NATIONAL TRANSPORTATION SAFETY BOARD

Office of Railroad, Pipeline and Hazardous Materials Investigations

Washington, DC

RRD21MR017

Amtrak Train No. 7 Derailment

Joplin, Montana

Track and Engineering Group Chairman Factual Report

September 25, 2021

Accident Information

Date of Accident:	September 25, 2021
Time of Accident:	3:56 p.m. daylight savings time
Railroad Owner:	BNSF
Derailed Equipment:	Amtrak Train No. 7
Fatalities:	3
Injuries:	28
Type of Accident:	Amtrak Train Derailment
Location of Accident:	Joplin, Montana
NTSB Ref. No.	RRD21MR017

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Track and Engineering Group

Blain Luck Rail Integrity Specialist Federal Railroad Administration	Quinn Ligon Track Safety Inspector Federal Railroad Administration	Todd C. Anderson Track Safety Inspector Federal Railroad Administration
Robert Nagel Engineering Department Amtrak	Dan Radeke Engineering Department Amtrak	Michael Trosino Deputy Chief Engineer Amtrak
Ryan Ringleman General Director- Safety BNSF	Chris Pickard General Director- Track BNSF	Roy Morrison Director of Safety BMWED
Richard Hipskind Railroad Accident Investigator Assistant Track Group Chair NTSB	Troy A. Lloyd Railroad Accident Investigator Track Group Chair NTSB	Brian Marquis Chief, Structures & Dynamics DOT Volpe Center

Investigative Parties

Parties to this NTSB investigation include the Federal Railroad Administration, Amtrak, BNSF Railway, Brotherhood of Maintenance of Way Employes, the International Sheet Metal, Air, and Rail Transportation Union – Transportation Division, the Brotherhood of Locomotive Engineers and Trainman, and the DOT Volpe Center.

Accident Summary

On Saturday, September 25, 2021, at 3:56 p.m. DST, National Railroad Passenger Corporation (Amtrak) train 7 (also known as the Empire Builder) carrying 154 people derailed in a 1°33-minute right-hand curve at mile post 1014.57. The train was operating at 78.5 mph and traveling westbound on the BNSF Railway Hi Line Subdivision near Joplin, Montana.[1] (See figure.) The maximum allowable speed on this section of track is 79 mph for passenger trains, and 60/55 for freight trains depending on tonnage and operative train braking. The train consisted of two locomotives and ten railcars.

Eight of the ten railcars derailed; four railcars derailed on their sides, one railcar derailed leaning, two railcars derailed upright, and one railcar derailed the trailing truck.[2] The locomotives and the front two railcars remained on the rail. Three passengers riding in the lounge (Car No. 33049) car were ejected and fatally injured. An additional 28 passengers and crew were transported to the hospital with injuries, 11 of those passengers' required hospitalization. The initial accident damage was estimated to be $21,947,116 in damages to Amtrak passenger equipment and $566,000 related to track and signals. The sky was clear with no precipitation at the time of the accident.

During the on-scene phase of the investigation, the NTSB conducted track and mechanical inspections, reviewed signal, and train control data logs, obtained data from the lead locomotive

[1] (a) All times in this document are local time unless otherwise noted. (b) *Amtrak* is a passenger railroad service that provides medium and long-distance inter-city passenger rail service in the contiguous United States and to nine cities in Canada. Train No. 7 operates from Chicago, Illinois to Seattle, Washington with a portion of the train removed at Spokane, Washington and then continuing to Portland, Oregon as Train No. 27.

[2] A *truck* is the frame assembly under the cars that contain the axles, wheels and for locomotives electric motors.

forward facing image recorder and event recorder, and conducted interviews. The NTSB investigation is ongoing. Future investigative activity will focus on track and engineering, mechanical, survival factors, and crashworthiness.

Parties to this NTSB investigation include the Federal Railroad Administration, Amtrak, BNSF Railway, Brotherhood of Maintenance of Way Employes, the International Sheet Metal, Air, and Rail Transportation Union – Transportation Division, the Brotherhood of Locomotive Engineers and Trainman, and the DOT Volpe Center.

Figure 1- Derailed Amtrak railcars

Hi-Line Subdivision Description

The Hi-Line Subdivision extends from milepost 964.8 in Havre, Montana, to milepost 1217.5 in Whitefish, Montana, in a timetable east-west direction.[3] The mileposts on the Hi-Line Subdivision increase traveling in a westward direction. The subdivision consists of 133.40 miles of single main track and 119.30 miles of double main track with 13 passing sidings. Maximum authorized timetable speed is 79 mph for passenger trains and 60 mph for freight trains under 100 ton per operative brake and 55 mph for 100 ton and over per operative brake. Along this portion of the Hi-Line, BNSF operates an average of 25 daily freight trains and 2 daily passenger trains (Amtrak train No.7 and Amtrak train No. 8), and averages 83.2 million gross tons (MGT) annually across the line.

In the vicinity of the accident area, BNSF authorizes train movements with a Traffic Control System (TCS). Train movements are coordinated by a BNSF train dispatcher located at the Dispatch Center in Fort Worth, Texas. Train movements on the Hi Line Subdivision are governed by operating rules, special instructions, timetable instructions, and the signal indications of the traffic control system and supplemented with an overlaid Positive Train Control (PTC) system.

The signal system uses coded track circuits for train occupancy detection. Wayside signals are color-light signals with upper and lower signal heads capable of displaying green, yellow, and red aspects for train movements in either direction. Hot wheel bearing defect detectors, dragging

[3] Hi Line Subdivision Timetable No. 2, effective April 21, 2021

equipment detectors and slide fence detectors are also present on the subdivision that broadcast detected defects to traincrews.

Track Description Leading to Point of Derailment

The derailment occurred on a single main track between milepost 1012.00 (Joplin) and milepost 1014.70 (East Buelow). The accident track was constructed with wood crossties that measured 9 inches by 7 inches, measuring 8’6” long. The crosstie center-to-center spacing was measured to be 19.5” from the point of derailment located at milepost 1014.57, back east to the private railroad crossing located at milepost 1014.00. Investigators did count and measure about 45 older existing crossties center-to-center measurements that ranged between 16 inches to 22 inches, due to being skewed and off-center to the running rails. Investigators noted that about 400 new 8’6” crossties had been installed between milepost 1014.00 to milepost 1014.57. Investigators also discovered about 22 load bearing defects on old existing and deteriorated crossties, where the head of a standard cut spike, or the corner edge of an existing crosstie plate was discovered under the base of the rail.

Track Description- High-Rail

The high-side running rail, or south/left rail traveling westbound consisted of 141-pound Railway Engineering (RE) section rail, vacuum treated (VT), Nippon Steel, Kokan Mill, Japan (NKK), manufactured in January 2003. From about milepost 1014.60 to about milepost 1014.40, investigators measured the high-rail to have a consistent gauge side curve wear pattern of about 3/8 inches throughout the full-body of curve No. 1014, down through the point of derailment located at milepost 1014.57, and rail head tread wear loss of about 3/8” (.375 inches). Investigators noted that the high-side running rail was observed to be dry with no indication of friction modification (grease) extending along the gauge portion of the rail. The high-side running rail was secured to the crossties utilizing standard double shoulder tie plates and standard cut spikes.

The high-side running rail spiking patten was inconsistent between milepost 1014.00 to milepost 1014.60, with the older ties having a spiking pattern of one rail holding spike on the gauge and field side of the running rail, and one plate holding spike on the gauge and field side of the running rail, totaling four spikes per older crosstie. Newly installed crossties had only one rail holding spike on the gauge and field side of the running rail, inconsistent with the spiking pattern on the older existing ties.

Track Description- Low Rail

The low-side running rail, or right/north rail traveling in a westbound direction consisted of various sections (weight) of running rails. The majority of the running rail from milepost 1012.00 to milepost 1014.554 consisted of 136-pound Railway Engineering (RE) section rail, vacuum treated (VT), Nippon Steel, Kokan Mill, Japan (NKK), manufactured in October 1995. The low-side running rail was secured to the crossties utilizing standard double shoulder tie plates and standard cut spikes.

Investigators noted a low-side plug rail with two bolted suspended rail joints that measured 19’6” long between milepost 1014.554 and milepost 1014.550. The 19’6” plug rail consisted of a 132-pound—RE—CC—USS—Illinois—manufactured in January 1982. The bolted plug rail was secured to the existing low-side running rail with standard six-hole joint bars measuring 36” long. Each plug rail joint was drilled for in-track welding, and had four--6.5” standard bolts, nuts and locking washers securing the joint bars. Investigators noted that the east suspended plug rail joint had evidence of train wheel flange contact at the top surface of the gauge side joint bar (see figure 2).

Figure 2- East low/north plug rail joint showing indication of wheel flange contact

[A picture of the track structure containing wooden crossties and a rail joint. In the background of the picture are standing investigators.]

As found by investigators during postaccident track inspections, investigators noted that the east low-side suspended plug rail joint was hanging out of the crosstie plates about 1- inch, with evidence of an additional 1- inch of underloading vertical deflection (movement up and down) measured on the sides of the crossties.[4] Investigators also noted during postaccident track inspections that the west low-side suspended plug rail joint was also hanging out of the crosstie plates about 5/8" (.625 inches), with an additional ½" (.50 inches) of vertical deflection measured on the sides of the crossties. (See figure 3)

[4] As found by investigators is described as noting the accident track conditions and measurements (see figure 3) during postaccident track inspections.

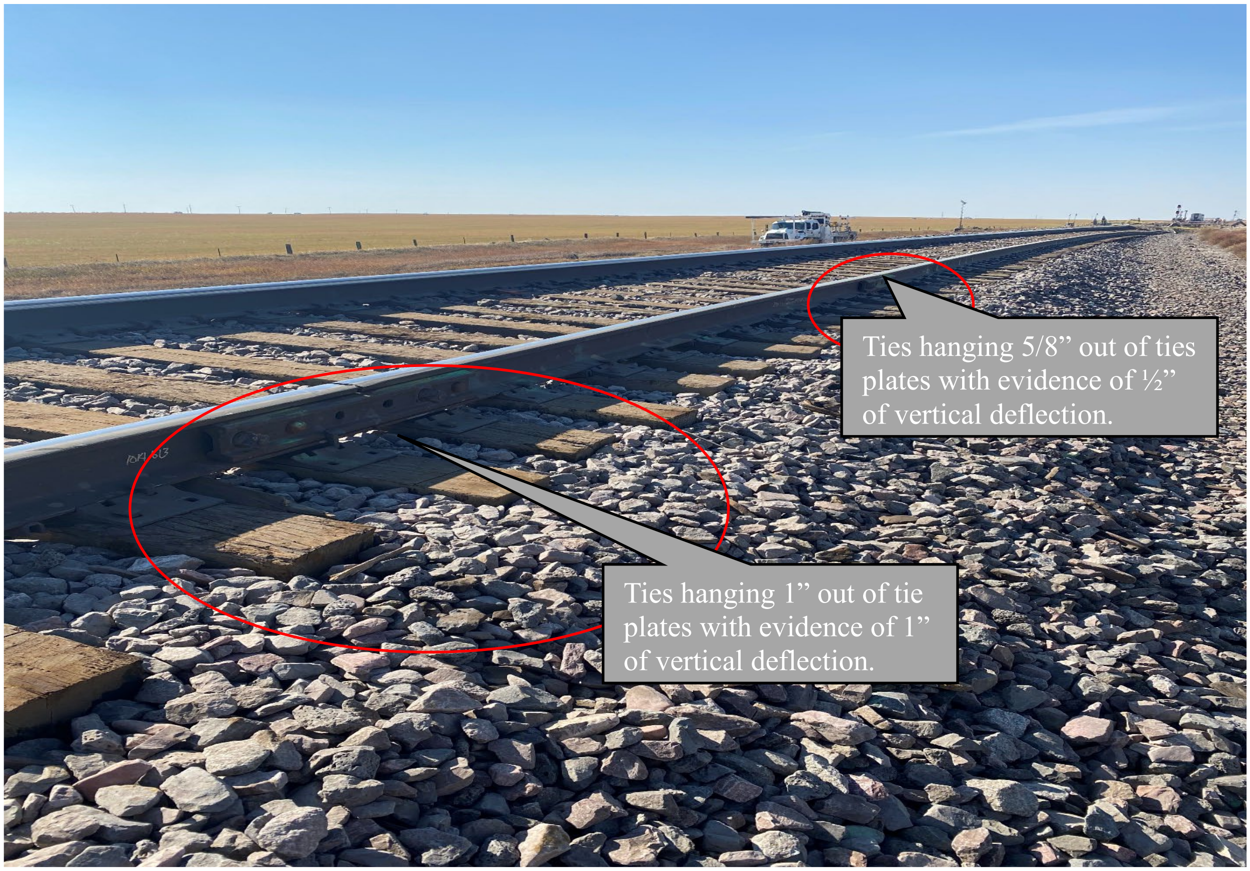

Figure 3- “As found” by investigators- non-supporting ties under suspended plug rail joint

[A picture containing the track structure and two plug rail joints with callout boxes]

Track Description- Low Rail Plug Rails and Welds

The investigative track group measured and agreed upon the following measurements: Walking eastward from the POD, and in the vicinity of the in-track bolted 19’6” plug rail, investigators discovered two more existing 19’6” welded plug rails located immediately east of the jointed plug rail. The west rail end of the welded plug rail was bolted up to the east plug rail joint at milepost 1014.55. From milepost 1014.55, the first welded plug rail extends 19’6” east to a field weld located at milepost 1014.546. From milepost 1014.546, the second welded plug rail extends another 19’6” east and ends at a field weld located at milepost 1014.543. (See figure 3) The two existing field welded plug rails consisted of 132-pound—RE—CC—USS—Illinois, manufactured in April 1983. According to the web of rail markings near the two field welds, the two field welds were completed on February 4, 2020, with rail gap---1.25”—pulled—2.25” and adjusted 400 feet when the field welds were completed.

Walking East from CP East Buelow Point of Switch to POD at Milepost 1014.5740	
From switch point to 883 feet east- high rail	Encounter POD at MP 1014.5740
Walking East from the POD at Milepost 1014.5740	
From POD to 100 feet east- low rail	Encounter west plug rail joint- MP 1014.5545
From POD to 119.5 feet east- low rail	Encounter east plug rail joint- MP 1014.5507
From POD to 139 feet east- low rail	Encounter west field weld- MP 1014.5469
From POD to 158.5 feet east- low rail	Encounter east field weld- MP 1014.5431

Figure 3- Photo of the in-track 19’6” bolted plug rail and two in-track welded 19’6” plug rails

[Alt text: A picture of the track structure and existing 19'6" plug rails circled in red.]

Investigators noted an inconsistent rail anchoring pattern between milepost 1014.00 to milepost 1014.60, with both locking style and channel style rail anchors being utilized on both the high-side and low-side running rails.[5] The newly installed crossties had a consistent "box anchored" rail anchoring pattern on the high-side and low-side running rails with the rail anchors being tight and sound up against both sides of the crossties. The older existing ties had an inconsistent rail anchoring pattern between milepost 1014.00 and milepost 1014.60, whereas rail anchors were missing, and most of the rail anchors were not tight and sound up against the sides of the crossties.[6]

Investigators measured longitudinal rail movement between 1.5-inches to 4-inches under spike heads and through rail anchors (see figure 4). Further inspections showed indications of track lateral movement on both ballast shoulders by the indications of ballast voids at the ends of the crossties in the east tangent area of the track. Investigators measured some ballast voids at the ends of the crossties to be up to 2" in length.

The ballast section between milepost 1014.00 and milepost 1014.60 consisted of 2.5" fractured ballast. Both ballast shoulders extended out from the crosstie ends between 12" to 14" and seemed to be dressed by a ballast regulator. The crib ballast between both running rails were

[5] Rail anchor is a device attached to a rail, and bearing against a crosstie, to keep the rail from moving longitudinally as a result of temperature changes or forces from rail traffic. Also called anti-creeper.

[6] For new crossties being installed, the existing rail anchors bearing against the sides of the old crossties are spread (moved away) by hand or by machine (anchor applicator/spreader/squeezer) from the crossties to create room to remove and insert the crossties. Once the new crosstie is installed, the rail anchors are then squeezed tightly up against both sides of the crosstie.

filled between three-quarters to seven-eighths full. Investigators noted no fouled or dirty ballast on both ballast shoulders and crib ballast sections. From about milepost 1014.56 to milepost 1014.60, which includes the area of the point of derailment, the ballast section had been disturbed as a result from the postaccident derailed equipment, whereas the track had been shifted downhill (north direction) between six and eight feet.

Figure 4- Photo showing longitudinal rail movement through spike.

[A picture of a wooden crosstie, crosstie plate and rail spike. A tape measure is showing the length of rail movement.]

Point of Derailment

The point of derailment (POD) was measured and confirmed by the investigative track group to be at milepost 1014.57, located along the high-rail in curve No. 1014. Investigators measured the POD to be about 883 feet east of the point-of-switch at CP East Buelow. Representatives from BNSF measured (wheeled-off) the POD to be approximately 2,943 feet west of milepost 1014.00, placing the POD at milepost 1014.5740.

According to the lead locomotive event recorder, Amtrak train No. 7 was traveling westbound at 78.5 mph (115 feet per second) on BNSF's Hi-Line Subdivision when it derailed in a 1°33-minute right-hand curve with 4.5" of superelevation. The POD was agreed upon by the investigative group to be at milepost 1014.57, along the high-side running rail in curve No. 1014. Evidence of high-rail wheel departure marks indicate that the high-side train wheels derailed to the outside of the high-rail. Investigators also discovered impact markings on the high-rail approximately eleven feet west of the POD from an inside wheel brake disc. Investigators also noted wheel departure markings on the low-rail and inside the gauge crossties, indicating that the low-side train wheels derailed into the gauge of the track, or in the direction of the high-rail.

Figure 3- Point of Derailment looking west. High rail or south rail showing wheel departure marks

[Photo showing the track structure and derailed wheel departure marks along the high/south rail. To the right of the picture shows a derailed Amtrak railcar on its side. In the background of the picture shows a derailed Amtrak railcar.]

Figure 4- low side rail show wheel departure marks

[Photo shows the track structure, and the wheel departure marks along the low/north rail.]

Figure 5- Head-end of Amtrak train No. 7 showing misaligned track

[Alt text: Pictures shows the track with misaligned rails, or bent looking rails]

Track Physical Characteristics

Starting at Joplin located at milepost 1012.00 to the POD located at milepost 1014.57, Amtrak Train No. 7 traversed the following track characteristics according to BNSF's Hi-Line Subdivision track chart:

- Amtrak train No. 7 traversed tangent (straight) track on a .5% descending grade between milepost 1012.00 to milepost 1012.70 (3,863 feet)
- From milepost 1012.70 to milepost 1013.00, the train traversed tangent level track, on level grade (1,655.7 feet).
- At milepost 1013.00, two rail lubricators were installed.
- From milepost 1013.00 to milepost 1013.90, the train traversed tangent track on a .2% to .5% ascending grade (4,682 feet)
- From milepost 1013.90 to milepost 1014.10, the train traversed level track, on level grade (1,033 feet).
- From milepost 1014.10 to milepost 1014.375, the train traversed tangent track on a .99% ascending grade (1,435 feet)
- From milepost 1014.375 to milepost 1014.57, the train traversed a 1-degree—33-minute right-hand curve (curve No. 1014) with 4 ½" of super-elevation, on a .95% ascending grade.
- Train derails to the high-side of the curve at milepost 1014.57.

Track Maintenance History

Welded Plug Rails

On the low-rail located at the west end of curve No. 1014, investigators noted two 19’5” welded plug rails that contained two in-track field welds. The reference dates recorded from the field side web of rail shows that in-track field welding was conducted on February 4, 2020, to eliminate the in-track rail joints. The in-track field welds appeared to come from the previous installation of a 19’5” plug rail due to the appearance of having drilled joint bar bolt holes. The welding information recorded from the field side of the rail indicated the following:

- Rail 1.25 inches
- Pulled 2.25 inches
- Approximate adjustment length 400 feet

Jointed Plug Rail

On the low rail at the west end of curve No. 1014, investigators noted a 19’5” plug rail with rail joints on the east and west ends of the rail. Investigators determined that this plug rail was installed on July 23, 2021, due to a 10% defective field weld defect discovered by BNSF’s rail flaw detection car. Upon the postaccident inspection, both 36” standard joint bars had the required four track bolts, nuts and washers installed.

Mobile In-Track Welding and Rail Adjustments

A review of BNSF’s CWR rail adjustment report dated October 20 2021, shows a total of eight in-track field welds and other track work completions between July 23, 2021, and August 22, 2021. The following work information was transcribed from the report:

- July 23, 2021- shows work completed by gang number Z0036~M~0~N~100987 between mileposts 1014.517 and milepost 1014.517 showing the installation of the 19'6" plug rail on the right rail, and its required rail adjustment values. In the "open or resolved" field, it states "audited within safe zone". The following adjustments occurred: Gap- 1.75 inches, Pull- 1.75 inches, Rail temperature- 55°, Prebreak RNT 105.56°, and Final RNT 105.56.
- August 9, 2021- shows work completed by gang number Z0036~5~3598~N~10010 between milepost 1014.940 to 1014.940 showing in-track field welding right rail, and its required adjustment values. In the "open or resolved" field, it states "resolved". The following adjustments occurred: Gap- 1 inch, Pull- 2.50 inches, Rail temperature-53°, Prebreak RNT- 94.78°, and Final RNT- 119°.
- August 9, 2021- shows work completed by gang number Z0036~5~3598~S~10013 between milepost 1014.941 to 1014.941 showing in-track field welding left rail, and its required adjustment values. In the "open or resolved" field, it states "resolved". The following adjustments occurred: Gap- 1.50 inches, Pull- 2.50 inches, Rail temperature-53°, Prebreak RNT- 104.17°, and Final RNT- 119°.
- August 18, 2021- shows work completed by gang number Z0036~M~0~N~101062 between milepost 1014.750 to 1014.750 showing in-track field welding right rail, and its required adjustment values. In the "open or resolved" field, it states "resolved". The following adjustments occurred: Gap- 2 inch, Pull- 3.00 inches, Rail temperature-49°, Prebreak RNT- 112.96°, and Final RNT- 108°.
- August 18, 2021- shows work completed by gang number Z0036~M~0~N~101062

between milepost 1014.750 to 1014.750 showing in-track field welding right rail, and its required adjustment values. In the “open or resolved” field, it states “resolved”. The following adjustments occurred: Gap- 2 inch, Pull- 3.00 inches, Rail temperature-49°, Prebreak RNT- 112.96°, and Final RNT- 104°.

- August 22, 2021- shows work completed by gang number Z0036~M~0~N~101070 between milepost 1014.270 to 1014.270 showing in-track field welding right rail, and its required adjustment values. In the “open or resolved” field, it states “resolved”. The following adjustments occurred: Gap- 2.50 inch, Pull- 3.50 inches, Rail temperature-54°, Prebreak RNT- 114.44°, and Final RNT- 108 °.
- August 22, 2021- shows work completed by gang number Z0036~M~0~S~101106 between milepost 1014.270 to 1014.270 showing in-track field welding left rail, and its required adjustment values. In the “open or resolved” field, it states “resolved”. The following adjustments occurred: Gap- 3 inch, Pull- 4.00 inches, Rail temperature-54°, Prebreak RNT- 120.20°, and Final RNT- 113°.

TP-05 Crosstie Installation

Between the dates of August 26, 2021, and August 27, 2021, the TP-05 crosstie production gang installed an average of around seven-hundred 8’6” standard crossties between milepost 1014.00 and milepost 1015.00, which includes the area of the accident. The crossties were removed and installed from the high-side rail of the curve with trip machines. The work also included the tamping of only the installed ties, and the squeezing of rail anchors only on the newly installed ties. On the morning of August 27, 2021, the TP-05 head foreman placed a 30/30 mph speed restriction on the affected limits of the track due to unfinished track surfacing work.

Local Surfacing Gang

On September 2, 2021, the Shelby, Montana local surfacing gang was called by the Roadmaster to surface the track that TP-05 just worked. The surfacing gang foreman had his surfacing equipment to work in an eastward direction, towards Joplin. He had his tamper to start plotting curve 1014 between CP East Buelow and the west end of the curve. The surfacing foreman stated that the track reference measurements taken from the curve stakes wasn't adding up to the configuration of the curve. The surfacing foreman utilized the tamper plots to conduct the finish track surfacing of the curve. The plot measurements from the Jackson 6700 tamper called for 2 inches of uphill throw of the curve, and the surfacing foreman called for 4.5 inches of superelevation, according to his curve chart. The surfacing crew averaged around 2,200 feet of track surfaced. After the completion of the track surfacing work on the evening of September 2, 2021, BNSF's speed restriction records shows that the foreman placed a 30/30 mph speed restriction over the affected track for "compaction". On September 3, 2021, the same records show that the speed restriction over the affected track was increased to a 45/45, but was immediately reduced back down to 30 mph on September 3, 2021, due to the on-going crosstie replacement project that occurring east in the area of Control Point Joplin. The continued tie replacement work that imposed additional speed restrictions extended into the derailment curve. These speed restrictions remained through the derailment curve and were not lifted to normal operating speed until September 14, 2021, 11-days before the accident.

Hi-Line Speed Restrictions

As stated in BNSF's speed restriction policy; Chapter 4- Temporary Speed Restrictions, the Maintenance of Way (MW) Department is responsible for the condition of Burlington Northern

Santa Fe's (BNSF's) roadway, track structure, bridge structures, and drainage. MW must issue a temporary speed restriction for any condition that might prevent trains from operating safely at maximum authorized speed. The speed restriction policy applies to all trackage on the BNSF. Temporary speed restrictions protect crews, trains, freight, facilities, and the general public.

Section 4.3.4- Checking Speed Restrictions, states that quailed personnel must inspect locations covered by temporary speed restrictions and remove the restrictions as soon as possible. Periodically check the superelevation of curves within slow order limits to detect any increases in superelevation. The weight of trains moving slowly through curves can cause increased superelevation, which can cause wheel climb, especially if track alignment or cross level is irregular. Recently undercut track is particularly susceptible to these conditions. Check restrictions daily, if necessary, to ensure that they are at the proper speed.

The following speed restrictions was in place on the Hi-Line, and includes the derailment footprint:

- July 22—23, 2021- 50/50 mph speed restriction due to a defective weld. Speed restriction installed between milepost 1014.4 and milepost 1014.60.
- August 26, 2021, to September 2, 2021- 30/30 mph speed restriction due to out of face crosstie replacement. Speed restriction installed between milepost 1014.00 and milepost 1015.20.
- September 2, 2021, to September 3, 2021- 30/30 mph speed restriction due to track surfacing. Restriction for "compaction" only. Speed restriction installed between milepost 1014.00 and milepost 1015.20.
- September 3, 2021, to September 4, 2021- 45/45 mph speed restriction due to track

surfacing. Restriction for “compaction” only. Speed restriction installed between milepost 1014.00 and milepost 1015.20.

- September 3, 2021, to September 9, 2021- 30/30 mph speed restriction due to out of face crosstie replacement. Speed restriction installed between milepost 1012.10 and milepost 1014.30.
- September 9, 2021- 15/15 mph speed restriction due to disturbed track. Speed restriction installed between milepost 1013.3 to milepost 1014.3.
- September 10, 2021 to September 14, 2021- 45/45 mph speed restriction due to out of face crosstie replacement. Speed restriction installed between milepost 1013.3 to milepost 1014.3. Speed restriction was removed on September 14, 2022 which allowed freight and passenger trains to operate at maximum authorized speeds.

BNSF Track Field Notes Measurements

On September 25, 2021, BNSF investigators measured the track structure at intervals (stations) at a distance of 15 ½ feet apart. In all, they collected geometry measurements at 72 stations. The form used to record the measurements indicated they started at milepost 1014.3. Milepost 1014.3 is east from the point of derailment (POD) in the east spiral of the accident curve. The form noted that the curve is one degree and 33 minutes with a designed elevation of 4½ inches. The measurements and stationing were made going in a westward direction or increasing milepost locations. The track field notes measurements included the following: crosslevel; designation of right rail as the low rail; maximum difference in 62 feet; gauge (inches); mid-ordinate 62-foot chord (inches); designation of the left rail or high rail used to record chord measurements; mid-ordinate 31-foot chord (inches); and designation of using the left rail or high rail for the 31-foot chord measurements.

The form noted that freight train operational speed for this area of the Hi Line was 60 mph, and that the passenger train operational speed was 79 mph. These operating speeds would require that the track measurements be in compliance with FRA Class 4 track safety standards.

The station measurements began on undisturbed track (stations 1 to 57) and moved westward into stations where the track had shifted (stations 58 to 72) in varying amounts to the right or to the low side of the curve. Also, the measuring began at station 1 which was located in the east spiral of the curve. No measurements were taken on tangent track before the curve. Track note measurements identified the POD to be located between stations 71 and 72.

The following is a summary of the station locations and range of values for the specific geometry measurements working east to west:

- In the undisturbed track, the crosslevel at station 25 was measured at 4 ½ inches. At station 56, the crosslevel was measured at 5 11/16 inches.
- Where the track was noted as shifted, the range of crosslevel was 5 1/16 inches at station 68 to 6 ½ inches at station 62.
- In the undisturbed track, the maximum difference of crosslevel in 62 feet in the body of the curve ranged from 1/8 of an inch at station 39 to 9/16 of an inch at stations 26 and 28.

In the shifted track, the difference in crosslevel measurement ranged from 3/8 of an inch at station 59 to 2 inches at station 70.

- In the un-disturbed track, the gauge measurement ranged from 56 7/16 inches at station 24 to 57 inches at multiple stations---17, 28, 36, 39 and 41.

- In the shifted track, the gauge measurement ranged from 56 3/8 inches at station 59 to 57 inches at station 69.
- In the un-disturbed track, the mid-ordinate 62-foot chord measurement (degree of curvature) ranged from 1 5/16 inches at station 26 to 1 7/8 inches at station 33.
- In the shifted track, the mid-ordinate 62-foot chord measurement ranged from 1¾ inches at station 69 to 2 11/16 inches at station 60.
- In the un-disturbed track, the mid-ordinate 31-foot chord measurement in the body of the curve ranged from 1/8 of an inch at stations 26 and 30 to 9/16 of an inch at stations 42 and 50.
- In the shifted track, the mid-ordinate 31-foot chord measurement in the full body of the curve ranged from 5/16 of an inch at station 68 to 7/8 of an inch at station 60.

FRA Track Inspection Activity Records

The Hi-Line Subdivision extends from milepost 964.8 in Havre, Montana, to milepost 1217.5 in Whitefish, Montana, in a timetable east-west direction.[7] The mileposts on the Hi-Line Subdivision increase traveling in a westward direction. The subdivision consists of 133.40 miles of single main track and 119.30 miles of double main track with 13 passing sidings. Maximum authorized timetable speed is 79 mph for passenger trains and 60 mph for freight trains under 100 ton per operative brake and 55 mph for 100 ton and over per operative brake. Where the maximum authorized speed is 79 mph for passenger trains, the FRA requires compliance with FRA Class 4

[7] Hi Line Subdivision Timetable No. 2, effective April 21, 2021

Track Safety Standards (TSS). FRA requires that main tracks be inspected twice weekly with at least one day between inspections. In addition to being a passenger route, the Hi Line Subdivision is a high tonnage and hazardous materials route.

During the on-scene phase of the investigation, NTSB requested FRA Railroad Track Safety Inspector records of their activity on BNSF's Hi Line Subdivision for 2021. In November of 2021, NTSB later requested activity reports filed with BNSF for 2020 and 2019. NTSB received the requested records on January 6, 2022.

The following is a breakdown of the assigned FRA Railroad Track Safety Inspector's activity for BNSF's Hi Line Subdivision over the three-year period:

On-scene September 26, 2021

NTSB requested FRA activity documents for their on-scene investigation and received those documents on January 27, 2021. As part of FRA investigator's adherence to accident investigation protocols, one of the FRA inspectors performed a walking track inspection of BNSF's Hi Line Subdivision from MP 1012.70 (Joplin, MT) to MP 1014.0, the accident scene area that generated two reports. The following is a description of two reports, Report No. 202, dated September 26, 2021, and Report No. 203, dated September 26, 2021, a violation that was filed with BNSF regarding that activity.

In report No. 202, the inspector noted the following:

- The FRA inspector noted he walked several miles from MP 1012.70 to 1014.0.
- The FRA inspector noted 15 items on a three-page report, 14 of the items were track deficiencies coded as 213.123B—Metal object between the base of the rail and the bearing surface of the tie plate causing a concentrated load in Class 3 through 5 track.

In item number 1 of the report the inspector wrote:

FRA Inspection of the mainline tracks two miles from the derailment location walking westward to the Point of Derailment. High volume of 213.123.B (tie plate defects), in a short area walked. This report is associated with FRA-TCA-203. Defects were identified with yellow ribbon. Milepost locations are approximate. Accidents require FRA to walk/inspect track from a distance into the accident location and exiting the accident location.

In report No. 203, the inspector wrote the following:

- Item 1--This is a report of a violation being recommended for 213.123.B (Tie Plates). Walking the would ties on the main tracks -Track Class 5 (70 MPH). High volume of defects documented in the short distance walked. One line item recommended for violation with TWO occurrences as the defects were located on the same tie. Milepost locations were approximate, but the defects tagged with yellow ribbon. ALL defective conditions requiring remedial action were relayed to the Supervisor. This report is associated with FRA-TCA-202.
- In items 2 and 3, the inspector cited two deficiencies of 213.123B at the same milepost location, MP 1013.92 and recommended those for violations and denoted that BNSF would need to provide a written response to FRA.

For 2021:

- In 2021, prior to the accident, the FRA inspector filed seven reports with BNSF.
- Four hy-rail/walking inspection activity reports were filed from 6/14/21 to 6/17/21 that covered 49 miles of track (MP 1057 to MP 1058; MP 1071 to MP 1091; MP 1065 to MP 1067 and MP1090 to MP 1116).

- Three hy-rail/walking inspection activity reports were filed on 6/30/21, 7/13/21 and 7/14/21 that covered 50 miles of track (MP 964 to MP 987; MP 1138 to 1165 and MP 1138 to 1139)
- In calendar year 2021 and prior to the accident, the assigned FRA track inspector for BNSF's Hi Line Subdivision covered 100 miles of the 252.7 miles of the Amtrak route.

For 2020:

- In 2020, the same FRA track safety inspector, filed 13 inspection activity reports with BNSF.
- Over a three consecutive day period from 2/18/20 to 2/20/20, the FRA inspector filed eight reports denoting train riding activity from MP 964 to MP 1219. These reports reflected coverage of the entire BNSF Hi Line Subdivision [Reports 21, dated 2/18/20; 22, dated 2/18/20; 23, dated 2/19/20; 24, dated 2/19/20; 25, dated 2/1920; 26, dated 2/20/20; 27, dated 2/20/20; and 28, dated 2/20/20.]
- Report No. 27 coded with train ride activity on 2/20/20 noted the following in item 1 of that report followed by a list of observations in item 2:

[This is a report of an FRA Train Ride Inspection conducted from the head of AMTK #8, unit 9. I observed track from the head end of the train from Cut Bank West Switch (milepost 1090.7) to Gildford East Switch (milepost 988.8)]

[The following line item is a comment only. These are locations that I had observed a poor ride quality that may be caused by alignment or surface. It is important to note that ride quality can be affected by speed, direction, and dynamics of the train it is observed from. I am advising the rail carrier to inspect these locations to insure the track is in compliance with their maintenance standard and minimum federal regulations safety standards. Milepost locations were gathered from the counter on a moving locomotive so may not be exact]

(Item No. 2)

Description - [** Comment to Railroad/Company **]

West Sw. Dunkirk, alignment?

Bridge ends at Devon, surface, runoff?

1045.8 - 1045.6, surface

1044.9 - 1044.4

1040.3 - 1040

1037.5 1027.3

1023.5 switch

1023.1 switch 1022.2 switch

1017 curve, alignment in the main body west of the crossing

1009 detector, surface

Main 2 1008.1 switch,

Main 2 1006.8 switch,

Main 2 1006.7 switch,

Main 2 1003.3 switch,

Main 2 alignment

- A one-page report was filed on 7/29/20 that listed inspection activity on BNSF's Hi Line Subdivision from MP 1065 to MP 1124. The inspection point was listed as walking. The report included the following comment to the railroad:

Description - [** Comment to Railroad/Company **]

[I observed a workers utilizing Form B protection working on main one in Shelby and a MOW section working at Cut Bank and Browning. I also inspected tracks and switches in the Browning area. No defects have been noted on this report]

- On 10/22/20, the same FRA Railroad Safety Inspector filed four activity reports with BNSF (Reports 113; 114; 115 and 116) denoting riding FRA's Automated Track Inspection Program (ATIP) car over BNSF's Hi Line Subdivision from MP 964 to MP 1219.
- For the FRA activity reports requested and received from FRA for BNSF's Hi Line Subdivision for 2020, there were no reports denoting any hy-rail activity for any portion of the Hi Line.

For 2019:

- During 2019, an FRA Railroad Safety Inspector filed a total of 21 activity reports with BNSF for inspections on their Hi Line Subdivision.
- Hy-rail/walking activities were noted for a total of 153 miles of the Hi Line Subdivision (some activity included a repeat activity of some of the 153

miles).

- Activity reports included inspection of Shelby Yard, attending a meeting and activity on a report filed on 8/21/19.
- A review of 2019 activity reports identified that on 8/22/19, Report 102, an FRA Railroad Safety Inspector inspected the main track from MP 1006 to MP 1022. These miles included the area of the curve between MP 1014 and MP 1015. For the records provided to NTSB, the 102 report was the last record of an FRA inspector with "boots-on-the-ground" prior to the accident or two years and one month.

Postaccident BNSF Records Inspection by FRA

NTSB requested and received FRA records of their activity for post-accident records inspection of BNSF's track inspection records for their Hi Line Subdivision. An FRA Railroad Safety Inspector filed two reports with BNSF, one on 10/4/21 and one on 10/13/21. Report 208, dated 10/4/21, denoted "TREC" with 6 units and 40 subunits for BNSF's Hi Line Subdivision for MP 1014 to MP 1015. The report included a comment to the railroad:

> Description - [** Comment to Railroad/Company **]
>
> [Looking at BNSF Records, for this portion of track. The time frame for this examination - April 01, 2021, to September 30, 2021. FRA Track records for this portion of track that the BNSF EAM have supplied show defects that do not document the remedial actions taken, requests to the railroad for these conditions have been requested prior to writing defects to help better understand the documents supplied. Further action may be necessary at a later date]

On 10/13/21, the same FRA inspector filed a second report, Report 211, with BNSF that denoted "TREC" with 12 units and 83 subunits for BNSF's Hi Line Subdivision for MP1015 to MP 1014. That report included the following comment to BNSF:

> Description - [** Comment to Railroad/Company **]
>
> [Review track inspection records for the time frame of September 2020 to September 2021. The reports provided to the FRA do not explain or document curve inspections, special inspections, or other railroad inspections that could document ANY conditions to support the track conditions in the area. They are not required to, by regulation. The monthly turnout inspections are being recorded, defects being repaired are being recorded, similar defect is then being re-entered at a later date for the same location. This is not a defect/violation, but it does raise questions]

BNSF Geometry Data

NTSB investigators requested and received BNSF geometry car test data for the most recent five test dates prior to the accident date. The geometry measurement data received were for July 17 and 24, 2021; August 19 and 25, 2021; and September 1, 2021. The September geometry data was the last test date before the accident. The September test data occurred after BNSF production forces had installed crossties in 1014 mile on August 25th but before the curve was surfaced on September 2, 2021. BNSF records documented that a rail plug was installed on the low rail of the accident curve on July 23, 2021.

The BNSF operates both manned and unmanned geometry test vehicles. The orientation of the right rail data is always in the direction of ascending milepost locations. The right rail data for the curve is the north rail or inner rail of the curve, the low rail. The left rail data applies to the south rail or outer rail, the high rail. A negative alignment value means the track shifted to the north or the low rail direction.

In addition to measuring the track structure, the BNSF geometry car produces a curve characteristics portrait, the length of the curve, degree of curvature and superelevation as well as the maximum operating speed for trains, the Vmax formula results. In an interview with BNSF personnel, they identified for investigators that the single-track segment of the Hi Line Subdivision receives more geometry car tests because this area of the Hi Line is "bridge" to other line segments tested with their geometry vehicle. They indicated that whenever the car is traversing trackage that it is in the testing mode collecting measurement data.

A BNSF investigator took a Global Positioning System (GPS) coordinate for the POD. The coordinates were N48.557638º and W-110.812º. While on-scene and in association with conducting track field notes measurements, investigators measured from the POD to various track maintenance locations (rail joints and field welds) including the west rail joint located on the low rail. The distance to the rail joint 100 feet from the POD. The east rail joint of the rail plug was 19 ½ feet east of the west rail joint or 119.5 feet from POD. The low rail also had two field welds (from a rail plug that was installed in February 2020 and subsequently welded in place) located east of the rail plug. The first field weld encountered going east from the rail plug was an additional 19.5 feet or 139 feet from the POD. And the second field weld (the other end of the welded rail plug) was another 19.5 feet east of the first field weld or 157.5 feet from POD. In the direction of the accident train (westward), it would have traversed over the curve on a low rail that included a field weld, a second field weld 19.5 feet to the west, a rail joint located 19.5 feet west and a second rail joint located 19.5 feet from the first rail joint.

Test Data for July 17th8

The foot-by-foot (FBF) filtered data received from BNSF was presented via an Excel spreadsheet. The spreadsheet included a numerical sequentially reference line numbering (RLN) associated with each FBF entry. The FBF data for mile 1014 of BNSF's Hi Line begins with RLN 2. Mile 1014 measured as a "short mile"—less than 5,280 feet in length. The last FBF entry for mile 1014 is 5,123; however, the RLN associated with the end of the mile is 5,091 or a difference of 32 FBF data entries. The FBF data exceeds the RLN association by 32 entries. Investigators decided to use the RLN data as the measured distances for identifying locations.

The July 17th test was the last geometry data collected prior to the installation of a 19' 6" rail in the low rail of the curve. Investigators focused on the area of the RLN data that was identified as the location of the POD according to the GPS coordinates going eastward back towards the milepost far enough that included the track anomaly as seen in the still images captured from the head-end video of the accident train. The following is a breakdown of the RLN listed in the spreadsheet from RLN marker 2,947 east to RLN marker 2,600. This is the same area of the curve the accident train moved over prior to its derailment.

In terms of gauge and crosslevel measurements, the data indicated on the BNSF geometry file that:

- A segment of track showed narrower gauge measurements than the track preceding and after its location.
- Beginning at RLN 2,770 (or FBF 2,782) the gauge measurement was -0.01 or

[8] NTSB asked BNSF for an explanation for the difference in FBF and RLN or missing lines of data and did not receive a response.

56.49”. The gauge varied from 56.49” to 56.60” for a length of 18 feet to RLN 2,788 (or FBF 2,800).

- In the preceding 170’ from the narrower gauge location, investigators observed that the data indicated a variation of gauge measurements beginning at RLN 2,600 (or FBF 2,612) to 2,787 (or FBF 2,799). At RLN 2,702 and 2,701, the gauge measurement recorded in the geometry data was 57.08” and at RLN 2,749 (or FBF 2,761) the gauge value recorded was 56.53”.
- In the data listed for the area 158’ after the narrower gauge location, at RLN 2,789 (or FBF 2,801) the gauge value recorded was 56.59”. The widest gauge value recorded was 57.08” at two locations—RLN 2,876 and 2,877 (or FBF 2,888 and 2,889, respectively). The end point reviewed was at RLN 2,947 (or FBF 2,959).
- According to the track chart for the Hi Line Subdivision, it listed the curvature for the accident curve at 1º and 33 minutes. The geometry data recorded crosslevel at RLN 2,502 to 2,504 (or FBF 2,513 to 2,515) at a value of 5.33”.

Test Data for July 24th[9]

The foot-by-foot (FBF) filtered data received from BNSF was presented via an Excel spreadsheet. The spreadsheet included a numerical sequentially reference line numbering (RLN) associated with each FBF entry. The FBF data for mile 1014 (foot 2) of BNSF’s Hi Line begins with RLN 6. Mile 1014 measured as a “short mile”—less than 5,280 feet in length. The last FBF

[9] NTSB asked BNSF for an explanation for the difference in FBF and RLN or missing lines of data and did not receive a response.

entry for mile 1014 is 5,087; however, the RLN associated with the end of the mile is 5,091 or a difference of four FBF data entries. The FBF data exceeds the RLN association by four entries. Investigators decided to use the RLN data as the measured distances for identifying locations.

Investigators focused on the area of the RLN data that was identified as the location of the POD according to the GPS coordinates going eastward back towards the milepost far enough that included the track anomaly as seen in the still images captured from the head-end video of the accident train. The following is a breakdown of the RLN listed in the spreadsheet from RLN marker 2,937 east to RLN marker 2,567. This is the same area of the curve the accident train moved over prior to its derailment.

In terms of gauge and crosslevel measurements, the data indicated on the BNSF geometry file that:

- A segment of track showed narrower gauge measurements than the track preceding and after its location.
- Beginning at RLN 2,737 (or FBF 2,733) the gauge measurement value recorded was 56.6”. The gauge varied from 56.6” to 56.43” for a length of 18 feet to RLN 2,755 (or FBF 2,751).
- In the preceding 170’ from the narrower gauge location, investigators observed that the data indicated a variation of gauge measurements beginning at RLN 2,567 (or FBF 2,563) to 2,754 (or FBF 2,550). At RLN 2,711 (or FBF 2,707), the gauge measurement recorded in the geometry data was 57.16” and at RLN 2,736 (or FBF 2,732) the gauge value recorded was 56.64”.
- In the data listed for the area 182’ after the narrower gauge location, at two

locations, RLN 2,814 (or FBF 2,810) and at RLN 2,880 (or FBF 2,876) the gauge value recorded was 57.08". The widest gauge value recorded was 57.08" at two locations—RLN 2,814 and 2,880 (or FBF 2,810 and 2,876, respectively). The end point reviewed was at RLN 2,937 (or FBF 2,933).

- According to the track chart for the Hi Line Subdivision, it listed the curvature for the accident curve at 1° and 33 minutes. The geometry data recorded crosslevel at RLN 2,752 (or FBF 2,748) at a value of 5.35" and at RLN 2,681 (or FBF 2,677) a crosslevel value of 5.37".

Test Data for August 19th [10]

The foot-by-foot (FBF) filtered data received from BNSF was presented via an Excel spreadsheet. The spreadsheet included a numerical sequentially reference line numbering (RLN) associated with each FBF entry. The FBF data for mile 1014 (foot 39) of BNSF's Hi Line begins with RLN 3. The data for footage 1—38 was not present in the file. Mile 1014 measured as a "short mile"—less than 5,280 feet in length. The last FBF entry for mile 1014 is 5,126; however, the RLN associated with the end of the mile is 5,090 or a difference of 36 FBF data entries. The FBF data exceeds the RLN association by 36 entries. Investigators decided to use the RLN data as the measured distances for identifying locations.

Investigators focused on the area of the RLN data that was identified as the location of the POD according to the GPS coordinates going eastward back towards the milepost far enough that

[10] NTSB asked BNSF for an explanation for the difference in FBF and RLN or missing lines of data and did not receive a response.

included the track anomaly as seen in the still images captured from the head-end video of the accident train. The following is a breakdown of the RLN listed in the spreadsheet from RLN marker 2,943 (or FBF 2,979) east to RLN marker 2,604 (or FBF 2,640). This is the same area of the curve the accident train moved over prior to its derailment.

In terms of gauge and crosslevel measurements, the data indicated on the BNSF geometry file that:

- A segment of track showed narrower gauge measurements than the track preceding and after its location.
- Beginning at RLN 2,739 (or FBF 2,775) the gauge measurement value recorded was 56.67”. The gauge varied from 56.67” to 56.72” for a length of 18 feet to RLN 2,757 (or FBF 2,793).
- In the preceding 170’ from the narrower gauge location, investigators observed that the data indicated a variation of gauge measurements beginning at RLN 2,604 (or FBF 2,640) to 2,738 (or FBF 2,774). At RLN 2,703 (or FBF 2,739), the gauge measurement recorded in the geometry data was 57.19”.
- In the data, the widest gauge value recorded for the area of 186’ after the narrower gauge location can be found at two locations, RLN 2,880 (or FBF 2,916) and at RLN 2,878 (or FBF 2,914) the gauge value recorded was 57.14”. The end point reviewed was at RLN 2,943 (or FBF 2,979).
- According to the track chart for the Hi Line Subdivision, it listed the curvature for the accident curve at 1^{o} and 33 minutes. The geometry data recorded crosslevel at RLN 2, (or FBF 2,843) at a value of 5.39” and at RLN 2,787 (or FBF 2,823) a crosslevel value of 5.38”. There aforementioned locations are 20 feet apart.

Test Data for August 25th[11]

The foot-by-foot (FBF) filtered data received from BNSF was presented via an Excel spreadsheet. The spreadsheet included a numerical sequentially reference line numbering (RLN) associated with each FBF entry. The FBF data for mile 1014 (foot 0) of BNSF's Hi Line begins with RLN 3. The data for footage 1—38 was not present in the file. Mile 1014 measured as a "short mile"—less than 5,280 feet in length. The last FBF entry for mile 1014 is 5,088; however, the RLN associated with the end of the mile is 5,091 or a difference of three FBF data entries. The FBF data exceeds the RLN association by three entries. Investigators decided to use the RLN data as the measured distances for identifying locations.

Investigators focused on the area of the RLN data that was identified as the location of the POD according to the GPS coordinates going eastward back towards the milepost far enough that included the track anomaly as seen in the still images captured from the head-end video of the accident train. The following is a breakdown of the RLN listed in the spreadsheet from RLN marker 2,934 (or FBF 2,931) east to RLN marker 2,568 (or FBF 2,565). This is the same area of the curve the accident train moved over prior to its derailment.

In terms of gauge and crosslevel measurements, the data indicated on the BNSF geometry file that:

- A segment of track showed narrower gauge measurements than the track preceding and after its location.
- Beginning at RLN 2,741 (or FBF 2,738) the gauge measurement value recorded

[11] NTSB asked BNSF for an explanation for the difference in FBF and RLN or missing lines of data and did not receive a response.

was 56.65". The gauge varied from 56.65" to 56.63" for a length of 18 feet to RLN 2,760 (or FBF 2,757). The narrowest gauge value recorded in the 18 feet was 56.52" at RLN 2,748 (or FBF 2,748)

- In the preceding 170' from the narrower gauge location, investigators observed that the data indicated a variation of gauge measurements beginning at RLN 2,568 (or FBF 2,665) to 2,757 (or FBF 2,754). At RLN 2,709 (or FBF 2,706), the gauge measurement recorded in the geometry data was 57.14".
- In the data, the widest gauge value recorded for the area of 174' after the narrower gauge location can be found at RLN 2,878 (or FBF 2,875), the gauge value recorded was 57.15". The end point reviewed was at RLN 2,943 (or FBF 2,979).
- According to the track chart for the Hi Line Subdivision, it listed the curvature for the accident curve at 1^{o} and 33 minutes with 4 ½ inches of elevation. The geometry data recorded a crosslevel value of 5.33" at three RLN locations 2,807 (or FBF 2,804), 2,808 (or FBF 2,805) and at RLN 2,787 (or FBF 2,785). These aforementioned locations are 19--20 feet apart.

Test Data for September 1st[12]

The foot-by-foot (FBF) filtered data received from BNSF was presented via an Excel spreadsheet. The spreadsheet included a numerical sequentially reference line numbering (RLN) associated with each FBF entry. The FBF data for mile 1014 (foot 0) of BNSF's Hi Line begins

[12] NTSB asked BNSF for an explanation for the difference in FBF and RLN or missing lines of data and did not receive a response.

with RLN 3 (or FBF 39). The data for footage 1—38 was not present in the file. Mile 1014 measured as a “short mile”—less than 5,280 feet in length. The last FBF entry for mile 1014 is 5,126; however, the RLN associated with the end of the mile is 5,103 or a difference of 23 FBF data entries. The FBF data exceeds the RLN association by 23 entries. Investigators decided to use the RLN data as the measured distances for identifying locations.

Investigators focused on the area of the RLN data that was identified as the location of the POD according to the GPS coordinates going eastward back towards the milepost far enough that included the track anomaly as seen in the still images captured from the head-end video of the accident train. The following is a breakdown of the RLN listed in the spreadsheet from RLN marker 2,946 (or FBF 2,969) east to RLN marker 2,581 (or FBF 2,604). This is the same area of the curve the accident train moved over prior to its derailment.

In terms of gauge and crosslevel measurements, the data indicated on the BNSF geometry file that:

- A segment of track showed narrower gauge measurements than the track preceding and after its location.
- Beginning at RLN 2,751 (or FBF 2,774) the gauge measurement value recorded was 56.62”. The gauge varied from 56.62” to 56.51” for a length of 18 feet to RLN 2,770 (or FBF 2,793). The narrowest gauge value recorded in the 18 feet was 56.51” at RLN 2,758 (or FBF 2,781)
- In the preceding 170’ from the narrower gauge location, investigators observed that the data indicated a variation of gauge measurements beginning at RLN 2,751 (or FBF 2,774) to 2,581 (or FBF 2,604). At RLN 2,716 (or FBF 2,739), the gauge

measurement recorded in the geometry data was 57.11”.

- In the data, the widest gauge value recorded for the area of 176’ after the narrower gauge location can be found at RLN 2,800 (or FBF 2,823), the gauge value recorded was 57.15”. The end point reviewed was at RLN 2,946 (or FBF 2,969).
- According to the track chart for the Hi Line Subdivision, it listed the curvature for the accident curve at 1° and 33 minutes. The geometry data recorded a crosslevel value of 5.31” at two RLN locations 2,798 (or FBF 2,821), 2,799 (or FBF 2,822).

BNSF Drone Video

On January 26, 2022, BNSF supplied the Track Group Chairman with BNSF conducted drone video footage via thumb-drive. The thumb-drive contained six video files which were uploaded to Kiteworks for investigative review for the entire Joplin investigative team.

BNSF Continuous Welded Rail (CWR) Program

BNSF’s CWR program, in accordance with FRA Part 213.118, is a document that details the railroads policy on installing, adjusting, maintaining, and inspecting continuous welded rail (CWR) track. Each chapter in the document details how BNSF applies its CWR construction and maintenance standards and procedures to comply with FRA standards. The procedures listed in this document apply to CWR on all main tracks, sidings, and other tracks over which trains operate. All CWR plans must be submitted to FRA for review by the Track Division, and then approval by the Associate Administrator for Railroad Safety/Chief Safety Officer. BNSF’s CWR plan has an effective date of March 4, 2021.

CWR Rail

CWR is defined as a continuous rail length that exceeds 400 feet. When rail is installed as CWR, it remains CWR regardless of whether a rail joint or plug-rail is installed after the initial installation of the CWR rail. This mainly applies to temporary rail joints and plug-rails that have been installed for safety and maintenances purposes due to rail flaw defects, or rail maintenance work. Variations in ambient temperatures does affect the length of CWR rail, whereas rail expands (lengthens) when heated, and contracts (shortens) when cooled.

CWR Rail Temperatures

A rail's *"Rail neutral temperature"* (RNT) is defined as the temperature at which a rail is neither in tension, nor compression. To safely control CWR rail tension and compression forces (rail longitudinal movement), BNSF has established CWR rail *"target neutral temperatures"* (TNT's), or target rail laying temperatures (TRLT's), which provides a specific desired rail neutral temperature to prevent track buckling occurrences. When installing or adjusting CWR rail, BNSF rail maintenance and construction crews utilize a regional map that references the different TRLT's for specific regions or territories. BNSF's CWR policy allows rail to be installed or adjusted ±20°F when utilizing the TRLT regional map for locations. For rails being installed or adjusted in tunnels greater than 800 feet in length, the policy states that rails are to be installed and maintained at tunnel ambient temperature, rather than referring to the TRLT regional map for that location.

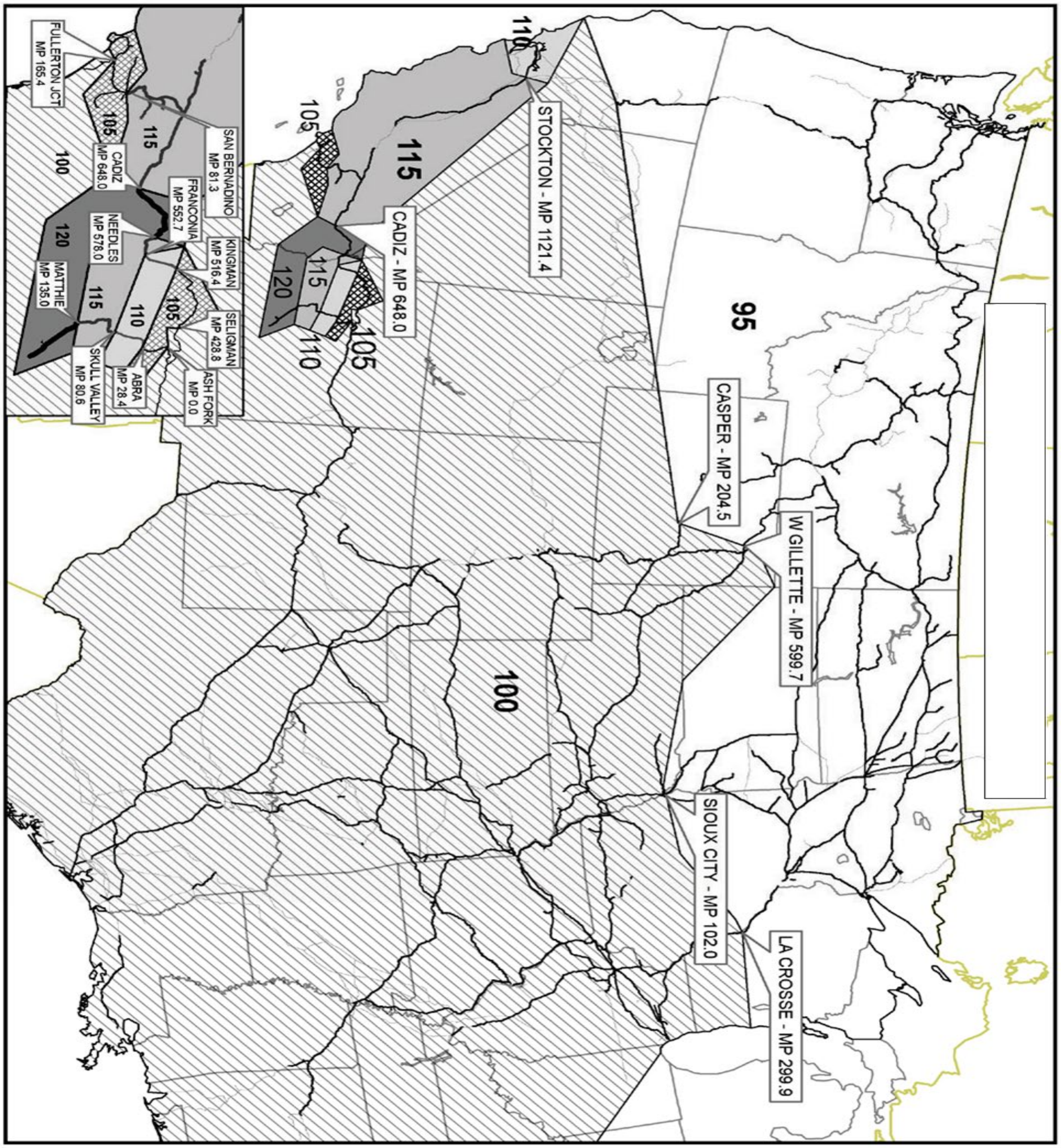

Figure 5- BNFS target rail laying temperature reference map.

[Alt-text: BNSF geographical map showing target rail neutral temperature ranges in different territories.]

CWR Rail Maintenance and Inspections

For a railroad to properly maintain CWR rail, and its desired neutral temperatures, specific maintenance, inspection, and reporting procedures and processes must be followed to prevent the risk of track buckling occurrences in hot weather, and rail pulling-apart in cold weather. These procedures must specifically address maintaining a desired rail installation temperature range when cutting CWR rail, including rail repairs, thermite, or in-track welding, and in conjunction with rail adjustments made in the area of tight track, a track buckle misalignment, or a rail pull-apart.

CWR Rail Joint Inspections & Records

CWR joint means: (a) any joint directly connected to CWR, and (b) any joint(s) in a segment of rail between CWR strings that are less than 195 feet apart, except joints located on jointed sections on bridges. Rail joints in CWR territory must be inspected by foot in the follow classes of track:

- Class 2 track where passenger trains operate
- Class 3 track and higher

Minimum Number of Inspections Per Calendar Year					
	Freight trains operating over track with an annual tonnage of:			**Passenger trains operating over track with an annual tonnage of:**	
	Less than 40 mgt	40 to 60 mgt	Greater than 60 mgt	Less than 20 mgt	Greater than or equal to 20 mgt
Class 5 & above	2x	3x	4x	3x	3x
Class 4	2x	3x	4x	2x	3x
Class 3	1x	2x	2x	2x	2x
Class 2	0	0	0	1x	1x
Class 1	0	0	0	01	0
Excepted Track	0	0	0	n/a	n/a
4x = Four times per calendar year, with one inspection in each of the following periods: January to March, April to June, July to September, and October to December; and with consecutive inspections separated by at least 60 calendar days. 3x = Three times per calendar year, with one inspection in each of the following periods: January to April, May to August, and September to December; and withconsecutive inspections separated by at least 90 calendar days. 2x = Twice per calendar year, with one inspection in each of the following periods: January to June and Julyto December; and with consecutive inspections separated by at least 120 calendar days. 1x = Once per calendar year, with consecutive inspections separated by at least 180 calendar days.					

When inspecting CWR joints on foot in track listed in Chapter 6.1 of theseCWR Procedures, inspectors must watch for (but not be limited to) the following rail joint conditions outlined in the table below. When such conditions are found, the appropriate action must be taken as outlined:

Rail Joint Condition	Action
Visible cracks in joint bar	Replace bar
Loose bolts	Tighten bolts
Bent bolts	Replace bolts OR Re-inspect as per Chapter 6.2
Missing bolts	Replace bolts
Broken or missing tie plate(s)	Replace tie plate(s) OR Conduct follow-up inspections every other week until repaired/replaced
Tie(s) not effectively supporting joint	Tamp tie(s) Replace or repair tie(s) OR Conduct follow-up inspections every other week until repaired /removed
Deteriorated insulated joint	Replace / repair joint OR Conduct follow-up inspections every other week until repaired / removed
Rail-end batter (More than 3/8" in depth and more than 6" in length measured witha 24" straight-edge)	Repair by welding the joint or removing rail OR Conduct follow-up inspections every other week until repaired / removed
Rail-end mismatch reaches limits specified by 49 FRA 213.115	Weld or grind
Longitudinal rail movement greater than 2"	Add or adjust rail anchors, tighten bolts, add or remove rail at appropriate time, OR Conduct follow-up inspections every other week until repaired / removed
Wide rail gap greater than 1.5"	Adjust rail gap and secure joint OR Conduct follow-up inspections every other week until repaired / removed
Joint vertical movement (profile) that exceeds 75% of the allowable threshold for the designated class of track	Surface joint OR Conduct follow-up inspections every other week until repaired / removed
Fouled ballast present in conjunction with joint vertical movement (profile) thatexceeds 75% of the allowable thresh-old for the designated class of track	Surface joint and provide drainage OR Conduct follow-up inspections every other week until repaired /removed
Joint lateral movement (in a curve or spiral) that reaches 3/4"	Correct lateral movement OR Conduct follow-up inspections every other week until repaired / removed

Initial and date the web of the rail at the joint after each inspection. Document and record in BNSF's electronic track records system (ETRS) each on-foot periodic and follow-up inspection on the date of the inspection by noting thefollowing information:

- Date
- Limits of the inspection
- Location and nature of CWR joint conditions
- Corrective or remedial action
- Name and signature of Inspector

FRA Safety Alert- 2013-05- Joint Failure on Continuous Welded Track

The FRA issued Safety Alert 2013-05 on August 5, 2013, to remind railroad track owners about the importance of properly inspecting CWR joints to identify and correct locations that indicate potential failures at rail joints that may cause derailments. The Safety Alert was issued in response to two derailments that the NTSB investigated where joint failure played a significant role in both derailments.

The Safety Alert goes on to remind track owners to review their CWR plans to ensure that the instructions properly identify the necessary track maintenance procedures to remedy indications of potential joint failure that lead to rapid joint failure. The Safety Alert recommends that track owners follow good maintenance practices to ensure that joints are adequately supported and, wherever possible, eliminate joints in CWR territory, especially in passenger and hazardous materials routes.

The Safety Alert further explains that joints located in CWR are considered one of the weakest elements of track structure, and that the track components at these joints are subject to stresses in vertical, lateral, and longitudinal planes. The Safety Alert goes on to explain that joint failure derailments can be catastrophic, especially if passenger trains or hazardous materials are involved. The Safety Alert recommends that following actions to track owners:

Rail joints in CWR warrant special attention and maintenance. Adequate support (which includes good tie condition, sufficient ballast, and good drainage) is essential to preventing joint failure. FRA recommends that track owners and railroads:

1. Review the requirements of their CWR plans and train employees responsible for inspecting CWR, with a focus on inspecting CWR track to identify conditions of actual or potential joint failure.
2. Review current internal engineering instructions to ensure that the instructions contain the appropriate track maintenance instructions to remedy joint conditions that cause joint bars to fail and cause derailments.
3. Follow good maintenance practices to ensure the joints are adequately supported, in addition to all of the requirements prescribed in § 213.119. Ties under and adjacent to CWR joints must be capable of supporting the traffic loading.
4. Perform appropriate ballast maintenance to ensure proper track drainage for adequate tie support.
5. Wherever possible, eliminate joints in CWR, especially compromise joints in passenger and hazardous materials routes.
6. Reinforce with employees responsible for inspecting track the importance of the proper installation and maintenance of joints by ensuring that sufficient anchoring, ballast, and ties ensure the integrity of the joint. This is especially important around compromise joints, which by design typically have a suspended joint configuration.

7. If joint bars (and particularly compromise joint bars) are found cracked or broken between the middle two bolt holes after a relatively short time after installation, determine the root cause that led to the premature failure of the joint bars and correct the deficiency.

FRA strongly encourages railroads and track owners to take actions that are consistent with the preceding recommendations to help ensure the safety of the Nation's railroad employees and the public. FRA may modify Safety Advisory 2013-05, issue additional safety advisories, or take other appropriate actions it deems necessary to ensure the highest level of safety on the Nation's railroads, including pursuing other corrective measures under its rail safety authority.

Special Weather Inspections

BNSF conducts "special inspections" when certain geographical high and low ambient temperatures reach a threshold. On main tracks, "hot weather inspections" must be performed as directed by the Division Engineer or General Director Maintenance or when the temperature is expected to exceed the threshold temperature for a territory. These hot weather inspections are conducted during the highest ambient temperature ranges during the day, primarily between 12:00 p.m. and 6:00 p.m. Inspectors conducting these hot weather inspections are required to look for signs of tight rail conditions which include:

- Kinky or wavy rail
- Rail canting or lifting out of crosstie plates
- Shiny marks on the base of the rail indicating that the rail is running throughthe anchors and the spikes
- Gaps in ballast at the ends of ties

- Churning ballast and ties

When any of the tight rail conditions are present such as above, a speed restriction of 25 MPH or less must be placed over the affected segment of the track, or the track removed from service until repair or adjustment is made. Inspectors should pay special attention to the following locations that may be prone to track buckling situations:

- Recently disturbed track
- Track at the bottom of sags
- Locations where heavy braking occurs
- Fixed track structures, such as turnouts and bridges
- Locations where rail has been repaired or welds made

On main tracks, "cold weather inspections" must be performed as directed by the Division Engineer or General Director Maintenance based on the TNT and weather extremes that occur across the railroad. BNSF divides their properties into two regions. Each region has a specific low ambient temperature that triggers a "cold weather" inspection. Inspectors conducting cold weather inspections must look for signs of track under tensile forces, such as:

- Broken rails
- Rail pull-aparts
- Curve movement
- Wide gap between rail ends (rail joint bar gaps)
- Bent bolts in rail joints
- Cracked or broken joint bars (conventional and insulated)

- Canted rail

Training in CWR Rail Maintenance and Inspection

All BNSF employees responsible for the inspection, installation, adjustment, or maintenance of CWR track must complete training on CWR procedures every calendar year. In addition, they shall beprovided a copy of these procedures and accompanying documents. A list of employees qualified to supervise restorations and inspect track in CWR territory will be maintained and will be made available to the FRA upon request. Training programs will address, but not be limited to, the following:

- CWR installation procedures
- Rail anchoring requirements
- Preventive maintenance on existing CWR track
- Monitoring curve movement following track surfacing and lining
- Placing temporary speed restrictions account track work
- Rail joint inspections
- Insufficient ballast
- Extreme weather inspections
- Recordkeeping

CWR Rail Records

The initial rail temperature, final adjusted rail neutral temperature, location, and date of the CWR rail installations must be recorded and must be retained for at least one year after the initial installation of the CWR rail. Because track maintenance can disturb both the lateral and longitudinal resistance of the track, records of the following must be kept for at least one year after corrections or adjustmentsare made:

- Record of each designated rail cut or in-service rail break location, including line and milepost location, rail temperature, date, rail adjustments, and the final rail neutral temperature. (rail adjustment)
- Record of each designated rail cut or in-service break location, including the rail temperature of the final RNT. (destressing rail)
- Where a curve has been staked and has shifted inward more than a maximum of 2 inches.
- CWR installation or maintenance work that does not conform to these written procedures.

The Division Engineer and Roadmaster must monitor these records to ensure that necessary corrections and adjustments are made.

Track Group Interviews

On Tuesday, September 28, 2021, the investigative track group conducted four interviews in Chester, Montana with the following BNSF employees:

- Track Inspector
- Roadmaster
- Surfacing Foremen
- Lead Thermite Welder

BNSF Track Inspector Interview

[*The track inspector was being represented by a BMWED representative*]

The track inspector was hired with BNSF in April 2011 in Billings, Montana. From April 2011 to October 2014, the employee worked various positions within the BNSF track department. In October 2014, the employee was promoted to Roadmaster in Shelby, Montana. The employee worked the Shelby Roadmaster job until 2016, or about two years. In 2016, after working the Shelby Roadmaster job for two years, the employee stated that he exercised his seniority rights and went back to a track inspectors' position. Primarily, the employee resigned from the Roadmaster position.

The employee stated that understanding the Montana Division is hard and is a tough division to work due to the changing of the seasons/weather. Temperatures swings can average up to 60° differences over a day. When asked about his track coverage, the employee stated that he inspects 70—80 miles of track per day. He stated that he has been covering the entire Shelby roadmaster territory, the entire Hi-Line subdivision, and portions of Conrad, line segment 134, Malta 67 up to the Sweet Grass border, and Malta's 138.8. Employee stated that he works a lot of 7-day weeks.

When asked about his inspections through the derailment footprint, specifically curve No. 1014, he stated that he last inspected that area of the Hi-Line on Thursday, September 23, 2021, in the company of his Roadmaster by hy-rail. The employee mentioned the joints in the curve and stated that it would be good to get the joints welder up, sooner than later. As the employee was going through the curve, he stated that he didn't notice any abnormalities in the curve. He stated that the curve, historically rides a little over-elevated. The reason why he mentioned the joint to the roadmaster is because typically, those joints have other plug rails, whereas the joints get beat up pretty bad because they are in the low rail of the curve. Stated that the curve road OK that day. He stated that he did point out the joints, but we didn't stop and look at the joints. Stated that he has had problems with joints and other plug rails in this area along the low rail with mismatch. Stated that trains ride that curve rough due to the plug rails being located along the low rail in the curve. He did state that the curve rides much better since having tie installed and surfacing.

The inspector stated that he has inspected the accident curve via hy-rail about 6—8 times since the completion of the tie and surfacing work, and up to the derailment of the Amtrak train. Stated that there have been no major changes to the accident curve, except for the installation of the plug rail and rail joints in July 2021. When asked about the rail conditions, he stated that the low rail is pretty thin, and the high rail has gauge face wear. Mentioned that the designated superelevation in the accident curve, he believes is 3.75 inches, and that the curve is directly sets between 4.75 inches, to 5.25 inches of superelevation. The curve normally gets surfaced once per year, sometimes twice before winter to bring the elevation back up.

The inspector stated that he has been inspecting the area of the derailment for over 2 years. When asked about performing walking inspections of the accident curve, he stated that he has not walked the accident curve since the fall of 2020, and that was a curve inspection. He has not walked the accident curve yet in 2021. He was asked about the cupping of ballast at the ends of the crossties and stated that he did not see any of that. It was just some pretty bad wear on the rail. Most conditions were discovered at the east end of the curve. He did mention that he has inspected curves where indications of lateral track movement (breathing), with the cupping of ballast at the ends of the ties was observed, but the movement was pretty much equal on both sides as the temperatures changed; two inches on this side, and 2 inches on that side.

Had refresher training in CWR in February--March 2021. Noticed that rail anchors in some spots was about 2—3 inches away from the crosstie. When asked about a typical work week, the inspector stated that he worked about 100 hours per week but stated that he gets his required FRA inspections completed. Stated again about the accident curve and curve 1015 over-elevating where surfacing crews would have to surface these curves twice per year. The employee was asked about monitoring curve movement, and the employee stated that he utilized curve stakes, but said sometimes he doesn't have the previous numbers, so that makes it tough to tell. When asked about his biggest problems in the accident curve, he stated that when joints are in there due to mismatch because of the worn rails. When asked about why plugs are being installed in the curve, he stated rail defects are causing the joints to be installed. The rail defects are primarily on the low rail in that curve, and there are a couple of spots that come to mind, and they are primarily on the low rail. The inspector stated that regarding the Hi-Line, curves with joints that have surface deviations do not get magically better. So, it is best to weld the joints up sooner than later, especially when welder is in the area, have them weld the joints and tighten up the ties.

The employee stated that the tie and surfacing crews did not drop additional ballast within the derailment footprint. Stated that is it's been awhile since ballast has been dumped in that area. Stated that he was working days, as the work on the track was taking place at night. Stated that walking inspections of curves is completed once per year; every curve will get a walking inspection. Stated that he has not performed a curve inspection in the accident curve this year. Stated that on his September 23, 2021, inspection, he did not notice anything that would not require us to stop, take measurements, and properly protect the curve. When asked about longitudinal rail movement markings, he stated that he would be concerned with six or more inches of movement for track buckling concerns. Stated that the joints looked solid with no pumping, pumping would be his main concern. Stated that in the two years of inspecting the accident curve, he has not noticed any alignment deviations. As a track inspector, the curve feels that it just gets over-elevated.

BNSF Roadmaster Interview

The Roadmaster was hired on June 6, 2005, out of the Chicago Division. Stated that he received his foreman's seniority pretty fast. Was promoted to Assistant Roadmaster in 2007 on the Undercutter unit and did that for about 14 months. Stated that he got divorced, received custody of his kids, and moved back home to raise his kids. Since the kids are now grown, in May 2020, he went out as an Assistant Roadmaster on a construction gang. Prior to that, he was a track inspector for eight years. Started the Shelby, Montana Roadmaster job on July 19, 2021.

Stated that he has not been on this territory for very long, so he trying to gain an understanding of the territory, control signal locations, track layouts, and getting to know his track inspectors, and his capabilities. Stated that he has hy-railed with the Hi-Line track inspector three times since taking this job. When asked about performing any walking inspections in the accident curve, he stated that he has not walked the curve, or when the work was taking place. Stated that he had no track concerns with the accident curve after the tie and surfacing job. When asked about his last track inspection through the derailment area, he stated last Thursday, September 23rd.

When asked about his work hours, he stated that it definitely depends on the day, you know, you average 12 to 16-hour days most days, but it's very few 8-hour days. When asked about concerning work, he mentioned stabilization work further down the line. When asked about any concerns regarding the accident, he stated that he had no concerns. Stated that he and the inspector stopped and looked at the two joints in the low rail as we went by, noting no surface irregularities. Believes that the curve could have used a little more ballast shoulder but is felt like it had sufficient ballast. Stated that he did not feel any rough rides through the curve. Stated that he was actually driving the hy-rail truck, and when he drove by the joints, he opened the doors and looked down at the joints from his truck. Stated that he noticed nothing when looking overtop the joints by opening his truck door. Stated that it appeared that the joints were not pumping, joints looked good. Stated that he noticed no track movement during his inspection on September 23rd. Stated that he was not familiar with the curve stakes. Stated that no slow orders were on the track during the September 23rd inspection.

When asked about the recent work that took place in the accident curve, he stated that he requested that the local surfacing crew surface the track. Also stated that he didn't recall the surfacing crew having ballast concerns. Also stated that no special inspections have been conducted prior to the train derailment. When asked about walking inspections vs. hy-rail inspections, he stated that if you see something, that you need to get out of the truck to look at it. A lot of times they walk switches, frogs, and switch points to make sure there is nothing there. Some things just need an extra eye on them that you cannot see from the cab of the truck. Stated that he has rode one BNSF track geometry car since taking the job, and there has only been one manned car since taking the job. Doesn't remember any geometry hits from the car. Stated that he has hy-railed through the accident area three times since taking the job but has not performed any walking inspections through the derailment area. Also stated that the curves need inspected yearly. When asked about his manpower, he stated that he has two welding gangs, three section gangs, two surfacing gangs, three track inspectors, which is roughly 26 employees for over 170 miles of track. Each track inspector probably has responsibility for over 50 miles of track and believes that is sufficient. Stated that all his track positions have been filled. Stated that he was not aware of the last curve inspection in the accident curve. When asked about his inspection reporting process, he stated that he generates no reports, and doesn't keep track of his inspections. Also stated that he has not performed any inspections with the FRA since taking the job on July 19, 2021.

Local Surfacing Foreman Interview

[*The track inspector was being represented by a BMWED representative*]

The employee started with BNSF on May 5, 2014, in Shelby, Montana, and was promoted to section foreman within one year. Worked the section foreman job off and on for about 4 ½ years, then went to mobile welding, then back to the section foreman position. When asked about measuring curves prior to surfacing, he referenced the use of curve stakes, including letting the tamper plot the curve as well. He also mentioned using curve data to match up the parts of the curve.

The surfacing foreman stated that he was called on September 2, 2021, to final surface the accident curve that TP-05 had just worked installing ties and a rough surface or first surfacing pass through the area. Stated that the surfacing work on September 2nd, took place during the day, and that the machines were working eastward, starting near CP East Buelow. Said that he showed up to the job site, had the tamper plot the curve, he walked along the side of the tamper as it plotted the curve, he also collected the data from the curve stakes, and noticed that the curve was down. Stated that he called the foreman of the TP-05 tie gang to collect the information for the curve. The foreman stated that he contacted the TP-05 surface crew and could not collect any data, they had no data to give him. The surfacing foreman stated that the TP-05 surfacing crew used the reference measurements that were pre-marked on the rails. So, the surfacing foreman asked the TP-05 crew who placed the reference measurements on the rails but received no feedback. So, the surfacing foreman call his Roadmaster and informed him of the situation. Stated that he told his Roadmaster that the best thing is to plot the curve and see what comes out.

Stated that he provided the curve information to the tamper operator, and that they started somewhere outside of the curve between the switch and the curve but could not state exactly where the operator started his curve plot. The tamper took the curve plot measurements as it went through the curve on its first pass. As the tamper was plotting, he stated that he was taking measurements off of the curve stakes. After completing the first plot pass and working through the curve, they looked to see how much they were able to throw the curve and realized that he was not getting enough lift of the track. He stated that according to his chart, the curve called for 4 ½" of elevation. I wasn't getting my lift, and the machine wasn't pulling the curve out, so we plotted and worked a second pass through the curve, The operator then plotted and worked a second pass through the curve adding crosslevel lift, and also to be sure that the machine could pull the curve out where the data said the curve should be. The surfacing foreman stated that he got his lift, and more pull from the machine. So, we got it as close as we could to the mark.

When asked about how for the curve was downhill, he stated that he didn't know particularly how far the curve was downhill, but he knew that what he was looking at, and what they wrote on the rails was off, and it didn't make any sense, it didn't look right. That's why I called the other foreman, to find out what this curve did, and how much did it move, or if it dropped on them. The surfacing foreman recalled having to work the high rail a lot. We had some exposed tie ends, so my regulator operator had to work in order to grab more rock for the high side shoulder. The surfacing foreman stated that his biggest concern was having enough ballast built up at least on the high side. I was pretty much focused on the high side, and the low rail side seemed to have enough ballast to work and tamp. Stated that his crew was working west to east, and they tamp every crosstie through the entire curve, and performed his runoff in the eastside tangent track.

Was asked how he measured the curve from the curve stakes, and he stated that he uses a laser, and measures from the curve stake to the base of the rail. Stated that from the measurements taken from the curve stakes, that curve was measuring downhill. Stated that he cannot exactly state the number, but he did know that it was measuring to be downhill, as of adding rail, a fair amount, between 2—3 inches. The surfacing foreman stated that his whole working machine consists of track jacks, a Jackson 6700 tamper, and a regulator. Stated that he doesn't have a mechanical stabilizer. Also stated that he prefers at least a 12" ballast shoulder, but he knew that couldn't be achieved. When asked about how he worked the curve, he stated that he worked strictly from the machines plotting information, and what information he received from curve stake measurements. He stated that he got his degree of curvature, and his elevation. He stated that one station showed the curve being downhill two inches. Stated that this was his first time surfacing the accident curve. When asked further regarding the final pass and final measurements of the accident curve, the surfacing foreman stated that he couldn't get any prior information off those particular measurements that they had on the rail. Stated that he doesn't know who wrote it, how they measured it. I voided what they had wrote on there, and I made my own measurements for that curve there. He also stated that he had records of the curve and plot measurements for the group. When asked about which way the curve was moved when surfaced, the foreman stated that the curve was moved out, or uphill. Was asked if his Jackson 6700 operator was competent, and the foreman answered yes.

Mobile Welder Interview

[*The track inspector was being represented by a BMWED representative*]

The employee was hired by BNSF on April 4, 2013, out of Shelby, Montana. The employee was FRA certified with six-months of his hire date and received his foreman training. Went to work as a mobile welder in November 2013 and promoted to head welder in January 2014. Has worked various foreman jobs including, surfacing and section foreman positions. Explained that he has experience with rail installation, frogs, and switch points, and doing whatever to help out the Roadmaster and section gangs. His main position as the head welder is to shoot thermite welds and perform frog welding. The employee explained the classes and steps that is required to become a mobile and head welder. Went on to explain the different classes such as grinding training, thermite welding training, frog welding training, basic welding, switch point welding and elements.

When asked about the thermite welds, he performed in the vicinity of the accident curve, the employee stated that his welding crew was going in front of the TP-05 ties gang before they started installing ties. Stated that his crew destress', cut's and pulls the rails prior to the tie gang starting work. So, we'll go out, cut the rail, see what it does. Stated that the crew utilizes a rail pulling chart. The head welder explained further that they utilize a target rail neutral temperature of 95° and explain the welding process on how to achieve the required expansion and pulling of rail to shoot a thermite weld without adding rail. The employee assures that there's no added rail there so when the tie gangs come through, you know, installing ties, lifting rail. Explained that utilizing this process prevents track misalignment issues when gangs like TP-05 perform work on the track.

When asked about how this welding process prevents track misalignments, the employee stated that what we're doing is we're taking out extra rail that possibly could be there and ensuring that there is no added rail there. The employee explained the use of match marks and how they show rail movement, even for later welding processes. The employee provided this example: if a section gang comes in at 30 below, and they can't pull a 5-inch gap, they're going to add 3 inches of rail and their match marks are going to show that. So, then we've got something to go off of (relating to the match marks). When we go back, we know we need to remove the three inches of rail. You know, if it's greater than this and we're going to destress, we're going to knock anchors off for 400 feet and adjust the rail accordingly. Expressed the importance of not add rail during when prepping rail for thermite welding.

Stated that he last worked the derailment location in late August, destressing rail ahead of the TP-05 gang. When asked about the importance of not adding rail, the employee explained if you have a big swap in temperatures, that can cause kinks, misalignment. Hotter temperatures, you're going to get thermal misalignment. You're going to get dog legs in it, sun kinks. When asked if his crews returned back to recheck the rail neutral temperatures where the TP-05 gang work, the employee answered that they did not. Did state that if the track inspector has a concern, then the crew would return back to cut the rail to be safe.

Employee is trained in CWR yearly. Employee was asked about knocking off anchors off for 400 feet in each direction, and the employee stated if we're doing a full out destress, yeah, we'll go 400 feet. If we're at a fixed object, we'll go outside the fixed object and bang the anchors, or at the location, we'll go 200 feet each way. The employee further explained, what we've been doing is cutting and pulling, seeing what the rail does, and then, because nine times out of ten, it's blowing open. If it doesn't, then we're taking the anchors off and doing full-out destress on it. The employee was asked about the four welds and locations that his crew shot the welds, the employee stated that they completed four welds in the east and west tangents, but one weld did leak, where the crew had to install a plug rail, adjusted, and welded in place. Employee stated that all welding records are in the system and stored. Stated that this work took place during the night shift. The employee was asked if he remembers seeing any anomalies in the track but stated that he did not see any anomalies in the track. He was also asked if he remembers seeing the jointed plug rail on the low rail, he stated that the plug rail was there when he was out there working ahead of the tie crew, and stated that the plug rail needs replaced, and it is not weldable, due to the rail batter.

On Wednesday, September 29, 2021, the track group interview the TP-05 gang foreman via phone. This interview was conducted inside the on-scene command center that was on site at the derailment location.

TP-05 Gang Foreman Interview

[*The track inspector was being represented by a BMWED representative*]

The employee was hired on with BNSF on April 6th of 2015. Stated that he went straight into a tie gang, did a little bit of work off and on with the rail gangs. But a good chunk of his career has been working on the tie gangs both as an operator and a laborer. Last year the employee received his tier two qualification, and in December 2020, he was promoted to TP-05 head foreman. Stated that his work responsibilities as head foreman are to oversee the gang, make sure, you know, the practices that BNSF implements are being followed, make sure everything's done safely. And at the end of the day, make sure that the track is safe for train movement or to restrict speed to what the track conditions will allow.

When asked what equipment he was assigned, he answered that two spike removing machines come through and pull the spikes, and we have one anchor spreader, two trip machines that kick out the crossties, four tie cranes, three more trip machines that insert the new crossties, one nipper tamper, three platers, one pup tamper, four spikers, two anchor squeezing machines, one mag crane, and one ballast regulator. When asked about the trip machines, the employee stated that the trip machine is going to have two hydraulic powered arms, one on each side, and it's going to have a lift table as well. The very front trip will come through, lift the rail just enough that we can slide out the tie halfway, it then set the rail back down, and moves to the next tie. Then we have two laborers that remove the plates from the tie, and once the plates are removed, the second trip machine comes along and removes the tie the rest of the way out from under the track. When ask about the lift-tables, the employee stated that he really doesn't know how to exactly describe it, but it clamps both rails, and it's got smart cylinders where you can adjust your lift height. We tell our operators to try to lift to where it's just above the lift of the plate, because if that plate catches, it can cause a deviation that the surface crew would have to fix before we can clear up. So, they're supposed to lift just enough that that plate will clear, and then they'll set it back down. The second trip machine doesn't lift. He has lift capabilities when a tie is not coming out smoothly, he can lift, but for the most part, the first trip is the only one that lifts. When the first trip machine goes through, it's called a half kick, he removes the tie approximately halfway. And then our troop laborers remove the plates, and the second trip machine removes the tie the rest of the way.

So, when the trip machines that kick the crossties come through, there's a small crib in the ballast line, and that's where the tie crane will set the ties. On all of the trip work heads, there is a swivel, so, when the next trips come along, they'll grab the tie, they'll rotate it, so that the tie will go under the first rail, then they'll readjust their grip, and slide it in the rest of the way under both rails. When asked about the inserter trip machines lifting the rail, the employee stated that they are not allowed to lift while inserting a crosstie. They operators will move the tie back and forth, digging down the ballast, so that no lift is needed. We kick and install from the high side. Our best practice is to remove no more than four crossties in a row.

When asked about his tie job within the accident curve, he said that his gang worked night shift, starting on August 26th, end on the morning of August 27th. We started all the way back on the other side of Buelow, and we worked through up to Joplin and that was the end of our night work, and then we continued on the double main for another two weeks or so. I mean, this was a large project, that (the derailment location) was just a small chunk of it. When asked about record report, the employee stated that mostly just our work location for our slow orders, our curve stake measurements, and then mostly everything else would just be stuff that we put in the daily report and if we ever needed it, we could go back to the daily report and see what we needed.

When asked about if he installed a speed restriction for his work, he replied that he placed a 30/30 over the track because he wasn't allowed to complete his work. He further stated that the tie work was completed, but there was still surfacing work to be done, and we were told that the division would handle that, which is why I left my slow order over the project when we left.

When asked about the anchor squeezing process, the employee replied so, the front machine will spread the anchors so that those don't catch up on the ties. Then our squeezers come through and re-squeeze them around the new ties, then we have guys walking behind to apply any anchors that might've fallen off. Stated that they only squeeze the newly installed ties.

Beech Grove Panel Interview

On November 17, 2021, NTSB investigators and members of the Track and Engineering group conducted a panel interview at Amtrak's Beech Grove facility in Beech Grove, IN. The interviewees included: FRA's Deputy Staff Director-Track (DSDT) for their track division; two officials for BNSF, 1) the Director of Technical Research and Development (DTRD); and 2) the General Director of Maintenance Support (GDMS); and Amtrak's Deputy Chief Engineer (DCE). Both of the interviewees for FRA and Amtrak chose to have a representative present during the interview; BNSF interviewees did not choose to be represented. With regard to representatives clarifying comments (CC), the Amtrak representative did not have any; however, due to the technical nature of the discussion with the DSDT, and the interpretations pertaining to the subject matter being discussed, both the DSDT and his representative agreed, and accepted NTSB's offer to have FRA's Staff Director of Track and Structures (SDTS) [the DSDT's representative at the interview] provide written CC to the investigation. The interview transcript and FRA's SDTS's CC document have been entered into NTSB's docket for the Joplin accident investigation.

The purpose of the panel type interview was to discuss Amtrak operations on a host railroad and to better understand how a host railroad maintains, monitors, and mitigates potential maintenance issues while staying in compliance with FRA's minimum Track Safety Standard's regulatory requirements.

FRA's Deputy Staff Director- Track Interview

The DSDT was asked to describe in layperson's terms the 213.57 regulation pertaining to curves and speed limitations.[13] He stated that 213.57 talks about curve, speed, elevation, and designs and it basically lays out the language that we use in our compliance manuals for elevating the outside rail above the low rail to counteract centrifugal force.[14] The DSDT also addressed the V_{max} formula by stating that the V_{max} formula describes the maximum speed limitation based on average of elevation, alignment, and cant deficiency, often referred to as underbalance, and those two terms are interchangeable.[15] He added that if someone speaks of cant deficiency, they're speaking of underbalance and that those terms are interchangeable. [16] In a clarifying comment (CC), FRA's SDTS wrote and added the following:

> [213.57 was designed to control the risk of derailments on curves (wheel climb, or rail rollover, or track panel shift). V_{max} formula is used to determine the (safe) maximum allowable operating speed given the designed curvature and superelevation, adding the allowable 3" of cant-deficiency (or unbalanced superelevation). The formula can be rearranged to determine if the curve is properly elevated or if the curvature has changed from the designed value.[17]
>
> The formula was derived using very simple physics by equating the lateral component of the vehicle weight (gravitation force) due to the curve superelevation with the centrifugal force resulting from the vehicle going around the curve. The "magic" number is not really magic. It was simplified by converting distance, time, and speed into consistent units and eliminating curve radius which has a

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[13] Panel Interview portion with the DSDT refers to "213.57," the full title of this section of FRA's Track Safety (TSS) is entitled, "§ 213.57 Curves; elevation and speed limitations."
[14] Panel Interview portion with the DSDT, page 9, lines 14—17.
[15] Panel interview portion with the DSDT, page 10, lines 3—8.
[16] Panel interview portion with the DSDT, page 10, lines 3—8.
[17] Clarifying Comments by FRA's SDTS, page 2, lines 6—11.

simple relationship with curve degrees][18]

In describing the terms superelevation and equilibrium, the DSDT stated that the term in railroads is usually superelevation, the railroad tracks are elevated above the grade of the -- usually above grade, so the tracks themselves are elevated. He added, we call the outer rail elevated above the low rail a super elevation of that structure, so, you'll often see that term written as super elevation, meaning the outer rails elevated above the low rail.[19] And with regard to equilibrium, the DSDT said he term equilibrium is a term where were looking at the equipment having equal balance on both rails at the same time -- on the low rail and the high rail at the same time, so, all equipment can handle underbalance so -- of up to three inches, so that would be the number that we would -- could elevate above that and run at faster speed.[20] In his CC, the SDTS wrote and added the following:

> [Superelevation is a term used to describe how much the high rail is elevated relative to the low rail. Cant-deficiency (also referred to as *"unbalanced superelevation"*) is a term used to describe the amount of superelevation that would have to be added if the train were to run at the balanced speed, when the vertical wheel load on both the high and the low rails will be the same, as described in *Track and Structures Compliance Manual Volume II, Chapter 1 – March 2018*. Therefore, 3-inch, 4-inch, etc. is just a number that would have to be added to achieve the balanced speed (or equilibrium)][21]

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[18] Clarifying Comments by FRA's SDTS, page 2, lines 23—25, page 3, lines1—2.
[19] Panel interview portion with the DSDT, page 11, lines 11—25, page 12, lines 1—5.
[20] Panel interview portion with the DSDT, page 11, lines 11—25, page 12, lines 1—5.
[21] Clarifying Comments by FRA's SDTS, page 4, lines 24—25, page 5, lines 1—5.

The DSDT was asked to comment on railroads setting their Vmax formula for 79 mph to accommodate passenger trains operating at 79 mph. He replied that it depends on the type of equipment if you mentioned four-inch underbalance and that mainly what you're discussing here is a class of track and a class of track for FRA would relate to both freight and passenger speeds, which would be different speeds for freight trains versus passenger speeds.[22] He added most railroads will write 79 miles an hour in there just so they're not going over speed for that particular class of track that they're operating. FRA's SDTS wrote and clarified with the following comment:

> [The maximum allowable operating speed on curves for Amtrak equipment would have to take into consideration the cant deficiency the equipment will generate. The cant deficiency cannot exceed the value allowed by the FRA regulations. Therefore, Amtrak train speed on curves varies with curve configurations. It could be lower or higher than 79 mph. But in any case, the speed cannot exceed the speed for the posted track class][23]

The DSDT was asked about trains operating at slower speeds on curves set for passenger train operations and whether there was more load bearing on the low rail and if train operations were in equilibrium. The DSDT replied that inherently built into class of track for FRA (Class 4—80 mph for passenger trains) also has a safety margin built in there for freight trains at 60 miles an hour and that obviously passenger trains have a superior suspension system over freight trains.[24] And with regard to railroads operating slower speeds for freight trains, the DSDT said that operating over 100-ton limits or something like that you measure, that is strictly an operations aspect of the railroad, and it has nothing to do -- or bearing on what we're saying about the speed

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[22] Panel interview portion with the DSDT, page 12, lines 6—25, page 13, lines 1—2.
[23] Clarifying Comments by FRA's SDTS, page 5, lines 18—22.
[24] Panel interview portion with the DSDT, page 13, lines 12—25, page 14, lines 1—15.

track and curvature operations for engineering standard.[25] FRA's SDTS wrote and added a comment about equilibrium with the following:

> [Just to clarify the term "equilibrium". When a train traverses the curve at a balanced speed, there would be an "equilibrium". At that moment, the lateral component of the gravitational force is equal to the centrifugal force. As a result, the vertical load on both high and low rails will be equal (as described in my previous comment on the terminology). The "balanced speed", if achieved, will be transient. Considering that all equipment is allowed to operate at 3" cant deficiency (or more for some passenger equipment), the "equilibrium", can rarely be achieved. In most cases, trains operate at a certain level of cant deficiency. Therefore, the high rail often bears more load. However, when the train traverses the curve at a speed slower than the balanced speed, for example, due to a slow order, the low rail will bear more load than the high rail. In that case, there won't be any cant deficiency, or the cant deficiency becomes negative - a situation referred to as "overbalance". This does not happen often][26]

The DSDT was asked if a railroad has to comply in terms of geometry, profile, and that a curve is not just simply the Vmax formula, it's the Vmax formula in conjunction with other elements of the track-safety standards. The DSDT stated no, we only look at the Vmax formula and what it is for curve, elevation, and design.[27] The SDTS wrote and added the following comment to clarify FRA's position:

> [This one (Q or A) clearly did not come across well. The simple answer is yes.

[25] Panel interview portion with the DSDT, page 14, lines 16—25, page 15, lines 1—2.
[26] Clarifying Comments by FRA's SDTS, page 7, lines 13—23.

[27] Panel interview portion with the DSDT, page 15, lines 3—23.

Regardless of the appropriate cant deficiency and operating speed, all regulatory requirements in part 213 TSS apply to curves][28]

The DSDT was asked to comment on what meant by centrifugal force when it comes to train operations through curves. The DSDT answered that it's a way of banking the tracks to counteract some of the speed that the train's going to incur and push towards the outside rail from the center body of the vehicles and that by banking or sometimes it's described as banking by elevating that curve to a sufficient level, we counteract centrifugal force -- those outside forces.[29] FRA's SDTS wrote and added the following clarification on centrifugal force:

[Any object going around a circle, or part of, will generate/subject to a centrifugal force. It is half of the V_{max} equation][30]

The DSDT was asked to comment on a train moving through a curve at slower than maximum authorized speed. The DSDT answered that trains, as they go around the curve, and whatever rail is elevated, the train wheels will want to go to that rail.[31] He further commented that even if trains go around a curve that aren't elevated for a quote, unquote optimal for that particular curve, they still are running at an underbalance, they just aren't running as a high of an underbalance or a lateral movement towards the high side.[32] The SDTS wrote and added his clarifying comment as follows:

[A train moving slow or through a curve that's based with a max of authorized speed" does not mean it runs in an over-balanced status. Only if the train runs below the balanced speed will it run in an over-balanced status. There is a 3-inch CD to cancel out before it goes below the balanced speed][33]

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[28] Clarifying Comments by FRA's SDTS, page 9, lines 24—25, page 10, line 1.
[29] Panel interview portion with the DSDT, page 16, lines 18—25, page 17, lines 1—9.
[30] Clarifying Comments by FRA's SDTS, page 11, lines 16—17.

[31] Panel interview portion with the DSDT, page 17, lines 12—25, page 18, lines 1—5.
[32] Panel interview portion with the DSDT, page 17, lines 12—25, page 18, lines 1—9.
[33] Clarifying Comments by FRA's SDTS, page 12, lines 6—9.

The DSDT was asked if he had any changes to his comments at the end of the interview and he said that he did not; however, NTSB did accept the CC written by the SDTS.

BNSF's General Director of Maintenance Support (GDMS) and Director of Technical Research and Development (DTRD) Interview

As background information, a review of BNSF's Timetable for the Hi Line Subdivision included the following:

- The Hi Line is about 250 miles long.
- There are three distinct maximum authorized speeds for various equipment:
    - For passenger operations it is 79 mph.
    - Trains with under a hundred-ton operating brake ratio at 60 mph.
    - Trains over a hundred-ton operating brake ratio at 55 mph.
- There are 36 permanent speed restrictions throughout the length of the subdivision.
- And several dozen speed restrictions for entering and exiting sidings or end of double track.

The BNSF interviewees were asked how they manage, monitor, and mitigate track conditions and to adjust the track maintenance to meet the operational speed changes in a safe manner for trains operating over the Hi Line. The GDMS replied that, I general, BNSF has engineering instructions that their employees use to help guide them from a maintenance standpoint on rail limitations, rail wear before replacement, and remedial actions for different types of rail and track defects.[34] The GDMS added that looking at the three different speeds between

[34] Panel interview portion with the GDMS and DTRD, page 22, lines 5—25, page 23, lines 1—24.

passenger, freight, the hundred TOB trains, there's three differences there, with the hundred TOB and the under hundred TOB are both considered freight trains. The GDMS stated that they design curves for freight trains, and we also design them for passenger trains, but that BNSF does have a difference between those two as far as an unbalance threshold that's specific to the type of curve and also that type of speed.[35] The GDMS said that with our [BNSF] engineering resources when we are making repairs, building new that will guide us through the Vmax formula and then allow the person who's trying to make that determination understand how much super elevation they need to put in the track based on those parameters with degree of curvature and also speed.[36] The DTRD did not add to the GDMS's comments.

The GDMS was asked to comment on how BNSF monitors all the conditions out there and how it gathers data to plan for track maintenance. The GDMS replied that BNSF is required to do visual inspections as part of the regulation within part 213 and that they also have geometry cars that test our entire network to collect data on the curves along with track conditions.[37] The GDMS added BNSF has several other technology items that also gather data for understanding on an annual basis and for forecasting on a three to five year basis about ties and thresholds for defective ties per mile for planning purposes of tie replacement.[38] The DTRD agree with the GDMS's comments.

The GDMS was asked if BNSF had any program or policy detailing the frequency, reporting and expectations whereby track inspectors are expected to walk curves. The GDMS stated that internal in the BNSF, within our track inspection section of our engineering instructions we do require an annual walking inspection of all curves by our track inspectors on an annual

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[35] Panel interview portion with the GDMS and DTRD, page 22, lines 5—25, page 23, lines 1—24.
[36] Panel interview portion with the GDMS and DTRD, page 22, lines 5—25, page 23, lines 1—24.
[37] Panel interview portion with the GDMS and DTRD, page 23, line 25, page 24, lines 1—25, page 25, lines 1—2.
[38] Panel interview portion with the GDMS and DTRD, page 23, line 25, page 24, lines 1—25, page 25, lines 1—2.

basis; they're allowed to input freeform text, if they have deficiencies, they can input defects against that.[39] The GDMS added that there is optional if a local manager wants or so chooses, they can increase that frequency or the qualified inspector can request to look at this curve two times a year instead of once a year and that BNSF can make those adjustments within the asset database and then it'll populate for them to record that each year.[40]

The DTRD was asked to comment on some terminology used by FRA in describing equilibrium, three-inch unbalanced and four-inch unbalanced and how BNSF applies those terms to freight and passenger operations. The DTRD answered that BNSF designs their curves for freight with a two-inch unbalance and passenger, we design to a three-inch unbalance. The DTRD added, if you were to use the Vmax formula, we would look at the current elevation, and then add that unbalance, and that would give us the Vmax, and then we round down to the near five mile an hour to say what that curve is safe for, but when we inspect, we do inspect to the three inch for freight and four inch for passenger, which is what the FRA recommends.[41] Both interviewees agreed that the elevation for passenger trains is set higher than it would be for freight trains; however, they indicated that it would depend upon the degree of curvature.[42]

Both interviewees were asked to comment on how curves are monitored and the procedure for gathering data. The GDMS said that BNSF uses geometry cars for testing and gathering data and that they prioritize some defects in a progressive scale using a color-coded tag system-- yellow tags, orange tags, red tags, with the yellow and orange tags are advisory.[43] When asked about the

[39] Panel interview portion with the GDMS and DTRD, page 25, lines 3—25, page 26, lines 1—9.
[40] Panel interview portion with the GDMS and DTRD, page 25, lines 3—25, page 26, lines 1—9.
[41] Panel interview portion with the DTRD, page 26, lines 3—25, page 27, lines 1—25, page 28, lines 1—7.
[42] Panel interview portion with the DTRD and GDMS, page 28, lines 8—25, page 29, lines 1—10.

[43] Panel interview portion with the DTRD and GDMS, page 29, lines 11—25, page 30, lines 1—11.

frequency of geometry car testing both interviews answered. They stated that the goal was a minimum of three times a year but because of its location, some portions of the Hi Line get tested more frequently as it is a bridge to other lines that are tested.[44] The GDMS agreed that there is no FRA requirement to conduct geometry car testing, but he did state that when FRA runs their ATIP geometry car that FRA shares the data with BNSF.[45]

The GDMS was asked to describe BNSF's CWR program and goals BNSF may have towards rail joint elimination. The GDMS stated that BNSF has a regulatory approved CWR program and in terms of a rail joint elimination goal that each division sets those goals, and most people are trying to maintain their entire territory with a joint count of less than one joint per mile on the overall average.[46]

The GDMS was asked if track inspectors are required to walk and document inspection of rail joints and the frequency of those inspections. The GDMS described that BNSF's CWR policy depends upon characteristics of type of traffic and million gross tonnages, typically, the inspections are performed and recorded electronically within their database quarterly on a lot of their main routes.[47]

Both interviewees were asked if they were aware of two publications, 1) a Department of Transportation and the FRA, Federal Railroad Administration filed a report that came out in February 2020 that describes cant excess for freight train operations or in shared track; 2) and another one that was done by Rail Sciences in early January of 2006, about super elevation

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[44] Panel interview portion with the DTRD and GDMS, page 30, lines 12—25, page 31, lines 1—25, page 32, lines 1—8.
[45] Panel interview portion with the GDMS, page 31, lines 1—25, page 32, lines 1—8.
[46] Panel interview portion with the GDMS, page 32, lines 9—25, page 33, lines 1—15.
[47] Panel interview portion with the GDMS, page 38, lines 6—18.

problems and solutions and also gets into Vmax formulas on shared railroads, Amtrak running on host railroads, freight trains running on Amtrak. Both interviewees replied they either had not read them or were not aware of them[48]

The GDMS was asked about other types of measuring devices BNSF uses to gather data. The GDMS said there several technological advances within the industry like VTI, vehicle track interaction (mounted on locomotives with accelerometers), that measures for specific kip loading and vertical car body movements; optical recognition test equipment (BNSF's acronym is THOR for track health optical recognition is the definition) that takes pictures of rail joints, looks for broken rails, digital imaging that will capture these different assets.[49] The GDMS added that BNSF scan wood ties for planning purposes for capital replacement programs and they use ground penetrating radar that helps drive some different characteristics with our capital maintenance program and helps guide our ballast maintenance and other types of issues.[50]

NTSB requested that the GDMS provide the investigation with a fuller accounting of more programs for data collection. The GDMS responded that he could do that.[51] However, upon follow-up correspondence requesting an additional program list, BNSF elected not to respond.

Both the GDMS and DTRD were asked if they wanted to change any of their comments or had suggestions about preventing a reoccurrence. The GDMS responded by stating keep with the standards, keep collecting data, analyze that data, draw conclusions that can help improve the

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[48] Panel interview portion with the DTRD and GDMS, page 39, lines 3—25, page 40, lines 1—8.
[49] Panel interview portion with the GDMS, page 42, lines 7—25, page 43, lines 1—19.
[50] Panel interview portion with the GDMS, page 42, lines 7—25, page 43, lines 1—19.
[51] Panel interview portion with the GDMS, page 43, lines 20—25, page 43, lines 1—9.

infrastructure and the standards we have.[52]

Amtrak's Deputy Chief Engineer (DCE) Interview

The DCE was asked to comment on how Amtrak accommodates freight train operation on their properties. The DCE described that there is local freight traffic throughout the entire length of the Northeast Corridor (NEC) and that between Bayview, Maryland and Wilmington, Delaware he estimated there is about 37 to 40 million gross tons on that segment and various through freight service on several other areas.[53] The DCE was also asked to describe the FRA Classes of track for the NEC versus the Class 1 to 5 TSS that BNSF uses on their operations for the Hi Line Subdivision. He replied that depending upon where one would be on their railroad that the FRA standards applicable were from Class 2 up to Class eight and that their passenger trains operate at speeds up to 135 mph, soon to be 145 mph. He said that the higher classes of track beginning at Class six require the use of geometry cars annually for data collecting and that the frequency of operating geometry cars increases as the class of track increases Class seven effectively requires every other month and Class eight is monthly.[54] The DCE added that the FRA standards for Classes seven and eight require the use of vehicle track interaction (VTI) equipment (accelerometers mounted on the truck frames and car bodies) that do continuous monitoring of the truck frame, truck axle box, and car body acceleration that gather real time, real world data collection, measurements of the track, the vehicle interface with the track.[55]

The DCE was asked to describe the monitoring, alerts and response time associated with

[52] Panel interview portion with the GDMS, page 64, lines 2—12.
[53] Panel interview portion with the DCE, page 45, lines 16—25, page 46, lines 1—15.
[54] Panel interview portion with the DCE, page 46, lines 16—25, page 47, lines 1—25.
[55] Panel interview portion with the DCE, page 48, lines 1—18.

the data from the VTI equipment. The DCE said the VTI equipment is basically on all of the time and reporting back to a central database they all report to the central database and whenever an exception is recorded by one of the units, it sends out email messages to a distribution list in near time whereby an assigned person initiates a remedial action, if necessary, after verification based upon a numerically-coded severity system much like what BNSF uses with their geometry cars.[56,57]

The DCE was asked if Amtrak has other programs to monitor or collect data about the track. The DCE stated that like BNSF Amtrak uses geometry cars; ground penetrating radar for ballast conditions; Sperry car runs to conduct rail flaw detection and joint bar conditions; and line-scan camera equipment to look at ties, ballast, and rails.[58]

The DCE was asked to describe some of the elements of their approved CWR program. The DCE said that Amtrak had an approved CWR program for years until recently FRA informed Amtrak that their CWR program was no longer valid and that it had to be updated into what FRA wanted as a generic plan much like the one BNSF currently has.[59]

The DCE was asked to comment on Amtrak's goals, policy, and their approach to joint elimination. The DCE responded that it is a worthy goal to eliminate all joints, it is almost an impossible goal because a railroad is constantly conducting rail flaw detection and repairs (creating joints) and constantly finding service rail failures.[60]

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[56] Panel interview portion with the DCE, page 48, lines 19—25, page 49, lines 1—25, page 50, lines 1—14.
[57] While BNSF uses a color-coded severity system, yellow, orange and red; Amtrak uses a numerical severity system with levels 1, 2 and 3.
[58] Panel interview portion with the DCE, page 51, lines 19—25, page 52, lines 1—10.
[59] Panel interview portion with the DCE, page 53, lines 21—25, page 54, lines 1—20.
[60] Panel interview portion with the DCE, page 54, lines 21—25, page 54, lines 1—10.

The DCE was asked about the timeliness of eliminating rail joints. The DCE responded by saying the intention is that if we introduce joints in the track, to come back and eliminate those joints at some point in the future and hopefully before 60 days, which is what our CWR plan says. The DCE added that rail joint elimination is dependent upon budgets and other resources like available track time and personnel.[61]

The DCE was asked about certain values that appear in the track pertaining to harmonic rock. The DCE said their VTI system measures the vehicles' reaction to track geometry at specific speeds spelled out in the track safety standards for classes six, seven, eight, and nine, those limits are spelled out in the CFR.[62] And in answering a question about the timing of vehicle reaction time, the DCE said that the VTI systems are looking at the reaction of the vehicle to a track condition and on the suspension and that natural frequency is going to result in vehicle harmonics that are good or bad depending on how the geometry lines up with the vehicle's natural frequency. And the DCE added if you have a combination of geometric shapes that are in tune with the vehicle's natural frequency, the vehicle's going to react badly to it.[63] The DCE was asked if he was aware of how quick a reaction can happen. The DCE indicated there are numerous papers on that subject where the reaction time depends on the vehicle, on the geometry of the vehicle, on the suspension type of the vehicle, on the inertial masses, where they are, and how they're located, and the vehicle will react to track geometry in a way that may or may not correspond to the track safety standards, which is why the VTI systems are useful in that respect because it does not

[61] Panel interview portion with the DCE, page 55, lines 13—25, page 56, lines 1—21.
[62] Panel interview portion with the DCE, page 56, lines 22—25, page 57, lines 1—13.
[63] Panel interview portion with the DCE, page 57, lines 14—25.

necessarily mean there is a track defect.[64] And to address where the VTI equipment is used, the DCE said that those resources are concentrated on their NEC and not on the broader national passenger network. The DCE added that to equip locomotive and cars (some 200 locomotives and 13 hundred cars) off corridor would cost a lot of money and that it would be complicated because of the necessary human and computer analyzed infrastructure and the resulting communication challenges to others who would not be part of the system.[65]

Volpe Center- Chief, Structures and Dynamics Interview

The interviewee described his education and experiences as being the division chief of the Structures and Dynamics Division at the Volpe Center. He has a bachelor's and master's degree in mechanical engineering from Tufts University. He joined the Volpe Center in 1994 where he started out working on problems related to rail crash worthiness. Shortly thereafter, since around 1997, he has been involved in vehicle-track interaction working on related to vehicle-track interaction for the Federal Railroad Administration. He explained that vehicle-track interaction is a railroad engineering topic that has been around for as long as railroading has been really. He explained that VTI has been studied since the development of railroading. Nadal was looking at what kinds of forces it takes to keep the locomotives on the track. He further explained that vehicle-track interaction looks at the dynamic interaction of rail vehicles over the track. It, in a very short way, looks at the vehicle on the track as a system and it really tries to identify what it takes to keep vehicles on the track, what it takes to keep vehicles operating efficiently, and as well a number of other problems.

[64] Panel interview portion with the DCE, page 58, lines 3—15.
[65] Panel interview portion with the DCE, page 58, lines 16—25, page 59, lines 1—25, page 60, lines 1—19.

In order to study vehicle-track interaction, the fact that it is sort of a system look at things, you do need to know quite a bit about both the vehicle and the track. So, that takes into consideration details about the vehicle, its weight, its design, its suspension, its wheel profile, et cetera. It also takes into account many factors on the track side meaning things like the track geometry, the rail itself, the rail profile, whether or not the track is tangent, whether or not the track is curved, whether you are in a spiral, whether you are in special track work. It also takes into account the operation; you want to know things about what speed the vehicles are traveling at, whether or not you are operating at balanced speed, whether or not you are operating at some level of cant efficiency or excess, or also known as underbalance or overbalance. But all of these things come into play, they are all a part of factors that need to be considered when trying to understand those forces that develop at the wheel-rail interface. These forces are very important because these forces at the wheel-rail interface re obviously what makes railroading successful. These forces are required in order to make a train move and go around track. But at the same time, they can at times become excessive and then become a problem either in the form of a derailment, in the form of overloading the track structure, in the form of resulting in wear and tear on the system. The interviewee went on to say that vehicle-track interaction can be studied many different ways. Vehicle-track interaction can be studied empirically by doing testing. For example, You can go out there and just conduct a test with instrumentation and say here is a particular track condition, I am going to run my vehicle over it, I am going to measure acceleration, forces, displacements, and when I go over that track at varying speeds or whatever, I am going to make some assessment of what the safety associated with that. I believe that some of the earlier research that I was mentioning whether it has been AAR's research, or Amtrak's, or some of the other railroad's, a lot of it was based on early empirical-type studies. But the other way to study this problem is using computer modeling and computer modeling has advanced quite a bit over the last 20 years or even longer. I mean, that is also a research that has been around for a while. But it has gotten to the point where it is very informative, and people have now used that as a tool to further those empirical studies and to study additional problems that you could not necessarily capture and study with testing because it is impossible to test all conditions.

When asked about cant deficiency, the interviewee explained that so with cant deficiency, we are talking about speed to a curve. In particular, we are trying to understand when you go through a curve with a certain radius and a certain superelevation at various speeds, there is a speed at which you will go through the curve and balance both the weight, force, as well as the centrifugal force, the components of those, because one is acting out of the curve, the other one is acting down. There is a speed that you go through the curve at which you balance those two components, meaning that you will effectively feel no lateral force and that there will be a vertical force downwards to the track, the elevated track, and that vertical force will be equally shared on both of the rails. And that is only at that one particular speed, that is what we call the balance speed. If you happen to go faster than the balance speed, you will now see a transfer of vertical load to the outside of the rail, to the outside rail, so therefore you are in a condition where there is more loading on the outside rail, less loading on the inside rail, as well as you are feeling a lateral force pushing you to the outside.

When asked about cant excess the interviewee stated that when you have a curve of a certain curvature in superelevation, passenger cars are obviously interested in going faster and they tend to operate at speeds higher than the balanced speed and therefore are operating at a cant deficiency. Whereas it might be, the opposite might be true for a freight operation for that same case. It may

5 operate slower than the balanced speed, in which case, there is too much superelevation, and we call that cant excess. So, you can have either one of them if you go faster or slower than the curved speed so to speak; the balanced speed for that curve. And I will just add this, the effect of this is to transfer when you do not operate at the balanced speed, the effect of this is to transfer load one way or the other, either to the high rail or to the low rail.

When asked about how heavy freight train effect the track structure when operating at slower speed in curves, absolutely, particularly when you have heavy loads. For example, when the car that is being operated is the heavy loaded vehicle, the freight car, you know, if it is operating at a cant excess condition, it is going to throw a lot of additional load into the low rail and that load has to be paid attention to. It could require additional track maintenance because of the degradation that is going to be associated with that. But that said, I just want to put a caveat there that it

16 also depends upon what factors were taken into consideration from the get-go, meaning that in some situations, you may have accounted for the fact that is it is going to need to operate this

19 way and therefore, designed the strength of the track structure in a way to accommodate that. I am not saying that's always the case, but in general, I would say that operating at a cant excess or slower than the balanced speed because of a slow order is going to result in higher forces that are going to degrade over time the low rail.

NTSB Research and Engineering Support

The NTSB Research and Engineering Division (RE 40/60), has been taken with the following investigative support tasks:

- Head-End Video Factual- A representative from RE-60 has been tasked to review the head-end image recordings from Amtrak train No. 7 to factually document the trains movements through the accident footprint. A video review group consisting of NTSB, FRA, BNSF, Amtrak, Volpe, BMWE, BLET and SMART will assemble virtually on February 1, 2022 to review the head-end video and to verify still images for use in the video factual report.

- Still Image/Track Misalignment Analysis- A representative from RE-60 has been tasked to review and analyze the still image of the track misalignment location to 1) formulate a length (how long) of the track misalignment at the time of the derailment, and 2) formulate a measurement of the amount of misalignment (alignment value) in the track at the time of the derailment.

Discussion on Low Rail Degradation

NTSB investigators researched a study produced by the Transportation Technology Center, Inc., (TTCI) with FRA support, entitled Cant Excess for Freight Train Operations on Shared Track, wherein TTCI conducted a study (a white paper) to review and summarize current practices and issues related to shared operations—particularly freight train operations on curves with cant excess.[66] TTCI conducted their research from March to December of 2015 at its Pueblo, Colorado facility. In its Executive Summary TTCI provided the following:[67]

[Shared-track curve design requires a compromise between higher-speed passenger and lower-speed freight operations. Significant superelevation helps passenger trains operate at higher speeds, but it causes deterioration on rail, ties, and surface condition due to freight operations at substantially lower speeds. To develop best practice for such shared operations, future research is

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66 Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Executive Summary, page 1.

67 Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Executive Summary, pages 1 and 2.

recommended in this report]

The research team conducted the following work:

• Reviewed and summarized past studies related to cant excess for freight operations.

• Reviewed documents regarding vehicle-track interaction and rolling contact fatigue (RCF) related to curving and superelevation.

• Summarized a survey and discussions with railroads and other stakeholders regarding current planning, design, and maintenance practices, and determined gaps and needs for improvement.

• Presented statistical analysis on curvature and underbalance from 12 corridors with shared operations.

This study discusses that the design of curves on shared track requires a compromise between higher-speed passenger and lower-speed freight operations. Significant superelevation helps passenger trains at higher speeds, but it causes deterioration on rail, ties, and surface conditions due to freight operations at substantially lower speeds. The most common issues related to cant excess identified by the literature review are the following:

• Gauge spreading due to high lateral load on the low rail

• Rail seat deterioration (RSD) due to significant gauge spreading and rail rollover forces for concrete ties

• Deformation and cracking (or RCF) of the low rail due to a shifting of the load to the low rail

• Increased risk of derailment due to tipping is higher, especially if the train comes to a stop on the curve.

The issues brought up from the survey and discussions with railroads confirmed those listed in the literature review. More specifically, surveyed railroads indicated the following common issues for curves with excess cant:

• Excessive flattening or plastic flow on low rail

• Gauge widening

• Rollover of the low rail

• Increased potential of internal rail defects

• Adverse impact on rail, tie, and surface condition due to the elevated vertical loading on the low rail and the increased axle steering forces that result.

To develop a best practice for shared operations in curves, the TTCI research team recommends further research, including modeling and testing for understanding vehicle and track parameters that affect operating safety and track degradation in curves with shared operations.

In their research, TTCI provided several definitions defining engineering terminology for curves, superelevation, cant, and excess cant. With reference to curves, TTCI defines curve track as follows:[68]

[When a track goes through a curve, the outer rail is raised above the inner rail so that the centrifugal force from the turn, when combined with the weight of the train, remains normal to the track surface. This difference in height between the inner and outer track is called superelevation, in other countries it is also referred to as cant and is usually measured by the difference in height between the two rails. However, because the centrifugal force depends on the velocity of the train and the radius of the curve, the superelevation of a curve is balanced at only one speed. When a train goes through a curve too quickly, centrifugal force causes it to lean to the outside of the curve, thus placing more weight on the high (outside) rail. This is called cant deficiency or overbalance.

[68] Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Section 2, Definitions, page 6.

Cant excess, or underbalance, occurs when a train goes through a curve too slowly and places more weight on the low (inside) rail. Both cant excess and deficiency are commonly measured in the amount of inches or millimeters needed to correct the superelevation]

In TTCI's study, they further defined balanced speed with the following:[69]

[At a specific speed, called the balance speed, the compensation due to superelevation balances the acceleration due to curving. Relative to the track plane, the perceived lateral acceleration is then zero. At speeds under the balance speed, the lateral acceleration component is less than the superelevation component. This is called cant excess, meaning the track has excessive cant for the present speed. At speeds over the balance speed, the lateral acceleration component is greater than the superelevation term. This is called cant deficiency, meaning the track has insufficient cant for the present speed. With cant deficiency, perceived accelerations are to the outside of the curve; with cant excess, perceived accelerations are to the inside of the curve]

TTCI also provided their definition of cant excess and cant deficiency with the following excerpts from their study, in part:[70]

[Cant deficiency or excess is often expressed as an amount of insufficient or excess superelevation—defined as in inches of cant deficiency. They are expressed sometimes as uncompensated acceleration—in ft/sec². As a conversion, 1 inch of cant deficiency corresponds to just over 1/2 ft/sec² of uncompensated lateral acceleration. The forces due to centripetal acceleration through a curve must ultimately be reached at the wheel-rail interface. Curve

[69] Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Section 2.1, Balance Speed, page 6.

[70] Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Section 2.2, Cant Excess and Cant Deficiency, page.

lateral acceleration and the compensating effect of track superelevation can be expressed mathematically]

TTCI further studied issues and problems associated with cant deficiency and wrote the following in section 3.2 of their report, in part:[71]

[Cant excess can cause many of the same problems as cant deficiency, as well as a few different problems. For example, HAL freight trains often operate with cant excess, so the lower rail is subjected to higher vertical loads in cant excess than the high rail. Also, because the track is already tipping slightly inward, the chance of derailment due to tipping is higher, especially if the train comes to a stop on the curve. Another cant excess issue is commuter discomfort due to lateral accelerations in passenger trains, and in freight trains lateral forces are a concern. A significant derailment risk at high cant deficiency comes from the fact that the vehicle attempts to push the track out from under itself. As the cant deficiency increases, the lateral forces on the low rail wheel of the trailing axle of a truck also tend to reverse direction and then increase until there is a net lateral force on the trailing axle acting to push the track to the outside. This safety issue is closely related to track buckling (also known as track panel shift). High speed trains may encounter speed restrictions during extremely hot weather. According to Klauser (2014), "Greater track longitudinal forces due to temperature and greater net axle lateral forces due to cant deficiency increase the risk of track buckling."[72]]

[71] Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Section 3.2, Issues with Cant Deficiency or Excess, pages 9—10.
[72] Klauser, P. (2014). Operating at High Cant Deficiency. Interface: The Journal of Wheel/Rail Interaction. Available at http://interfacejournal.com/archives/581.

NTSB investigators found in TTCI's report that they addressed the effects of heavy axle load (HAL) trains on curves in Section 3.2.3, which states, in part, the following:[73]

[Curves on freight lines often have excess superelevation for HAL operation. As a result, HAL trains tend to operate at cant excess, rather than cant deficiency. "Increasing cant deficiency tends to improve curving behavior and reduce RCF damage. Conversely, traveling slower in curves can increase damaging forces and increase the risk of flange-climbing derailment of the leading wheels." [8] A reduction in superelevation would move freight trains to operating at balance speed or slightly above balance speed (slight cant deficiency). This change would be accompanied by small but nonetheless realizable benefits. [9, 10, 11] One is a reduction in low rail plastic deformation. There is also potential for a reduction in total wheel and rail wear. Finally, there is a reduction in gauge-widening force. Operating at cant deficiency reduces the low rail lateral load more than it increases the high rail lateral load. Thus, the net gauge spreading load will be reduced. Since low rail rollover is generally of greater concern than high rail rollover, reducing the lateral load on the low rail is a further benefit. However, if superelevation is increased to accommodate higher-speed passenger trains, HAL trains would then operate with more cant excess. Operating at cant excess shifts the load to the low rail. Since hollow-worn wheels generate large contact stresses on the rail field side, crushing, plastic flow, and surface defects are likely more severe with cant excess.

Previous research [9, 10, 11, 12, 13, 14, 15, 16] has shown that other issues for HAL trains at cant

[73] Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Section 3.2.3, HAL Train Issues, pages 12—13.

excess include:[74,75,76,77,78,79,80]

• Increased chance for high rail flange climb due to decreased vertical load on outside rail.

• Increased gauge-widening forces and rail rollover due to increased vertical load on low rail.

A significant portion of the lateral force that acts to push the wheelset into flange contact with the high rail in curves is generated by the low rail wheel. This lateral force increases with increasing vertical load on the low rail wheel. The corresponding drop in vertical force on the high rail wheel tends to increase the high rail L/V ratio, increasing the risk of flange climb derailment.

This increased lateral force on the low rail wheel is reacted by the rail in the outward, gauge widening direction. The increased vertical load from HAL trains also tends to flatten the low rail, which can contribute to the wheel contacting the rail on the field side. This contact condition, in combination with the increased low rail lateral forces, leads to increased risk for rail rollover.]

In TTCI's report in Section 5, Conclusion, the last paragraph states the following:[81]

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[74]the following seven footnotes are for research articles listed in TTCI's report as [9,10,11,12,13,14, 15].
Tournay, H., Cakdi, S., Trevithick, S., and Morrison, K. (2014, July). The Effect of Track Cant on Vehicle Curving (1): Theory and Single Car Test Results. Technology Digest TD-14- 013. Pueblo, CO: Association of American Railroads, Transportation Technology Center, Inc.

[75] Tournay, H., Akhtar, M., Cakdi, S., and Morrison, K. (2014, July). The Effect of Track Cant on Vehicle Curving (2): In-service Site Selection & Analysis. Technology Digest TD-14-014. Pueblo, CO: Association of American Railroads, Transportation Technology Center, Inc.

[76] Tournay, H., Akhtar, M., Cakdi, S., and Morrison, K. (2014, July). The Effect of Track Cant on Vehicle Curving (3): In-service Test Results. Technology Digest TD-14-015. Pueblo, CO: Association of American Railroads, Transportation Technology Center, Inc.

[77] Wu, H., and Wilson, N.G. (2006), Railway Vehicle Derailment and Prevention. In Simon Iwnicki (Ed.), Handbook of Railway Vehicle Dynamics. Boca Raton, FL: CRC Press, Taylor & Francis Group.

[78] Elkins, J.A., and Carter, A., (1993), Testing and Analysis Techniques for Safety Assessment of Rail Vehicles: The State of the Art. Vehicle System Dynamics, 22.

[79] Wilson, N.G., Fries, R., Witte, M., Haigermoser, A., Wrang, M., Evans, J., and Orlova, A. (2011). Assessment of Safety Against Derailment Using Simulations and Vehicle Acceptance Tests: A Worldwide Comparison of the State-of-the-Art Assessment Methods. State of the Art Papers of the 22nd IAVSD Symposium, Special Issue of International Journal of Vehicle Systems Dynamics, 49(7), 1113-1158. Boca Raton, FL: Taylor & Francis.

[80] Wu, H., and Kerchoff, B., (2011, December). Root Causes of Rail Roll/Reverse Rail Cant and Remedies. Technology Digest TD-11-052. Pueblo, CO: Association of American Railroads, Transportation Technology Center, Inc.

[81] Transportation Technology Center, Inc., (TTCI) study, entitled Cant Excess for Freight Train Operations on Shared Track, Section 5, Conclusion, page 40.

[It is important that the compromise between higher-speed passenger and lower-speed freight operations be addressed when designing and maintaining curves on shared tracks. Significant superelevation helps to achieve passenger trains' higher speeds, but it causes deterioration on rail, ties, and surface condition due to cant excess for freight operation at substantially lower speeds]

NTSB investigators also studied an article published in January of 2006 by the president of Rail Sciences (RS) entitled, Curve Superelevation: Problems and Solutions. In the article, Rail Sciences offers a series of potential problems associated with determining and maintaining track with the optimal superelevation and sites many challenges with the following:[82]

In the real world of railroad operations, speed is a variable, and many trains operate at less than the timetable speed for a variety of reasons:

- Locomotives fail to develop full horsepower.
- Slow orders placed on the track.
- Train running at restricted speed due to signal or warrant control.
- Train over tonnage.
- Trains running on approach signals.
- Sticking brakes.
- Inexperienced crews.
- Weather conditions.

Rail Sciences, in its article, points out that one should consider the 'real world' conditions with train operating at less than authorized speed with the following:[83]

[82] Rail Sciences, Curve Superelevation: Problems and Solutions, page 4.
[83] Rail Sciences, Curve Superelevation: Problems and Solutions, pages 4—5.

[By taking into account the reality of operating under the speed limit, it is possible to find an optimum elevation that accommodates the predominance of trains that pass through the curve. In addition to degradation of the track structure, excessive elevation in curves can increase the risk of derailment. When running significantly under balance speed, or operating on over-elevated curves, a significant portion of the vertical weight of the car is transferred to the low rail. This weight transfer to the low rail increases derailment risk for the following reasons:

• Greater vertical weight on the low rail increases spalling, the attendant growth of potential fatigue defects, and the increased potential for broken rail derailments.

• Loss of vertical weight on the high rail of the curve increases the chance of high rail wheel climb due to either harmonic rocking or moderate track twist.

• Greater vertical weight on the low rail increases the lateral creep forces on the low rail and the possibility of rail rollover of the low rail, especially where the low rail has become canted to the field side.

• Greater vertical weight on the low rail increases the risk of battered joints due to dynamic impact.

And in terms of possible solutions for calculating superelevation for curves and mitigating derailment risks, RS offered the following:[84]

In an ever-changing rail environment, curve elevations need to be constantly assessed to prevent the development of adverse consequences. Train speed needs to be assessed realistically, and not simply based on timetable speeds. Engineering and Operating Departments need to work together to assess proper curve elevations. If low rail spalling persists, the curve is gaining elevation, or

[84] Rail Sciences, Curve Superelevation: Problems and Solutions, section The Solutions, page 7.

there have been wheel climb derailments, remediation is in order. Some possible solutions are:

• Decrease train speeds on the downhill side of ruling grades to make them more in line with the uphill train speeds.

• Normalize speed limits across a territory to eliminate unnecessary up and down changes in speed limits.

• Work with passenger train operators to reduce passenger train speed limits—even a nominal amount. Since the centrifugal force is a factor of the speed squared, a modest reduction in speed of 10 mph can dramatically improve the balance of vertical wheel loads for the heavier freight cars.

• Increase freight train speed limits.

• Re-elevate the curves based on realistic operating speeds, not timetable speed limits.]

[END OF REPORT]