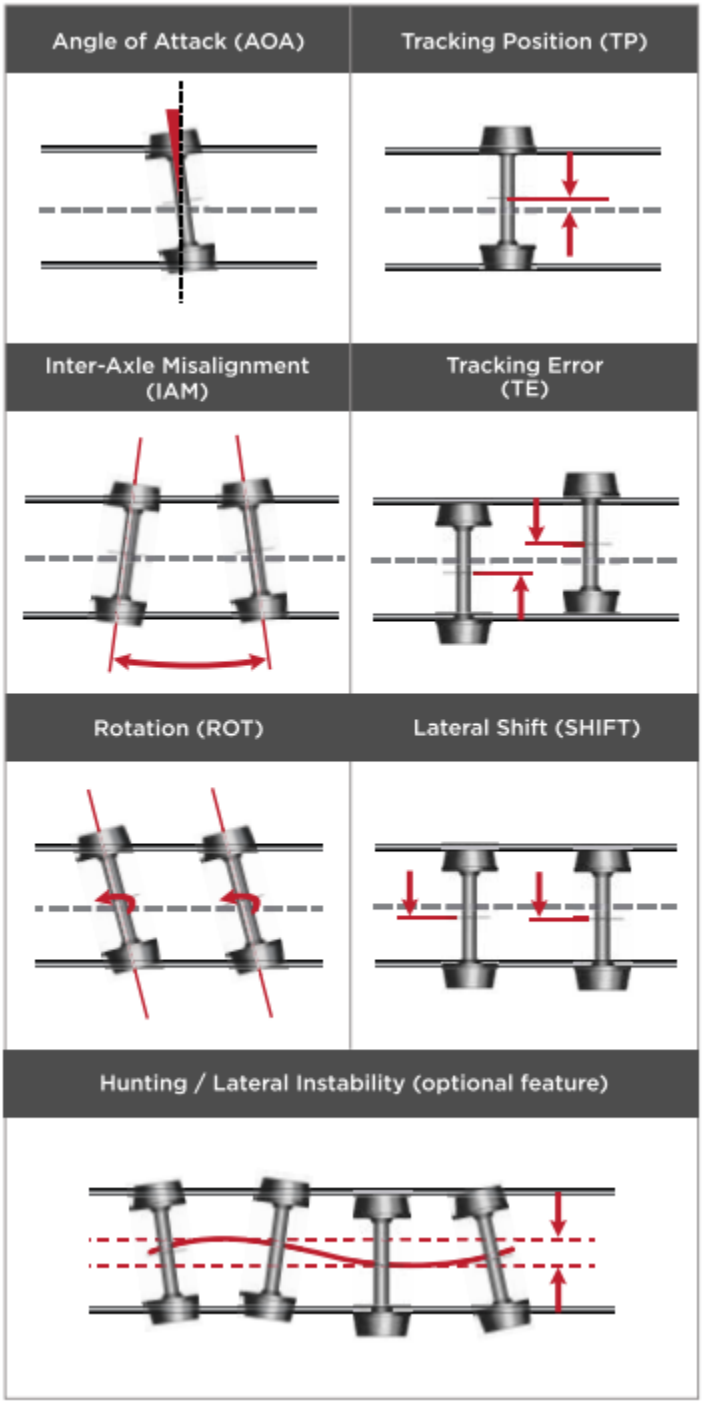


Figure 37. TBOGI measurements. (Manufacturer sales document)

Following the accident, NS officials provided the TBOGI data for RMEX 08 and RMEX 06. There were no exceptions noted with RMEX 06. For RMEX 08, TBOGI identified large angles of attack on axle numbers 4 and 2, -9.5 milliradians and 7.9 milliradians respectively.[7] Additionally, axle number 3 displayed a tracking position

[7] A milliradian is an SI unit for angular measurement which is defines as a thousandth of a radian. They

error of 12.9 millimeters. These conditions are not subject to Federal regulations or industry standards and are therefore not considered "defective" on their own. Rather, the railroad uses these measurements for maintenance scheduling and post-accident analysis to make improvements as needed.

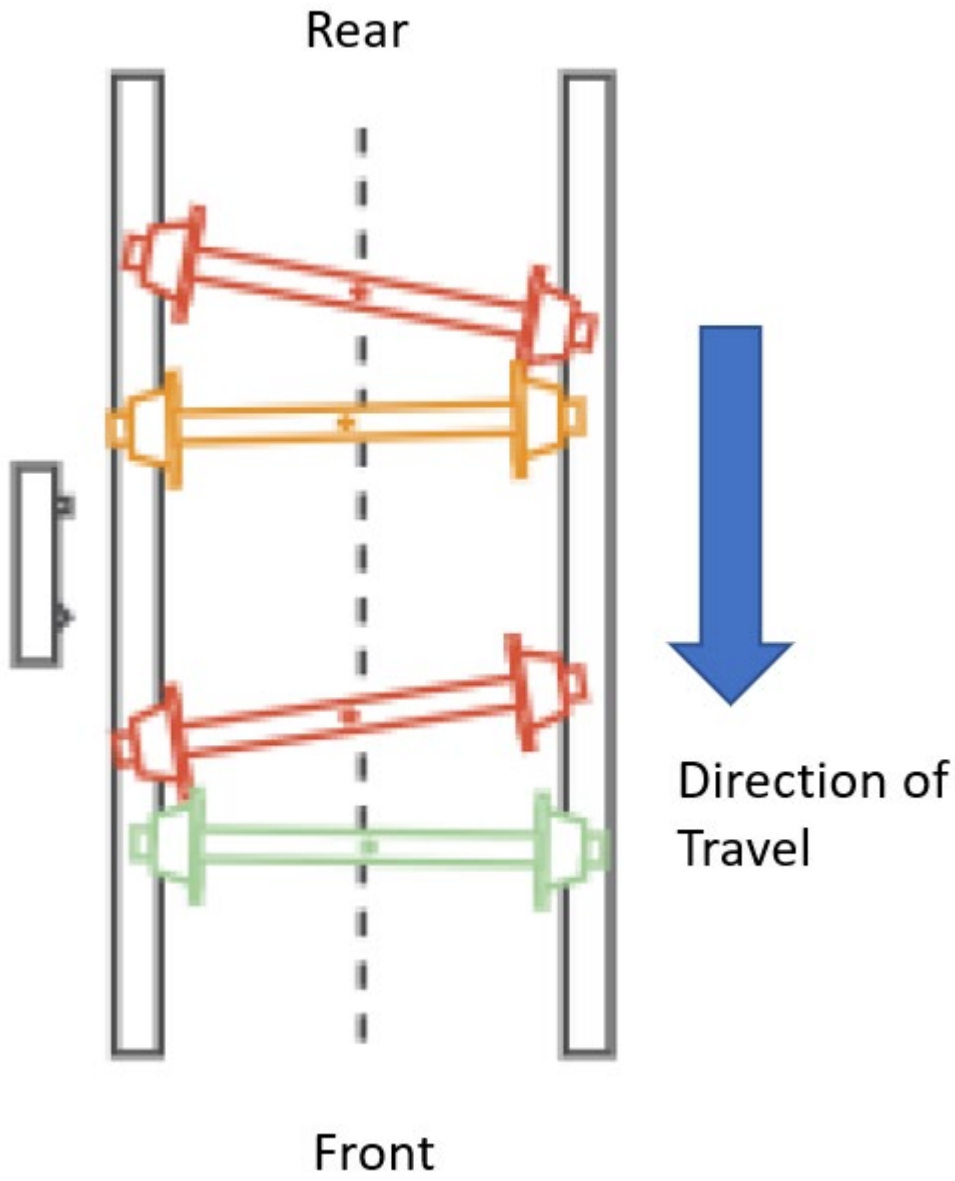


Figure 38. RMEX 08 TBOGI Data

are generally used for very small angles.

RMEX 08 at TBOGI Site (Speed 52 km/h)	Angle of Attack (mrad)	Tracking Position (mm)
Axle 1	-0.8	-5.0
Axle 2	7.9	10.2
Axle 3	1.5	12.9
Axle 4	-9.5	2.5

4.4 Locomotive Bolster Stop Blocks

Locomotives RMEX 06 and RMEX 08 were equipped with bolster stops, at the time of the derailment, two bolster stops were missing/broken.[8] Alignment control couplers and bolster stops both serve to limit coupler angles and coupler rotation. Bolster stops are applied to locomotives with pin-type couplers and no alignment control features to allow operation in consists with locomotives capable of high dynamic braking effort (but not over 200,000 pounds). Bolster stops are designed to prevent jackknifing when locomotives are subject to high dynamic braking effort.[9] Norfolk Southern rules do not account for the use of bolster stops.

Locomotive RMEX 06 was missing the stop block at the right rear location. Locomotive RMEX 08 was missing the stop block at the left rear location. The brackets holding the stop blocks were broken at the 90-degree bend. The rusty and worn condition of the brackets is consistent with 'old' break. The mechanical working group determined the bolster stop blocks were broken/missing before departure of the train from Atlanta.

[8] Bolster stops are removable blocks mounted to the truck side frame that resist the lateral movement of the locomotive body bolster.
[9] https://tsb.gc.ca/eng/rapports-reports/rail/2002/r02c0050/r02c0050.html

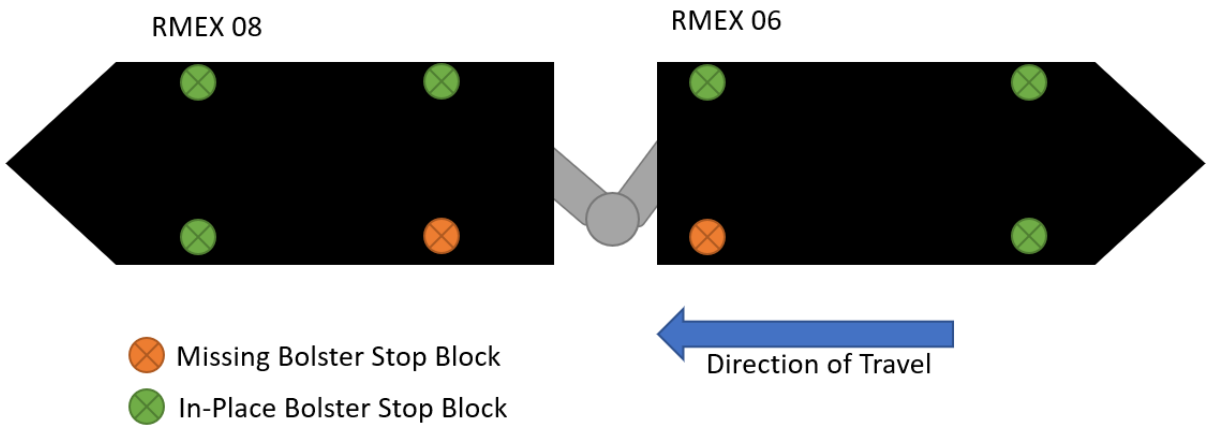


Figure 39. Location of missing bolster stop blocks

Figure 40. RMEX 08 Bolster stop bock in the normal configuration.

Figure 41. RMEX 08 broken bolster stop block

4.5 In Train Forces

NS conducted TOES in-train force modeling for three different scenarios. Scenario 1 was a recreation of the accident events using all available data. Scenario 2 was a recreation of the events the train experienced near Mile Post 707 where investigators noticed a chance for higher in-train forces prior to the derailment sequence. Finally, Scenario 3 attempted to simulate in-train forces near the POD, but with the rear articulated cars moved to the front position just behind the locomotives.

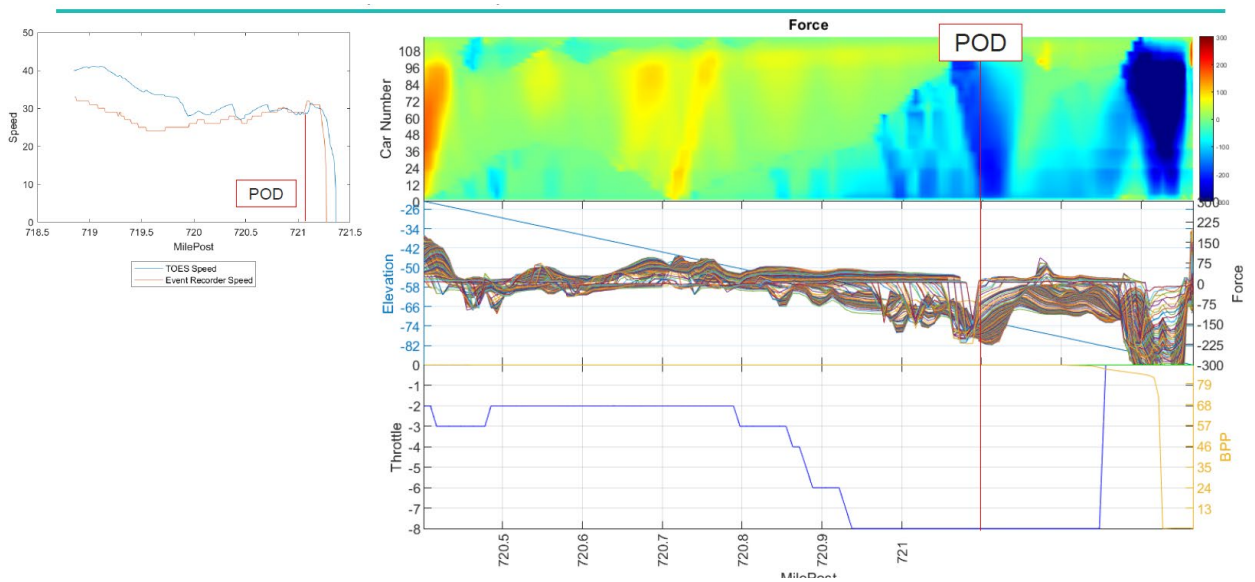


Figure 42. TOES Scenario 1

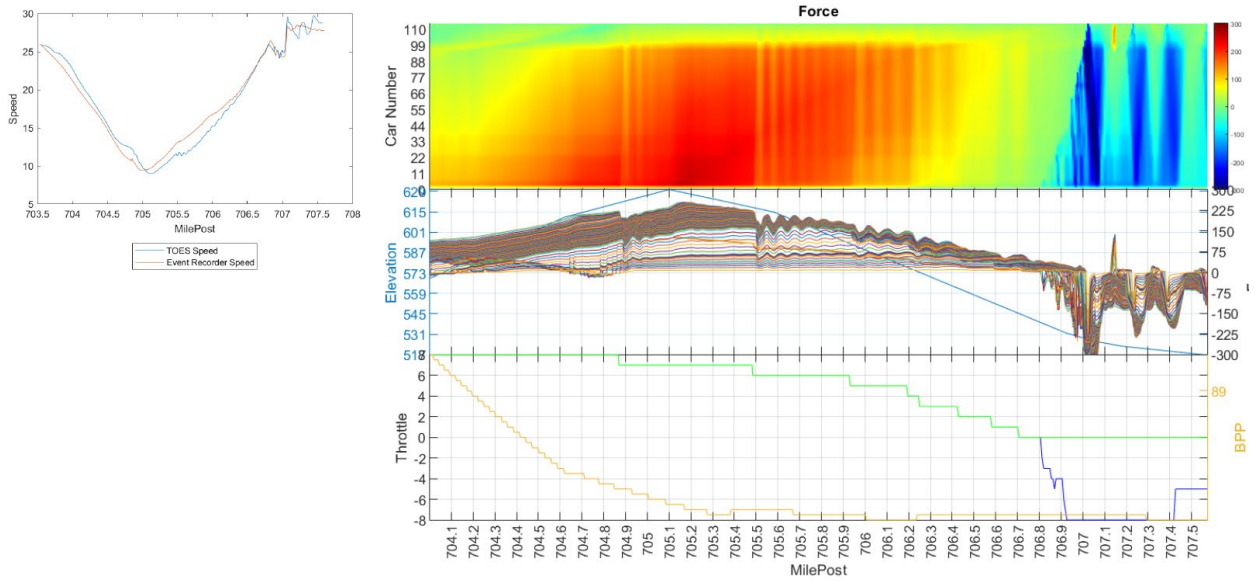


Figure 43. TOES Scenario 2

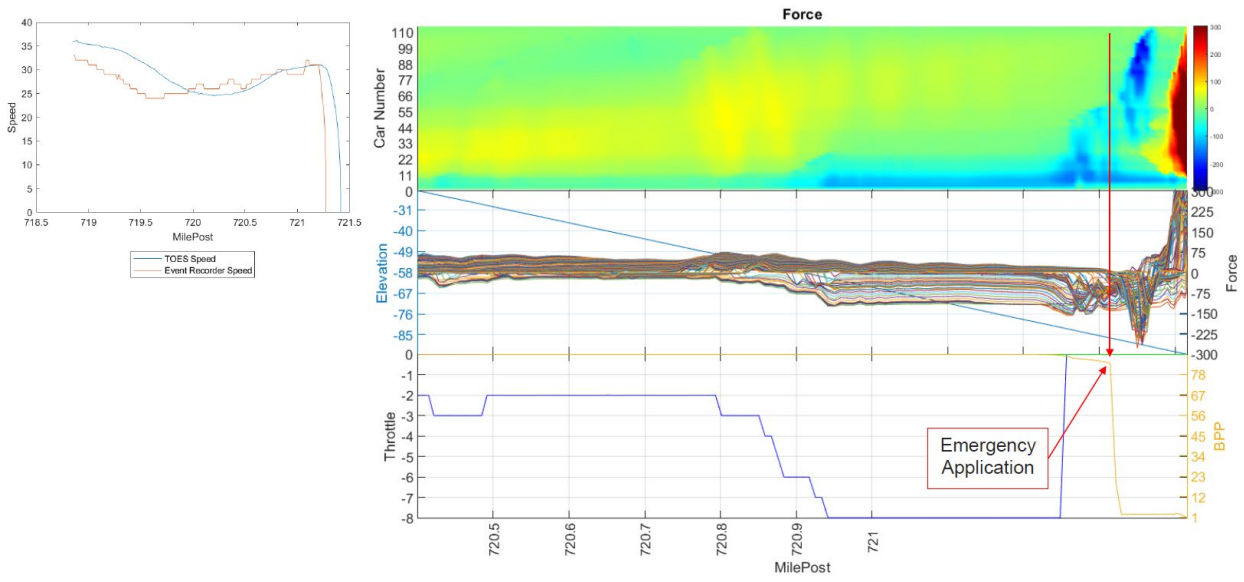


Figure 44. TOES Scenario 3

4.6 Coupler Angle Calculations

Investigators measured the lateral coupler travel for locomotives RMEX 06 and RMEX 08.

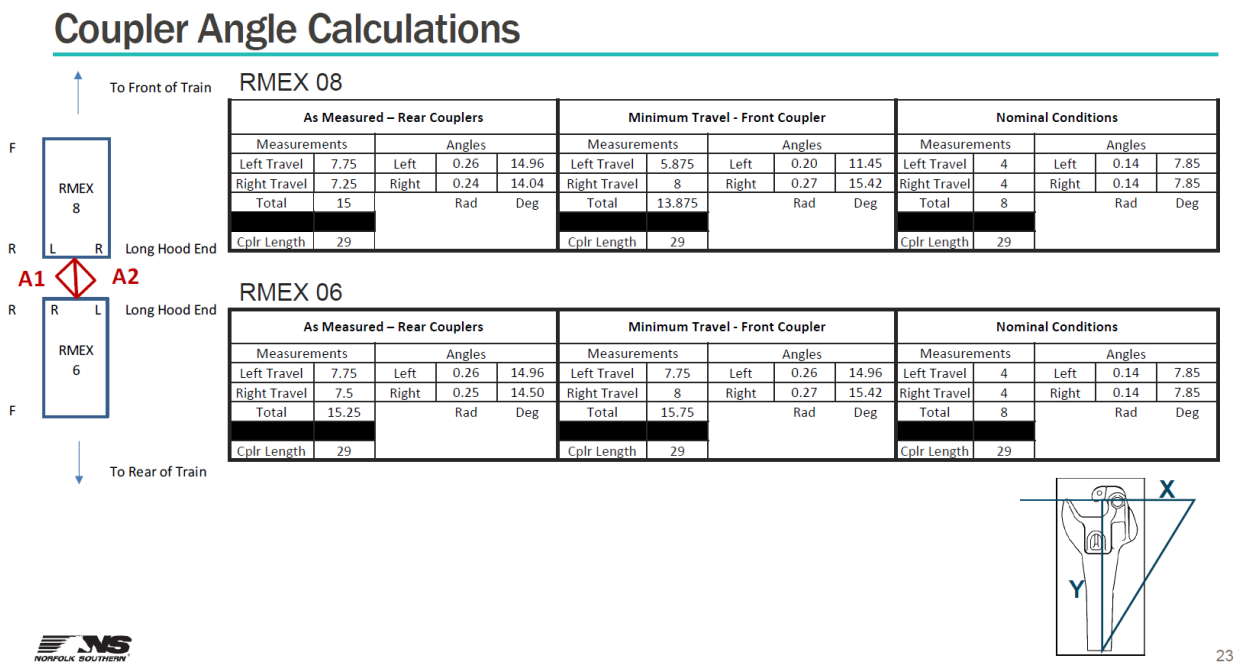


Figure 45. Locomotive coupler angle calculations.

4.7 Rolling Radius Differential

Although wheel flanges are designed to interact with the rail, in principle, in low degree curves a rail vehicle can guide itself around curves in the track without the

wheel flanges touching the rails.[10] This phenomenon arises from the conical shape of the wheel profile. When a wheelset deviates to one side, as in a curve, the conical wheel tread will mover relative to the rail surface so that its effective rolling radius increases while at the same time the other wheel will have its effective rolling radius decrease. The difference in radius between the two wheels of a wheel set is known as the rolling radius differential. Rail wheels wear over time, creating a worn profile with differing rolling radius. The process of reshaping a worn wheel into an ideal profile is known as truing and was described in this report above.

The risk for a derailment through wheel climb or rail-rollover mechanisms can be calculated using the Lateral-over-Vertical force index or threshold.[11] In a rail-rollover derailment, the L/V index is primarily a function of the wheel-rail contact points, lateral forces applied by the wheel flange (including any in-train forces translated from the couplers), and by the height and base dimensions of the rail section (known as Base-over-Height, or B/H ratio).

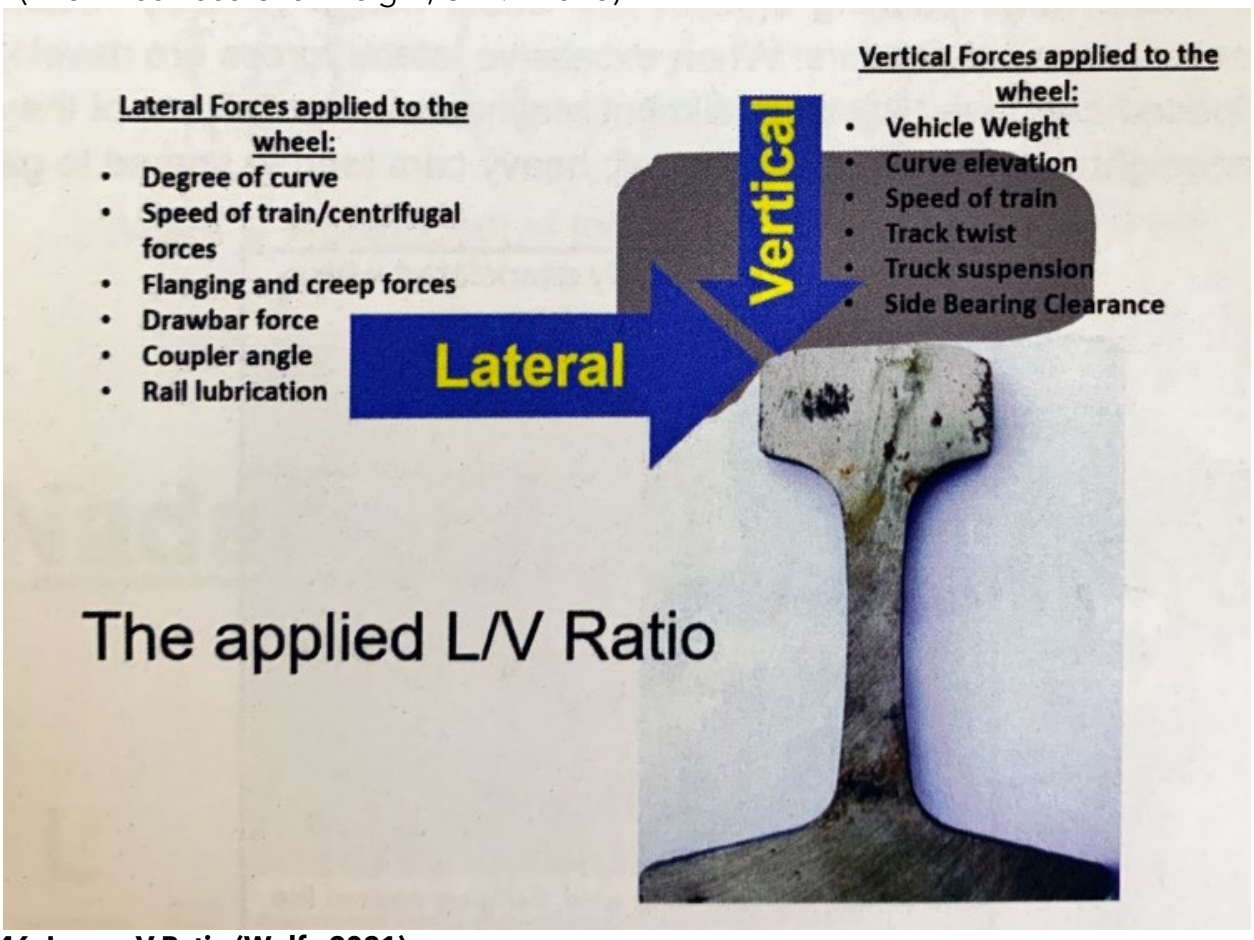


Figure 46. L-over-V Ratio (Wolfe 2021)

[10] https://the-contact-patch.com/book/rail/r0415-curving
[11] Wolfe (2021)

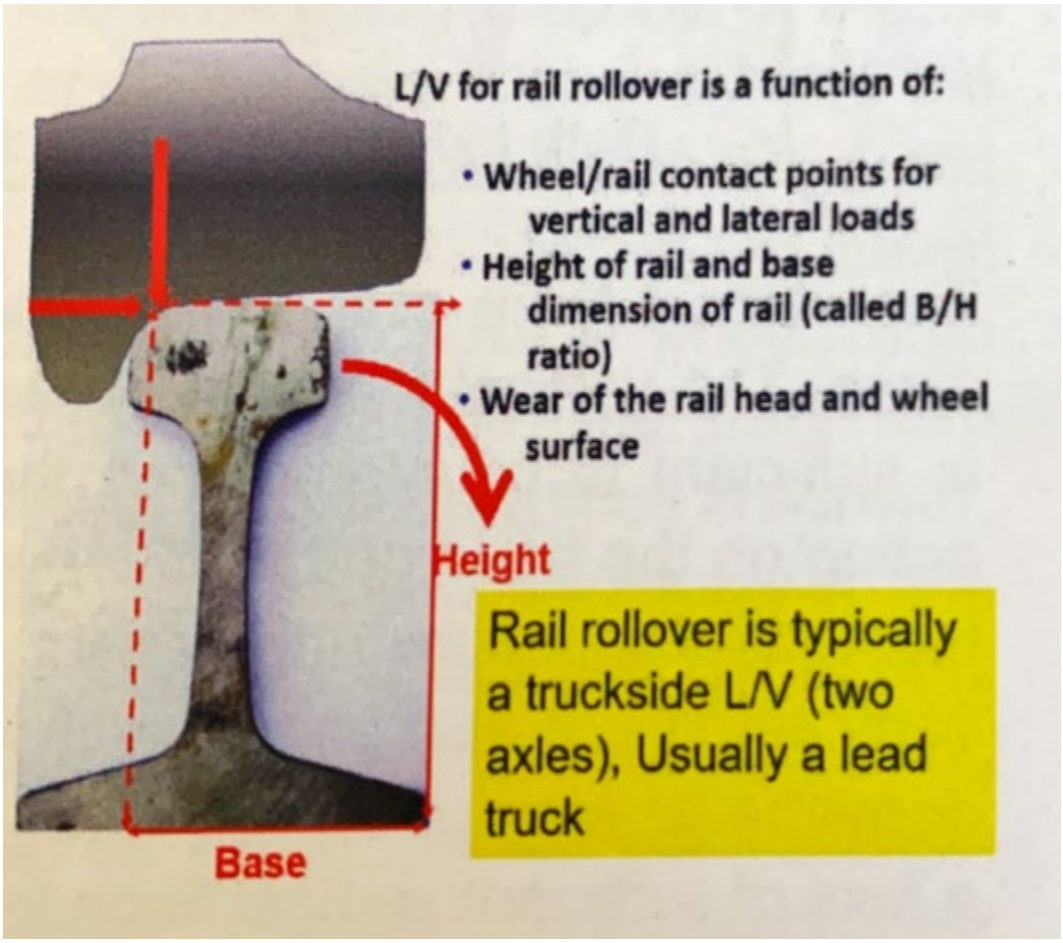


Figure 47. B/H Description (Wolfe 2021)

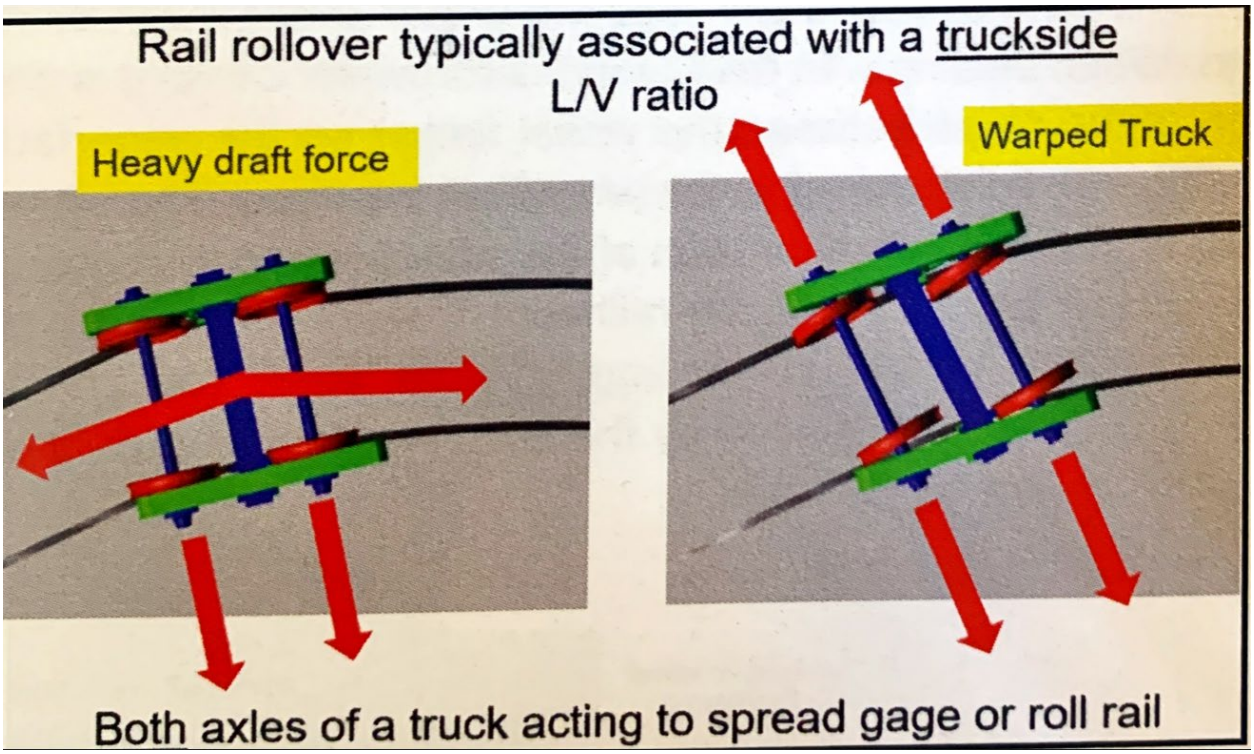


Figure 48. 'Typical' rail rollover derailment mechanisims (Wolfe 2021)

Investigators calculated the rolling radius differentials and wheel-rail contact points for the locomotive consist. The information for RMEX 08 is below, the other data will be in the docket for this investigation.

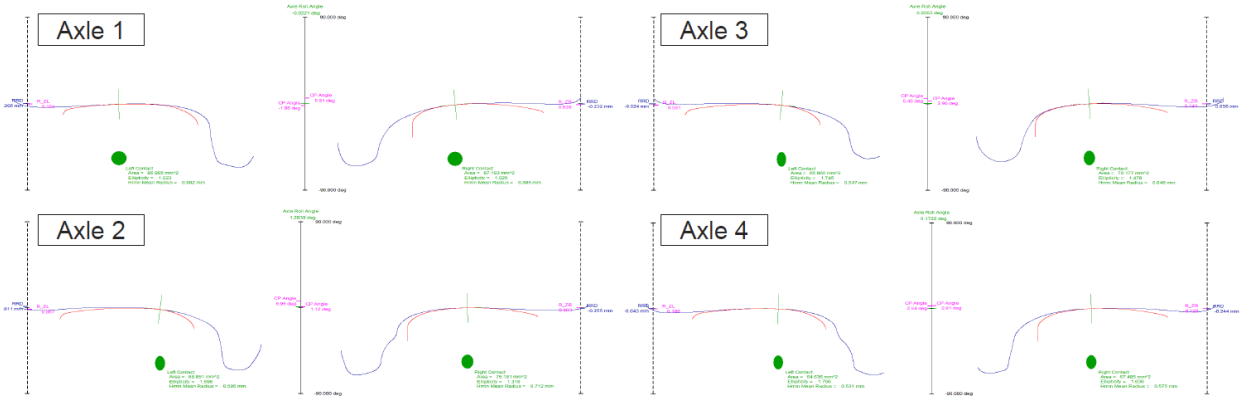


Figure 49. RMEX 08 wheel-rail contact data.

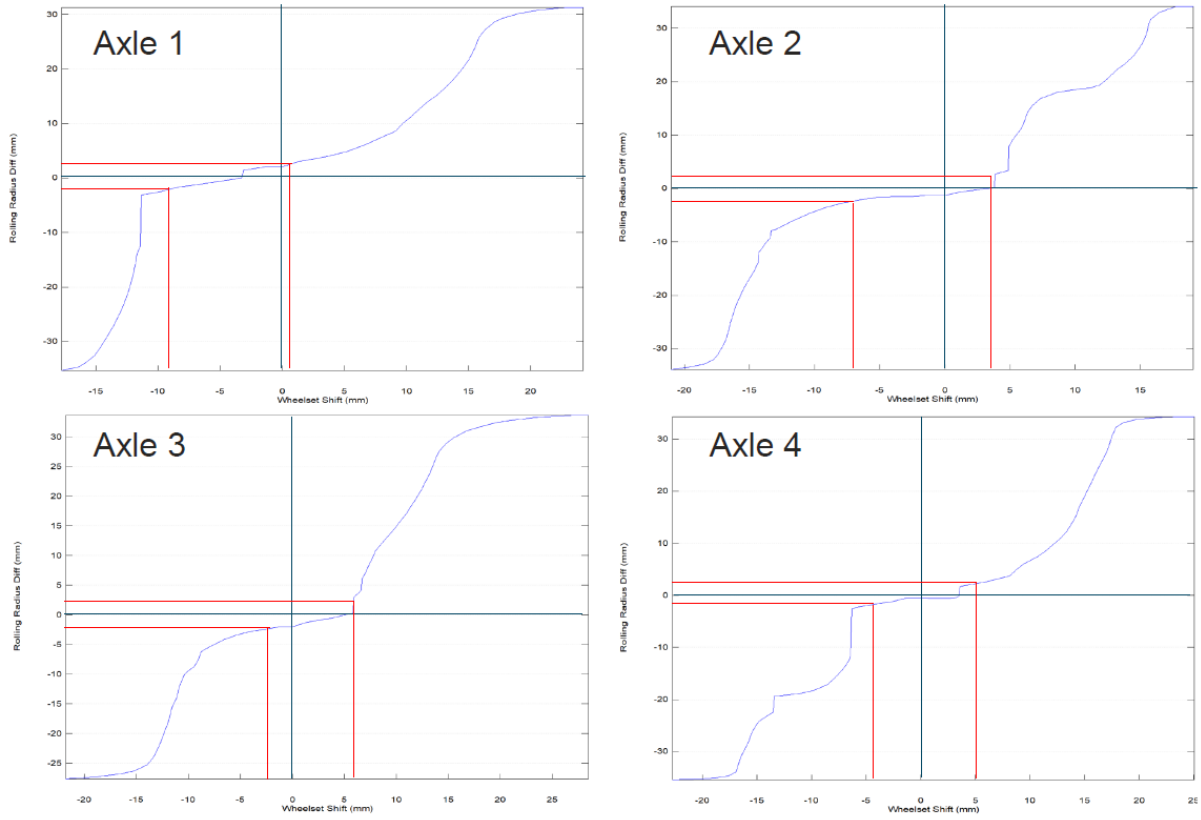


Figure 50. RMEX 08 Rolling Radius Differential plots

4.8 Mechanical Condition

Investigators conducted inspections and air brake tests on the EOT and non-derailed portion of the train. Two cars had brakes that failed to apply during the air brake test, however the brakes were not re-tested.

Investigators noted the following conditions not mentioned in Section 3.0.

- RMEX 06 and RMEX 08 were equipped with non-alignment control couplers.
- The RMEX 06 was missing the right-rear coupler pocket stopping block. The welded securement tab had evidence consistent with a recent break. The alignment block was not recovered from the accident wreckage.
- RMEX 08 had wheel flanges greater than 1.5-inches at the R2, R4, and L4 locations.
- RMEX 08 had brake shoe rigging securement bolt with a missing cotter key.
- RMEX 08 had the right rear switching step loose, a loose safety appliance, a disconnected sanding hose, and possible side bearing excessive clearance on the front truck which needed to be reinspected on level and tangent track.
- RMEX 06 had an auxiliary light missing, window glazing shattered, excessive front pilot height, switching step improperly secured, fuel safety shut off not labeled, defective MU valve handles, and a walkway tripping hazard.
- Locomotives NS 4408 and NS 9485 did not have blue cards or daily inspection records.

- Near MP 721.05 (post derailment) two bulkhead flat cars, COER 804792 and COER 804785, came to rest with 'jackknifed' couplers pushed to the south. Investigators observed the couplers re-center when the rear portion of the train was pulled away.
- One car had a loose safety appliance, one car had a broken safety appliance
- One car had one brake shoe with the backing plate in contact with the wheel.
- One car had an inoperative uncoupling lever (consistent with derailment damage)
- CALIPI and Miniprof wheel profiles were taken on the locomotive consists.

E. DOCUMENTS REVIEWED

- NS Train 245A109 Consist Printed 03/09/23 07:03 PM CST
- Interview transcripts from Locomotive Engineer, Conductor, and NS Managers
- ME-925 For RMEX 06 (Dated 1/18/23) and RMEX 08 (Dated 2/2/23)
- NS Locomotive Department Instruction (LDI) 1-21
- NS LDI 10-11
- NS-1 – Rules for Equipment Operation and Handling (Eff. 1/1/2019)
- Email communications between NS staff regarding RMEX 06 and RMEX 08
- Train pre-departure inspection and test documents
- NS Drone Imagery
- CALIPRI and Miniprof Wheel and Rail Profile Data
- Wayside Detector data including TBOGI and Wheel Profile
- NS Presentation to Mechanical Working Group including wheel profile and TOES model data.
- FRA Inspection Reports (F6180.96)
- Train Profile information derived from WILD detector data and train consist data
- Locomotive Event Recorder Data
- Track Profiles
- EOT Download Data
- Inspection, testing, and maintenance records
- Waybills
- Blue Cards
- UMLER Records
- NS Gold Card Instructions and Forms
- NS Presentation on results of TOES modeling, wheel and track profile measurements, etc. Given to the Mechanical Working Group in Chattanooga; April 2023

Submitted by:

John Manutes
Railroad Accident Investigator, Mechanical Working Group Chair