National Transportation Safety Board

Railroad Accident Brief

BNSF Railway Unit Ethanol Train Derailment

Lesterville, South Dakota

The Accident

On September 19, 2015, about 6:18 a.m., central daylight time, BNSF Railway Company (BNSF) unit ethanol train GMNXDPK717, with 3 locomotives, 96 loaded tank cars, and 2 hopper cars filled with sand, derailed at a small bridge at milepost (MP) 597.7 near Lesterville, South Dakota.[1] Seven cars (tank car 2 through tank car 8 from the head end of the train) derailed. Two of the derailed cars breached and released 49,743 gallons of denatured fuel ethanol (ethanol) that caught fire. A third car leaked ethanol from its bottom outlet valve. There were no injuries and no evacuation. The estimated damage was $1.1 million.

Figure 1 shows an overhead view of the accident site.

Figure 1. The accident site. (Photograph provided by BNSF.)

[1] (a) *Unit trains* are trains that contain all of the same type of cars and commodity. (b) The two hopper cars that were filled with sand served as buffer cars, in compliance with Title 49 *Code of Federal Regulations* (*CFR*) Part 174.85 "Position in train of placarded cars, transport vehicles, freight containers and bulk packagings," which requires that when the train length permits, placarded cars must not be nearer than the sixth car from the engine or occupied cars. Cars loaded with ethanol are placarded and, therefore, require separation from the locomotives.

The train crew, consisting of a conductor and a locomotive engineer, boarded the train in Scotland, South Dakota. The BNSF train dispatcher issued a track warrant at 5:40 a.m., authorizing the crew to depart Scotland and to occupy the main track from MP 605 to MP 566 which, according to the locomotive event recorder, the crew did 3 minutes later.

The maximum timetable speed for this segment of track was 25 miles per hour (mph); however, a BNSF *General Track Bulletin* restricted the train speed to 10 mph between MP 600.8 and MP 587.9.[2] According to the locomotive event recorder, the train primarily traveled at 10 mph, but the speed varied between 8 mph and 13 mph until the derailment.[3]

The train crewmembers said the 1-hour trip before the derailment occurred was uneventful, although they added there was heavy fog and poor visibility, and the sight distance was between 50 and 100 feet. The video recording from the outward-facing camera on the lead locomotive confirmed the existence of dense fog as the train approached and traversed the bridge near the derailment site.

Shortly after the locomotives crossed the bridge at MP 597.7, the emergency air brakes applied, without crew initiation.[4] According to the event recorder, the locomotive continued for about 80 feet before stopping.

The engineer and conductor stated they looked back and could see that the cars had derailed behind the locomotive and had caught fire. After the engineer reported the derailment and fire to the train dispatcher, he and the conductor gathered the train consist documents, left the locomotive, and walked a safe distance from the fire.

At the request of the emergency responders, the train crew returned to the locomotive and separated the buffer car and the two locomotives from the derailed train and moved them a safe distance from the fire. They also cleared the highway-railroad grade crossing to allow access by the fire department.

Track and Structure

Site Description

The BNSF has owned the Aberdeen Subdivision, consisting of a single main track between MP 777.0 (Aberdeen, South Dakota) to MP 513.0 (Sioux City, Iowa), since 2005. The track was

[2] BNSF Railway Company, *BNSF General Track Bulletin No. 32595*, September 19, 2015.
[3] Title 49 *CFR* Part 240 and BNSF company policy allow these speed variations.
[4] *Emergency air brakes* engage through the rapid release of air pressure from the brake pipe, resulting in the correspondent increase of brake pressure. Engineers and conductors can apply the emergency air brakes from their brake valves on the locomotive. However, the emergency brake may also engage because of a broken brake pipe or disconnected air hoses.

90-pound jointed rail sections near the point of derailment (POD).[5] This rail was installed in 1929, and had manufacturing dates varying from 1909 to 1918. In 2010, BNSF surfaced the track and renewed the crossties.[6]

Postaccident Rail Recovery

The POD at MP 597.7 was just east of the bridge. A forward-facing video from BNSF 5135, a train that traversed this section of track the day before this accident, showed misalignment of the track at the eastern end of the bridge.[7] (See figure 2.) Further, the audio track on this video captured an obvious "clunking" sound when the engine traversed this location.

Figure 2. Still photograph from a forward-facing video from the day before the accident. (Photograph provided by BNSF.)

The POD was about 10 feet east of the east-end bridge abutment on the right-hand rail in the direction of the train's movement. This location corresponded with the image noted from the previous day's forward-facing video.

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[5] Rail is classified by its linear weight for every 3 feet. This rail was designated as 9020 rail. Early rail designations showed slight changes in rail profiles and weights and other minor increases with 9020 and 9030 rail. For simplicification, in this report, the rail is referred to as "90-pound rail."

[6] *Surfacing* a track involves tamping ballast (gravel) tightly against the ties between the rails and building up the proper amount of ballast against the ends of the ties on both sides of the track. This process stablizes the track structure, improves drainage, and returns the track to the required geometry specifications.

[7] A forward-facing video recording from train BNSF 5135 captured a misalignment of the rail at the POD as it traversed the site at 4:07 p.m. on the previous day. This can be found in NTSB Public Docket DCA15FR016.

The derailment shattered the rail into many pieces. Investigators gathered the rail and reassembled the track at the derailment site. Pieces of broken rail from the east end of the bridge were sent to the NTSB materials laboratory in Washington, DC, for examination. (See figure 3.)

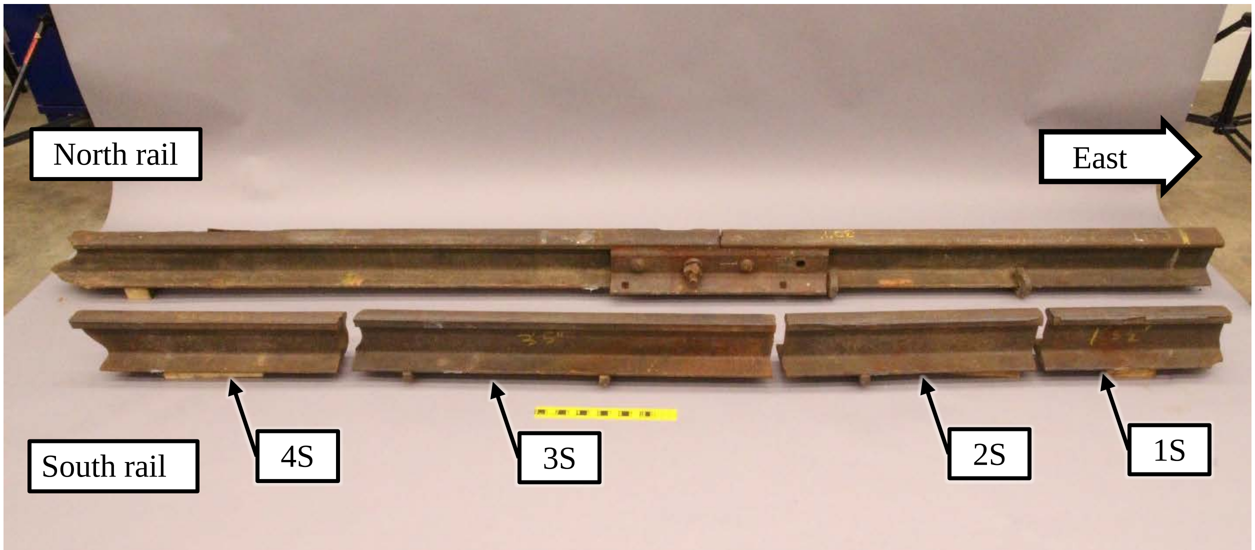

Figure 3. Recovered right-hand rail just east of the bridge.

The laboratory examination of the break between rail pieces 3S and 2S showed wear marks where the mating fracture faces had been moving up and down against each other. Therefore, the rail broke before the accident train derailed.

Two issues were identified at the site of the broken rail:

(1) the track gage was "tight" or narrow, and
(2) the east end of the bridge approach needed additional surfacing to better support the track structure

During geometry inspections, it was noted that the gage was tight between MP 596.72 to MP 596.67.[8] Standard gage for rail is 4 feet, 8 1/2 inches measured in a plane 5/8 inches from the top of the rail head. Federal Railroad Administration (FRA) track standards allow a minimum gage of 4 feet, 8 inches; however, as early as 2014, this section of track was measured and reported to be tighter than 4 feet, 8 inches. On April 8, 2015, the BNSF track geometry car reported tight gage (that is, 9/16-inch more narrow than the FRA minimum) at MP 596.67 and the BNSF inspector noted that this was a repeated defect from the previous year. BNSF had a contractor evaluate the track geometry on October 27, 2014, and August 8, 2015. The contractor also found gage that was more narrow than the FRA minimum standards at two other locations near the POD—one was 5/16-inch too tight, and the other was 13/16-inch too tight. The contractor did not report the defects because the instrumentation showed a spike in the laser, which means the reading could be unreliable.

[8] For additional information, see 49 *CFR* 213.53 "Gage".

The rail at the POD showed signs of wheel wear against the inside head (top) of the rail. In tangent (straight) track, the wheel flange generally does not touch the inside of the rail head and the wheels of the cars center themselves on the top of the rail head.[9] The wear patterns on the rail indicated the tightening of the gage, which would have applied lateral pressure to the rail by the wheels of passing trains.

The wooden cap on bent #2, at the east end of the bridge, was replaced on April 13, 2015.[10] The BNSF bridge inspector said the repairs to the bridge affected the track approaching the bridge by altering the alignment and disturbing the ballast that supports the track structure. According to the bridge inspector, the following improvements were needed: repairing the erosion of the east-end slope, constructing wing walls, and the lining and surfacing of the track.[11] Train crews also reported track issues on the east end of the bridge, according to the bridge inspector.[12] However, the BNSF track supervisor, who had worked the territory since 2013, said that he was unaware of the bridge repairs.

The gage tightened at the POD and the track was unstable, which required repair. However, by designating the track as Class 1, BNSF was able to defer maintenance on the track. These issues, along with lateral pressure on the rail from the tight gage and the poor track structural support, increased the likelihood of rail failure.

Track Maintenance and Inspections

The FRA track standards are based upon track category classifications.[13] The categories for conventional railroad territories range from Class 1 for the lowest classification and escalate to Class 5.[14] Railroads designate the classification of track for given territories, which subsequently determines the tolerances allowed during maintenance, the minimum structural requirements, the frequency of inspections, and the allowed track speed. A lower track classification results in greater tolerances, less-frequent inspections, and a lower maximum speed. Railroads often lower the classification of a track to defer maintenance on routes that have lower train traffic. At one time, the Aberdeen Subdivision had been designated as a Class 2 track; however, when BNSF lowered the speed limit at the accident area to 10 mph several years earlier, this section of the subdivision became a Class 1 track.[15] In addition, the track supervisor said that because fewer trains operated on this section of the Aberdeen Subdivision, it had a lower priority for maintenance.

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[9] The *wheel flange* is the inside rim which projects below the tread.

[10] *Bents* are part of the upright supports that the deck of the bridge rests upon.

[11] A *wing wall* is an extension of an abutment wall which retains adjacent earth and/or deflects or guides a stream into pipes, culverts, and the waterway of a bridge. The bridge inspector noted that wing walls were never constructed for this bridge, despite being needed.

[12] Train crews will report locations in the track where they feel a rough spot or if the engine makes unusual movements while traversing.

[13] Track classifications are outlined in 49 *CFR* 213.9 “Classes of track; operating speed limits”.

[14] High-speed train operations have their own classifications which are covered in 49 *CFR* Part 213, Subpart G “Train Operations at Track Classes 6 and Higher”.

[15] The track supervisor said that the Aberdeen Subdivision had been classified as Class 1, with a speed limit of 10 mph, when he was assigned the territory in 2013.

A BNSF track inspector visually inspected the track once a week, as required by regulation.[16] The track inspector said that he normally operated the test vehicle at speeds between 5 and 7 mph when he inspected the jointed rail. He said that he had inspected the track at the accident site on September 15, 2015—4 days before the accident. During the 6 to 7 weeks prior to the accident, the track inspector's supervisor accompanied him twice during inspections.

BNSF evaluated the track geometry on this subdivision twice a year, alternately using a specially equipped railcar and contracting with an outside company.[17] The three most recent track geometry evaluations prior to the accident occurred on October 27, 2014, April 8, 2015, and August 8, 2015. These evaluations identified tight gage, as discussed in the section on Postaccident Rail Recovery.

BNSF also had a contractor scan the rail for internal defects on a quarterly basis.[18] The most recent internal defect inspections prior to the accident were held on April 22, 2015, and July 9, 2015, neither of which detected a defect in the rail at the POD. However, several other locations on this track were noted as "shelled, spalled, and corrugated" (SSC), which is a surface condition that limits the ability of the instruments to detect internal defects. If there was a length of track with extensive SSC surface conditions, the contractor was required under FRA regulations to note that a valid search for internal defects was not conducted. There was also an additional subjective requirement that if the surface condition was "bad enough," the operator—in this case, the contractor hired by BNSF—was required to perform a visual inspection of the rail. The records indicated that the contractor stopped and inspected the rail where the SSC had obscured the internal scans.

Postaccident Inspections and General Rail Condition

During postaccident examinations, investigators found many track defects near the accident site, including:

- a break in a portion of the rail head on the north rail at MP 596.65, about 250 feet east of the POD
- a 6-inch vertical split head on the field side of the rail head near MP 596.68, which was where the internal defect report of July 9, 2015, showed SSC, and where the contractor performing the scan had visually inspected, but did not note finding any defects
- two significant vertical split heads were found between MP 595.2 and MP 596.6—one was 13-inches long, and the other was 96-inches long
- excessive rail head wear

[16] Title 49 *CFR* 213.233 "Track inspections".

[17] This railcar is known as a "STAR car." *STAR* is an acronym for Strength, Testing, Analysis, and Recording. It has a split axle that applies a 10,000-pound lateral load to both rail heads and measures the geometry under a load.

[18] Internal rail defects are found by using ultrasonic or electric induction methods. If possible, BNSF would have a contractor conduct a second inspection in the fourth quarter so there would be five inspections for internal defects per year.

BNSF track standard wear limits for rail heads were based on the specified weight of the rail and allowed more wear for heavier rail.[19] All rail that weighed less than 119 pounds had a 0.5-inch vertical wear limit.[20] In the case of a 90-pound rail, such as the one shown in figure 4, 0.5-inch of vertical wear would reduce the rail head to the extent where it may not be able to support the weight of a modern tonnage train and could increase the possibility that the rail would fail.[21] Although the wear on the accident rail had not reached the level for replacement for 90-pound rail by the BNSF wear limit, NTSB investigators considered the wear in the accident rail to be excessive because the remaining head area in the worn 90-pound rail was less than the remaining head area in heavier rail at the wear limits listed in the BNSF track standard.

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[19] Heavier rail generally has more mass in the rail head.

[20] *BNSF Engineering Instructions, Rail,* revised December 1, 2015, Table 6-1: "Rail Head and Side Wear Limits".

[21] *Tonnage trains* are heavy trains that carry large loads.

Figure 4. Excessive rail head wear on a 90-pound rail from the Aberdeen Subdivision.

Despite being limited because of rail surface issues, BNSF conducted track geometry and internal scanning inspections that exceeded the FRA requirements. However, BNSF continued to operate high-hazard flammable unit trains (HHFUT) on a track with significant defects.[22] Because BNSF lowered this track's classification to Class 1, none of the defects required either a suspension of train operations or increased maintenance requirements. Further, the track met the FRA Track Safety Standards found in Title 49 *Code of Federal Regulations* (*CFR*) Part 213. Since the

[22] An *HHFUT* is a single train transporting 70 or more loaded tank cars containing Class 3 flammable liquid.

accident, BNSF rerouted unit ethanol trains (HHFUT) so that they no longer operate on the Aberdeen Subdivision.

Rail Wear and Train Weights

According to the second edition of *Railroad Engineering*, rough estimates show that 10 pounds of rail weight can carry 3,000 pounds of load—or in this case, if it were new 90-pound rail, 27,000 pounds.[23] The maximum weights for the tank cars for this train were 286,000 pounds and 263,000 pounds. The wheel loading for 286,000-pound cars with four axles was 35,750 pounds per wheel, and the wheel loading for 263,000-pound cars with four axles was 32,875 pounds per wheel. Railroads did not use cars of this size at the time when the rail on this track was manufactured. Therefore, the 90-pound rail may have been overloaded regardless of the excessive head wear.

Modern high-strength steel rail is harder than the century-old rail used on this track and wears down at a lower rate. The hardness of the rail at the POD was about 30 percent lower than the minimum acceptable value for today's rails. Older rail is susceptible to head checks, spalls, and other rolling contact fatigue damage; deformed rail head flow; and increased wear rates.[24] The rail segments recovered at the scene of the accident showed evidence of rolling contact fatigue.

According to BNSF, since January 2015, at least one loaded unit ethanol train, such as the accident train, traversed the Aberdeen Subdivision each week. Excluding the locomotives, the accident train weighed 12,585 tons and had an average wheel loading of 32,104 pounds.[25] More significantly, 98 cars delivered this excessive wheel loading. The age of the rail compounds the fatigue and wear caused by the unit trains with heavy wheel loading. The NTSB believes that freight railroads and the FRA should more closely consider the weight of rail when operating high tonnage trains, particularly those containing highly flammable material.

Hazardous Material/Tank Cars

Retrofit and Phase-out

The Fixing America's Surface Transportation (FAST) Act is a funding and authorization bill governing United States surface transportation spending.[26] Section 7304 of the Act requires that all tank cars used to transport Class 3 flammable liquids must meet US Department of Transportation (DOT) specifications DOT-117, DOT-117P, or DOT-117R in 49 *CFR* Part 179, regardless of train composition. These specifications make tank cars less susceptible to breaching and releasing flammable or hazardous contents during a derailment.

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[23] William W. Hay, *Railroad Engineering*, 2nd Ed. (Hoboken, New Jersey: Wiley, 1982).

[24] These conditions are all examples of SSC.

[25] Investigators used the following calculation to arrive at this total: 12,585 tons ÷ 98 cars = 128 tons per car x 2,000 pounds = 256,826 pounds per car ÷ 8 wheels per car = 32,104 pounds per wheel.

[26] Public Law No. 114-94.

The FAST Act contains a schedule for phasing out tank cars in crude oil and ethanol service and requires fleets to be fully DOT-117 compliant by May 1, 2025. However, the FAST Act requires retrofitting or removing from service tank cars transporting other Class 3 Packing Group I flammable materials by May 1, 2025, and Class 3 Packing Groups II and III flammable materials by May 1, 2029.[27] On August 15, 2016, the Pipeline and Hazardous Materials Safety Administration (PHMSA) published a final rule codifying the phase-out schedule for all DOT Specification 111 tank cars used to transport crude oil, ethanol, and other Class 3 flammable liquids.[28]

Continued damages, injuries, and loss of life caused by accidents involving flammable liquids in rail transportation are intolerable given that multilayered mitigation measures involving the tank car, railroad operating practices, and emergency response were painstakingly developed, but are far from being fully implemented. The NTSB is concerned that the ethanol fleet of about 27,900 unmodified DOT-111 legacy tank cars and Association of American Railroads (AAR) Casualty Prevention Circular (CPC)-1232 tank cars may continue to remain in service without safety retrofits during the next 6 years.[29] Operators are required to retrofit or phase out ethanol fleet tank cars in parallel with that of an estimated 127,000 tank cars that carry other flammable liquids.

The first two tank cars to derail in this accident were constructed using the CPC-1232 specifications; both tank cars remained intact. The remaining derailed cars were part of the older DOT-111 legacy tank car fleet. While the ethanol releases and the postaccident pool fire might have been prevented had the two affected tank cars had head shields and tank jackets, these features are not required for nonjacketed DOT-111 tank cars in ethanol service until May 1, 2023. The NTSB believes that the continued use of DOT-111 tank cars in trains transporting flammable hazardous materials emphasizes the importance of routing trains on tracks that are well maintained and less likely to cause derailments.

Routing High-Hazard Flammable Trains

Postaccident examinations of the track near Lesterville revealed multiple rail defects that could result in derailments. Some of these defects were not found during routine inspections; had they been identified, the Class 1 track designation would still have allowed BNSF to defer making the repairs. The FRA Track Safety Standards use a strategy of lowering the classification of track, thereby lowering the speed of the trains, to mitigate the risk of a catastrophic derailment.[30]

[27] The *Packing Group* of a hazardous material is based on the degree of danger it presents: Packing Group I - Great Danger, Packing Group II - Medium Danger, Packing Group III - Minor Danger.

[28] "Hazardous Materials: FAST Act Requirements for Flammable Liquids and Rail Tank Cars," *Federal Register* 81, no. 157 (August 15, 2016): 53935.

[29] (a) K. Neels & M. Berkman, *A Review of the Pipeline and Hazardous Materials Safety Administration's Draft Regulatory Impact Analysis*, Docket No. PHMSA 2012-0082 (HM-251), prepared for the Railway Supply Institute Committee on Tank Cars (November 2014); (b) AAR CPC-1232 required that tank cars ordered for crude oil or ethanol service after October 1, 2011, include a thicker shell and half-height head shield for greater puncture resistance than other Specification-111 tank cars.

[30] Title 49 *CFR* 213.113 "Defective rails".

Although this may be a practical approach for low-density, slow-speed tracks that handle general freight, the results of even a minor derailment can be catastrophic when a high-hazard flammable train (HHFT) is involved.[31] The NTSB believes that the maintenance standards allowed for Class 1 track increases the risk of derailments, particularly of HHFTs, to unacceptable levels.

Although both newer tank cars and older legacy DOT-111 tank cars were involved in the derailment, only the legacy DOT-111 tank cars breached. The legacy DOT-111 tank cars are eligible to transport ethanol until May 1, 2023. The NTSB believes that routing trains that transport flammable hazardous materials on well-maintained tracks lowers the possibility of derailment, which counteracts the increased risk of tank car failures caused by the continued use of legacy DOT-111 tank cars.

On March 31, 2016, PHMSA changed its regulations to require railroads to analyze HHFT routes. Railroads are required under 49 *CFR* 172.820 to perform a risk analysis to determine the routing of a train identified as an HHFT. Appendix D to Part 172 lists 27 items for railroads to consider when performing the risk analysis. Item 5 of appendix D states, "Track type, class, and maintenance schedule." However, the regulation does not provide specific direction for railroads to analyze the risks associated with the track type, class, and maintenance schedule. Further, the list in appendix D does not mention the increased risk associated with the use of the older DOT-111 tank cars. The NTSB believes that three additional significant factors must be considered when routing HHFT trains: (1) the increased derailment risk associated with Class 1 track, (2) the weight of the tank cars in relation to the weight of the rail, and (3) the potential failure of legacy DOT-111 tank cars during derailments. Therefore, the NTSB recommends that PHMSA include the increased derailment risks associated with Class 1 track, the relationship between the weight of the railcars and the weight of the rail, and the potential failure of legacy DOT-111 tank cars during derailments in the list of items for railroads to consider when determining the routes for HHFTs or HHFUTs, as found in appendix D of 49 *CFR* Part 172. In addition, the NTSB recommends that PHMSA and the FRA work together to develop specific guidance for railroads when using the list of items found in appendix D of 49 *CFR* Part 172 in their risk assessments and apply the information gathered in those risk assessments when analyzing proposed routes for HHFTs or HHFUTs.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the broken rail, derailment, and subsequent fire was BNSF Railway Company's decision to defer track maintenance and continue to operate high-hazard flammable unit trains on the Aberdeen Subdivision. Contributing to the accident was the Federal Railroad Administration's track maintenance regulation that allowed high-hazard flammable unit trains to continue to operate after the track was reclassified to a lower standard. Contributing to the tank car breach and subsequent fire was the continued use of legacy US Department of Transportation-111 tank cars to carry flammable products.

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[31] An *HHFT* is a single train transporting 20 or more loaded tank cars of a Class 3 flammable liquid in a continuous block or a single train carrying 35 or more loaded tank cars of a Class 3 flammable liquid throughout the train consist.

Recommendations

The National Transportation Safety Board makes the following new safety recommendations:

To the Pipeline and Hazardous Materials Safety Administration:

> Include the increased derailment risks associated with Class 1 track, the relationship between the weight of the railcars and the weight of the rail, and the potential failure of legacy US Department of Transportation-111 tank cars during derailments in the list of items for railroads to consider when determining the routes for high-hazard flammable trains or high-hazard flammable unit trains, as found in appendix D of title 49 *Code of Federal Regulations* Part 172. (R-17-05)

To the Pipeline and Hazardous Materials Safety Administration and Federal Railroad Administration:

> Work together to develop specific guidance for railroads when using the list of items found in appendix D of title 49 *Code of Federal Regulations* Part 172 in their risk assessments and apply the information gathered in those risk assessments when analyzing proposed routes for high-hazard flammable trains or high-hazard flammable unit trains. (R-17-06)

For more details about this accident, visit www.ntsb.gov/investigations/dms.html and search for NTSB accident identification **DCA15FR016**.

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Adopted: June 26, 2017

Appendix

The operating speed limits for the various classes of track are as follows:[1]

Table 1. Speed limits for classes of track.

Type of track	Maximum speed for freight trains	Maximum speed for passenger trains
Excepted track	10 mph	N/A
Class 1 track	10 mph	15 mph
Class 2 track	25 mph	30 mph
Class 3 track	40 mph	60 mph
Class 4 track	60 mph	80 mph
Class 5 track	80 mph	90 mph

[1] Title 49 *CFR* 213.9 “Classes of track: operating speed limits”.