National Transportation Safety Board
Washington, DC 20594

Safety Recommendation Report

Placement of DOT-111 Tank Cars in High Hazard Flammable Trains and the Use of Buffer Cars for the Protection of Train Crews

Introduction

The National Transportation Safety Board (NTSB) is investigating two separate derailments of high hazard flammable trains (HHFT) in Draffin, Kentucky, and Fort Worth, Texas, which resulted in breached tank cars and hazardous material fires.[1] The NTSB found that in both derailments, least-protective US Department of Transportation (DOT)-111 tank cars were placed in positions that increased the risk of derailment and breaching of the tank cars, resulting in release of their hazardous materials contents. Additionally, in Draffin, Kentucky, the lead locomotives were separated from the hazardous materials tank cars by only one buffer car, which shortened the distance between the breached tank cars and the crewmembers, increasing the risk of injury or death.[2] The NTSB is issuing one recommendation to the Association of American Railroads (AAR), the American Short Line and Regional Railroad Association (ASLRRA), and the Renewable Fuels Association (RFA); reiterating one recommendation to the Federal Railroad Administration (FRA); and reiterating two recommendations to the Pipeline and Hazardous Materials Safety Administration (PHMSA). Information to support these recommendations is provided below.

Ongoing Investigations

Draffin, Kentucky

On February 13, 2020, about 6:54 a.m. local time, CSX Transportation (CSX) ethanol unit train K42911 derailed three locomotives, one buffer car, and four tank cars on a mountainside near Draffin, Kentucky. Train K42911 was an HHFT with one buffer car at the head of the consist and one at the rear end of the train. Following the head end buffer car were 96 denatured ethanol tank cars. According to wireless uploads from the train's energy management system, at the time of the derailment the train speed was about 25 mph.[3] The track in this area consisted primarily of single main track that was maintained to operate trains at 25 mph.

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[1] A *high hazard flammable train* (HHFT) is defined in Title 49 *Code of Federal Regulations* (*CFR*) 171.8 as a single train transporting 70 or more loaded tank cars containing Class 3 flammable liquid.

[2] *Buffer cars* are nonplacarded cars that are used to separate locomotives from hazardous materials freight cars. The requirements for positioning in trains of placarded cars are provided in 49 *CFR* 174.85.

[3] The energy management system incorporates track topology, train consist information, route data, operating constraints, and goals. The system helps train operators to run in the most energy and fuel efficient manner over a

Heavy rainfall occurred in the area prior to the accident. The train was heading east when it encountered track obstructed by a landslide. The train derailed toward the rain-swollen Russell Fork river, with the cab of the lead locomotive partially submerged. The tank cars in positions two through five of the consist derailed. Two specification DOT-111 tank cars were breached and released about 38,400 gallons of denatured ethanol, which in combination with about 11,300 gallons of released locomotive diesel fuel ignited into a postaccident pool fire. Smoke and heat prompted the locomotive engineer and conductor to evacuate the lead locomotive through the front door onto the walkway platform. Flames from the ethanol pool fire engulfed both sides of the locomotive and precluded safe egress onto the mountainside. The crewmembers were trapped on the platform facing the rapidly flowing river. About 8:04 a.m., the train crewmembers were rescued after the responding trainmaster entered the river, swam toward the train crew, and persuaded them to step from the locomotive into the chest-deep water. A fire department swift water rescue team extracted the train crewmembers from the riverbank, and they were transported by ambulance to a local hospital for treatment.

Local police advised occupants of 6 to 10 nearby homes to evacuate. There were no civilian injuries and the evacuation advisory was lifted by 10:30 a.m. CSX restored train service on the subdivision 8 days later, on February 21, 2020.

Fort Worth, Texas

On April 24, 2019, about 12:30 a.m. local time, Union Pacific Railroad (UP) unit train UEBLTG 20, an HHFT carrying denatured ethanol, derailed 25 tank cars in Fort Worth, Texas. The train consisted of three lead locomotives, two buffer cars, and 96 loaded tank cars. At the time of the derailment, the train was traveling southbound at 26 mph on a track with a maximum authorized speed of 30 mph.

The derailed tank cars were in positions 17 through 41 of the consist. Three tank cars were breached and released 65,270 gallons of denatured ethanol. These breached tank cars included one severely damaged legacy DOT-111 tank car. The released ethanol ignited and formed pool fires. The local police evacuated nearby homes. Some of the released ethanol entered a tributary of the Trinity River. No individuals were injured. However, three horses in a barn were killed and three horses were injured.

The NTSB has completed the on-scene portions of the investigations into the Draffin, Kentucky, and Fort Worth, Texas, accidents.

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given route by automatically controlling throttle and dynamic brakes. Progress Rail: A Caterpillar Company, "Energy Management", accessed May 28, 2020, https://www.progressrail.com/en/innovation/energymanagement0.html.

Safety Issue #1: Placement of DOT-111 Tank Cars in High Hazard Flammable Trains

At the Draffin, Kentucky, accident scene, the two punctured legacy DOT-111 tank cars were placed in positions three and four of the consist.[4] A DOT-117R tank car was the first hazardous materials tank car in the consist behind the buffer car, followed by three DOT-111 tank cars (two of which were breached), then three DOT-117R tank cars. Though the DOT-117R tank cars in front of and to the rear of the DOT-111 tank cars sustained significant impact damage, their head shields protected these cars from breaching. The rest of the train was composed of a mixture of legacy DOT-111, retrofitted DOT-117R, and newly constructed DOT-117J tank cars.[5]

At the Fort Worth, Texas, accident scene, a punctured DOT-111 tank car in position 25 (TCBX 194145) was the source for most of the released ethanol and the resulting pool fire that occurred. The tank car was punctured in two locations during the derailment sequence. First, the unprotected B-end head was likely punctured as the car was pushed into the separated B-end coupler of the leading tank car. Next, the left side of the B-end head and the left-half of the tank shell sustained a very large tear as the car was pushed past another car's protruding coupler or draft sill. TCBX 194145 had been positioned between two 286,000-pound DOT-117J tank cars, which are designed with thicker tank heads and shells and equipped with jackets and head shields. Similar in outcome to the Draffin, Kentucky, accident, the adjacent DOT-117 tank cars were exposed to the same derailment environment as TCBX 194145, but did not breach.

The derailment speeds of 25 mph in Draffin, Kentucky, and 26 mph in Fort Worth, Texas, were above the expected best-case coupler-to-shell puncture threshold for jacketed DOT-111 tank cars.[6] The lack of a head shield, the lack of a jacket, and the relatively thin tank shells used in DOT-111 tank car construction all contributed to the tank car breaching damages in these accidents.

There are no federal regulations, industry standards, or best practices that address the placement of tank car types within a train consist based on the tank car's likelihood of derailing and experiencing a breach. The two breached tank cars in the Draffin, Kentucky, accident were positioned at the head of the train, the highest-risk location of becoming involved in a derailment, as explained below. Similarly, the three breached tank cars in the Fort Worth, Texas, accident were placed in locations in the front third of the train, having greater risks of derailing in an accident.

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[4] Legacy DOT-111 tank cars are older tank cars built to specifications that are no longer authorized for manufacture in flammable liquids service, but which may continue in service for specified commodity-based time periods, as required by the Fixing America's Surface Transportation (FAST) Act. For tank cars in ethanol service, the FAST Act phase-out for nonjacketed and jacketed DOT-111 tank cars is May 1, 2023; for nonjacketed CPC-1232 tank cars is July 1, 2023, and for jacketed CPC-1232 tank cars is May 1, 2025. By the specified compliance date, the tank car must be either removed from flammable liquids service or retrofitted with prescribed protective features, such as a head shield, jacket, and thermal protection.

[5] DOT-117R tank cars were originally DOT-111 tank cars with 7/16-inch or 1/2-inch thick heads and shells that were retrofitted with the addition of the following: 1/2-inch thick head shields, tank jackets and thermal protection blanket, a bottom outlet valve operating mechanism designed to remain closed under accident conditions, and top fittings protective housings. DOT-117J tank cars are newly constructed with 9/16-inch thick heads and shells, and have all the lading protection features found on DOT-117R tank cars. DOT-117R and DOT-117J tank cars have a gross rail load (GRL) of 286,000 pounds, while some DOT-111 tank cars are 263,000 pounds GRL.

[6] Federal Railroad Administration, *Full-scale Shell Impact Tests of a DOT-111 Tank Car.* RR 14-29 (Washington, DC: US Department of Transportation, Federal Railroad Administration, 2014).

Both the Draffin, Kentucky, and the Fort Worth, Texas, trains contained other types of tank cars with better lading retention performance that could have been placed in these higher-risk locations. These accidents show that there is an opportunity for shippers and carriers to further reduce risk and liability by adopting car placement strategies that account for tank car type.

Researchers generally agree that cars positioned at the rear of a train have a lower probability of being derailed and, therefore, a lower probability of sustaining mechanical breaching damages. For example, in 2005, the researchers from the University of Illinois at Urbana-Champaign presented a report at the Heavy Haul Railway Conference in which they conducted a statistical analysis and used modeling techniques to estimate the probabilities of derailment for individual cars as affected by train length, operating speed, and their position within a consist.[7] As shown in figure 1, a graphic from Anderson and Barkan's study, the frequency of derailment for each position in the train was obtained by counting the number of times cars in each location derailed for the study of 4,661 Class 1 railroad mainline freight train derailment accident reports for all consist lengths. The average speed of derailment for the 10-year study period was 24.8 mph. Based on this research, the positioning of the breached DOT-111 tank cars in both the Draffin, Kentucky, and Fort Worth, Texas, accidents made them two to three times more likely to derail in an accident than had they been placed near the end of the train. (See figure 1.)

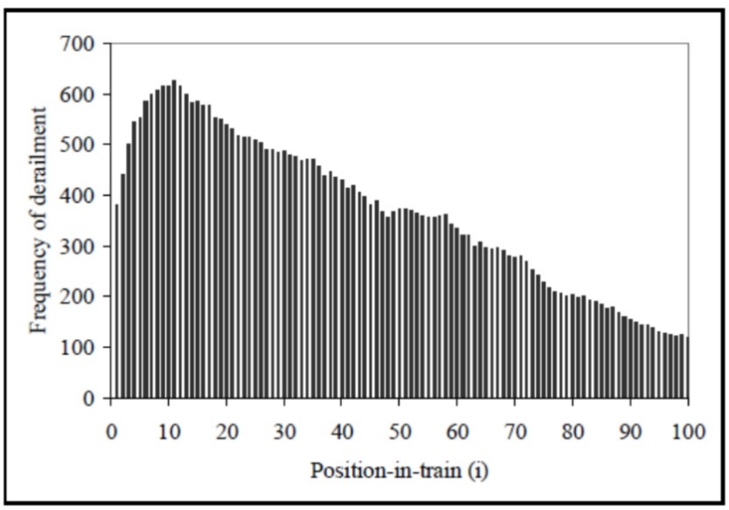

Figure 1. Car frequency of derailment vs. position. (Anderson and Barkan)

More recently, the Rutgers University Department of Civil and Environmental Engineering conducted research to develop a generalized risk analysis approach for comparing hazardous materials transportation in unit trains versus mixed freight trains.[8] Their methodology accounted for the number and placement of tank cars in a train, among other factors, and showed that placing tank cars in positions that were less prone to derailment could reduce overall risk. Figure 2, a

[7] R.T. Anderson and C.P.L. Barkan, "Derailment Probability Analyses and Modeling of Mainline Freight Trains," in *8th International Heavy Haul Railway Conference Proceedings,"* University of Illinois (Rio de Janeiro*:* International Heavy Haul Association, 2005).

[8] X. Liu, "Risk Comparison of Transporting Hazardous Materials in Unit Trains Versus Mixed Trains," *Transportation Research Record: Journal of the Transportation Research Board*, No. 2608, 2017, pp. 134–142.

graphic from the Rutgers research, shows derailment probabilities for derailment speeds of 25, 40, and 50 mph. This research suggests that in a derailment of a 100-car unit train at 25 mph, tank cars placed near the front of the train have a 15 to 20 percent chance of derailing, whereas a tank car placed in position 99 would only have a 5 percent chance of derailing. Derailment risks are greater at the head end with increasing train speed.

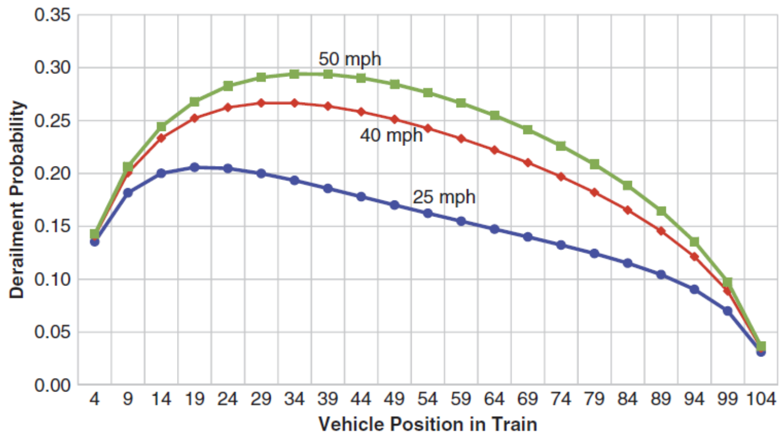

Figure 2. Position-dependent car derailment probability per train derailment. (Liu)

A third example of train position and derailment risk is found in a 2005 report published by the FRA.[9] The Hazardous Materials Transportation Authorization Act of 1994 mandated that the FRA address the placement of hazardous materials cars in trains with the purpose of avoiding harm to crewmembers or interaction of hazardous materials should a train accident or other unintended release occur. The FRA report referenced data from 5,451 train derailments that occurred between 1982 and 1985 to determine the positions of derailed cars. The FRA found that the risk of derailment was significantly lower toward the rear of a train. Figure 3, from the Batelle Memorial Institute, illustrates this finding in a three- and four-section analysis of the data, showing that the risk of derailment is less in the rear of a train (right side of figure) and implies little difference in the relative safety of the first two-thirds or three-quarters.

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[9] Federal Railroad Administration, *Safe Placement of Train Cars: A Report to the Senate Committee on Commerce, Science and Transportation and the House Committee on Transportation and Infrastructure* (Washington, DC: US Department of Transportation, Federal Railroad Administration, 2005).

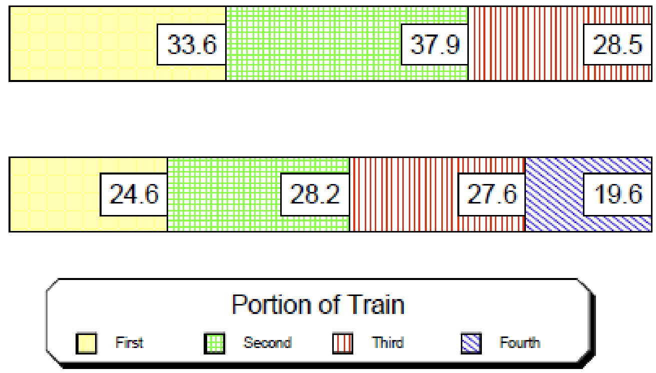

Figure 3. Percentage of risk of cars becoming involved in a derailment based on their in-train position. (Batelle Memorial Institute)

NTSB found no research on the optimal placement in the train of tank cars with differing performance standards carrying hazardous materials. The Draffin, Kentucky, and Fort Worth, Texas, accident trains were assembled without regard to the individual tank car's lading protection or derailment risk. The most vulnerable nonjacketed DOT-111 tank cars were placed immediately behind the locomotives and positioned throughout the rest of the train in the highest areas of derailment risk. Thus, it was more likely that a derailment would involve at least one DOT-111 tank car.[10] Both the Draffin, Kentucky, and Fort Worth, Texas, trains contained sufficient numbers of more robust puncture-resistant DOT-117J tank cars, which could have been positioned in the front third of each train, decreasing the risk of flammable hazardous material releases. Finally, the DOT-111 baseline legacy tank cars could have been placed in the lowest-risk positions for exposure to derailment or collision—and far away from occupied locomotives.

High coupler forces and derailment energy are other factors that increase the risk of damage to DOT-111 tank cars placed near the front of trains. In the Draffin, Kentucky, and Fort Worth, Texas, accidents, the DOT-111 tank cars were positioned at the front and front third of the train, respectively. Derailments that begin toward the front of the train expose tank cars to the trailing tonnage or to the rolling mass of the length of train cars behind them. In a derailment, this trailing mass of train cars and their lading would continue to progress forward as the energy state of the cars dissipate before coming to a rest. The collision behavior of the derailing cars often exposes the structurally vulnerable DOT-111 tank cars to high energy impacts and severe mechanical damage as the wreckage collapses into a pile. Had these more vulnerable tank cars been placed at the rear of the other loaded cars in the train, the reduction in the energy state could have substantially reduced car-to-car impact forces. The NTSB concludes that the severity of the Draffin, Kentucky, and Fort Worth, Texas, accidents could have been mitigated had the DOT-111 tank cars been placed in locations within the train where they were less likely to derail or to sustain accident damage.

[10] The poor lading retention performance of DOT-111 tank cars has been well documented in numerous accidents the NTSB has investigated. National Transportation Safety Board, *Derailment of CN Freight Train U70691-18 with Subsequent Hazardous Materials Release and Fire, Cherry Valley, Illinois*, *June 19, 2009*, RAR-12/01 (Washington, DC: National Transportation Safety Board, 2012).

Until DOT-111 tank cars are phased out of service in HHFTs, as provided in Title 49 *Code of Federal Regulations* (*CFR*) 173.242(a)(1) and 173.243(a)(1), these trains may be composed of DOT-117J, DOT-117R, CPC-1232, and DOT-111 tank cars, each having significantly different lading protection features.[11] The likelihood that a consist would include cars of varying levels of protection is high given that the North American flammable materials tank car fleet is currently composed of roughly equal numbers of DOT-117J, DOT-117R, CPC-1232, and DOT-111 tank cars.[12] Furthermore, not all DOT-117R tank cars have equivalent levels of safety, and none match the crashworthiness of the DOT-117J car. According to AAR statistics, the DOT-117R portion of the North American fleet is currently composed of about 51 percent retrofitted from legacy DOT-111 tank cars with 7/16-inch thick shells, about 28 percent retrofitted from CPC-1232 tank cars with 7/16-inch thick shells, and 20 percent retrofitted from CPC-1232 cars with 1/2-inch thick shells. All the DOT-117R tank cars involved in the Draffin, Kentucky, accident and most of the DOT-117R tank cars involved in the Fort Worth, Texas, accident were among those with the least effective lading protection features.

Previous Attempts to Address Tank Car Placement

The NTSB previously recommended that the FRA develop requirements for the placement of cars carrying poison-inhalation hazard (PIH) materials to lessen their risk of derailment.[13] As a result of the January 6, 2005, derailment of a Norfolk Southern Railway Company train in Graniteville, South Carolina, that resulted in the release of chlorine, the NTSB issued the following safety recommendation to the FRA:

> Require railroads to implement operating measures, such as positioning tank cars toward the rear of trains and reducing speeds through populated areas, to minimize impact forces from accidents and reduce the vulnerability of tank cars transporting chlorine, anhydrous ammonia, and other liquefied gases designated as poisonous by inhalation (R-05-16) (Status: "Closed—Unacceptable Action".)

Safety Recommendation R-05-16 was classified, "*Closed—Unacceptable Action*" on August 19, 2010, after PHMSA issued a January 13, 2009, final rule on improving the safety of tank car transportation of hazardous materials, which did not include operational requirements for

[11] The AAR Casualty Prevention Circular (CPC)-1232 is an industry-consensus specification intended to enhance the safety of DOT-111 tank cars ordered after October 2011 and used to transport crude oil and ethanol. CPC-1232 tank cars have thicker shells or jackets, are protected with head shields, and have more robust top fittings protection than DOT-111 tank cars. Construction requirements are specified in the AAR *Manual of Standards and Recommended Practices*, *Specifications for Tank Cars*, M-1002.

[12] AAR, "Status of the North American Flammable Liquid Fleet as of 4th Quarter 2019," Data Provided to the AAR Tank Car Committee (Washington DC: 2020). CPC-1232 tank cars have this industry-sponsored specification, intended to be safer than DOT-111 tank cars for carrying petroleum crude oil and ethanol. Tank cars ordered after October 2011 were required to meet this specification. These tank cars include a pressure relief valve, more extensive top fittings protection than on the DOT-111 rail tank cars, and a full height or half-height head shield. The shell of nonjacketed tank cars must be 1/2-inch thick, and for jacketed tank cars must be 7/16-inch thick. Information obtained from website of U.S. Department of Transportation, "Tank Car Specifications & Terms," last modified April 18, 2018, https://www.bts.gov/surveys/annual-tank-car-facility-survey/tank-car-specifications-terms.

[13] National Transportation Safety Board, *Collision of Norfolk Southern Freight Train 192 with Standing Norfolk Southern Local Train P22 with Subsequent Hazardous Materials Release at Graniteville, South Carolina, January 6, 2005*, RAR-05/04 (Washington, DC: National Transportation Safety Board, 2005).

PIH hazardous materials placement in a train. Furthermore, PHMSA stated in its final rule that the DOT did not believe that Safety Recommendation R-05-16 could be effectively implemented without introducing additional safety risks and an extreme economic burden on the industry, and that it did not intend to consider further action concerning tank car placement measures.

While the question of where to position DOT-111 tank cars in a mixed unit train of DOT-117R and DOT-117J tank cars is no longer relevant to crude oil by rail shipments, it remains a concern for ethanol until the scheduled DOT-111 phaseout in May 2023.[14] Because the Fort Worth, Texas, accident demonstrated that DOT-117J tank cars have significant resilience over retrofitted DOT-111 variants, mixed consists of DOT-117J and DOT-117R tank cars that will remain in service together for many years to come deserve similar positioning consideration to reduce exposure of the more vulnerable tank car equipment to breaching damage risks.

Opposition to car placement requirements seems influenced by the presumed negative impacts this would have on normal railroad operating practices and efficiencies, because building train consists would require additional switching moves whenever hazardous materials cars are involved.[15] The FRA stated that hazardous materials car placement, instead of the normal practice of building train consists in station-order blocks, would require additional switching moves in classification yards and with train movements en route in the pick up and set out of cars.[16] However, when flammable liquid tank cars are shipped by unit train, risk-based positioning could be facilitated by unit trains that tend to remain together for extended periods of time.[17] Additional risks and inconvenience caused by switching movements could be avoided when every car in a unit train carries the same hazardous material to the same destination and the consist order need not be changed once established, with the exception of occasional set outs for repairs or maintenance.

Although some ethanol shippers have installed loop tracks for improved loading efficiency, not all facilities have the available track infrastructure and space necessary to conduct full unit train loading.[18] For example, the shipper of record in the Fort Worth accident would have to break trains up into blocks of 20 cars for loading, complicating the sorting of tank cars by derailment risk. Thus, some facilities might require additional logistical considerations and switching movements to adjust the placement of various tank car types. In managing the safety of their flammable liquid tank car fleets, such shippers might consider the benefits of safer car placement against the hazards associated with additional car handling to achieve an ideal risk-based consist.

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[14] In accordance with the FAST Act, all nonjacketed and jacketed DOT-111 tank cars carrying crude oil have been phased out of service as of January 2018 and March 2018, respectively. DOT-111 tank cars in all other flammable liquids service, except for ethanol and crude oil, must be phased out by May 2029.

[15] Letter from FRA to NTSB, September 2, 2009, regarding response to Safety Recommendation R-05-16.

[16] A classification yard is a rail yard consisting of usually parallel tracks used in building train consists.

[17] Pipeline and Hazardous Materials Safety Administration, *Final Regulatory Impact Analysis, Docket No. PHMSA-2012-0082* (Washington, DC: U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, 2015).

[18] *Loop tracks* increase loading efficiency by allowing unit trains to stay together on the same track without the need for coupling and uncoupling during the loading process. Efficiency is maximized when the loop track is large enough to handle the entire train in a single pass without breaking the train up.

Furthermore, the FRA argued that while it may make sense to consider placing hazardous materials cars near the rear of trains to reduce the severity of derailments, as recommended in R-05-16, any benefit would likely be offset by an increased risk of release caused by rear-end collisions.[19] However, the FRA did not provide any data to support this assertion. The NTSB is aware of only one rear-end collision occurrence (discussed below) among the North American HHFT accidents that occurred between 2006 and 2020. The majority of these HHFT accidents involved track-related derailments. Concerns about rear-end collisions should be addressed by the implementation of positive train control (PTC) on routes used by HHFTs.[20] In addition, railroads could fortify the very rear of the train with more robust DOT-117 tank cars to buffer more vulnerable DOT-111 cars. For example, on April 30, 2017, a standing Canadian National Railway (CN) crude oil unit train, consisting of 2 head end locomotives, 114 loaded tank cars, 2 buffer cars, and a rear-end distributed power (DP) locomotive was struck in the rear by another CN freight train in Money, Mississippi.[21] The standing train DP locomotive was impacted, driven forward, and punctured a jacketed CPC-1232 tank car. The CPC 1232 tank car was pushed forward into a DOT-117 tank car, stripping its stub sill and underframe from the tank and displacing them forward. Released crude oil from the CPC-1232 car fueled a pool fire that engulfed the DOT-117 tank car. The DOT-117 tank car was not breached and did not release any hazardous material. The fire was extinguished shortly after the accident without causing any cascading thermal damage to adjacent tank cars in the train.

In 2015, the FRA, with the participation of PHMSA, established a Railroad Safety Advisory Committee (RSAC) hazardous material working group to consider revisions to the Hazardous Materials Regulations, 49 *CFR* Parts 100-185. This working group considered revisions to 49 *CFR* Part 174, specifically relating to train placement, among other issues.[22] While the RSAC examined train placement regulations pertaining exclusively to the use of buffer cars for the protection of train crews, the issue became deadlocked by lack of consensus and, consequently, no regulatory revisions have been acted upon to date. This lack of regulatory progress on an issue related to train placement, coupled with FRA's unacceptable action on Safety Recommendation R-05-16, suggests that successful implementation of a regulatory solution for improving tank car placement practices is unlikely. The NTSB concludes that industry guidelines and recommended practices for the placement of DOT-111 tanks cars in low-risk positions of train consists are the most expeditious means for shippers and carriers of HHFTs to achieve the safety benefits of fewer breached tank cars in derailments. Therefore, the NTSB recommends that AAR, ASLRRA, and RFA develop and adopt guidelines and recommended practices for the systematic placement of the most vulnerable tank cars in HHFTs, such as unmodified DOT-111 tank cars, in positions of trains where they are least likely to derail or to sustain mechanical damage from the effects of trailing tonnage or collision in an accident.

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[19] Letter from FRA to NTSB, September 2, 2009, regarding response to Safety Recommendation R-05-16.

[20] *Positive train control* (PTC) is a system of train control to prevent train-to-train collisions, enforce speed restrictions, protect roadway workers and their equipment by preventing incursion into established work zones, and prevent the movement of a train through a main track switch in the improper position.

[21] See NTSB docket number DCA17SH002.

[22] Railroad Safety Advisory Committee Hazardous Materials Working Group, "Task Statement: Hazardous Materials. Task No. 15-04." Presented to the RSAC, Washington DC, November 5, 2015.

Safety Issue #2: Use of Buffer Cars for the Protection of Train Crews from Hazardous Materials Releases

Hazardous materials train placement requirements are found at 49 *CFR* 174.85. The regulation specifies that "when train length permits, [a] placarded car may not be nearer than the sixth car from the engine or occupied caboose." However, when the train is not long enough to allow for a five-car buffer, trains may operate with a minimum of one buffer car. Railroads commonly use this exception to operate unit trains carrying hazardous materials with only one nonplacarded (buffer) car separating the hazardous materials tank cars from locomotives, in contrast to the requirement for five buffer cars separating placarded hazardous materials cars from locomotives on mixed-freight trains. The FRA, PHMSA, and the Class 1 railroads have interpreted the regulation to allow use of a single buffer car between the locomotives and the first placarded car on unit trains, increasing the risk to train crews from hazardous materials releases that occur near the head end.[23]

Draffin, Kentucky

The CSX train crewmembers in Draffin, Kentucky, were separated from the first hazardous materials tank car in the consist by two head-end locomotives and a single empty high-sided gondola car that was placed in position one of the consist as a buffer car. The two trailing locomotives, buffer car, and first two tank cars all came to rest ahead of the occupied locomotive following the derailment. The two breached DOT-111 ethanol tank cars came to rest uphill and nearly in contact with the trailing end of the occupied locomotive. Spilled ethanol fueled the postaccident pool fire, which engulfed the head-end occupied locomotive. (See figure 4.) In addition, first responders observed the third tank car in the consist, a breached DOT-111, intermittently released fireballs in the direction of the train crew as they waited for rescue on the outside platform of the locomotive.

[23] (a) Letter from PHMSA Office of Hazardous Materials Standards to NTSB, reference number 06-0278 regarding the October 20, 2006, derailment of a Norfolk Southern Railway Company train transporting ethanol in New Brighton, Pennsylvania, March 29, 2007. (b) National Transportation Safety Board, *Derailment of Norfolk Southern Railway Freight Train 68QB119 with Release of Hazardous Materials and Fire, New Brighton, Pennsylvania, October 20, 2006*, RAR-08/2 (Washington, DC: National Transportation Safety Board, 2008).

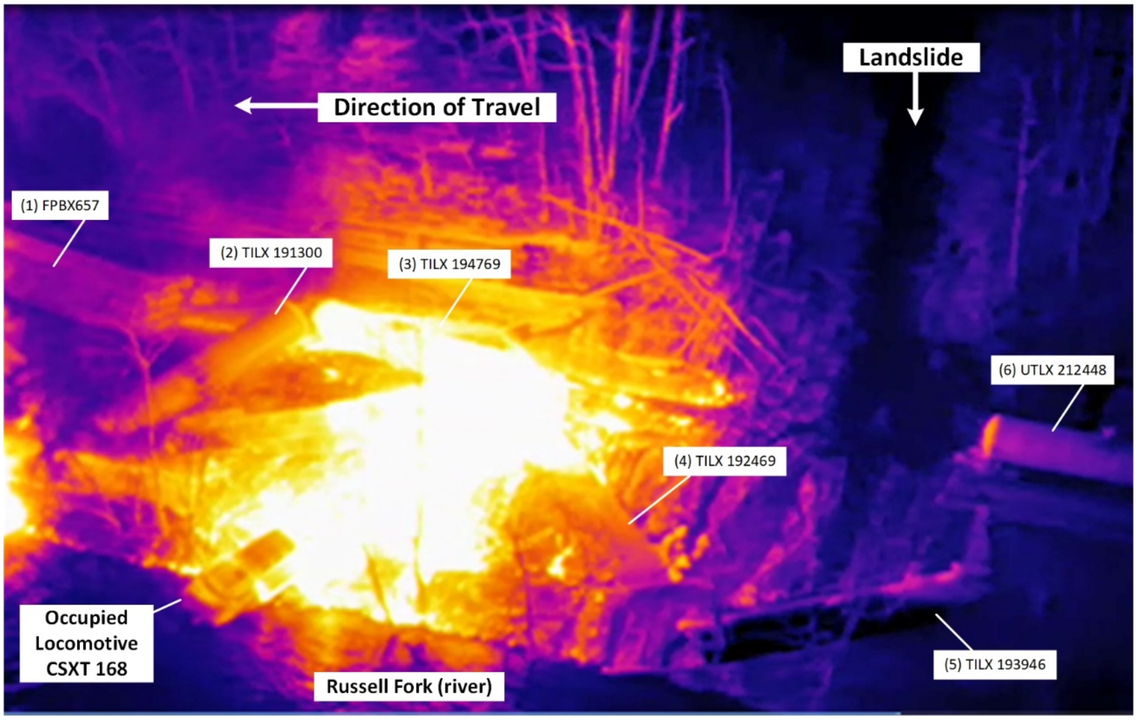

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Figure 4. Draffin, Kentucky, derailment scene thermal image. (Courtesy of Pike County, Kentucky, Emergency Management Agency.)

The Pike County deputy emergency management director told NTSB investigators that firefighters observed the train crew grasping to the front of the lead locomotive while a large fire burned near them. He said the cab of the locomotive was engulfed in flames that came within 10 feet of the crew. The deputy emergency management director stated, "the fire was right at them and they appeared to be panicking … their choices were to go toward the fire or jump into the river." The train crew entered the water and was ultimately rescued by emergency responders.

The first derailed tank car in the consist was a specification DOT-117R, TILX191300, which sustained a severe angular dent to its leading head, most likely during impact with one of the derailed locomotives as the tank car was pushed forward by trailing tonnage. The ability of the first tank car to retain all its lading was due in large part to it being equipped with a head shield. However, the second and third tank cars, both legacy specification DOT-111 tank cars, were not so equipped. The second tank car, TILX 194769, was punctured in its unprotected leading head and right-side tank shell after experiencing similar derailment impact conditions, and it released its entire load of denatured ethanol to form a pool fire. The unprotected leading head of the third DOT-111 tank car, TILX192469, was punctured when it impacted the third locomotive's front platform or pilot structure.[24] The pool fire engulfed all three locomotives, including the lead locomotive cab, which was destroyed by the fire. As evident from this accident sequence, the lack of sufficient separation distance between the lead locomotive and DOT-111 ethanol tank cars placed the train crew at risk of death or serious injury from the hazardous materials release.

[24] The *pilot* is a fender-like structure mounted at the front of a locomotive to deflect obstacles on the track.

Previous Safety Recommendations

This is not the first time the NTSB has investigated instances in which train crews operating unit trains of hazardous materials were placed at risk from exposure to released hazardous materials. On December 30, 2013, a BNSF Railway crude oil unit train derailed in Casselton, North Dakota, and the train crew narrowly escaped their locomotive before it was destroyed by the eruption of a postaccident fire and energetic fireballs from breached tank cars.[25] As a result, the NTSB issued the following safety recommendations to PHMSA:[26]

> Evaluate the risks posed to train crews by hazardous materials transported by rail, determine the adequate separation distance between hazardous materials cars and locomotives and occupied equipment that ensures the protection of train crews during both normal operations and accident conditions, and collaborate with the Federal Railroad Administration to revise 49 *Code of Federal Regulations* 174.85 to reflect those findings. (R-17-01) (Status: Open—Acceptable Response.)

> Pending completion of the risk evaluation and action in accordance with its findings prescribed in Safety Recommendation R-17-01, withdraw regulatory interpretation 06-0278 that pertains to 49 *Code of Federal Regulations* 174.85 for positioning placarded rail cars in a train and require that all trains have a minimum of five nonplacarded cars between any locomotive or occupied equipment and the nearest placarded car transporting hazardous materials, regardless of train length and consist. (R-17-02) (Status: Open—Acceptable Response.)

As a result of the Casselton accident, the NTSB also issued the following companion recommendation to the FRA:[27]

> Evaluate the risks posed to train crews by hazardous materials transported by rail, determine the adequate separation distance between hazardous materials cars and locomotives and occupied equipment that ensures the protection of train crews during both normal operations and accident conditions, and collaborate with the Pipeline and Hazardous Materials Safety Administration to revise 49 *Code of Federal Regulations* 174.85 to reflect those findings. (R-17-03)
> (Status: Open—Acceptable Response.)

PHMSA initially replied to Safety Recommendations R-17-01 and -02 on June 7, 2017, when it said that in 2015 it collaborated with the FRA under the scope of the RSAC Hazardous Materials Issues Working Group, Task No. 15-04, to address the separation distance issue, but

[25] National Transportation Safety Board, *BNSF Railway Train Derailment and Subsequent Train Collision, Release of Hazardous Materials, and Fire, Casselton, North Dakota, December 30, 2013*, RAB-17/03 (Washington, DC: National Transportation Safety Board, 2017).

[26] These safety recommendations superseded Safety Recommendation R-08-13, which called for PHMSA to work with FRA to determine the optimum separation requirements between occupied locomotives and hazardous materials cars, and revise 49 *CFR* 174.85 accordingly.

[27] This recommendation superseded Safety Recommendation R-08-12, which called for FRA to assist PHMSA to determine optimum separation requirements between occupied locomotives and hazardous materials cars, and revise 49 *CFR* 174.85 accordingly.

stakeholder disagreement and lack of established incident data resulted in a lack of consensus.[28] With regard to Safety Recommendation R-17-03, on May 31, 2017, the FRA said that it was "working with PHMSA to inform a potential revision of 49 *CFR* 174.85."[29]

In an August 7, 2020, letter PHMSA updated the NTSB on its actions to satisfy Safety Recommendations R-17-01 and -02.[30] With regard to Safety Recommendation R-17-01, PHMSA said that in April 2019, it initiated a research project at the John A. Volpe National Transportation Systems Center (Volpe Center) to determine the appropriate separation distance of train crews from hazardous materials cars. The study proposes to review existing literature on separation distances, identify gaps in the existing studies, areas for further research, and determine what conclusions, if any, can be drawn from this information. PHMSA said that a final report about this study, including its findings was expected by the end of 2020. PHMSA also discussed a similar study by Transport Canada, and PHMSA's plan to share with Transport Canada the progress and results of the two studies.

With regard to Safety Recommendation R-17-02, PHMSA said in its August 7, 2020, letter that withdrawing the letter of interpretation 06-0278 would not change the regulatory requirement for separation distance of hazardous materials cars from train crews, and that adopting a minimum five-car separation distance standard would require a rulemaking action.[31] PHMSA planned no action until after completion of the Volpe Center and Transport Canada studies. PHMSA also said that the current five-car separation distance required by 49 *CFR* 174.85(d) applies when the train length permits. As set forth in regulatory interpretation 06-0278, PHMSA regards the train lengths permitting the five-car separation to be when there are enough nonhazardous materials cars in the train. When there are not enough nonhazardous materials cars in the train, a placarded car must be placed near the middle of the train, but not nearer than the second car from an engine or occupied caboose.

The NTSB disagrees with PHMSA's position that withdrawing regulatory interpretation 06-0278 would not change the requirement for separation distance. In the absence of regulatory interpretation 06-0278, the exception on placarded car placement contained in 49 *CFR* 174.85(d), "when train length permits," would only apply when the train is too short to achieve five-car separation from the first placarded car. Regulatory interpretation 06-0278 in practice removes the requirements of 49 *CFR* 174.85 for the operation of HHFTs. The intent of Safety Recommendation R-17-02 is for 49 *CFR* 174.85(d) to be interpreted as it is currently written, requiring a minimum of five nonplacarded cars separating the locomotive or occupied equipment from the nearest placarded car transporting hazardous materials until such time as the adequate separation distance is determined as called for in Safety Recommendation R-17-01.

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[28] Letter from PHMSA to NTSB, June 7, 2017, regarding response to Safety Recommendations R-17-01 and -02.

[29] Letter from FRA to NTSB, May 31, 2017, regarding response to Safety Recommendation R-17-03.

[30] Letter from PHMSA to NTSB, August 20, 2020, regarding Safety Recommendations R-17-01 and -02.

[31] Following the October 20, 2006, derailment of Norfolk Southern Corporation train 68QB119 on a bridge over the Beaver River in New Brighton, Pennsylvania, the NTSB requested PHMSA to clarify the train placement requirements prescribed in 49 *CFR* 174.85 for unit trains consisting of hazardous materials. In response, on March 29, 2007, PHMSA issued regulatory interpretation 06-0278 stating that when the length of a train does not permit placement of a placarded car no nearer than the sixth car from the engine or occupied caboose, the placarded car must not be placed nearer than the second car from the from the engine or occupied caboose.

The circumstances of the December 13, 2013, accident in Casselton, North Dakota, and the February 13, 2020, accident in Draffin, Kentucky, demonstrate the need to implement appropriate separation distance requirements. The NTSB urges PHMSA and FRA to consider the circumstances of these accidents, which should serve to reinforce the urgency of implementing appropriate separation distance requirements. The NTSB concludes that a single buffer car does not provide sufficient separation distance from train crews when the head end of a high hazard flammable train becomes involved in a derailment because the higher energy state caused by the trailing tonnage and run-in forces can push breached hazardous materials tank cars dangerously close to occupied locomotives. The NTSB is concerned that this safety issue could further imperil train crews since PHMSA issued final rule HM-264 on July 24, 2020, that authorizes the transportation of liquefied natural gas in unit trains of DOT-113 tank cars without establishing requirements for crew separation distance from cars carrying hazardous materials.[32] Therefore, the NTSB reiterates Safety Recommendations R-17-01 and R-17-02 to PHMSA, and Safety Recommendation R-17-03 to the FRA.

PHMSA's sponsorship of the Volpe Center study initiated in April 2019 and scheduled to be finished by the end of 2020 is partially responsive to Safety Recommendation R-17-01. Pending completion of the study, and revisions to 49 *CFR* 174.85 to provide adequate separation from hazardous materials in both normal operations and accident conditions, Safety Recommendation R-17-01 remains classified "Open—Acceptable Response." Because PHMSA does not plan to withdraw regulatory interpretation 06-0278 or take any interim action to address the demonstrated safety risk from inadequate separation between placarded cars transporting hazardous materials and any locomotive or occupied equipment, Safety Recommendation R-17-02 is classified "Open—Unacceptable Response."

Findings

1. The severity of the Draffin, Kentucky, and Fort Worth, Texas, accidents could have been mitigated had the US Department of Transportation-111 tank cars been placed in locations within the train where they were less likely to derail or to sustain accident damage.

2. Industry guidelines and recommended practices for the placement of US Department of Transportation-111 tank cars in low-risk positions of train consists are the most expeditious means for shippers and carriers of high hazard flammable trains to achieve the safety benefits of fewer breached tank cars in derailments.

3. A single buffer car does not provide sufficient separation distance from train crews when the head end of a high hazard flammable train becomes involved in a derailment because the higher energy state caused by the trailing tonnage and run-in forces can push breached hazardous materials tank cars dangerously close to occupied locomotives.

[32] (a) *Federal Register* 84, no. 206 (October 24, 2019): 56966; (b) *Federal Register* 85, no. 143 (July 24, 2020): 44994.

Recommendations

New Recommendation

As a result of this report, the National Transportation Safety Board makes the following safety recommendation:

To the Association of American Railroads, the American Short Line and Regional Railroad Association, and the Renewable Fuels Association:

> Develop and adopt guidelines and recommended practices for the systematic placement of the most vulnerable tank cars in high hazard flammable trains, such as unmodified US Department of Transportation-111 tank cars, in positions of trains where they are least likely to derail or to sustain mechanical damage from the effects of trailing tonnage or collision in an accident. (R-20-27)

Classified and Reiterated Recommendations

To the Pipeline and Hazardous Materials Safety Administration:

> Evaluate the risks posed to train crews by hazardous materials transported by rail, determine the adequate separation distance between hazardous materials cars and locomotives and occupied equipment that ensures the protection of train crews during both normal operations and accident conditions, and collaborate with the Federal Railroad Administration to revise 49 *Code of Federal Regulations* 174.85 to reflect those findings. (R-17-01)
>
> Safety Recommendation R-17-01 is classified "Open—Acceptable Response."
>
> Pending completion of the risk evaluation and action in accordance with its findings prescribed in Safety Recommendation R-17-01, withdraw regulatory interpretation 06-0278 that pertains to 49 *Code of Federal Regulations* 174.85 for positioning placarded railcars in a train and require that all trains have a minimum of five nonplacarded cars between any locomotive or occupied equipment and the nearest placarded car transporting hazardous materials, regardless of train length and consist. (R-17-02)
>
> Safety Recommendation R-17-02 is classified "Open—Unacceptable Response."

Reiterated Recommendation

To the Federal Railroad Administration:

> Evaluate the risks posed to train crews by hazardous materials transported by rail, determine the adequate separation distance between hazardous materials cars and locomotives and occupied equipment that ensures the protection of train crews during both normal operations and accident conditions, and collaborate with the

Pipeline and Hazardous Materials Safety Administration to revise 49 *Code of Federal Regulations* 174.85 to reflect those findings. (R-17-03)

Safety Recommendation R-17-03 is classified "Open—Acceptable Response."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Date: December 2, 2020