FEDERAL RAILROAD ADMINISTRATION

1200 New Jersey Avenue SE, Washington, DC 20590

TECHNICAL ACCIDENT REPORT
Derailment of CSX Transportation, Inc.'s Unit Crude Oil Train K08014
Transporting Crude Oil for Plains All American
Mount Carbon, West Virginia

November 4, 2015

Contents

EXECUTIVE SUMMARY

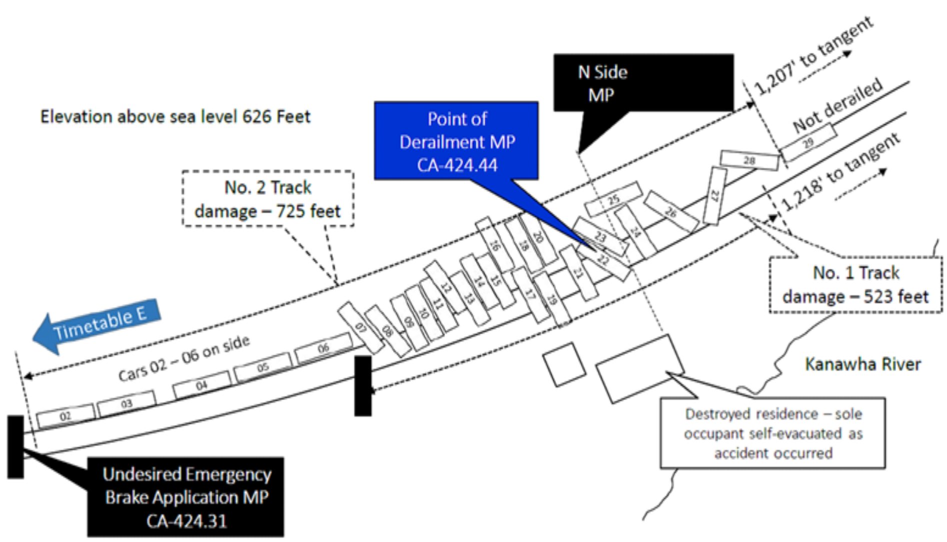
On February 16, 2015, at 1:15 p.m. Eastern Standard Time (EST), eastbound CSX Transportation, Inc. (CSXT) Train K08014, transporting crude oil for Plains All American and operating on CSXT track, derailed west of Mount Carbon, West Virginia. The incident occurred on the CSXT Huntington Division, New River Subdivision, at Milepost CA-424.44. The derailment occurred when the train traversed over a rail with an internal defect, causing the rail to break.

Train K08014 was traveling at a speed of 33 mph, below the 50 mph maximum authorized speed for that segment. The train consisted of two engines, 107 fully loaded tank cars carrying crude oil, and two covered hopper buffer cars.

A total of 27 tank cars derailed in the incident. Two tank cars were punctured, released crude oil, ignited, and caught fire. The fire spread quickly, resulting in a pool fire that eventually led to thermal tears in 13 additional derailed tank cars. Ultimately, 24 of the 27 derailed tank cars sustained damage in the incident and resulting fire. The fire injured one person (smoke inhalation), destroyed one home and one garage.

CSXT determined the train released 362,300 gallons of crude oil during the incident—much of it lost to atmospheric burn, pool fires and ground absorption.

Figure 1: Accident site schematic.



Response

Following the derailment, the crew alerted the CSXT dispatcher of the train's condition and the fire. While awaiting emergency responders, the train crew directed motorists away from the accident site.

At 1:25 p.m., 10 minutes after the derailment, emergency responders arrived at the accident site, closed West Virginia State Route 61, and moved residents away from the incident.

Law enforcement and first responders later ordered a four-day evacuation within a half-mile of the incident site, affecting approximately 1,100 residents.

Approximately one hour after the derailment, at 2:30 p.m., West Virginia American Water treatment intakes were closed at Montgomery, West Virginia, as a precautionary measure.

Investigation

With its technical expertise in railroad safety and investigating railroad accidents, FRA led an investigative team that included representatives from 10 organizations.

The on-scene accident investigation team included experts from each of the FRA railroad safety disciplines: Operating Practices, Hazardous Materials, Signal & Train Control, Motive Power & Equipment, and Track. FRA's thorough investigation into the first four disciplines identified no factors that contributed to the derailment.

FRA's track investigation determined the cause of the Mount Carbon derailment was a broken rail.

Rail flaw

The broken (low) rail developed a flaw known as a vertical split head (VSH) during the course of the weeks and months leading to the derailment. A VSH is a longitudinal fracture in the upper part of a rail, used for supporting and guiding the wheels of railroad cars. Prior to the derailment, two separate tests conducted by Sperry Rail Service (Sperry), a contractor hired by CSXT to detect rail flaws in the New River Subdivision, showed evidence of the VSH.

During a December 17, 2014, test, Sperry's test equipment recorded indications of a rail flaw at what would become the point of derailment. A subsequent test, on January 12, 2015, noted a similar but more significant rail flaw indication at the same location. Despite indications of potential flaws, the Sperry operator failed to conduct a ground visual examination or hand tests to confirm the flaws as required. When asked by FRA investigators why he did not leave the cab of the test equipment to complete the required visual inspection, the operator stated his assumption that rough rail surface conditions, not a structural flaw, caused a positive test. Despite the Sperry operator's 15 years of experience on this CSXT territory, he had not receive the enhanced training given to new employees.

FRA's assessment is that a vertical split head in the rail caused the rail to fail.

FINDINGS AND RECOMMENDATIONS

Findings

- The Mount Carbon derailment was preventable. Digital rail flaw test data records show indications of VSH defects at the point of derailment for two tests prior to the derailment (December 2014 and January 2015).
- Following the digital indications noting potential flaws, neither the operator of the rail-flaw detection equipment nor CSX performed a visual inspection or hand test of the specified track.
- The presence of a VSH in the railhead was a prime factor in the degradation of the rail structural integrity.

Recommendations for CSXT

- FRA recommends CSXT routinely train operators of internal rail flaw detector cars so that they can more effectively identify and investigate non-valid testing locations and suspected rail flaws.
- FRA recommends CSXT continue to use improved technology comparing previous inspection data with data collected in real-time, increasing the likelihood of detecting rail flaws.
- FRA recommends CSXT establish a plan to identify and replace track with VSHs or similar flaws on high-hazard flammable train routes, to reduce the risk of future derailments on these high-stake corridors. The plan should be submitted to FRA for review.

Recommendations for Sperry

- FRA recommends Sperry routinely train all operators to more effectively identify suspected rail flaws. This routine training will reduce the risk of a test operator failing to conduct a necessary hand test after digital flaw indications are obtained.
- FRA recommends that this training include review of previous digital rail flaw tests immediately before new testing is conducted and/or real-time comparison of previous results with current, incoming data so that operators can more accurately identify areas that should be hand tested.

ACCIDENT NARRATIVE

On February 16, 2015, at 1:15 p.m. EST, eastbound CSXT Train K08014, transporting crude oil for Plains All American and operating on CSXT track, derailed west of Mount Carbon, West Virginia. The incident occurred on the CSXT Huntington Division, New River Subdivision, at Milepost CA-424.44. Train K08014 consisted of two engines and 109 cars (107 fully loaded tank cars and two covered hopper buffer cars). The train traveled eastbound on No. 2 Track at a recorded speed of 33 miles per hour (mph), below the 50 mph maximum authorized speed for that segment. Twenty-seven of the 107 loaded tank cars, located at positions 2 through 28, derailed when the train traversed over a rail with an internal defect, causing the rail to break. The internal defect, a well-developed vertical split head (VSH) in the low rail on the inside of the curve, likely grew in size during the weeks and months preceding the derailment.

Figure 2: Tank cars burning.

At the point of derailment, one or more tank cars in the train consist derailed and damaged the air brake line, causing an automatic emergency brake application.[1]

The tank cars were model DOT 111 tanks cars with Association of American Railroads (AAR) CPC-1232[2] type modifications. These modifications included half-height head shields, bottom skid plates, and dome protection. All tank cars were non-jacketed and non-insulated. These cars are commonly referred to as "unjacketed or non-jacketed 1232s."

Location and Weather Conditions

The derailment occurred on the south bank of the Kanawha River, at the foot of the geological formation known as Mount Carbon (elevation 1,800 feet). Approximately eight inches of snow was on the ground and the temperature was fifteen degrees Fahrenheit.

Train Crew Actions

Following initiation of the emergency brakes, the two engines and the lead buffer car detached from the rest of the train due to the derailment and traveled approximately 636 feet and came to a complete stop at Milepost CA-424.31.

---

[1] An automatic application of a train's air brake system occurs when the train line's brake pipe pressure vents due to a hose uncoupling, a hose or pipe breaching, or another system failing. FRA regulations define an "emergency application" as "an irretrievable brake application resulting in the maximum retarding force available from the train brake system." See Title 49 of the Code of Federal Regulations (CFR) section (§) 232.5.

[2] "CPC" stands for "Casualty Prevention Circular."

Realzing there had been an emergency brake application, the engineer broadcasted an emergency radio transmission to the CSXT train dispatcher. The CSXT train dispatcher responded to the engineer's call via radio.

Figure 3: Post-derailment fire burning behind house.

After the derailment, the conductor left the engine and walked back to inspect the train. The conductor saw that multiple tank cars had derailed and were on fire and then returned to the lead engine to inform the engineer of the train's condition. The engineer relayed to the CSXT train dispatcher that the train had derailed and caught fire.

After approximately eight and a half minutes, the crew recharged the brake system and moved the two engines and the one buffer car approximately 1,000 feet east to a safer location near Milepost CA-424.0. This location adjoined West Virginia State Route 61 that runs on the south side of the railroad right-of-way. While awaiting emergency responders, the train crew directed motorists away from the accident site.

Emergency Response and Fire

At 1:25 p.m., 10 minutes after the derailment, emergency responders[3] from Kanawha and Fayette counties arrived at the accident site. Responders met the train crew and exchanged information about the contents of the train and the train consist, closed WV State Route 61, and directed motorists and residents to move away from the area.

Two tank cars suffered mechanical punctures during the derailment and caused the initial fire. As the fire burned, crude oil in the derailed tank cars began to heat up, increasing the pressure inside the tank cars. The heat eventually caused thermal tears in 13 additional derailed tank cars. Thermal tears are explosive tears in tank cars that result in the sudden release of large amounts of product, resulting in explosions or large fireballs.

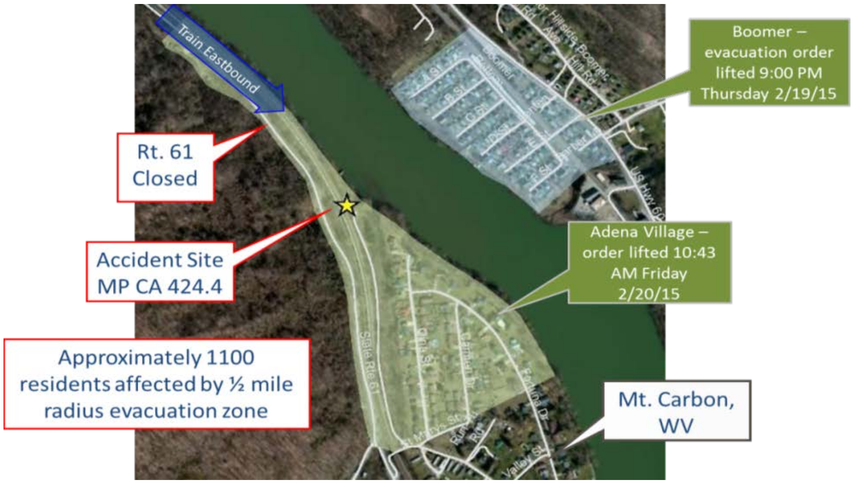
Emergency responders reported that the first two thermal failures with explosions occurred about 25 minutes following the derailment. Four additional thermal failures with explosions occurred approximately 65 minutes after the derailment.

[3] The following governmental entities participated in the emergency response and investigation: Fayette County Emergency Management, FRA, Pipeline and Hazardous Materials Safety Administration, National Transportation Safety Board, Kanawha County Emergency Management, U.S. Environmental Protection Agency, U.S. Coast Guard, West Virginia Department of Environmental Protection, West Virginia Department of Highways, West Virginia Department of Transportation, West Virginia Public Service Commission (Railroad Safety), West Virginia State Fire Marshall, and West Virginia State Police. The following entities participated in the environmental and hazardous materials remediation: Arcadis, Center for Toxicology and Environmental Health, LLC (CTEH), Conestoga-Rovers & Associates (CRA), Environmental Management Specialists, Inc. (EMS, Inc.), EnviroScience, HEPACO, Miller Environmental Group, Quick Response, Specialized Professional Services, Inc. (SPSI) W.E.L., Inc., and United States Environmental Services (USES). The following entities participated in the re-railing: CSXT; R. J. Corman Railroad Group; Cranemasters, Inc.; and Donahue Brothers, Inc.

Evacuation

Due to the possibility of additional explosions and thermal events, as well as smoke and fumes, law enforcement and first responders issued a half-mile evacuation order the day of the derailment. The half-mile evacuation affected approximately 1,100 residents. The Red Cross assisted with setting up an evacuation shelter at Valley High School in Smithers. The evacuation ended four days later on February 20, 2015. FRA did not investigate impacts to local businesses or government services.

Figure 1: Diagram of the accident site and surrounding area.



Injuries

The fire injured one person (smoke inhalation), destroyed one home and one garage. The occupant self-evacuated from the home and was treated and released from a local hospital. The house was located between CSXT's right-of-way and the shoreline of Kanawha River, at the confluence of Armstrong Creek. A second injury was recorded due to a resident's loss of power. The resident was not in the mandatory evacuation area. Emergency workers checked on the resident the next day and found her unresponsive. She was transported to the hospital and treated for hypothermia.

Environmental Impact

Over the course of the incident, an estimated 362,300 gallons of crude oil were released from 20 tank cars. CSXT estimates that 293,348 gallons of crude oil burned off into the atmosphere, and 78,879 gallons of crude oil burned in pool fires or seeped into the ground. The remainder of the oil was recovered and removed.

Figure 2: Tank cars that derailed.

While much of the spill was limited to the accident site, crude oil was detected in Armstrong Creek and the Kanawha River.

Approximately one hour after the derailment, at 2:30 p.m., West Virginia American Water treatment intakes were closed at Montgomery, West Virginia, as a precautionary measure. The treatment intakes are approximately three miles west of the accident site. The West Virginia American Water system serves approximately 2,000 customers in the West Virginia communities of Montgomery, Smithers, Cannelton, London, Handley, and Hughes Creek. The company established bottled water distribution sites at the Montgomery Town Hall and Valley High School.

After three rounds of water quality testing on Tuesday, February 17, 2015 (one day after the derailment), West Virginia American Water restarted its water treatment plant and issued a precautionary boil water advisory for all Montgomery customers. Multiple water samples taken at different locations in the Kanawha River and at the treatment plant did not show abnormal readings.

Figure 6: Inspecting a tank car after the fires stopped burning.

Environmental responders took steps to mitigate the environmental impact of the accident. A week after the derailment on Wednesday, February 18, 2015, responders created a containment trench at the accident site and installed a boom on the river. By vacuuming, the responders removed approximately 5,000 gallons of a crude oil-and-water mix trapped by ice. Additional vacuuming was used to collect crude oil that had pooled on the ground.

Local fire officials also allowed the ignited cars to burn out rather than introduce additional run off to the river.

On Thursday, February 19, 2015, responders pumped the remaining crude oil from tank cars into highway tankers. On Monday, February 23, 2015, a CSXT contractor installed 280 feet of sheet piling along the shoreline of the Kanawha River in the accident area to further contain the oil and facilitate reclamation work (*See Appendix A–Environmental Impact*).

Note: West Virginia Department of Environmental Protection and the U.S. Environmental Protection Agency were the lead agencies for environment and water for this incident.

<u>Estimated Damage Cost</u>

CSXT estimated the total cost for the accident to be at least $23 million. This estimate does not include economic damages and loss of economic activity to the community. Damage estimates included:

- Track (725 ft. of Track No. 2; 523 ft. of Track No. 1 destroyed) - **$199,832**
- Equipment damage (27 tank cars) - **$2.5M**
- Environmental remediation (as of 5/12/15) - **$20.9M**

Rebuilding, Reopening, and Returning

Law enforcement officials lifted the evacuation order on the fourth day following the derailment, allowing residents to return to their homes while CSXT crews continued to work at the site. West Virginia State Route 61, which had been closed due to the fire, was reopened at 5 p.m. on Thursday, February 19, 2015. CSXT and its contractors completed clean-up work and installation of new track on February 25, 2015. Ten days after the derailment on February 26, 2015, rail service on the line was restored and the first train traveled through the accident site.

Figure 7: Re-railing tank cars.

FRA INVESTIGATION

Investigation Team

FRA led an investigative team that included representatives from 10 organizations. The team participated in the on-scene investigation and post-accident testing.

The on-scene accident investigation team included experts from each of FRA's railroad safety disciplines: Operating Practices, Hazardous Materials, Signal & Train Control, Motive Power & Equipment, and Track. In accordance with FRA's accident investigation procedures, the team focused on identifying, recovering, and examining materials and gathering other information necessary to determine the primary cause of the accident, as well as identifying other defects or actions that may have contributed to the cause or severity of the accident.

The post-accident testing team included hazardous materials, track, and mechanical experts from both inside and outside FRA. These experts conducted in-depth analysis of all materials involved in the accident, including the track, tank cars, and the crude oil.

The following portion of the report outlines the process, results, and conclusions for the derailment sequence and each of the five safety disciplines FRA investigated. Each section begins with how and where FRA gathered information and follows with a detailed explanation of what FRA uncovered. At the end of each portion, a brief summary of the findings and whether the cause of the accident, or a contributing factor, was determined.

Table 1 – Accident Investigation Teams[4]

ORGANIZATION	POSITION
FRA	Region 2 Administrator
FRA	Region 2 Deputy Administrator
FRA	Inspector in Charge
FRA	Track Inspector
FRA	Track Inspector
FRA	Hazardous Material Inspector
FRA	Hazardous Material Inspector
FRA	Hazardous Material Inspector
WV – DOT	Hazardous Material Inspector
FRA	Signal and Train Control Inspector

[4] For further explanation of acronyms and shortened terms, see the List of Acronyms and Shortened Terms at the end of the report.

FRA	Motive Power and Equipment Inspector
FRA	Motive Power and Equipment Inspector
FRA	Motive Power and Equipment Inspector
FRA	Operating Practices Inspector
WV – DOT	State Rail Program Manager
PHMSA	Hazardous Material Specialist
PHMSA	Hazardous Material Specialist
FRA	Track Specialist – Rail Reconstruction
FRA	Tank Car Specialist – Car Reconstruction/inspection
FRA	Director Rail Integrity Division – Rail Reconstruction
FRA	Tank Car Quality Assurance Specialist
FRA	Research and Development Specialist
FRA	Hazardous Material Inspector
NTSB	Hazardous Material Accident Investigator
TSB Canada	Material Analysis and Structures
GATX	Mechanical Engineer
Trinity Rail	Mechanical Engineer
ESI for RSI/AAR	Principal Engineer
CSXT	Hazardous Material Specialist
PHMSA	Enforcement Officer
PHMSA	Engineer
ARI	Vice President of Engineering

CSXT TRAIN K08014 OPERATIONS

CSXT Train K08014 originated in Manitou, North Dakota, on Thursday, February 12, 2015, bound for the Plains Marketing (former Amoco) bulk terminal in Yorktown, Virginia. At the time of departure from North Dakota, Train K08014 consisted of two engines, two buffer cars[5] (located on each end), and 104 tank cars loaded with crude oil from the Bakken shale deposits of North Dakota (UN1267, Petroleum Crude Oil, Class 3, Packing Group I). Three tank cars loaded with crude oil were subsequently added to the lead (head) end of the train in Hamler, Ohio, on Sunday, February 15, 2015.

The operating crewmembers on board Train K08014 at the time of the accident went on duty at 7:30 a.m., Monday, February 16, 2015 at Russell, Kentucky (their home terminal for hours of service[6] purposes) and took possession of the train from the inbound crew. The train crew consisted of an engineer and a conductor and was not scheduled to pick up or set out any tank cars during this trip.

Derailment Sequence

FRA derived the following derailment sequence from interviews with the crew and other witnesses, and a review of external rail-side detection equipment (referred to as "wayside detectors"), internal "event recorders," and cameras.

The onboard event recorder indicated that Train K08014 was operating with the throttle in the #8 position (full power) for 2 minutes and 53 seconds and travelling at 33 mph as the train approached the accident site.

After the lead end of the train passed Milepost CA-424.44 (later identified as the point of derailment), the train travelled approximately 573 feet[7] farther down the track when the trailing end of the car derailed, likely at position seven.[8] A total of 27 tank cars, located at positions 2 through 28, derailed in the incident. At the moment of the derailment, the two engines and lead buffer car uncoupled from the trailing tank cars, which caused the emergency brakes to automatically engage at Milepost CA-424.31. The two engines and lead buffer car traveled approximately 636 feet in 27 seconds before coming to a complete stop at Milepost CA-424.19.

Twenty of the 27 derailed tank cars were significantly damaged in the accident:

- Two tank cars had mechanical tears/punctures causing crude oil to be released.
- Three tank cars' bottom outlet valves nozzles were sheared off, causing one tank car to release crude oil.
- Two tank cars experienced minimal leakage.
- Thirteen tank cars developed thermal tears (rips caused by pool fire/expanding gases).

---

[5] Buffer cars are rail cars that do not carry hazardous material and that are placed at both ends of a series of cars that do carry hazardous material (e.g., crude oil), to insulate engines and other cars from the potential effects of an accident involving a car carrying hazardous material.

[6] See Title 49 U.S.C § 21103.

[7] FRA determined the point of derailment (POD) to be at Milepost CA424.44, which was at the 1-degree 30-minute middle segment of a compound curve (2-degree 15-minute east end and 2-degree 15-minute west end). The lead 42 percent of the train was on an average 0.10-percent descending grade, the middle 35 percent was level, and rear 22 percent was on an average 0.10-percent ascending grade.

[8] For car position No. 7, the final resting position, indications of severe dragging, anchoring effect, and reaction of the trailing cars indicate it was likely the first car to derail.

At 3 a.m. the following day, Tuesday, February 17, 2015, CSXT pulled the unaffected tank cars in positions 30 through 109 clear of the accident site to the west.

The following table lists the likely sequence of events at the time of the derailment:

Table 2 – Derailment Sequence

Sequence	Event
1. (1:15:27 p.m.)	**Milepost CA-424.44:** Lead end of train passed over soon-to-be POD.
2. (1:15:37 p.m.)	Lead end at **Milepost CA-425.34:** Derailment likely occurs at car seven (Milepost CA-424.44). Derailed equipment traveled approximately 200 feet east to a stop, forming an “anchor” to the cars ahead.
3.	Cars two through six rolled to the side during extreme train axial tension build-up in curve (forcing cars into a tangent).
4.	The two engines and lead (buffer) car uncoupled from the remaining tank cars and traveled an additional 112 feet (approximate).
5. (1:15:41 p.m.)	The lead end of the train, at **Milepost CA-424.31**, experienced an automatic emergency brake application, and then traveled 636 feet farther.
6.	The remaining portion of the train (96 cars), weighing approximately 12,768 tons, continued moving forward due to the normal delay in the conventional air brake system. This compressed cars in positions 8 through 28 (originally arranged linearly along a distance of 1,239 feet) into a 419-foot expanse in an accordion-style pile-up.
7. (1:16:08 p.m.)	**Milepost CA-424.19** - initial stop point of the lead end. At this point the conductor left the locomotives to view the trailing cars. He returned to the lead locomotive and told the engineer that the train was on fire.
8. (1:24:32 p.m.)	The crew moved the two engines and lead (buffer) car approximately 390 feet east.
9. (1:25:42 p.m.)	Crew stopped the two engines and lead car for approximately 30 minutes.
10. (1:55:01 p.m.)	Crew made final movement east 607 feet.
11. (1:57:57 p.m.)	**Milepost CA-424.00:** Crew’s final stop approximately 1,000 feet east of their initial stop.

Operating Practices Systems Investigation and Assessment

The operating practices investigators reviewed CSXT's bulletins, job briefs, and dispatcher reports; conducted interviews of the crew and witnesses; reviewed reports from external rail-side detectors, internal cameras, and event recorders; and inspected the accident site.

At the accident site, there were two railroad tracks, one on the north and one on the south, numbered No. 1 and No. 2. Minutes before Train K08014 derailed it passed Train E51215, a westbound empty coal train traveled on (north) No. 1 Track. FRA reviewed the head-end videos of Trains K08014 and E51215. The videos did not record or indicate any irregular details.

Prior to the derailment, Train K08014's crew operated on a 30-mph permanent speed restriction that ended at Milepost CA-426.9. After clearing the speed restriction in Montgomery, West Virginia, the train's event recorder documented the train's throttle moved from position #7 to position #8. The train's throttle was in position #8 for 2 minutes and 53 seconds when the automatic emergency brake application occurred at Milepost CA-424.31. When the brakes applied, the train's engines were moving at 33 mph.

At the time of the derailment, the train was operating in a right-hand compound curve (sometimes referred to as an S-curve). At the end of the curve (Milepost CA-424.44), the rail on the low side (inside) of the curve failed, and the rail cars stopped abruptly and piled up.

At the time of the derailment, the first one-third of the train was on a slight descending grade, the middle third of the train was level, and the rear third of the train was on a slight ascending grade (*See Appendix B – Physical Characteristics).*

Table 3 – Train Relation to Grade

Relation of Train (15,261 Tons) to Grade			
Train Portion	Front	Middle	Rear
Type and percent of grade (average)	Descending -0.10	Level	Ascending +0.10 (compensated 0.04 per degree = +0.158)
Miles of train length	0.54	0.45	0.28
Percent of train length	42.5	35.4	22.0
Weight (tons)	6,485	5,402	3,357

Train Crew: The train crew consisted of an engineer and a conductor. Both received their statutory rest period under the hours of service laws prior to reporting for duty. Once on duty, the crew participated in a job briefing during which they reviewed the speed restrictions for the trip, the train profile, and the hazardous materials documentation for the train. The train crew performed a Class III (or continuity) brake test and reported departing Russell, Kentucky, at 9:20 a.m. on Monday, February 16, 2015.

FRA reviewed the train crew's hours of service, certification, training, and testing and found the crew to be in compliance with FRA regulations.

Toxicology: The crew of Train K08014 submitted to post-accident drug and alcohol testing. Both the engineer and the conductor tested negative.

Fatigue: FRA evaluated the train crew for potential fatigue issues by reviewing the crew's previous 10-day work history. FRA concluded that engineer or conductor fatigue was not a cause of the derailment.

Table 4 – Train Crew Information

	Engineer	Conductor
On-duty time	7:30 a.m.	7:30 a.m.
Prior off-duty period	44 hours, 10 minutes	56 hours, 51 minutes
Years of service	9 years	34 years
Certification	December 31, 2013	December 31, 2012
Book of rules	March 17, 2014	February 19, 2014
Toxicology test	Yes - Negative	Yes - Negative

***FRA's Assessment of Operating Practices Systems*: Based on its review of event recorder data, required train movement paperwork, and interviews, FRA determined that there were no train handling issues before or during the derailment of Train K08014. The crew was qualified and rested at the time of the accident.**

Motive Power and Equipment Systems Investigation and Assessment

FRA reviewed a variety of records from throughout the train's journey, including: car movement records, Automatic Equipment Identification printouts, repair history records, Class I brake test records, and all equipment detector information available.

Equipment: FRA performed a detailed mechanical investigation to identify or discover any non-compliant conditions that may have contributed to or caused the derailment. FRA thoroughly inspected and checked all equipment for any identifiable non-compliant condition or evidence that may have contributed to the derailment.

Train K08014 consisted of two head-end engines, one head-end buffer car, and one rear-end buffer car (each stenciled "Buffer Service Only"), and 107 tank cars. The train was 6,575 feet in length and weighed 14,847 trailing tons.

The lead engine, CREX No. 1349, was a six-axle, two-truck design, 4,400 horsepower, General Electric (GE) model ES44AC locomotive, built in 2013, equipped with CCB2 type air brake equipment, and weighed 207 tons. BNSF Railway performed the last periodic inspection on December 12, 2014, in Kansas City, Kansas. The previous required 33-day mechanical calendar day inspection recorded was on January 17, 2015, in Minot, North Dakota. The last calendar day inspection recorded on the engine (on-board record) was February 15, 2015, at Fostoria, Ohio. FRA found no regulatory deficiencies.

The trailing engine, CSXT No. 5243, was a six-axle, two-truck design, 4,000 horsepower GE model ES40DC locomotive. It was built in 2005, equipped with CCB2 type air brakes, and weighed 207 tons. Its last periodic inspection was performed on October 23, 2014, in Waycross, Georgia. The previous required 33-day mechanical calendar day inspection was recorded February 13, 2015, and the last calendar day inspection recorded on the engine (on-board record) was February 15, 2015, at Fostoria, Ohio. FRA found no regulatory deficiencies.

The head-end buffer car, BNSF Railway Company (BNSF) 808704, was a covered hopper car loaded with sand. It was positioned between the first tank car and the trailing engine. The train did not contain distributed power (mid-train remote engines) or rear-end helpers.

The train originated at Manitou, North Dakota, with 104 loaded tank cars. CSXT listed the train on its extended haul train list (Line 581 on the February 20, 2015, CSXT Extended Haul List Revision) for testing and inspection purposes. On Sunday, February 15, 2015, CSXT added three loaded tank cars to the head-end of the train at Hamler, Ohio, before it continued to Columbus, Ohio.

All 107 tanks cars were DOT-111 (AAR CPC-1232 industry type cars) tank cars with modifications. These modifications included half-height head shields, bottom skid plates, and dome protection. All tank cars were non-jacketed and non-insulated. These cars are typically referred to as non-jacketed or unjacketed 1232s.

The main pile-up of 19 tank cars involved cars in positions 7 through 25 of the train. These cars sustained most of the fire damage. Three of the tank cars (positions 26 through 28) derailed upright and stood at different angles across the track. Investigators tested the brakes of the rear 79 cars in positions 30 through 109. No mechanical regulatory deficiencies were noted regarding these cars.

Review of Records: FRA reviewed the information and records from wayside detectors throughout the routes traveled by Train K08014. The detector information FRA reviewed included wheel bearing temperature trending, wheel impact readings, truck hunting index readings, wheel profile data, wheel bearing acoustic data, and car weight readings. The review included the detector information from September 2014 to the date of the accident. FRA did not find any regulatory deficiencies. The mechanical condition of the engines did not contribute to this accident.

Accident Reconstruction: Upon collection of wheels, trucks, and associated components, CSXT transported equipment to Handley Yard in Handley, West Virginia, for further analysis and inspection. An extensive review and series of inspections occurred at Handley Yard, with FRA inspecting tank car components including wheels, axles, and truck assemblies.

The reconstruction of the accident indicates that as Train K08014 passed over Milepost CA-424.44 the tank car in position seven likely derailed, continued east for approximately 3.5 car lengths (approximately 200 feet), and "anchored" to a stop. Consequently, the tank cars in positions two through six derailed due to a "string-line" condition[9] and rolled over. The rail car in position one uncoupled from the car in position two, which caused the train's brakes to apply automatically.

While FRA identified broken wheels and other mechanical issues as collateral impact damage, FRA found no relevant regulatory deficiencies.

Brake System Evaluation: When FRA reviewed the brake system records, FRA found that CSXT did not comply with the requirements listed in 49 CFR§ 232.213(a)(5)(i), which reads in part:

Cars added to the train en route shall be inspected pursuant to the requirements contained in paragraphs (a)(2) through (a)(5) of this section at the location where they are added to the train.

Although qualified mechanical inspectors performed the required freight car mechanical inspection in Hamler, Ohio, they did not comply with the requirements for a Class I brake test on the three cars added in Hamler, Ohio. FRA provided an inspection report documenting the exception taken to this "failure to inspect." While this was a "failure to inspect," it did not cause the accident.

Train K08014 had a conventional train-line brake system. This conventional system uses train-line air pressure to transmit brake signals to the brake valves (to apply or release the brakes) as well as charges the air reservoirs on each car. When a full service or emergency brake

[9] String-line derailment is caused when the trailing end of a line of rail cars becomes anchored in a curve while the lead cars continue forward. When the slack between the moving and anchored cars is expended, the rail cars often snap to the inside of the curve and derail.

application is made, the valve on each car directs the pressure from the reservoir of each car to the brake cylinders sequentially, from car-to-car along the train.

Electronically Controlled Pneumatic (ECP) Brakes: In this accident, it took several seconds for all brakes in the train to activate. This delay allowed the continued movement of the tank cars to pile-up into the accident site before all energy was dissipated and the cars fully stopped.

Beginning on January 1, 2021, trains with more than 70 tank cars of crude oil will be required to employ Electronically Controlled Pneumatic (ECP) brakes.[10] ECP brakes use an electronic train line signal to activate air-powered brakes on all cars throughout the train at the same time. Applying the brakes uniformly and instantaneously provides better train control, shortens the stopping distances, and leads to a lower risk and reduced severity of a derailment and therefore fewer cars will become part of the pile-up.

The Federal Railroad Administration and Sharma & Associates performed an initial analysis of the dynamics encountered by Train K08014. This analysis focused on the potential benefits of ECP brakes. The analysis concluded that it is likely two fewer cars in the train consist would have been involved in the equipment pile-up had the tank cars been ECP-brake-equipped, thus reducing the wreckage and mitigating the impacts of the accident.

<u>FRA Motive Power and Equipment Systems Assessment</u>**: After completing all inspections and reviewing the available documentation, no items were identified that would be considered a mechanical or equipment cause or contributing factor to the derailment of Train K08014** *(See Appendix C – Car Damage).*

[10] FRA regulations at 49 CFR § 232.5 define "ECP brake system" as a train power braking system actuated by compressed air and controlled by electronic signals from the locomotive or an ECP-EOT [end-of-train device] to the cars in the consist for service and emergency applications in which the brake pipe is used to provide a constant supply of compressed air to the reservoirs on each car but does not convey braking signals to the car. ECP brake systems include dual mode and stand-alone ECP brake systems.

Hazardous Materials Systems Investigation and Assessment

FRA reviewed a variety of records, including original work orders, emergency response information, shipping documents, and bills of lading provided by the crude oil shipper. The agency also performed a chemical analysis of the product.

Hazardous Materials Information Investigation: FRA investigators reviewed the original work order for Train K08014 and all applicable train documents on the description of the tank cars, their standing order in the train, and the emergency response information. From this review, investigators found no regulatory deficiencies.

Tank Car Damage Investigation: FRA conducted an inspection and damage assessment on the 27 tank cars that derailed. The assessment found the tanks cars involved were in dedicated crude oil service, and in "like new" condition. Each of the cars had half-height head shields, enhanced bottom outlet valve skid plates, and top fittings protection. None of the cars had thermal protection or jacketing.

The inspection found 13 cars with thermal tears, two mechanical tears (one unknown cause, one coupler impact confirmed by FRA during re-railing), three bottom outlet valve failures (two partially open, one seat damage due to fire), and two dislodged liquid line valves (pushed upward); the remaining seven derailed tank cars had no structural tank damage.

Tank cars CTCX 743030 (position 16) and CTCX 742778 (position 19) sustained mechanical tears, released crude oil, and caught fire. The coupler from car CBTX 741431 (position 18) impacted and punctured the right side of car CTCX 743030 (position 16). The entire contents of the cars released and ignited, creating a large fire. On car CTCX 742778 (position 19), there were two breach locations. The first and larger breach location was in the center of the right side, and was the result of unknown impact; the second was on the B-end from an apparent coupler impact. The car released approximately 21,223 gallons of crude oil that ignited, creating a large fire. An estimated 8,300 gallons remained in the car and was trans-loaded.

Tank cars GATX 286241 (position 7) and GATX 286274 (position 11) both had bottom outlet valve handles sheared off. In these two cases, the valves were opened slightly. This allowed approximately 29,773 gallons of product to spill, 8,490 gallons from GATX 286241 (position 7), and 21,283 gallons from GATX 286274 (position 11). Impact damage to the flange area of the bottom outlet valve on Car GATX 286233 (position 5) resulted in the valve seat shifting and a minimal amount of product loss. In all, there were three bottom outlet valve failures.

Tank cars CBTX 741926 (position 13) and CBTX 741702 (position 15) had their flange bolts sheared off the liquid line valves, resulting in the release of approximately 20,866 gallons. In addition, car CBTX 741926 (position 13) suffered a thermal tear. FRA identified and marked three cars to have sections of the rail car tanks removed (these cut-away sections are referred to as "coupons") for metallurgical testing, with two whole cars scheduled for side impact testing at the Transportation Technology Center in Pueblo, Colorado.

American Railcar Industries, Inc., built the entire consist of tank cars involved. All cars were built after 2011 to a CPC-1232 standard[11] and the DOT111A100W1 standard. However, some were marked as a DOT111S100W1 industry standard, a standard DOT does not recognize.[12]

On March 3, 2015, representatives from several government agencies (National Transportation Safety Board, Pipeline and Hazardous Materials Safety Administration, Canada's Transportation Safety Board, and FRA) and industry (General American Tank Car, Trinity Rail Car, American Railcar Industries, and CSXT) participated in a damage assessment of the derailment.

Crude Oil Shipment Investigation: The investigation team reviewed shipping documents and bills of lading provided by the crude oil shipper and performed a chemical analysis of the product. The inspection included cars that were not involved in the derailment to verify the proper securement of closures.

FRA concluded that the shipper properly classified the material, selected the proper package, and properly prepared the shipments for rail transportation. Shipper functions had no bearing on the outcome of this derailment.

Train Shipment Documents Investigation: After reviewing the train manifest documents in detail, FRA determined that CSXT complied with the Hazardous Materials Regulations regarding shipping documentation, hazardous materials description, and train placement. FRA determined the carrier's documentation was in compliance, did not cause the derailment or aggravate its effects, and had no negative effect on the emergency response.

Table 5 – Train K08014 Manifest (or "Consist")

Train K08014 Manifest	
Train length	6,575 feet trailing length (plus engines = 6,721 feet, or 1.27 miles)
Tons	14,847 trailing tons (plus engines = 15,261 tons)
Axles	436 (plus engines = 448)
Engines	Lead CREX 1349, GE Model ES44AC, 207 tons, length 73 feet Trailing CSXT 5243, GE Model ES40DC, 207 tons, length 73 feet
Buffer car at each end of the revenue consist	BNSF covered hoppers with sand load, lead car BNSF 808704 (rear 808455) covered hopper, 117 tons, length 73 feet each
Revenue	107 tank cars (mix of CBTX, GATX, and CTCX) approximately 3.1

[11] CPC stands for Casualty Prevention Circular. The Association of American Railroads issued Circular letter CPC-1232 which specifies new rail tank cars standards for transporting crude oil or ethanol. As of October 10, 2011, new tank cars built for transporting crude oil and ethanol comply with these new specifications: Half-Height Head Shields; Thicker tank and head material; Normalized steel; Top fitting protection; Pressure Relief Device.

[12] The DOT111S100W1 standard meets the DOT111A100W specification but indicates that the tank car is equipped with a head shield.

consist	million gallons, all cars CPC 1232, average gross vehicle weight 133 tons (266,000 lb. axle load), length 59 feet each

***<u>FRA's Hazardous Materials System Assessment</u>*: FRA concluded that although the tank cars received severe damage, including thermal and mechanical tears, none of these cars' conditions contributed to the cause of this accident. Rather, the tank damage was a secondary occurrence because of the accident. All tank cars were properly classed, billed, and marked as containing Petroleum Crude Oil, UN 1267, Class 3, Packing Group I** (*See Appendix C - Car Damage).*

Signal & Train Control Systems Investigation and Assessment

FRA inspected and tested the railroad's signal system west of the derailment site.

On the section of track where the derailment occurred, the method of operation on both the No. 1 and No. 2 Tracks was "traffic control with wayside signals." Both tracks had automatic block signals to support operation in either direction. However, predominate traffic flow was eastbound on No. 2 Track and westbound on No. 1 Track. While this route is designated for future implementation of a Positive Train Control (PTC) system, the circumstances of this accident indicate it was not PTC-preventable.

On February 26, 2015, an FRA representative (with CSXT signal personnel present) conducted a field inspection, testing, and investigation of the railroad signal system in the immediate area west of the derailment site. These tests included operational testing of the last control point (CP) passed by Train K08014 prior to the derailment, CP Eagle at Milepost CA-425.5. The post-accident inspection found the signal cases locked and secured with no indications of tampering or vandalism to any of the signal equipment at CP Eagle. Operational testing of the signal system indicated that it was operating properly, as intended, and in accordance with Federal railroad safety regulations.

On February 27, 2015, an FRA representative conducted a review, inspection, and analysis of the required periodic signal system test records, GE ElectroLogIXS event recorder downloads, two Defect/Hot Box Detector (DD) downloads, and the Dispatch Control Operator logs. This review, inspection, and analysis revealed the signal systems, event recorder, and DDs were operating properly. Detailed review of the two DDs' event logs in eastward movement sequence for Train K08014 revealed the following:

- East Bank DD, Milepost CA-436.6, no defects reported with proper direction, and axle count recorded. This indicates the DD was functioning as intended.
- Owens DD, Milepost CA-450.0, no defects reported with proper direction, and axle count recorded. This indicates the DD was functioning as intended.

Thorough inspection and testing of the signal system, and inspection of pre-derailment test records revealed the signal system to be operating properly. FRA found no defects with the signal equipment.

***Signal and Train Control Systems Assessment*: FRA determined that the signal system was not a contributing factor in this derailment.**

Track Systems Investigation and Assessment

FRA reviewed a variety of records that included track inspection reports and rail inspection data, interviewed the Sperry Rail Service operator that conducted two internal rail flaw tests, and recovered and reconstructed rail from the accident site.

CSXT's maximum authorized speed for both tracks at the accident site were 50 mph for freight trains and 65 mph for passenger trains. These speed limits comply with FRA's Track Safety Standards (49 CFR Part 213): freight trains, 41 mph to 60 mph; passenger trains, 61 mph to 80 mph. *See also* 49 CFR § 213.9, Classes of track.

As noted previously, the derailment occurred on the No. 2 Track at Milepost CA-424.44. Track structure in the area of the derailment consisted of wood crossties (spaced 20 inches on center nominal), double shoulder tie plates, cut spikes, and continuous welded rail (box anchored every other tie). Box anchoring consisted of rail anchors on the base of each rail at a tie (four anchors). Averages of 22 crossties per 39 feet of track were noted.

At the derailment location, the rail was classified as 136-lb. American Railway Engineering Association (RE) cross section design[13] (*See Appendix D - Rail Section Design*). No defective crossties appeared in the undisturbed portion of the track near the accident site. The rail-fastening devices to the crossties included double shoulder tie plates secured with cut spikes. Rail anchors were "snap on" style, attached to the rails in a uniform fashion to prevent longitudinal (axial) rail movement.

Investigation and Assessment of FRA's and CSXT's Track Geometry Car Inspections

The most recent CSXT automated geometry car inspection on No. 2 Track occurred on May 9, 2014. FRA's most recent Automated Track [geometry] Inspection Program (ATIP) inspection of the No. 2 Track occurred on April 5, 2011. Neither run identified any deficiencies in the derailment area.

On February 19, 2015, investigators took track geometry measurements at undisturbed track locations leading into and out of the accident site and any undisturbed track within the accident site. Investigators took measurements at 15 "stations" at intervals of 15.5 feet apart. Measurements included lateral and vertical movement, under-loaded and unloaded conditions.

- Track gage: FRA found no regulatory deficiencies.
- Cross level: FRA found no regulatory deficiencies.
- Alignment: FRA found no regulatory deficiencies.
- Maximum allowable curving speed: FRA found no regulatory deficiencies.

To reconstruct the track geometry of disturbed track at the time of derailment, FRA used CSXT historical geometry car data (from an inspection by CSXT's contractor that occurred on October 20, 2014) to calculate the maximum allowable curving speed. Then, using FRA's V-max formula

[13] Bethlehem Steel Corporation (BSCO) in Steelton, Pennsylvania, had manufactured the rail at the accident site in March 1994. The rail branding marks showed "136 10 CC Beth Steelton 1994 III." The "136" indicates the weight in pounds every three feet, the "10" is the tread to the corner of the rail radius in inches, the "CC" is "controlled cooled," and "III" indicates the month of March. "Controlled cooling" is hydrogen gas elimination from the steel by gradual reduction to ambient temperature after the rail rolling process.

(where a one degree 30 minute curve with two inches elevation is acceptable for speeds up to 69 mph with 3 inches of unbalance) for calculating adequate track geometry. FRA found no geometry defects in this curve or the accident site. *See* 49 CFR § 213.57.

Investigation of CSXT's Visual Track Inspection History: Following the accident, FRA conducted an audit of CSXT's track inspection records for the portions of track at or near the accident site. FRA reviewed records for the period from December 1, 2014, to February 13, 2015. The FRA Track Safety Standards require a visual inspection of the track in the New River Subdivision to occur twice weekly with a one calendar day interval between inspections. *See* 49 CFR § 213.233. FRA found no regulatory deficiencies regarding the inspection frequency.

CSXT's inspectors recorded two track defects previously identified between Milepost CA-424.0 and Milepost CA-425.0. These defects consisted of two joint bolt defects. CSXT properly remediated the defects upon discovery. FRA determined that those repaired defects did not contribute to the cause of this accident.

The two most recent visual high-rail CSXT inspections on the New River Subdivision immediately leading up to the derailment occurred on Monday, February 9, 2015, for the No. 2 Track, and on Friday, February 13, 2015, for the No. 1 Track. These inspections were compliant with the inspection frequency required under 49 CFR § 213.233.

On February 9, 2015, FRA conducted a visual inspection of No. 2 Track where the accident occurred (accompanying CSXT employees) and found no regulatory deficiencies there.

Nearly a year earlier, however, on May 21, 2014, an FRA inspector inspected this same section of track and identified a 48-inch long rail flaw (vertical split head condition) with an 8-inch piece of track broken out on the field side of the railhead at Milepost CA-424.45. The defect was discovered within 70 feet of the derailment site. This May 2014 defect was repaired as appropriate, but it provides an early indication of the potential for future vertical split head rail conditions in this section of track.

Investigation of Sperry's Internal Rail Flaw Testing: Section 213.237 of the Track Safety Standards requires that, "[i]n addition to the inspections required by § 213.233, each track owner shall conduct internal rail inspections" of certain track. For the accident location (New River Subdivision), CSXT hired Sperry Rail Service (Sperry) to conduct its rail testing to detect internal rail defects. During the year prior to the derailment, Sperry had conducted nine tests for CSXT on the No. 2 Track between Milepost CA-423.5 and CA-426.0, with a monthly cycle starting in July 2014.[14] This level of inspection exceeded the minimum required number of annual inspections under 49 CFR § 213.237.

The most recent tests occurred on December 17, 2014, and January 12, 2015. These tests included ultrasonic and induction test equipment. A comparison of these two inspections showed that during the December 17, 2014, test, Sperry's test equipment recorded indications of a rail

[14] CSXT contracts with Harsco Rail Zeta Tech Consulting to determine rail-testing cycles based on speed, accumulated tonnage, rail section, traffic type, etc.

flaw (vertical ultrasonic channel equipment response and induction test-channel responses) at what would become the point of derailment.

During the following test, on January 12, 2015, Sperry's equipment noted a similar but more significant rail flaw indication at the same location. Also during these tests, the equipment responded to a potential longitudinal type railhead flaw condition (with multiple "boxed" equipment responses).[15] The reading indicated a rail flaw condition known as vertical split head. A VSH rail defect is a progressive longitudinal fracture in the head of the rail (i.e., the upper part of a rail, used for supporting and guiding the wheels of railroad cars), where separation along an internal seam, segregation, or inclusion propagates vertically through the rail head.

The formation of a VSH defect is found predominantly in locations where the train wheel stress loads off center on the rail head. Separation progresses longitudinally and vertically along the rail length, typically for some distance before turning to the gage or field side of the rail head, and is often rapid in nature with no apparent growth pattern interruption prior to failure.

Despite multiple indications of potential internal defects that were becoming more significant, the Sperry operator failed to conduct ground visual examination and/or hand tests to verify the multiple defect indications at or near what would become the POD. Failure to verify the internal defect indications violates 49 CFR § 213.113(b), which, in conjunction with 49 CFR § 213.5(f), provides that when a track owner, or a contractor conducting a rail inspection on behalf of the track owner, learns that a rail contains "an indication" of a VSH defect, then the track owner or the contractor must verify the indication within four hours (or immediately in some circumstances).

Although the Sperry operator's test equipment recorded indications of a VSH defect during the December 17, 2014, and January 12, 2015, tests, the Sperry operator did not properly verify the indications.

Interviews with Sperry's rail flaw detector equipment operator determined that he did not conduct a ground examination or hand test to validate the multiple flaw indications identified by test equipment in the two inspections prior to the derailment. When asked why he did not stop the equipment and hand check the flaw indications, the Sperry operator stated that he looked out the window of the equipment and said the rail looked "dirty." ("Dirty" in railroad jargon refers to rough rail surface conditions, including shelling, spalling, and corrugation.)

The operator also stated that he felt the rough rail surface caused false indications. The operator also noted that if the rail had appeared unmarred, he would have rerun the test. However, without examining the rail from the ground and/or hand-testing the potentially defective areas, the Sperry operator could not determine whether the equipment response was a result of the presence of surface conditions or was a result of the presence of an internal defect.

---

[15] "'Boxed' equipment responses" means probe responses that are outlined on a display screen with a lined box.

The Track Safety Standards at 49 CFR § 213.237(j)(4)[16] state that a qualified operator interprets whether a rail flaw test is valid or not. As noted in the Sperry Rail Service CSXT Customer File Part 5.6, when the detector car identifies rail flaw anomalies that the equipment operator determines to be an invalid test, the rail should be painted florescent green, and CSXT must then obtain a valid test within the timeframe allowed under 49 CFR § 213.237 (or change the rail, or reduce the speed in accordance with CSXT Remedial Action for Defects Identified by Rail Test Vehicles, MIWI 501-013) (*See Appendix* E – Remedial Action for Defects Identified by Rail Test Vehicles). To determine an area of an invalid test, the operator must consider the guidance referenced in "Sperry Rail Service CSXT Customer File" Part 5.5 "Rail Exceptions" and Part 5.6 "Non-testable Rail Sections" (*See Appendix F - CSXT Customer File*).

The Sperry operator had 15 years of experience on this CSXT territory. He did not, however, receive the same (enhanced) training as new Sperry employees, due to "grandfathering" of his previous experience as one of Sperry's rail flaw detection equipment operators. *See* 49 CFR § 213.238(f). The operator's recent training consisted of taking an online course each year and participating in "check" rides with his supervisors. During the interview with the Sperry operator, the operator stated that Sperry did not train him on how to identify shelling, spalling, and corrugation.

During post-accident interviews, Sperry claimed that the numerous Sperry rail flaw detection "vertical" defect responses were not from a vertical split head but only a result of "noise" because of surface conditions at the point of derailment (*See Appendix H- Forensic Rail Reconstruction*).

FRA's investigation confirmed that the Sperry rail flaw detection equipment had recorded evidence of multiple VSH defects at the derailment site prior to the accident *(See Appendix G – Digital Rail Analysis)*. Furthermore, FRA believes that if Sperry's operator had a complete understanding of all indications for various rail flaw conditions (including rough rail surface conditions) and verified the flaw indications found on December 17, 2014, and January 12, 2015, the indications could have been properly identified. CSXT would have then been put on notice of the need to take required remedial action under 49 CFR § 213.113, and the accident could have been avoided.

Forensic Rail Reconstruction Investigation: From March 17 - 19, 2015, CSXT and FRA jointly conducted a forensic reconstruction of the rail from the accident site. This reconstruction occurred at CSXT's Handley Yard at Handley, West Virginia, which is located approximately six miles west of the accident site. The reconstruction team examined each of the rail fragments and successfully reassembled a 49-foot length of the low rail from the curve at Milepost CA-424.44. This length of rail included the principal specimen "C" (SC) found at the west end of car position No. 25 on February 23, 2015, at Milepost CA-424.44 during the re-railing operation.

The forensic rail reconstruction revealed that a segment of the railhead five feet two inches long broke out with a VSH two feet six inches long on the west end. Additionally, rail end batter,

---

[16] "(j) * * *(4) *Valid search* means a continuous inspection for internal rail defects where the equipment performs as intended and equipment responses are interpreted by a qualified operator as defined in § 213.238."

indicative of a wheel crossing a broken rail, was apparent on the gage corner of the receiving end of the receiving rail when the rail separated from the 5-foot 2-inch long breakout. In addition, a wheel on a tank car dropped into the gage at this point, as shown by a strike mark on a rail anchor.

Track System Assessment: On August 31, 2011, CSXT replaced only the high rail with new rail. On April 5, 2011, FRA's ATIP vehicle recorded an average gage of 56.8 inches. When the rail was changed and gaged, it repositioned the vertical wheel-load contact point on the low rail about 0.30 inches. This likely resulted in asymmetrical loading and twisting at the head/web interface. A CSXT maintenance criterion for 136 RE top (tread) wear is 5/8 (0.625) of an inch. The measured wear at the point of derailment was 19/32 (0.59375) of an inch, thus only 1/32 (0.03125) of an inch from the limit (*See Appendix D – Rail Section Design*).

In short, this track was at the end of its wear limit and in need of repair or replacement. FRA's assessment is that asymmetrical loading contributed to the flattened, worn rail that was nearly at CSXT maintenance limit.

Track Geometry: Train K08014 was in "overbalance" (leaning toward the low rail) due to a low travel speed of 33 mph, which is below the maximum authorized speed of 50 mph under CSXT's operating rules governing this track for freight trains. CSXT engineering sets the curves on the New River Subdivision to accommodate Amtrak's higher passenger train speeds. The higher track super elevation amounts prevent wheel crowding on the high rail for the passenger trains as they traverse the curve, but create an overbalance condition for the lower-speed freight trains that places a disproportionate vertical force to the low rail. Overbalance causes excessive wear and exacerbates the effects of internal rail flaws regarding the head of the rail.

Production Track Maintenance: CSXT documentation indicates that the No. 2 Track had traffic levels of 35.21 annual million gross tons (AMGT). With the high rail changed on August 31, 2011, the traffic on this rail constituted 105 or more accumulated annual million gross tons (AAMGT). CSXT changed the low rail in 1994 or 1995. (CSXT was unable to provide the exact date.)

Train K08014 was in "overbalance" (leaning toward the low rail) due to travel speed of 33 mph, which is below maximum authorized speed (50 mph for freight trains and 65 mph for passenger trains) as designated in the CSXT timetable special instructions. The low rail subsequently accumulated an estimated amount more than 668 AAMGT. Of note, CSXT track charts for the New River Subdivision show 122 CB rail in track that has more than 1 billion AAMGT. These statistics highlight that rail with extremely large number of AAMGT and that exhibits heightened rail head wear is more susceptible to developing VSH rail flaws and, therefore, deserves increased attention by rail production maintenance crews.

The last tie and surfacing cycle on the New River Subdivision occurred in 2010. The most recent rail grinding operation occurred on August 3, 2014.

Rail-Wheel Interface: The low rail wheel action causes wheel flange to pull away from low rail with opposite wheel flanging (crowding) the high rail. However, some trucks can rotate with trailing axle shifted toward the low rail. This wheel action causes asymmetric wheel loading (rocking motion of the railhead). A seam within the railhead, causing VSH, and the rocking motion likely induced the secondary head web separation. This also explains the additional VSH specimens found at the derailment site and the numerous test equipment responses indicative of vertical discontinuities recorded by Sperry's equipment (specifically, the rail test (ultrasound and induction) responses from December 17, 2014, and January 12, 2015).

Additionally, in this instance, the operator either did not understand or did not follow CSXT policies governing when rail flaw indications are recorded but cannot be verified due to rough surface rail conditions.

The forensic reconstruction of the rail occurred March 17 through 19, 2015, revealed a well-developed VSH-type rail defect. The VSH defect normally develops from a "seam" or "stringer" in the parent metal associated with impurities in the manufacturing process. The laboratory metallurgical test of the rail confirmed manganese sulfide metallurgical impurities existed (*See Appendix I – ESI Metallurgical Investigative Report*).

The presence of the "seam" or "stringer" in the railhead was a prime factor in the degradation of the rail structural integrity. Specifically, with the rail tread worn vertically 0.59375 inches, a very small amount of contiguous railhead, 0.3125 inches, remained across the tread surface. This combination caused a structural deficiency, resulting in a catastrophic failure of the rail in the form of a VSH in the small amount of remaining contiguous rail tread.

For two internal rail flaw detection tests prior to the derailment, there were indications of multiple VSHs in the curve where the derailment occurred, and specifically at the point of derailment. The Sperry operator admittedly attributed the VSH indications to rail surface condition. Since the operator thought the indications were a result of a rail head surface condition, he never stopped the car to determine if a VSH was present.

***<u>Track Systems Investigation and Assessment:</u>* FRA's forensic rail reconstruction determined that the cause of the Mount Carbon derailment was a broken rail.**

FINDINGS AND RECOMMENDATIONS

Findings

- The Mount Carbon derailment was preventable. Digital rail flaw test data records show indications of VSH defects at the point of derailment for two tests prior to the derailment (December 2014 and January 2015).
- Following the digital indications noting potential flaws, neither the operator of the rail-flaw detection equipment nor CSX performed a visual inspection or hand test of the specified track.
- The presence of a VSH in the railhead was a prime factor in the degradation of the rail structural integrity.

Recommendations for CSXT

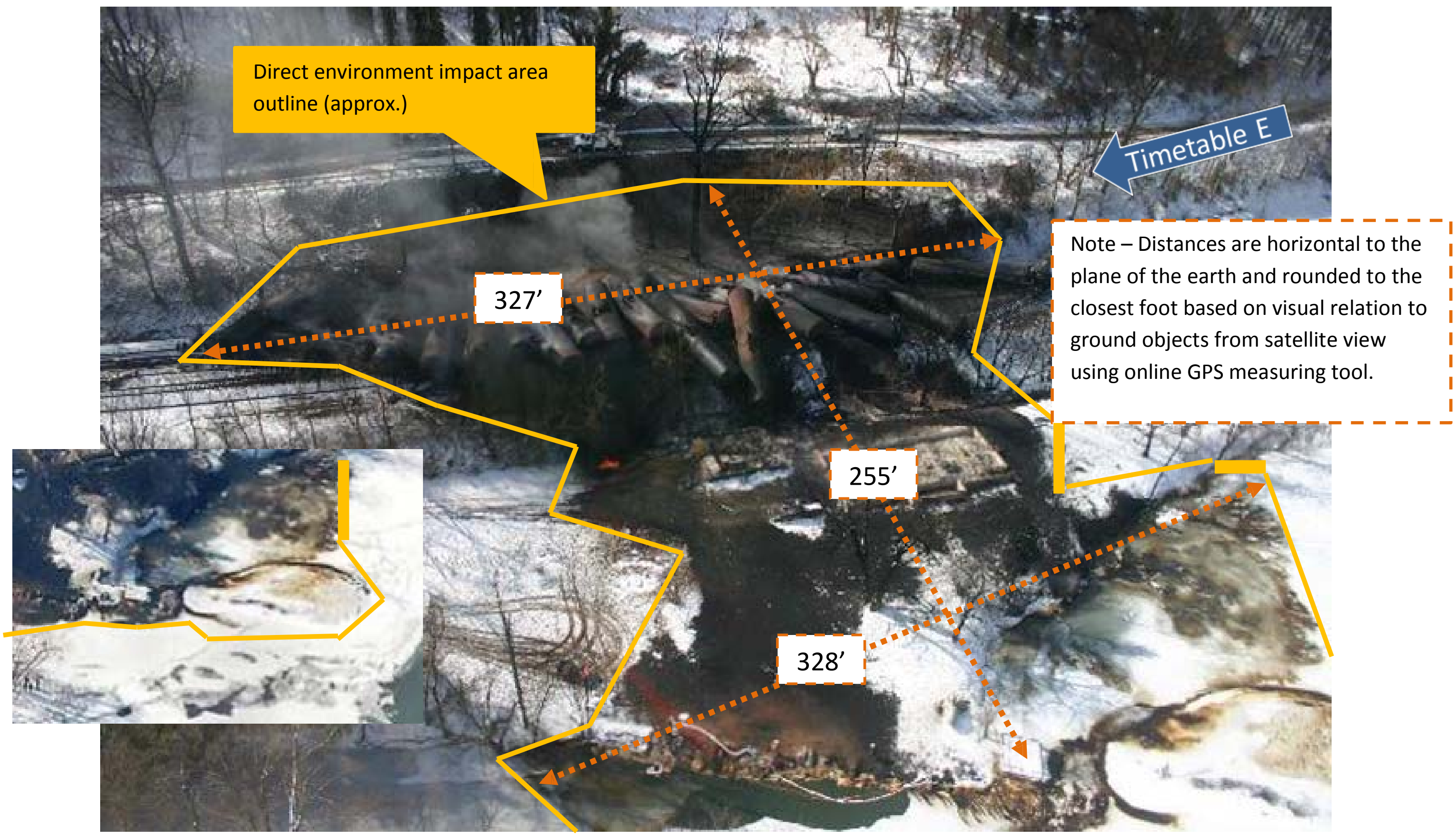
- FRA recommends CSXT routinely train operators of internal rail flaw detector cars so that they can more effectively identify and investigate non-valid testing locations and suspected rail flaws.
- FRA recommends CSXT continue to use improved technology comparing previous inspection data with data collected in real-time, increasing the likelihood of detecting rail flaws.
- FRA recommends CSXT establish a plan to identify and replace track with VSHs or similar flaws on high-hazard flammable train routes, to reduce the risk of future derailments on these high-stake corridors. The plan should be submitted to FRA for review.

Recommendations for Sperry

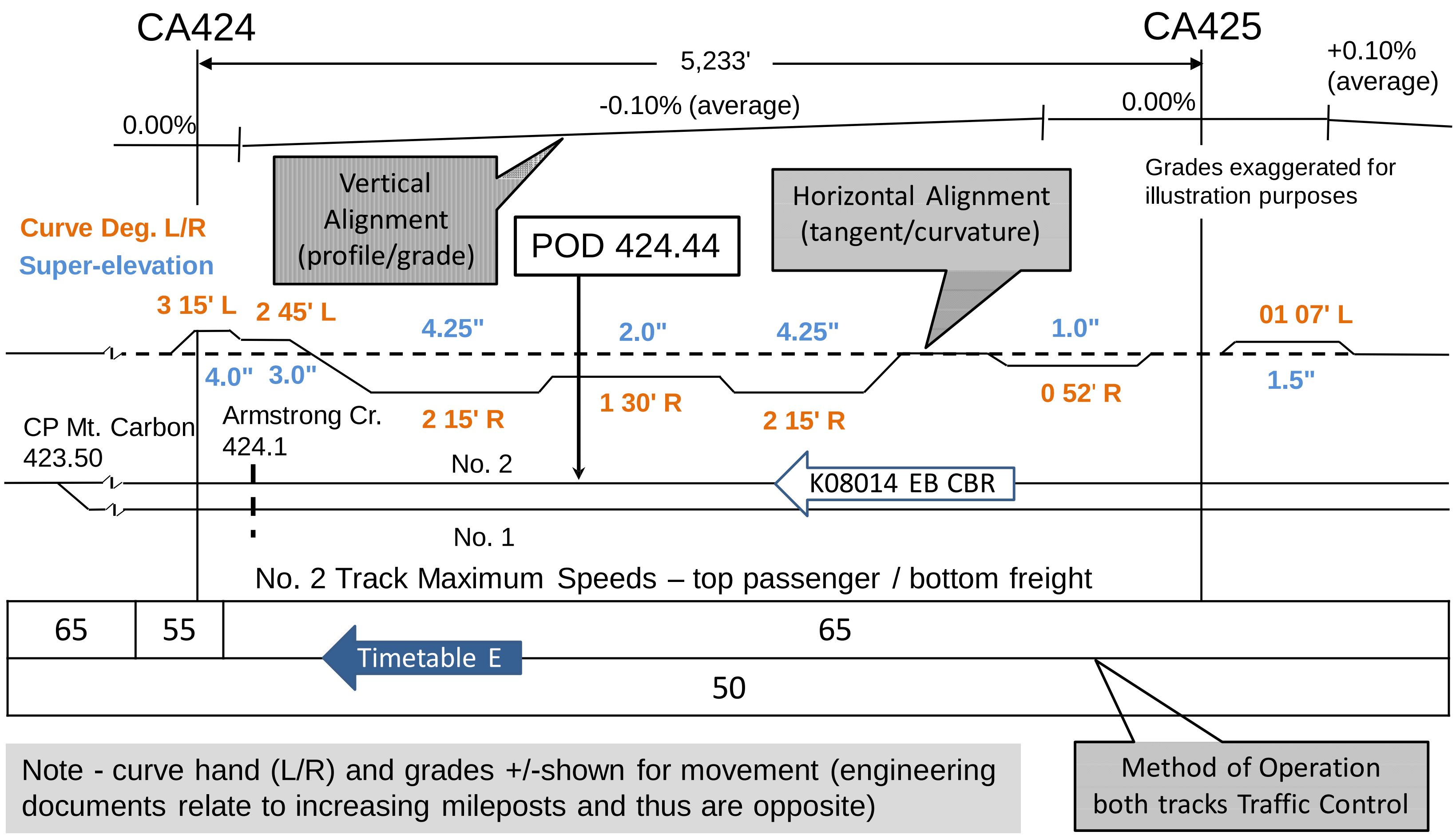
- FRA recommends Sperry routinely train all operators to more effectively identify suspected rail flaws. This routine training will reduce the risk of a test operator failing to conduct a necessary hand test after digital flaw indications are obtained.
- FRA recommends that this training include review of previous digital rail flaw tests immediately before new testing is conducted and/or real-time comparison of previous results with current, incoming data so that operators can more accurately identify areas that should be hand tested.

APPENDICES

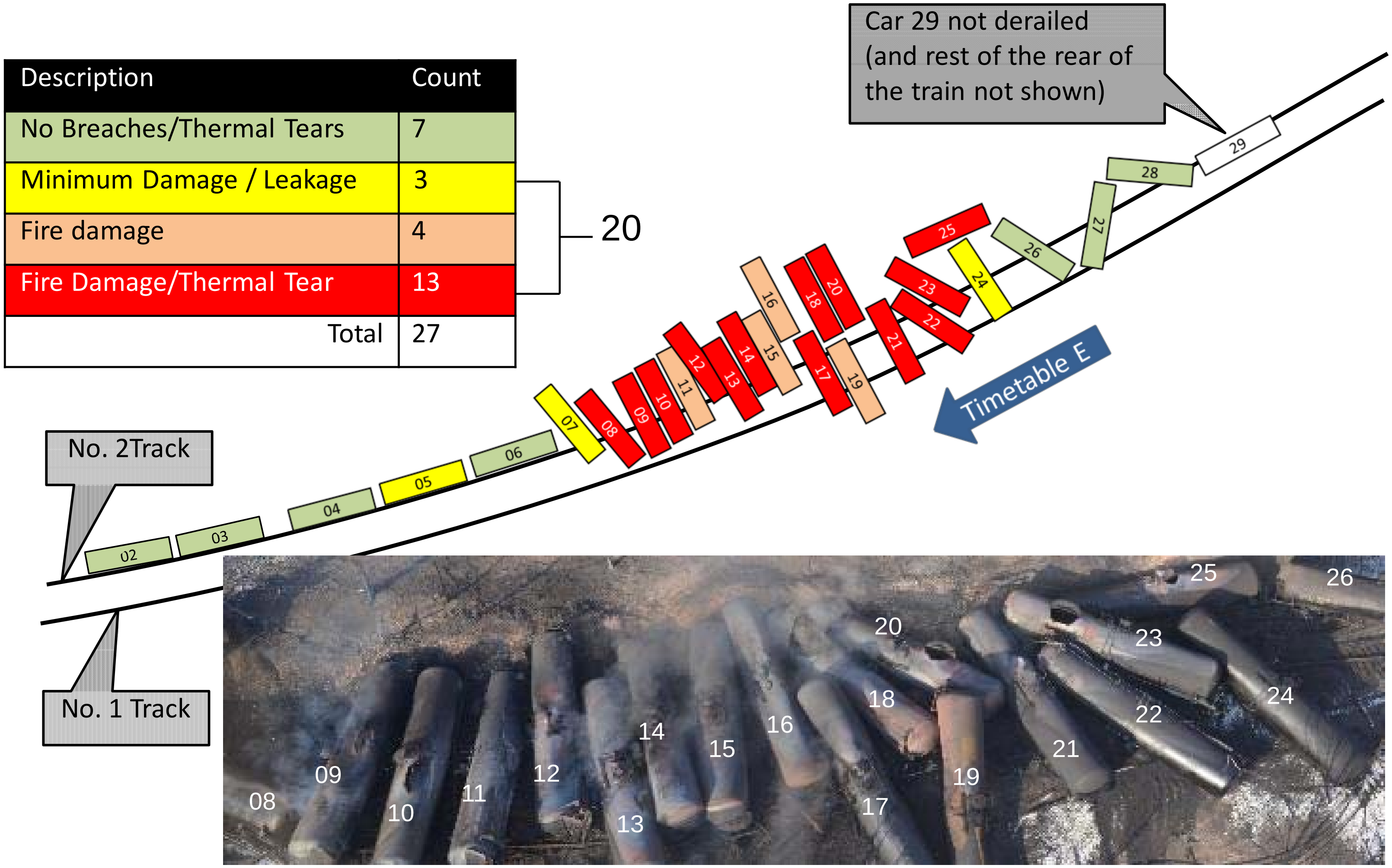
Appendix A: Environmental Impact



Appendix B: Physical Characteristics



Appendix C: Car Damage



Description	Count
No Breaches/Thermal Tears	7
Minimum Damage / Leakage	3
Fire damage	4
Fire Damage/Thermal Tear	13
Total	27

All Cars CPC-1232 Type (27 count)

Pos.	Tank Car	Quantity Removed (est.)	Flat Car/ Re-railed	FRA Damage Assessment 3/3/15	Amount Product Loss
02	CBTX 742201	Full load	Re-railed	No Breaches/Thermal Tears	None
03	CBTX 742774	Full load	Re-railed	No Breaches/Thermal Tears	None
04	CBTX 742792	Full load	Re-railed	No Breaches/Thermal Tears	None
05	GATX 286233	Full load	Re-railed	BOV Impacted, Minimal Leakage	Minimal
06	GATX 286285	Full load	Flat car	No Breaches/Thermal Tears	None
07	GATX 286241	21,100	Flat car	BOV open approx. 1/8	8,490 Gals.
08	GATX 286232	27,150	Flat car	Thermal Tear/ Heavy Fire Damage	8,520 Gals.
09	GATX 286214	1,500	Flat car	Thermal Tear/Heavy Fire Damage	27,951 Gals.
10	GATX 286292	0	Flat car	Thermal Tear/Heavy Fire Damage	29,433 Gals.
11	GATX 286274	8,150	Flat car	BOV Leakage/Slight Fire Damage	21,283 Gals.
12	CBTX 741512	10,050	Flat car	Thermal Tear/Heavy Fire Damage	19,390 Gals
13	CBTX 741926	16,180	Flat car	Thermal Tear/Liq. Line Dislodged	13,180 Gals.
14	CBTX 742035	5,650	Flat car	Thermal Tear/Heavy Fire Damage	24,019 Gals.
15	CBTX 741702	11,720	Flat car	Liquid Line Dislodged/Heavy Fire Damage	17,686 Gals.
16	CTCX 743030	0	Flat car	Coupler Impact Tear/Heavy Fire Damage	29,608 Gals
17	CBTX 741944	28,162	Flat car	Thermal Tear/Heavy Fire Damage	1,224 Gals.

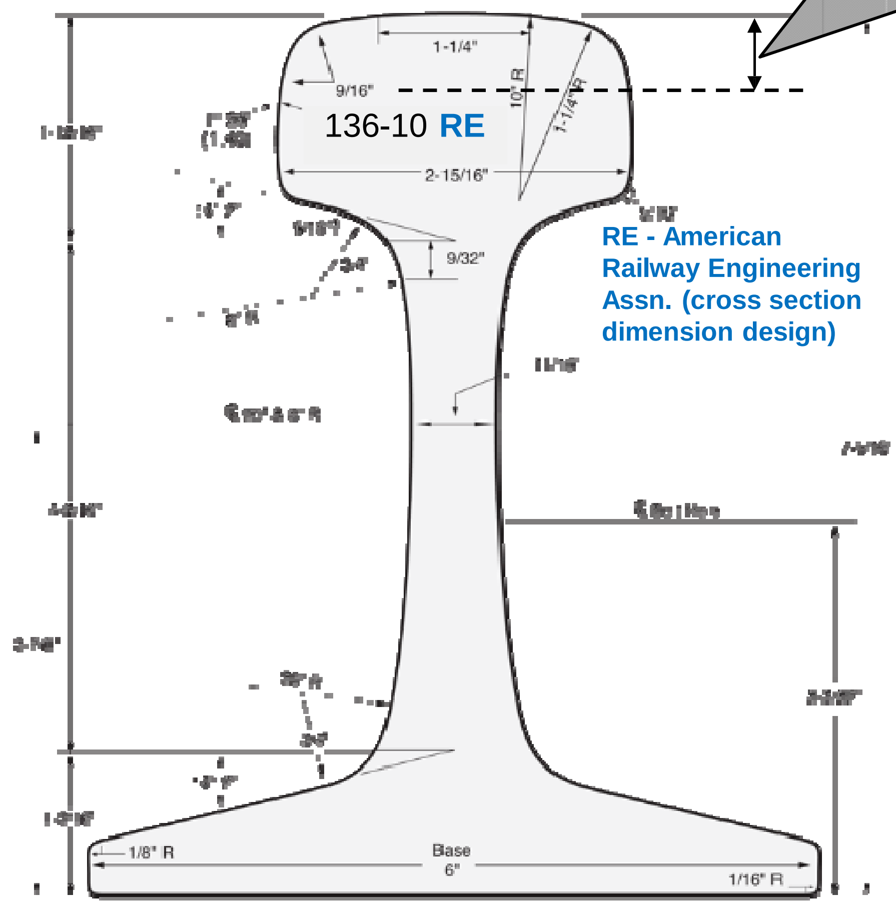
All 27 Cars CPC-1232

Pos.	Tank Car	Quantity Removed (est.)	Flat Car/ Re-railed	FRA Damage Assessment 3/3/15	Amount Product Loss
18	CBTX 741431	0	Flat car	Thermal Tear/Heavy Fire Damage	29,460 Gals.
19	CBTX 742778	8,300	Flat car	Mechanical Tear UK cause/Heavy Fire Damage	21,223 Gals.
20	CBTX 741516	0	Flat car	Thermal Tear/Heavy Fire Damage	29,556 Gals
21	CBTX 741651	0	Flat car	Thermal Tear/Heavy Fire Damage	29,350 Gals.
22	CBTX 742087	24,300	Flat car	Thermal Tear	5,005 Gals.
23	CBTX 741946	0	Flat car	Thermal Tear/Heavy Fire Damage	29,450 Gals.
24	CBTX 741956	25,600	Flat car	Product loss no apparent source	3,776 Gals
25	CTCX 743002	0	Flat car	Thermal Tear	29,430 Gals.
26	CBTX 741530	Full load	Re-railed	Dented	None
27	CBTX 741697	Full load	Re-railed	None	None
28	CBTX 743212	Full load	Re-railed	None	None

Appendix D: Rail Section Design

Vertical/tread wear on low/south rail 19/32 (0.59375)“ is 30.6% head loss

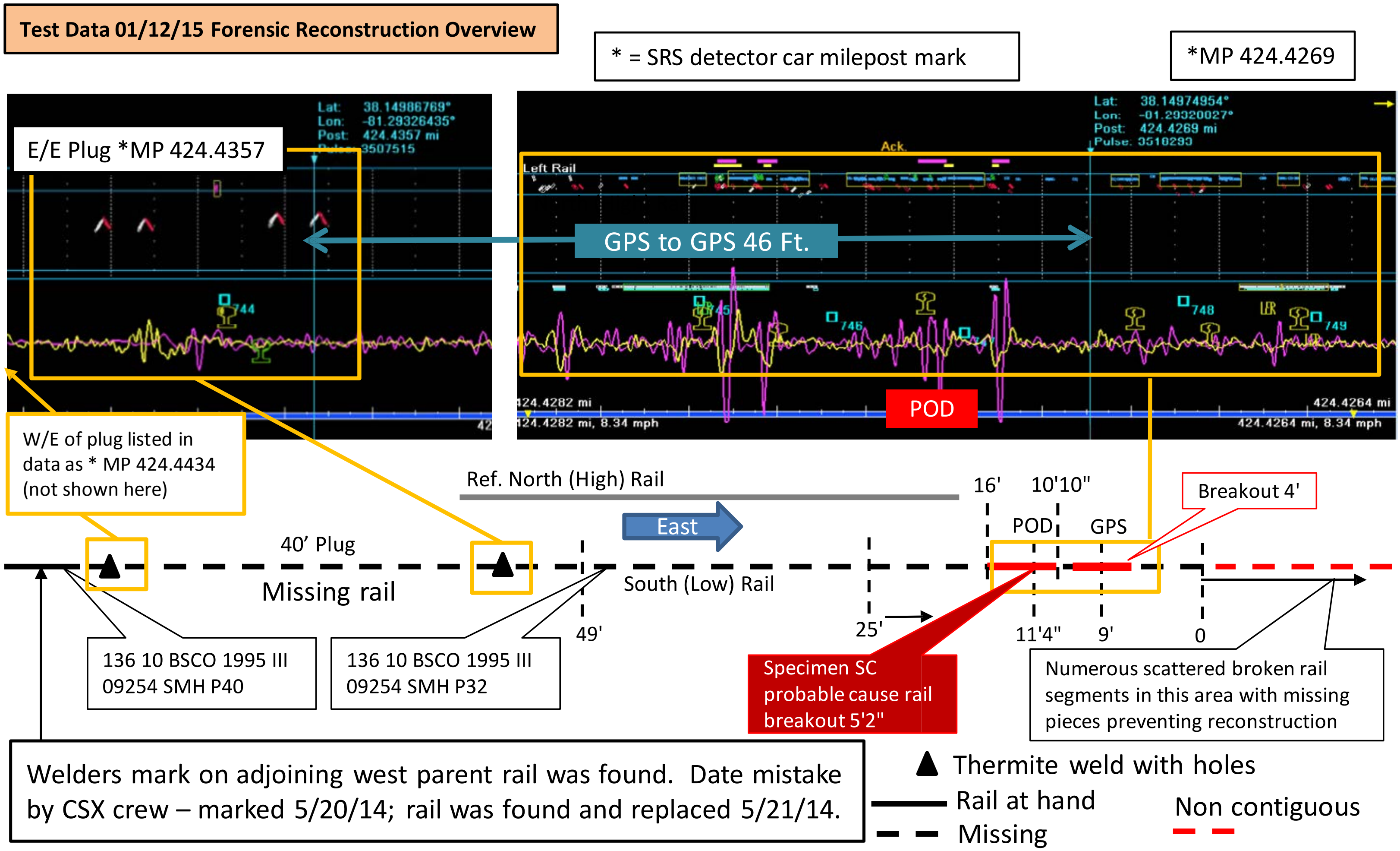
CSX maintenance criteria for 136 RE top (tread) wear is 5/8“ (0.625) - this rail 1/32 (0.01325)“ shy of limit



SMH Rail Specification 1994 Vintage Rail	
Carbon	0.80
Manganese	1.25
Chromium	0.25
Brinell hardness [1]	300

[1] Manufactured Bhn – work hardening changes the hardness

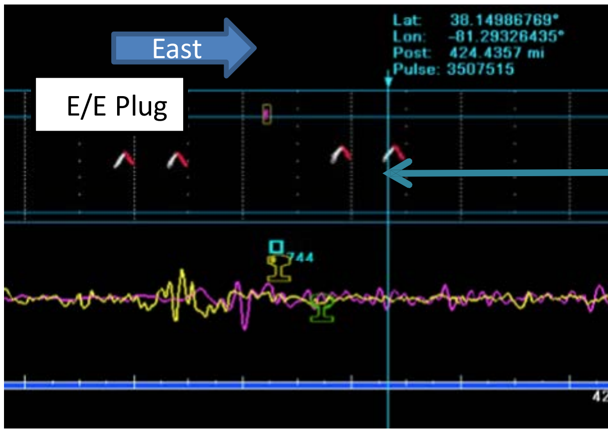
Appendix E: Digital Rail Analysis




Test Data 01/12/15 Screen Legend
FRONT
Ultrasonic Probe Indications (orientation)
REAR
Field 70
Center 70
Gauge 70
45
Side Locker
Zero
LER
Rail Top/Bottom Orientation Swapped vs. Field ("vehicle turned")
03/18/15
-81.29314
38.14975
Low (south) rail
POD
Analog induction responses to rail head surface conditions and/or longitudinal type defect
High (north) rail
East
Top Screen Focus Area
Operator Acknowledge
Lat: 38.14974954°
Lon: -81.29320827°
Post: 424.4269 mi
Pulse: 3516293
424.4202 mi
424.4264 mi
Active operator:
Previous operator:
Lat: 38.14976900°
Lon: -81.29321800°
424.4543 mi
424.4480 mi
424.4418 mi
424.4356 mi
424.4294 mi

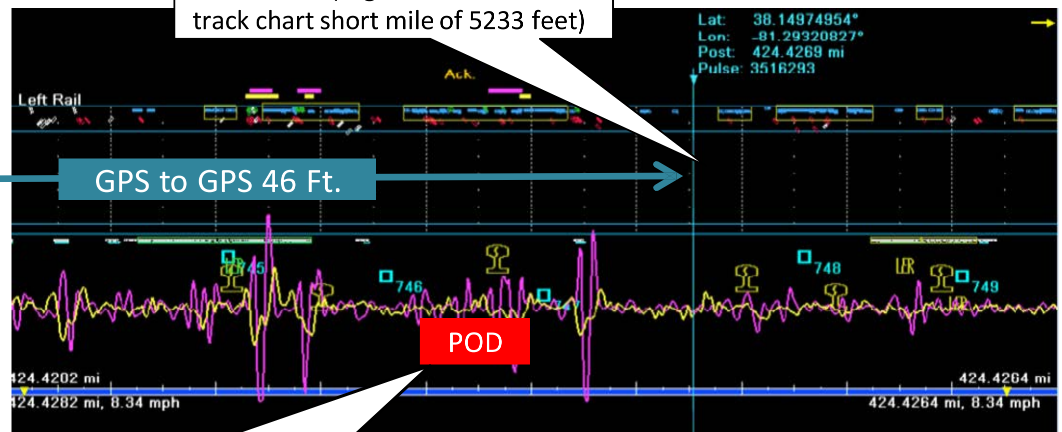
h

Test Data 01/12/15 Object Correlation



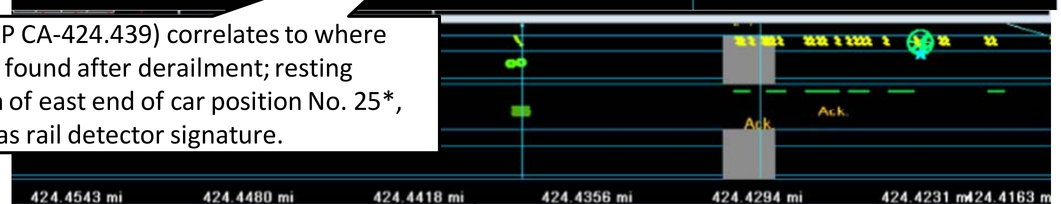
GPS to GPS 46 Ft.

Measured by wheel (3/18/14) MP CA-424 + 2294. Field GPS and SRS GPS very close match. MP is CA-424.438 (slight correction for track chart short mile of 5233 feet)



POD

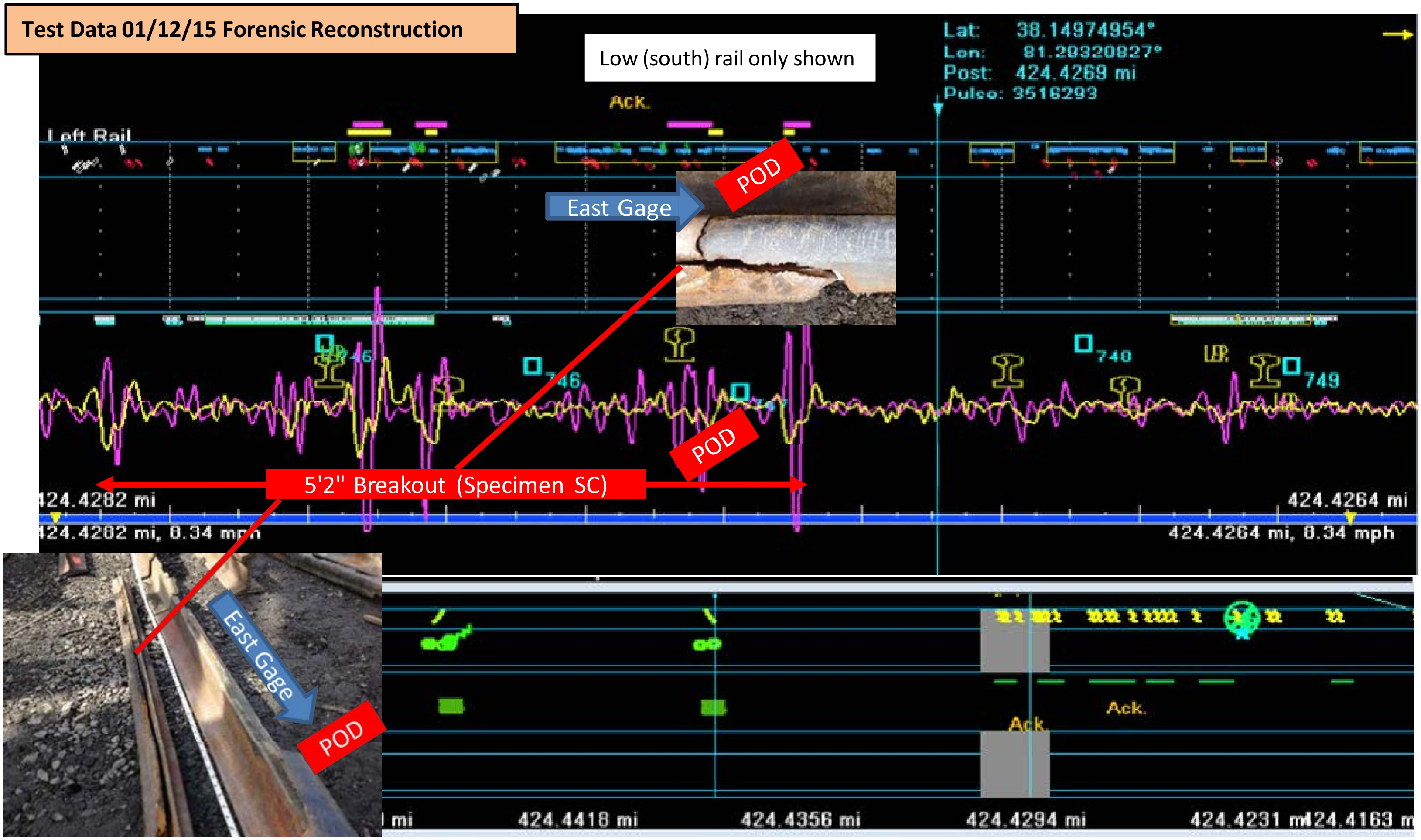
POD (MP CA-424.439) correlates to where rail was found after derailment; resting location of east end of car position No. 25*, as well as rail detector signature.

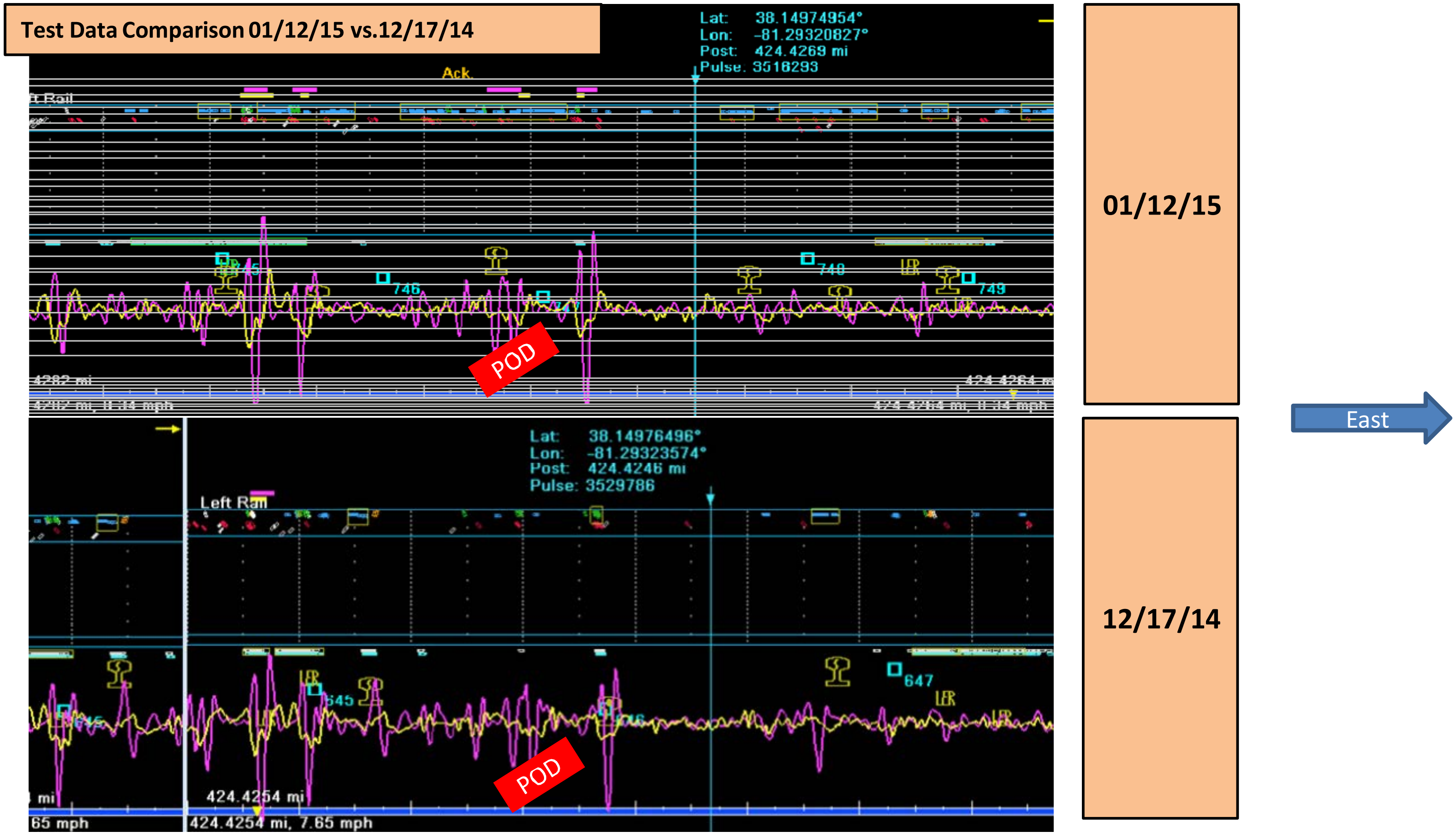


* E/E Car 25 same area adjacent to residence and between "burnt trees"

West burnt tree
38.14977
81.29327
MP CA-424.441

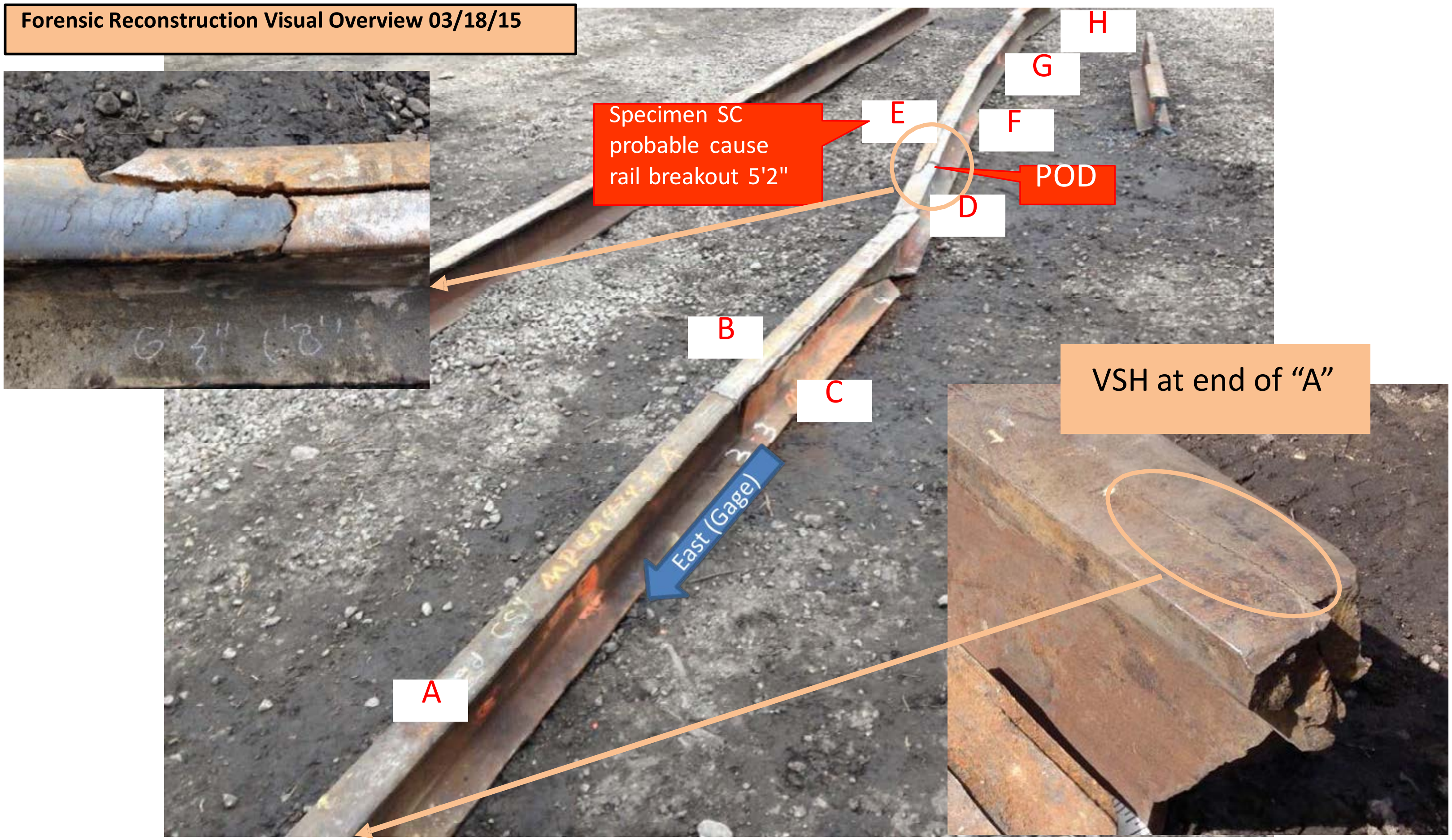
Large burnt tree
38.14977
81.12932
MP CA-424.424


Test Data 01/12/15 Forensic Reconstruction
Low (south) rail only shown
Lat: 38.14974954°
Lon: 81.29320827°
Post: 424.4269 mi
Pulse: 3516293
Ack.
Left Rail
East Gage
POD
POD
5'2" Breakout (Specimen SC)
424.4282 mi
424.4264 mi
424.4282 mi, 0.34 mph
424.4264 mi, 0.34 mph
740
749
East Gage
POD
Ack.
Ack.
424.4418 mi
424.4356 mi
424.4294 mi
424.4231 mi
424.4163 mi

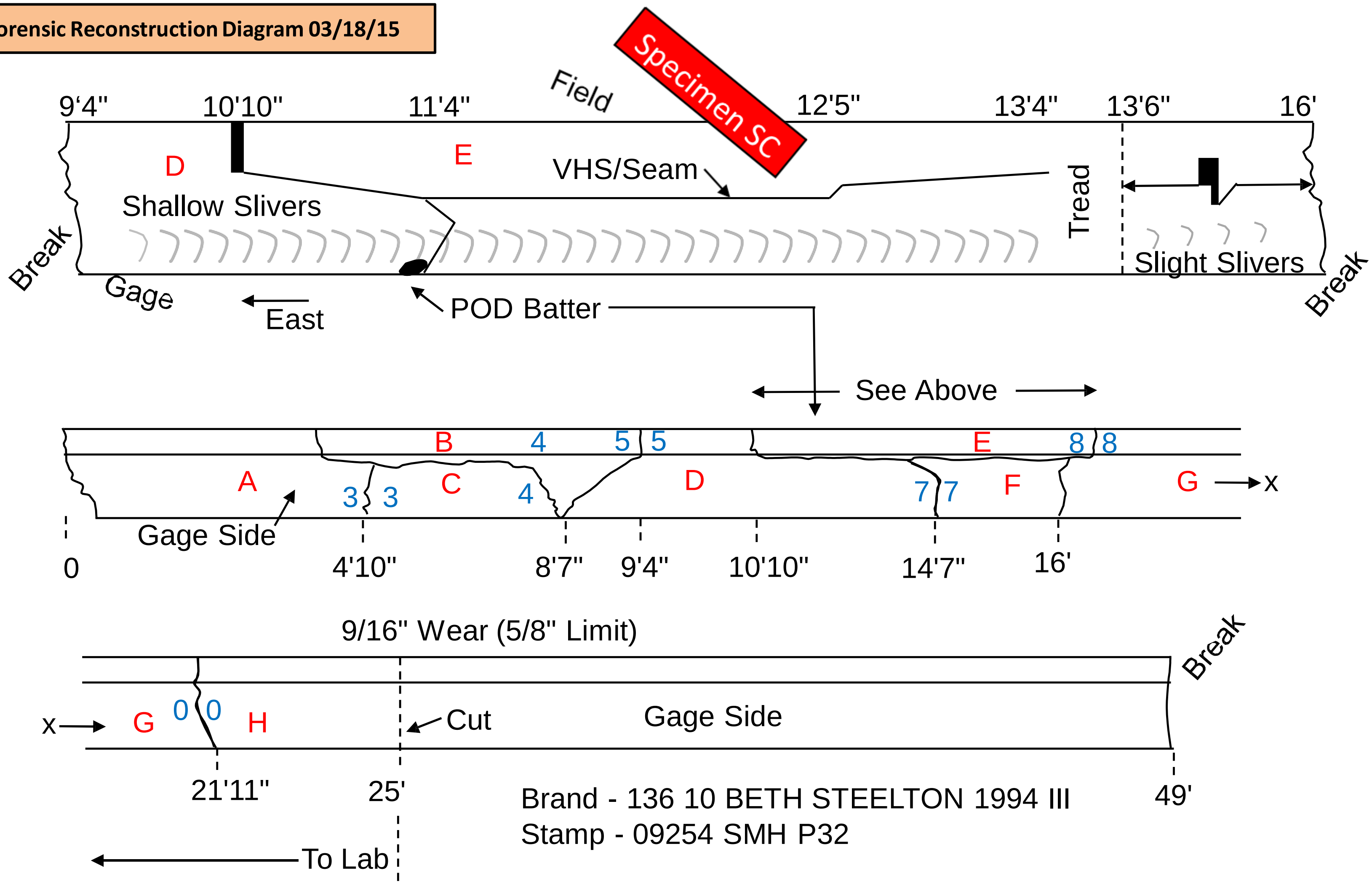

Test Data Comparison 01/12/15 vs.12/17/14
Lat: 38.14974954°
Lon: -81.29320827°
Post: 424.4269 mi
Pulse: 3518293
Ack.
746
748
749
POD
01/12/15
East
Lat: 38.14976496°
Lon: -81.29323574°
Post: 424.4246 mi
Pulse: 3529786
Left Rail
645
647
424.4254 mi
424.4254 mi, 7.65 mph
POD
12/17/14

k

Appendix F: Forensic Rail Reconstruction



Forensic Reconstruction Diagram 03/18/15

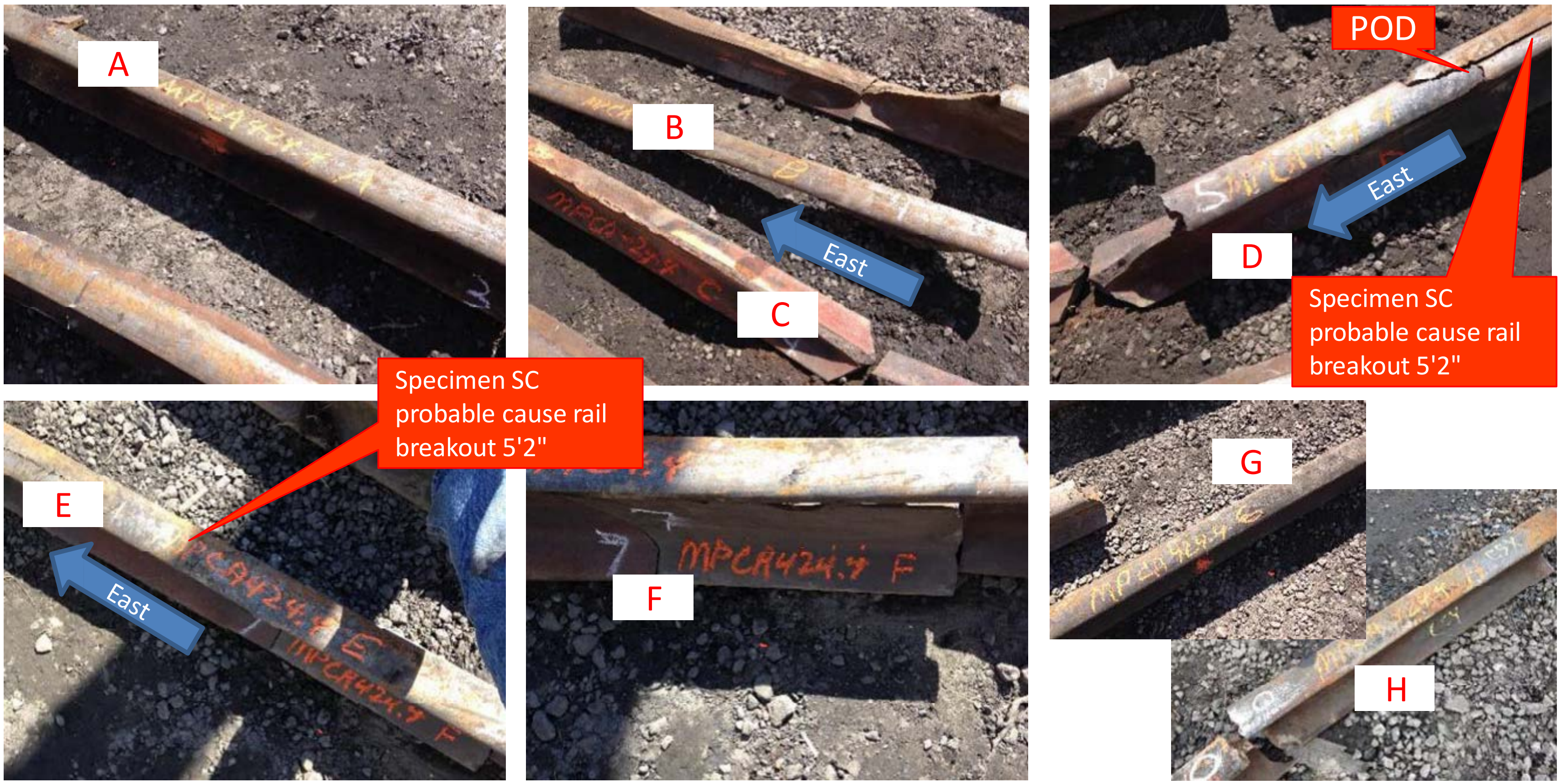


Brand - 136 10 BETH STEELTON 1994 III
Stamp - 09254 SMH P32

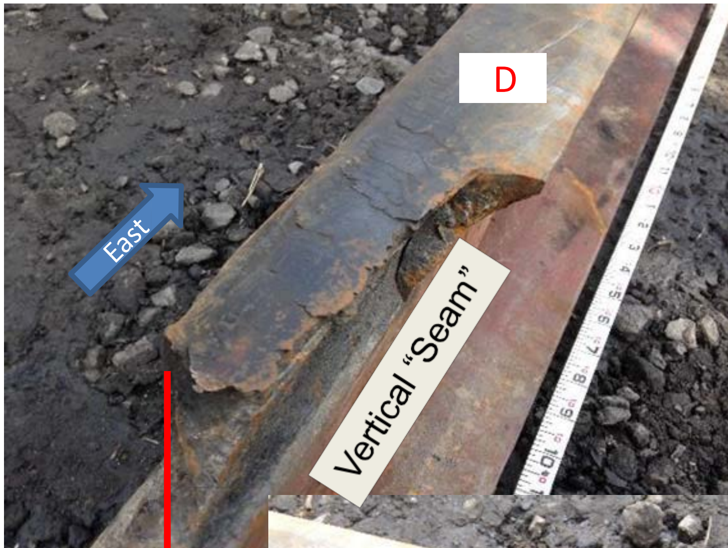
Forensic Reconstruction Element Match 03/18/15

Matches numbered as found. Match 1/1, 2/2, 6/6 determined not to be an element of this group.

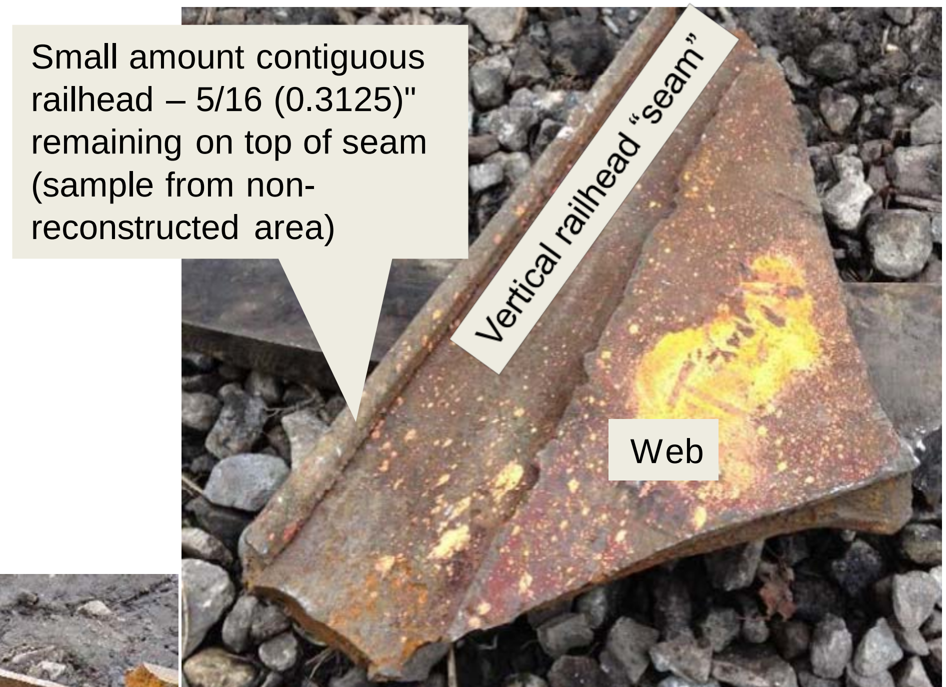
Forensic Reconstruction Element Catalog 3/19/15



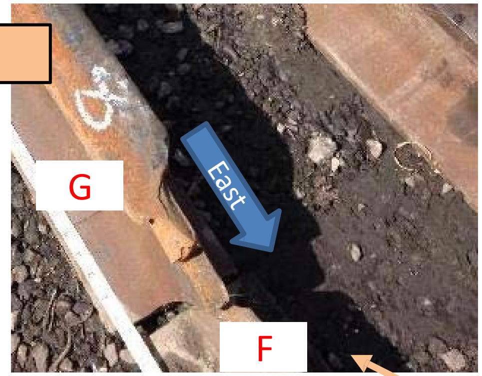
Forensic Reconstruction Failure Detail

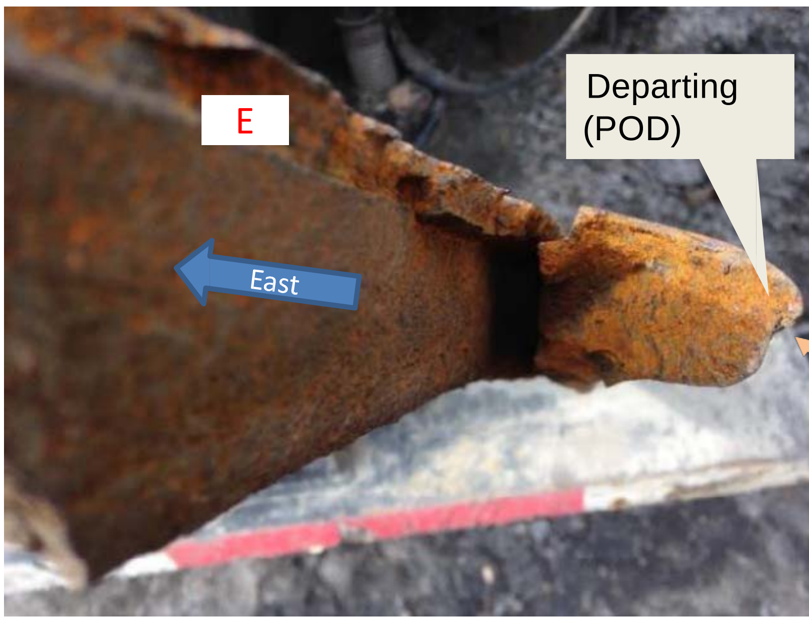


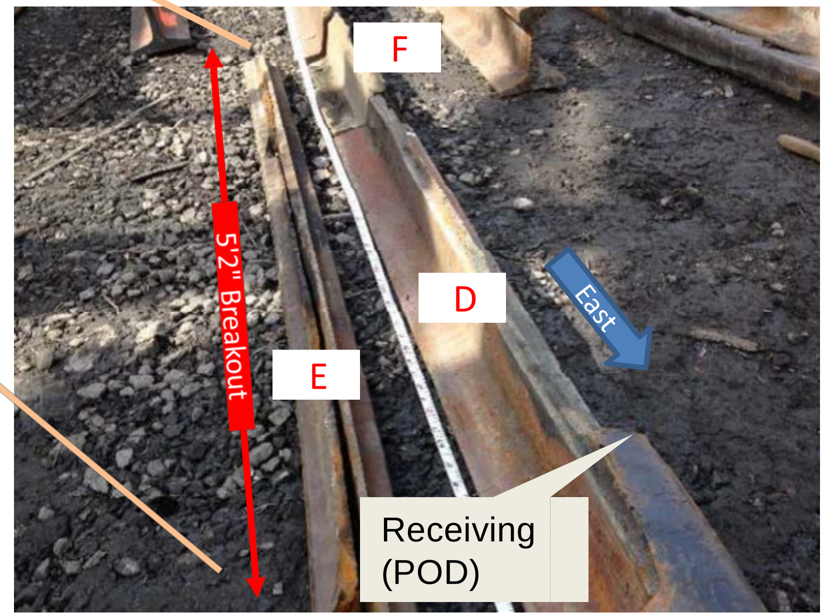
Batter (POD)



Forensic Reconstruction Failure Detail







Appendix G: ESI Metallurgical Investigative Report.

Investigative Report

Failure Analysis CSXT

Rail Fracture

ESI Project: 48208G

02/16/15 Derailment in Mt. Carbon, WV

r

6230 Regency Parkway
Norcross, GA 30071
Phone: 678-990-3280
Fax: 678-990-3285

Investigative Report

Failure Analysis CSXT Rail Fracture
ESI Project: 48208G
02/16/15 Derailment in Mt. Carbon, WV

Report Prepared for:

Mr. Robert B. Clark
CSX Transportation
500 Water Street, J430
Jacksonville, FL 32202

Submitted by:

David Pate
Technologist

Technical Review by:

Hans C. Iwand, P.E.
Principal & Practice Group Director
Nebraska P.E. | Expires: December 31, 2015

Introduction

Engineering Systems Inc. (ESI) received a total of twenty-feet of 136-pound rail sections from CSX (Figure 1). The rail sections collected at Mt. Carbon, West Virginia were reportedly involved in a derailment, which occurred February 16th, 2015 at 1:15 pm at milepost CA424.6. Markings on the rail indicate it was manufactured in March of 1994 by Beth Steelton (Bethlehem Steel). No indication or markings were found specifying grade or style of the rail. CSX requested ESI to determine if the rail was causative or failed during the derailment. The scope of ESI's investigation included visual examination, scanning electron microscopy, metallographic evaluation, chemical analysis, and mechanical testing.

Figure 1: As received rail sections

Analysis

Visual Inspection

Visual examination of the rail sections revealed evidence of progressive longitudinal crack growth through the head of the rail resulting in separation of the head and web (Figure 1 and Figure 2), otherwise known as Vertical Split Head (VSH). VSH originates at an internal defect and is normally attributed to manufacturing defects such as piping, segregation, or inclusions. VSH is not normally visible on the surface of the rail until it has grown several feet in length. At that point the railhead begins to widen and sag. Evidence of widening along with the vertical cracking in the railhead characterize VSH, and can be seen in Figure 3 and Figure 4. The VSH condition was evident in the entire length of submitted rail. VSH can cause wheels to climb on top of or drop inside the rail, resulting in a derailment.

In order to ascertain the origin of the VSH, one length of railhead that had broken at the web was sectioned transversely to separate the vertical fractures. Other regions of already exposed vertical fracture were also examined; however, no obvious vertical fracture origin was observed. Scanning electron microscopy of the exposed fracture surface revealed a transgranular cleavage fracture morphology, typical of rail steel (Figure 5).

Figure 2: Photograph of the broken rail sections laid out end-to-end

Figure 3: Photographs of a section of rail split vertically through the head.

Figure 4: Head widening is visible near the right (Top Left) as a cross-sectional view of the VHS (Top Right and Bottom Left and Right)

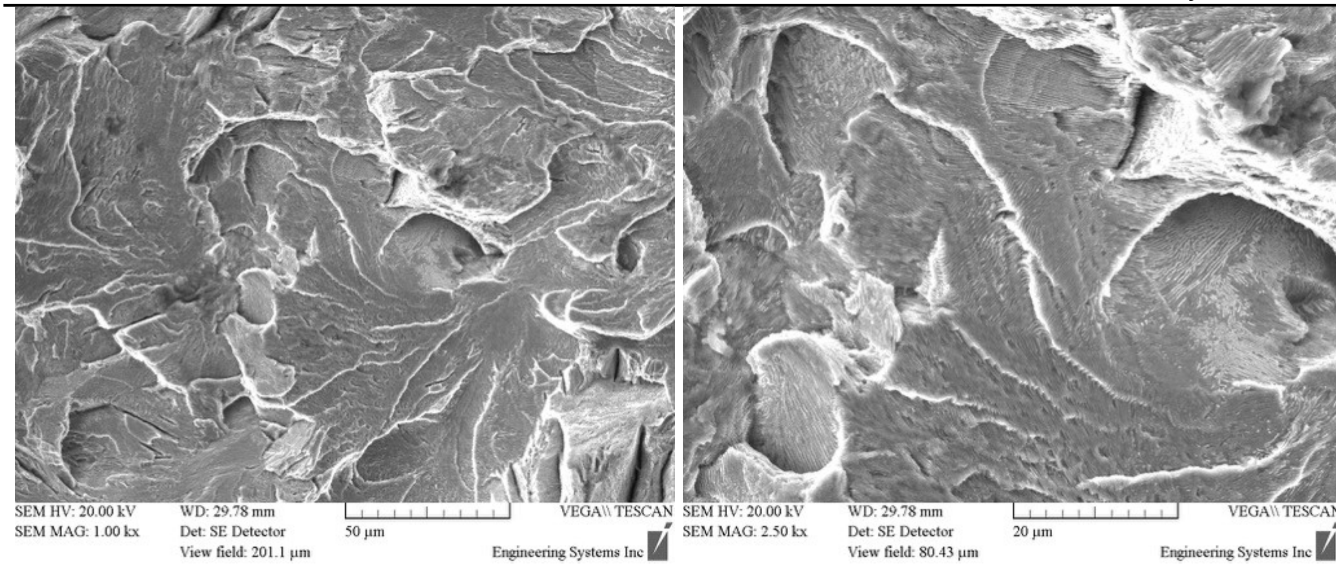


Figure 5: Representative fracture morphology on the exposed vertical fractures.

Metallurgical Evaluation

Interior Condition / Microcleanliness

As per AREMA specifications[1] a sample was sectioned from the head of a section of rail (Figure 6). After sectioning the sample, it was then prepared and evaluated following the ASTM Standard Practice E45 for determining the inclusion content of steel using the worst fields method (Method A). Preparation included mounting and then polishing the sample to a fine finish. Evaluation of the sample revealed thin type A-Sulfide inclusions that can be seen as light gray when viewed under brightfield illumination. Surveying the polished sample under 100 times magnification revealed six worst field locations (Figure 7). Each of these fields were then compared to Plate I-A and rated on a scale from 0 to 5 (Table 1). According to the AREMA specification for microcleanliness, each sample shall have a maximum average rating of 2 and a maximum individual rating of 3. The average rating of all six samples is 2.5 and therefore does not meet the standard.

[1] Reference AREMA- 2012 Chapter 4 Section 2 Manual for Railway Engineering Rails

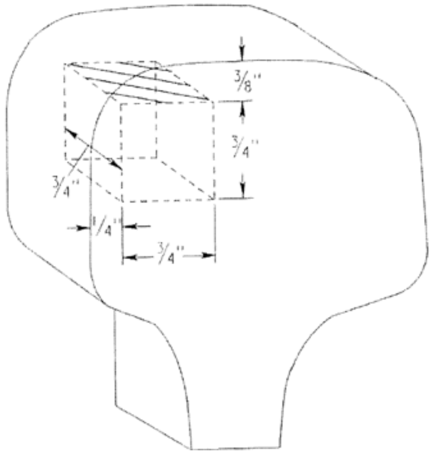


Figure 6: Location and size of section to be evaluated

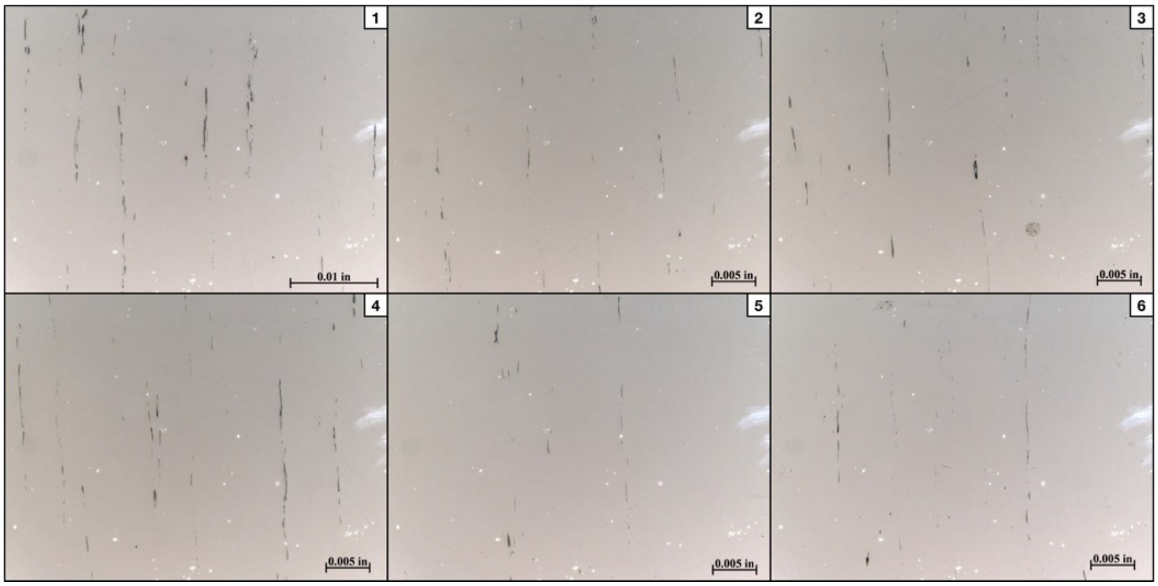


Figure 7: Worst fields 1-6

Table 1: Results of inclusion ratings

Field Number	Rating
1	3
2	2.5
3	2.5
4	3
5	2
6	2
Average	2.5

Macroetch Evaluation

As per AREMA chapter 4 section 2.1.9.2, a full transverse section of the rail was removed and prepared for macroetch evaluation (Figure 8). Some signs of centerline segregation extending into the head are present. According to AREMA chapter 4 section 2.1.9.3.1, must extend at least one inch into the head or base to fail; therefore, this sample is within the specification.

Figure 8: Macroetch showing centerline segregation

Mechanical and Chemical Evaluation

Mechanical testing confirmed that the rail material met the requirements for standard and intermediate strength rail (Table 2). Results from hardness testing performed on the running surface were low with a reading of 293 HB in comparison to the minimum 310 HB for new standard strength rail. Chemical analysis revealed that the subject rail had slightly elevated sulfur content that would correspond to the out of specification cleanliness (Table 3); however, AREMA specifies that up to 5% on any order may exceed 0.020 sulfur if purchaser and supplier agree, provided sulfur does not exceed 0.025 weight percent.

Table 2: Results of Mechanical Testing and AREMA Minimum Specifications

Specimen ID	Yield Strength (psi)	Ultimate Strength (psi)	Elongation After Fracture %
Subject Rail	81,500	148,000	11
Standard Strength	74,000	142,500	10
Intermediate Strength	80,000	147,000	8

Table 3: Results of Chemical Analysis and AREMA Specifications (wt%)

Element	Rail Specimen	Standard Strength
Carbon (C)	0.74	0.74 – 0.86
Manganese (Mn)	1.03	0.75 – 1.25
Phosphorus (P)	0.012	0.020 Maximum
Sulfur (S)	0.025	0.020 Maximum
Iron (Fe)	Remainder	
Aluminum (Al)	< 0.01	0.010 Maximum
Boron (B)	0.0006	
Chromium (Cr)	0.32	0.030 Maximum
Cobalt (Co)	0.01	
Copper (Cu)	0.31	
Molybdenum (Mo)	0.02	0.060 Maximum
Nickel (Ni)	0.10	0.25 Maximum
Niobium (Nb)	< 0.01	
Silicon (Si)	0.22	0.10 – 0.60
Titanium (Ti)	< 0.01	

Vanadium (V)	< 0.01	0.010 Maximum

Discussion

The presence of a vertical split head resulted in longitudinal crack propagation and rail failure during service. This would have caused the derailment. Mechanical testing confirmed that the rail met the strength requirements for standard and intermediate strength rail; however, hardness on the running surface was below AREMA specifications. Chemical analysis indicated elevated sulfur content, which corresponds to the rail being out of normal specifications (unless an exception was granted by the customer). Interior condition/microcleanliness inspection indicated the presence of manganese sulfide inclusions, and that the rail does not conform to microcleanliness standards.

Rail shear can occur when there are issues with track geometry or rail wheel interface. Rail shear failures look similar to vertical head failures, but occur closer to the edge of the rail. The cracks propagate horizontally as well as vertically, resulting in a jagged crack. Because the vertical split head in this instance occurred in the middle of the rail and propagated vertically along the line where segregation would occur, it is not likely that rail shear was the cause of the failure. While the macroetch did not reveal any segregation in the head of the rail, it is still possible the condition may have existed.

Formation of vertical split head defects can be linked to metallurgical issues during manufacturing of the rail. Detection of vertical split heads is difficult with typical rail inspection methods (ultrasonic) and is usually only observed during a visual inspection when it manifests as rust underneath the head. Currently, ESI does not have any specific information regarding the derailment and if other facts become apparent, we may update our opinions.

Please contact us if we can be of further assistance.

bb

Conclusions

1. The rail meets the applicable AREMA recommendations for tensile and ultimate strength, but fails to meet required hardness.

2. The rail has a slightly elevated sulfur content and does not meet microcleanliness recommendations

3. Because the failure occurred on the centerline of the rail, it is not due to rail shear; therefore, the failure is due to vertical split head (VSH) originating at centerline of the railhead.

✕ End of Report Text O