National Transportation Safety Board

Washington, DC 20594

Safety Recommendation

Date: Apri1 3, 2015

In reply refer to: R-15-14 through -17

The Honorable Timothy P. Butters
Acting Administrator
Pipeline and Hazardous Materials
Safety Administration
Washington, DC 20590

The National Transportation Safety Board (NTSB) urges the Pipeline and Hazardous Materials Safety Administration (PHMSA) to take action on the safety recommendations issued in this letter. These recommendations are derived from the NTSB's examination of damaged tank cars following the February 16, 2015, derailment of a CSX Transportation crude oil unit train in Mount Carbon, West Virginia, as well as a review of data collected from accidents that occurred in Gogama, Ontario, on February 14, 2015; Galena, Illinois, on March 5, 2015; and Gogama, Ontario, on March 7, 2015. These recommendations address the retrofitting of thermal protection systems for Department of Transportation (DOT) specification DOT-111 tank cars used to transport Class 3 flammable liquids. Based on the unacceptable performance of bare steel tank cars as evidenced in the four accidents listed above, the NTSB is issuing four safety recommendations to PHMSA. Information supporting these recommendations is discussed below.

Background

Tank cars used today to transport crude oil and ethanol include both the specification DOT-111 tank car that typically has 7/16-inch thick heads and shell with no head shield (legacy DOT-111 tank car) or the Casualty Prevention Circular (CPC)-1232 compliant DOT-111 tank car that is equipped with thicker heads and shell and half-height head shields.

On August 31, 2011, the Association of American Railroads (AAR) issued CPC-1232, establishing new requirements for tank cars built for the transportation of Class 3, Packing Groups I and II materials with the proper shipping names Petroleum Crude Oil, Alcohols, n.o.s., and Ethanol and Gasoline Mixture.[1] These standards published in the AAR *Manual of Standards and Recommended Practices, Specifications for Tank Cars*, C-III, M-1002, require that all such

[1] *n.o.s.* means not otherwise specified.

tank cars ordered after October 1, 2011, for use in specified Packing Groups I and II flammable liquids service must meet the following criteria:

> Class 111 tank cars used to transport Packing Group I and II materials with the proper shipping names Petroleum Crude Oil, Alcohols, n.o.s., and Ethanol and Gasoline Mixture, must have heads and shells constructed of normalized TC128 Grade B steel or normalized A516-70 steel. Tank car heads must be normalized after forming, unless approval is granted by the AAR Executive Director of Tank Car Safety on the basis that a facility has demonstrated that its equipment and controls provide an equivalent level of safety. For tanks constructed of normalized TC128 Grade B steel, non-jacketed tanks must be at least 1/2-in. thick and jacketed cars must be at least 7/16-in. thick. For tanks constructed of normalized A516-70 steel, non-jacketed cars must be at least 9/16-in. thick and jacketed cars must be at least 1/2-in. thick. In all cases the cars must be equipped with at least 1/2-in. half-head shields.

Neither the DOT-111 tank cars nor those manufactured to the CPC-1232 standard are required to be equipped with thermal protection systems to protect the tank from exposure to pool or torch fire conditions that can occur in accidents.[2]

Thermal protection systems for tank cars are intended to limit the heat flux to the containers when exposed to fire. Appropriately designed thermal protection systems will prevent a rapid increase in the temperature of the lading and commensurate increase in vapor pressure in the tank, and are intended to limit the volume of material required to be evacuated through the pressure relief device, thereby limiting dangerous overpressurization of the tank.

Exposing a bare steel, flammable-liquid filled tank car to a large pool fire from product released in an accident can result in tank failure from a thermal tear in the tank that was not otherwise breached in a derailment. When the tank is exposed to heat from a pool fire, the internal pressure increases while the strength of the tank decreases. The tank will rupture if the pressure relief device cannot sufficiently relieve internal pressure. The resulting thermal tear in the shell material suddenly releases built-up pressure, ejecting vapor and liquid to ignite in a violent fireball eruption. Research studying accidents involving tank cars has shown that use of tank cars with thermal protection and a jacket will significantly reduce the amount of product released in accidents.[3] PHMSA estimates that jacketed CPC-1232 tank cars with thermal protection systems could provide an 18 percent reduction in lading loss in accidents relative to comparable accidents involving nonjacketed CPC-1232 tank cars.[4]

Tank cars that are currently required to have thermal protection systems, such as pressure tank cars used to transport flammable gases, must comply with the performance standard of Title 49 *Code of Federal Regulations* (CFR) Section 179.18(a). This regulation requires the tank

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[2] Some tank cars may have insulation (typically fiberglass, mineral wool blankets, or foam) applied over the tank and enclosed within a metal jacket. Insulation is used to moderate the temperature of the lading during transportation, but disintegrates at high temperature. In contrast, a thermal protection system is designed to protect the tank car from the high temperature of a pool fire or torch fire.

[3] *Safety Performance of Tank Cars in Accidents: Probabilities of Lading Loss*, Report RA-05-02, Railway Supply Institute and Association of American Railroads Safety Research and Test Project (January, 2006).

[4] *Calculating Effectiveness Rates of Tank Car Options,* PHMSA Docket PHMSA-2012-0082.

car to have sufficient thermal resistance so that when subjected to a pool fire for 100 minutes or a torch fire for 30 minutes there will be no release of any lading from the tank car, except through the pressure relief device. The 100-minute survival time benchmark was established to provide emergency responders with adequate time to assess a derailment, establish perimeters, and evacuate the public as needed, while also giving time to vent the hazardous material from the tank through the pressure relief device and prevent an energetic tank car failure.[5]

As stated in 49 CFR 179.15, all tank cars used to transport flammable materials, regardless of whether equipped with thermal protection, must be equipped with a pressure relief device. Pressure relief devices are affixed to the top of the tank in the normal vapor space and are designed to limit internal tank pressure when exposed to fire to prevent catastrophic tank failure. Pressure relief devices are rated by their start-to-discharge pressure in pounds per square inch gauge (psig) and venting capacity in standard cubic feet per minute (SCFM). The pressure relief device performance standard of 49 CFR 179.15 requires in part that the pressure relief device must have sufficient flow capacity to prevent excessive pressure build up in the tank under fire conditions. The regulation further requires that the start-to-discharge pressure may not be lower than 75 psig, or exceed 33 percent of the minimum tank burst pressure.

To demonstrate compliance with the thermal protection performance standard of 49 CFR 179.18(a), the regulation requires a thermal analysis of the fire effects on the entire surface of the tank car. The Analysis of Fire Effects on Tank Cars (AFFTAC) model is is used by industry to conduct thermal tank car analysis.[6] Given certain assumptions and conditions, the AFFTAC model assesses the structural integrity of the tank and the performance of the pressure relief device for a tank car exposed to fire.

The AAR Tank Car Committee task force T-87.6 considered additional protective measures for tank cars in crude oil and ethanol service.[7] On March 1, 2012, the task force reported the results of modeling tank cars exposed to pool fire conditions using the AFFTAC model.[8] The modeling assumed a 30,000 gallon 7/16-inch thick tank, A516 steel, pure ethanol lading, a 75 psi start-to-discharge pressure relief device rated at 35,660 SCFM, and a 1,500° F pool fire. The task force report noted that the AFFTAC results (time to tank failure) could not be used to directly predict tank car performance in actual fire conditions. Rather, the results from different analyses were compared to understand how survival time improved with different types of protective measures. As a basis for not requiring thermal protection on CPC-1232 tank cars, the task force reported that the AFFTAC results of an overturned car (without thermal protection) at a 120-degree orientation from upright in a pool fire, yielded a calculated survival time of 108 minutes, which exceeded the 49 CFR 179.18(a) performance standard. The predicted times to thermal failure for a legacy DOT-111 tank car and a CPC-1232 tank car without thermal protection are essentially the same. Modeling for a CPC-1232 tank car equipped with a jacket and thermal protection yielded a calculated survival time of greater than 1,000 minutes, or a

[5] *Federal Register* 79, no. 148 (August 1, 2014): 45055.

[6] AFFTAC is a computer model that simulates the effects of fire on rail tank cars. It is used by the US Department of Transportation, Transport Canada, and tank car manufacturers for evaluating and qualifying thermal protection systems for tank cars.

[7] Title 49 CFR 179.4 requires that proposed changes in or additions to specifications for tank cars must be submitted to the Executive Director – Tank Car Safety, AAR, for consideration by its Tank Car Committee.

[8] *Federal Register* 79, no. 148 (August 1, 2014): 45030.

ten-fold improvement in survival time relative to the bare steel tank under the same assumed conditions.

The only task force initiative produced relative to the CPC-1232 tank car was a recommendation that the cars be equipped with a pressure relief device that has a flow capacity of not less than 27,000 SCFM and a start-to-discharge pressure of 75 psig to ensure a 100-minute pool fire survival time. Investigators have found that CPC-1232 tank cars involved in recent accidents were not equipped with pressure relief devices conforming to this task force recommendation. Furthermore, no revisions have been made to federal regulations or industry standards to address pressure relief criteria for these tank cars.

In the August 1, 2014, notice of proposed rulemaking, *Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains*, PHMSA, in coordination with the Federal Railroad Administration (FRA) proposes new tank car standards for certain trains transporting large volumes of Class 3 flammable liquids.[9] The proposed rule includes a new specification DOT-117 tank car that would be required, among other things, to have a jacket and a thermal protection system in accordance with 49 CFR 179.18(a). The proposed rule would require equivalent thermal protection system retrofits to legacy Class DOT-111 and the CPC-1232 tank cars to meet the same performance standard.

In September 30, 2014, comments to the PHMSA rulemaking docket, the AAR emphasized that thermal protection systems addressed in 49 CFR 179.18(a) are based on flammable gases transported in tank cars, and that tank cars transporting flammable liquids behave differently from the perspective of avoiding thermal ruptures.[10] The AAR stated that the Railway Supply Institute – AAR Tank Car Safety Research and Test Project (RSI-AAR Project), assessed the survivability of different tank car configurations in a pool fire using the AFFTAC model. The RSI-AAR Project concluded that the same thermal protection system used on flammable gas tank cars would provide at least 800 minutes of protection to so-equipped tank cars exposed to a pool fire, which is an eight-fold improvement in survival time over the modeling results for bare steel tank cars.[11]

Findings

On February 16, 2015, at 1:15 p.m. eastern standard time, an eastbound CSX crude oil unit train derailed 27 loaded tank cars in Mount Carbon, Fayette County, West Virginia. The train consisted of 2 locomotives followed by a buffer car, 109 tank cars, and a single trailing end buffer car. The train was transporting about 3.1 million gallons of Bakken crude oil, UN1267, Class 3, Packing Group I, from Manitou, North Dakota, destined for the Plains Marketing Terminal in Yorktown, Virginia. Event recorder data indicated that the train was being operated at 33 mph at the time of the accident, below the 50 mph maximum authorized speed. At the time

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[9] *Federal Register* 79, no. 148 (August 1, 2014): 45016.

[10] Comments of the Association of American Railroads before the Pipeline and Hazardous Materials Safety Administration, Docket No. PHMSA -2012-0082 (HM-251): Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains. September 30, 2014.

[11] The AAR states that some flammable gas tank cars are provided a thermal protective blanket having thermal conductivity no greater than 2.65 British thermal units (BTU) per inch, per hour, per square foot, and per degree Fahrenheit at a temperature of 2000 F, ± 100 F.

of the accident, CSX had a temporary 40 mph speed restriction on the territory due to cold weather. The weather was 15° F with eight inches of recent snow.

About 300 people were evacuated from within a one-half mile radius of the scene. About 378,000 gallons of crude oil was released in this accident from tank car punctures, damaged valves and fittings, and tank car shell thermal failures. Crude oil was discharged into the Kanawha River and contaminated soils in the area of the derailment, and fueled a postaccident fire. Much of the crude oil was consumed in the postaccident fire. Emergency responders allowed the fire to burn itself out and it was extinguished by 8:00 p.m. on February 17, 2015, more than 30 hours after the derailment.

All of the tank cars involved in this accident were compliant with the CPC-1232 industry standard. None of the tank cars had thermal protection. During the derailment sequence, two tank cars were punctured and released more than 50,000 gallons of crude oil. Of the 27 tank cars that derailed, 19 cars became involved in a pileup and postaccident pool fire. The pool fire caused thermal tank shell failures on 13 tank cars that otherwise survived the accident. Only one car at the edge of the pool fire survived without release. The eight tank cars on either side of the pool fire were not significantly damaged and did not release product.

Emergency responders reported that the first thermal failure occurred about 25 minutes after the accident. By about 65 minutes after the accident, at least four thermal failures with energetic fireball eruptions had occurred (see Figure 1). The 13th and last thermal failure occurred more than 10 hours after the accident.

Figure 1. Fireball eruption from Mount Carbon, West Virginia derailment scene, February 16, 2015. (Photo courtesy WWVA News Radio, Wheeling, West Virginia.)

The NTSB has also collected information relative to three additional recent accidents in which CPC-1232 tank cars derailed and breached due to postaccident thermal failures.

On February 14, 2015, a Canadian National (CN) crude oil unit train with 100 tank cars derailed 29 cars in a remote area near Gogama, Ontario, while traveling at 38 mph. All tank cars were less than 4 years old and were compliant with the industry CPC-1232 standard. Investigators found that 19 of the cars were breached and released more than 264,000 gallons of crude oil. Tank car inspections revealed at least five tank cars sustained postaccident thermal failures.

On March 5, 2015, a BNSF crude oil unit train traveling at 23 mph with 103 DOT-111 tank cars derailed 21 CPC-1232 tank cars in a rural area south of Galena, Illinois. A postaccident pool fire that began with product released from damaged valves and fittings on some tank cars resulted in five tank car thermal failures.

On March 7, 2015, a CN crude oil unit train with 94 DOT-111 tank cars derailed 39 CPC-1232 cars while traveling at 43 mph at the west end of a CN rail bridge that traversed the Macaming River near Gogama, Ontario, about 23 miles from the above-mentioned February 14, 2015, accident location. Five tank cars came to rest in the river and the remaining cars piled up on the west side of the bridge where tank cars were breached, released product, and ignited a large pool fire that destroyed the rail bridge. At least five of the derailed tank cars sustained postaccident thermal failures.

Preliminary investigation results indicate that a total of 28 CPC-1232 compliant tank cars thermally failed in these four accidents. One person was injured, and thousands of gallons of crude oil were released, causing significant property damage and environmental pollution. In these four accidents, investigators have found consistent evidence of shell bulging from overpressure, shell material thinning, and tank shell tears in the vapor space of bare steel CPC-1232 tank cars exposed to pool fire conditions (see Figure 2). The NTSB concludes that the thermal performance and pressure relief capacity of bare steel tank cars that conform to current federal and industry requirements is insufficient to prevent tank failures from pool fire thermal exposure and the resulting overpressurization.

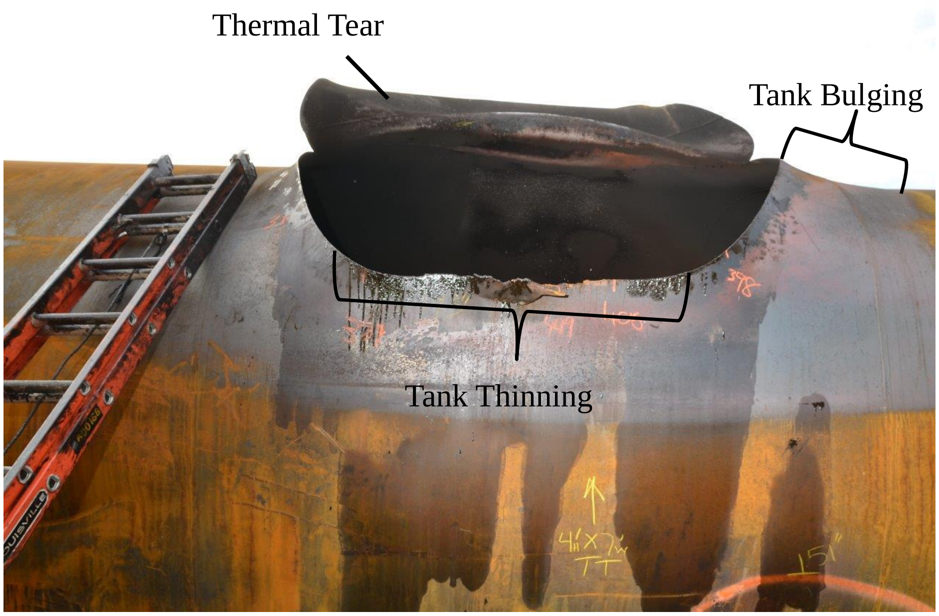

Figure 2. CPC-1232 tank car CBTX 741946 thermal shell tear surrounded by a bulging and thinning shell.

These findings also suggest that, contrary to model predictions the tank shell thermal resistance and the capacity of pressure relief devices of bare shell CPC-1232 cars are insufficient to prevent shell rupture within a relatively short period when exposed to a large flammable liquid pool fire. Tank car breaches from thermal failures in these accidents contributed to increased severity of postaccident fires and damage and demonstrate the potential for these breaches to affect adjacent tank cars and cause the release of additional flammable hazardous material. The NTSB concludes that tank failure of unprotected flammable liquid tank cars exposed to pool fires can occur in a much shorter time than the 100-minute benchmark provided by 49 CFR 179.18(a).

Given the demonstrated limitations of the AFFTAC modeling used to evaluate CPC-1232 tank car thermal resistance, particularly its disparity in time-to-failure with real-world performance in accidents involving tank cars transporting crude oil, PHMSA should take measures to ensure that thermal protection systems approved for the proposed DOT-117 tank car and for retrofitted tank cars are qualified using a robust performance standard that is sufficiently validated for the tank car configuration and the commodity transported. Tank cars that are involved in pool fires are likely to have impact damage or be subjected to other conditions that may affect tank survivability. Robust thermal protection systems should account for variable factors such as tank denting with decreased vapor space volume and damage that affects tank integrity. The NTSB is concerned that thermal protection systems designed to simply meet the performance standard in 49 CFR 178.18(a) may not be sufficiently robust to prevent unacceptable performance in accidents involving tank cars transporting flammable liquids. The NTSB believes that available thermal protection systems, such as jacketed ceramic blankets that are approved for use on tank cars used to transport liquefied petroleum gas, have the capability to provide protection that significantly exceeds the 49 CFR 179.18(a) performance standard when used on flammable liquids tank cars.

PHMSA has been working with Transport Canada to develop harmonized rules to enhance tank car protection requirements for cars used to transport flammable materials such as crude oil and ethanol, including the proposal of a Class DOT/TC-117 tank car, existing fleet retrofit requirements, and implementation timelines. The PHMSA NPRM proposes to require that new tank cars and retrofitted tank cars meet specific safety requirements with a compliance timetable set to have commodities identified as Class 3, packing group I transported in new or retrofitted railcars by October 1, 2017, packing group II by October 1, 2018, and packing group III by October 1, 2020.

On March 11, 2015, Transport Canada published an update of its new tank car standard development activities.[12] The proposal includes a gradual phase-out of legacy Class DOT-111 tank cars based primarily on tank car configuration and commodities (crude oil or ethanol) being transported. The update includes a proposed schedule that would allow CPC-1232 tank cars without thermal protection systems to remain in crude oil and ethanol service until 2025. Transport Canada noted that it continues to work in close collaboration with PHMSA and the FRA to develop stricter requirements for tank cars carrying flammable liquids in North America. As such, it is likely that the PHMSA final rule will be harmonized with the proposed Transport Canada regulations. The NTSB is concerned that any retrofit, repurpose, and retirement plan that establishes only a final deadline far in the future could encourage car owners to delay needed tank car safety improvements until the deadline date. The NTSB concludes that a comprehensive and aggressive implementation schedule with transparent progress reporting of intermediate progress milestones is necessary to ensure completion of tank car improvements within a reasonable time period.

The NTSB preliminary assessment of nonthermally protected CPC-1232 tank car survivability in recent crude oil unit train accidents has identified a significant vulnerability to thermal failures. This vulnerability exists with the legacy DOT-111 tank cars as well. The NTSB believes that a 10-year deadline for retrofitting or removing from service CPC-1232 tank cars is excessively long. With North American crude oil production expected to increase by more than 5 million barrels per day by 2024, the NTSB is concerned that such a timeline for action would present increasing risk of severe injury to persons, property, and environmental damage for many years to come.[13]

The NTSB continues to monitor the tank car rulemaking progress and the circumstances of accidents involving tank cars used to transport high volumes of flammable liquid fuels. If the DOT finds that tank car shop retrofitting capacity is insufficient to improve the thermal protection and puncture resistance of the existing fleet within an aggressive, phased time schedule, it could consider mandating additional risk mitigation measures on flammable liquids routes, such as significant speed restrictions for each class of track.

Investigators are still examining issues related to the aforementioned accidents and have not made final conclusions about all aspects of tank car performance. Nonetheless, the

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[12] This information is referenced at http://www.tc.gc.ca/eng/tdg/clear-modifications-menu-261.htm. (accessed March 20, 2015.)

[13] *The Economic Impacts of Changes to the Specifications of the North American Rail Tank Car Fleet*, American Petroleum Institute, Washington, DC (December 9, 2014).

preliminary findings have convinced the NTSB that the tank car safety deficiencies in pool fire survivability should be addressed expeditiously.

Therefore, the National Transportation Safety Board makes the following safety recommendations to the Pipeline and Hazardous Materials Safety Administration:

<u>R-15-14</u>

> Require that all new and existing tank cars used to transport all Class 3 flammable liquids be equipped with thermal protection systems that meet or exceed the thermal performance standards outlined in Title 49 *Code of Federal Regulations* 179.18(a) and are appropriately qualified for the tank car configuration and the commodity transported.

<u>R-15-15</u>

> In conjunction with thermal protection systems called for in safety recommendation R-15-14, require that all new and existing tank cars used to transport all Class 3 flammable liquids be equipped with appropriately sized pressure relief devices that allow the release of pressure under fire conditions to ensure thermal performance that meets or exceeds the requirements of Title 49 *Code of Federal Regulations* 179.18(a), and that minimizes the likelihood of energetic thermal ruptures.

<u>R-15-16</u>

> Require an aggressive, intermediate progress milestone schedule, such as a 20 percent yearly completion metric over a 5-year implementation period, for the replacement or retrofitting of legacy DOT-111 and CPC-1232 tank cars to appropriate tank car performance standards, that includes equipping these tank cars with jackets, thermal protection, and appropriately sized pressure relief devices.

<u>R-15-17</u>

> Establish a publicly available reporting mechanism that reports at least annually, progress on retrofitting and replacing tank cars subject to thermal protection system performance standards as recommended in safety recommendation R-15-16.

Chairman HART, Vice Chairman DINH-ZARR, and Members SUMWALT and WEENER concurred in these recommendations.

The NTSB is vitally interested in these recommendations because they are designed to prevent accidents and save lives. We would appreciate receiving a response from you within 30 days detailing the actions you have taken or intend to take to implement them. When replying, please refer to the safety recommendations by number. We encourage you to submit your response electronically to correspondence@ntsb.gov.

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By: Christopher A. Hart,
Chairman